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BIM Education in Higher Learning Institutions: A Scientometric Review and the Malaysia Perspective

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ABSTRACT

Over the last decade, digital applications and Building Information Modelling (BIM) have been introduced in the construction industry to realize a smart construction ecosystem. However, the construction industry has not completely accepted BIM as a standard, and the concept of using BIM applications in universities has not been thoroughly researched. This paper addresses the first scientometric study of BIM education in universities, identifying the state of BIM education practices, skillsets, and the level of BIM education in universities. The paper used scientometric analysis and the VOSviewer mapping technique to assess the most impactful publication sources with the most important impact on BIM education by searching "BIM Education" and using 250 bibliographic data extracted from the Scopus database from 2011-2020 to identify the existing research gaps and research direction. Second, a structured questionnaire was distributed to 343 Year 2 and Year 3 students from two public and two private Malaysian universities that use BIM in their learning. Descriptive data analysis using cross-tabulation in SPSS and relative importance index (RII) were used to analyze the data. The paper revealed two stages of BIM education research; and identified research gaps in the fields of BIM education, architectural education, e-learning, curriculum and information management. The paper also revealed Revit, Cost X and the Glodon Cubicost software as the most used applications, while the common skillsets are design authoring, modelling, and cost estimation. However, both public and private university students mainly design 3D models at BIM Stage 1. The study recommends that institutions and other stakeholders provide continuous BIM training, purchase BIM software, and integrate BIM into the curriculum of Built Environment higher learning institutions for the next generation to be the generation that uses virtual collaborative platforms.

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1. Introduction

Scientometrics is a large science and technology discipline that includes quantitative analyses of scientific literature. According to Zakka et al. (2021), scientometrics entails using co-citation networks and science mapping to visualise key research areas. A comprehensive literature review is an essential component of any research endeavor, and it plays a key role in scientific research, given the ongoing growth of science. Viergutz & Schulze-Ehlers (2018) state that literature reviews "give a framework for improving knowledge, supporting theoretical advancement, and suggesting opportunities for additional research. "Science literature is a type of big data analytics and mining (Chen et al., 2014), as well as a set of applications and tools that provide more information on the data's reliability and usefulness in strategic planning (Galetsi & Katsaliaki, 2019). As a result, information science and technology-based scientific mapping is becoming a more common transdisciplinary domain. It is the development and use of computer techniques for visualizing, comprehending, and modeling a wide range of scientific and technical procedures. formal characteristics.

Advanced technology and applications have been deployed in the construction industry, resulting in a smart construction world. Smart construction is the process of planning, organising, constructing, and running a structure using advanced digital computerised technologies and industrialised manufacturing techniques (Reddy and Kone, 2019). Smart technology in construction will improve project viability, sustainability, and quality, reduce building lifetime costs, and benefit a wider range of stakeholders.

In the Architecture, Engineering, and Construction (AEC) industry, BIM is a well-known new technology (Lim et al., 2021) that is used to improve project efficiency by finishing projects on time and on budget. BIM is a database that stores all of the information on the components of a building. Data processing can be improved, lowering the danger of losing project building specifics (Chiu and Lai, 2020; Hong et al., 2019). The usage of BIM will eliminate the cumbersome and time-consuming documentation. The BIM database facilitates the incorporation of information into the project and improves document management coordination. Students can save and keep all project files in the machine instead of utilizing manual storage or filing. As the building sector undergoes a revolution, the demand for BIM qualified professionals is surging (Arroteia et al., 2019). As a result, building businesses' use of BIM qualified workers has an indirect impact on potential BIM labor demand (Wu and Issa, 2014). On a global basis, more construction companies, particularly those in charge of large projects, are incorporating BIM into their project delivery systems. However, the supply of BIM workers is insufficient to meet demand, resulting in a BIM professional shortage.

The shortage of competent personnel in the construction business will have an impact on the economy, project efficiency, and project performance. According to numerous academics, there is a shortage of BIM competent experts (Liu et al., 2015; Ahmed and Hoque, 2018; Farooq et al., 2020), is one of the main factors preventing BIM implementation in the construction industryUpskilling can be accomplished through education, internships, and training. As a result, BIM education is being integrated into tertiary educational institutions in order to educate students with BIM knowledge and abilities, hence expanding the number of future BIM graduates. According to Enhassi et al. (2018), BIM education with credentials is an external method for adopting BIM into the construction sector and will accelerate BIM growth. Current BIM education, on the other hand, emphasizes on BIM software skills rather than open-BIM concepts, BIM management, and learning in a collaborative BIM working environment, according to Smith (2014). Industry technical organisations and bodies must maintain tight relationships with higher learning institutions to examine the BIM curriculum and guarantee that education is equipped with the new BIM expertise and abilities (Chan, 2014).

The Public Works Department (PWD) in Malaysia was the first to deploy BIM with government support in order to promote the use of BIM in construction projects (Latiffi et al.,2015). Similarly, most higher education institutions are emphasizing the integration of BIM into education due to the significant benefits that BIM can provide to students in their possible employment occupations as well as to satisfy industry needs. According to (Agirbas, 2020), the benefits of BIM implementation in education include students being able to understand the complex geometry of any building through 3D visualization using BIM software, understanding basic knowledge and information on sustainability, learning about the properties of the BIM climate, and preparing students for their future working environment. The Malaysian government should provide clear advice and standardization to lead the BIM adoption in education. Various parties are developing plans to integrate a robust BIM curriculum into higher education that takes into account a variety of factors. Students who have completed BIM training at a higher learning institution would be well-versed in BIM knowledge and abilities, equipping them for future employment opportunities.

Despite extensive use in the building industry in the United Kingdom and the United States, BIM adoption in Malaysia is still modest (Mamter and Aziz, 2016). This is owing to a scarcity of BIM-qualified personnel with practical experience with BIM technology and applications in the construction industry (Sun et al., 2017). The paucity is due to the minimal number of recent graduates with BIM expertise and knowledge. As a result, higher education institutions must prioritize BIM education in order to meet the growing need for BIM expertise. BIM integration into higher education syllabuses is still at a low practice level, according to Khiyon (2015), with no standardization.

Several factors aggravate this scenario, including a lack of understanding in the subject of BIM education research in higher education institutions. The present educational barriers to BIM adoption would steadily reduce the number of trained BIM specialists and the rate of BIM adoption. Furthermore, BIM higher education achievements do not fulfill industrial requirements (Liu et al., 2015). As a result, it's critical to recognize all potential roadblocks so that solutions can be found to solve the problem. In Malaysia's higher education system, the study focuses on BIM education methods, BIM implementation hurdles, and BIM implementation solutions. As a result, this research looks at the first global scientometric study on BIM education and the potential of BIM education in Malaysian universities. This study aims to answer the following five primary research questions based on the motivation of the study:

i. What are the phases of BIM education research according to the year of publication?
ii. What are the current research gaps and future direction in BIM education research?

iii. Which countries have the most influence in BIM education research?
iv. What are the most commonly used BIM applications among built environment students?
v. What are the most common BIM skillsets among built environment students?
vi. What is the level of BIM among built environment students?

2. Literature review

2.1 BIM and the Industry

Because of the digital revolution, which connects modern technology with the people who use it, the construction industry is witnessing the Industrial Revolution (IR) 4.0 (Alaloul et al., 2020). The Architecture, Engineering, and Construction (AEC) industry has largely adopted BIM technology, and its emergence into the worldwide market has boosted its application in the construction industry. According to Rostam (2019), 75 percent of construction projects cannot be completed on schedule due to the complexities of the processes. All construction operations, on the other hand, can be completed in a short amount of time and produce a cost-effective end product (Georgiadou, 2019).

A project is visualized using a 3D virtual model that incorporates all architectural element features and metadata. Design errors can be eliminated and design quality can be improved through visualisation when BIM is used. In addition, data about the building's lifecycle can be handled (Doan et al., 2020; Chiu and Lai, 2020; Enhassi, et al., 2018) and can predict the building's lifecycle to ensure that it is operated in a sustainable manner. Designing a sustainable design will be more effective if the design is reviewed using a BIM application.

The construction industry contributes significantly to Malaysia's Gross Domestic Product (GDP), accounting for 3% to 5% of the country's total GDP (Othman et al., 2020). As a result, BIM technology has been incorporated into the Malaysian construction industry, enabling for national-level construction efficiency. BIM has been used primarily in the private sector in Malaysia since the year 2000. However, the government sector, notably the Public Works Department (PWD), embraced BIM technology in the early year of 2007. Most construction parties are aware of this. (Latiffi, 2015). PWD has formed a BIM committee to evaluate BIM adoption in the construction industry by conducting research and determining the most acceptable media for usage in government public works projects. According to Yadav and Kanade (2018), a government commission chose and recommended Autodesk as the BIM platform for construction. The Public Works Departments (PWD) began using BIM software tools at the end of the year 2010, and the use of BIM technology in other construction-related occupations has grown since then. Furthermore, Malaysia's Construction Industry Development Board (CIDB) is a government entity that promotes BIM adoption in the construction industry. CIDB Malaysia supports BIM technology through seminars and is now working on a roadmap that will include BIM implementation guidance. The building concept is initially represented in two-dimensional (2D) text and sketches. Following that, the 2D system evolved into a computer-aided design (CAD) system Lattifi et al. (2015). A CAD framework, according to Kong et al. (2020), provides for the modeling of the building design process in three-dimensional (3D) space and the storage of architectural knowledge in the form of models and images. The CAD foundation will not be fully refined if non-graphic building details are generated using current graphics and models. As a result, Malaysia is using BIM, an advanced software and processing framework, to address all technological difficulties associated with the production of building information.

Malaysia's BIM adoption rate is growing at a slower rate than that of other countries. BIM deployment in Malaysia's construction industry is poor. A lack of expertise, legal backing, interoperability constraints, and other factors are all hindering BIM deployment in Malaysia's building industry Othman et al. (2020). According to Wong and Gray (2019), the most common hurdle to BIM adoption is a lack of BIM education, which accounts for 40.5 percent of the barriers. As a result, BIM training is critical for increasing BIM adoption in the Malaysian construction industry.

BIM is being increasingly widely used in the construction sector, which is increasing demand for BIM experts (Zhang et al., 2016). Building projects and implementation employing advanced BIM technologies are in need of BIM graduates. As a result, BIM should be included in BIM education so that students who work primarily in the Built Environment domain can gain BIM core knowledge and abilities that will prepare them for the actual world.

2.2 BIM and the Academia

The demand for BIM specialists is growing as information technology advances. Many construction companies want BIM graduates to be able to cover a wide range of positions. A shortage of BIM-trained professionals is the current global driving force for BIM deployment in institutions. BIM education in Malaysia is still in its early stages, according to a report by Belayutham and Ibrahim (2018). BIM education is defined as a "process of learning that covers BIM knowledge that an individual must be capable of as well as having an understanding of BIM processes" (Ana Karina et al., 2020). As a result, higher education institutions must incorporate BIM into their curricula so that all graduates are equipped with the necessary skills and knowledge.

Integration of BIM into higher education will aid in the advancement of AEC education and alleviate the shortage of competent BIM practitioners. The industry expects all possible graduates to obtain BIM skills and competence in order to meet the demand for BIM specialists (Zhao et al., 2015). BIM engineers, BIM planners, BIM project managers, BIM technicians, BIM coordinators, IT executives, and other jobs are available in the industry for BIM experts (Kolaric et al., 2019).

Incorporating BIM into higher educational curricula can help to improve AEC education and address the scarcity of competent

BIM experts. To meet the demand for BIM specialists, the industry expects all future graduates to have BIM skills and expertise (Zhao et al., 2015). The industry offers BIM specialists a variety of work options, including BIM engineer, BIM designer, BIM project manager, BIM technician, BIM coordinator, IT directors, and other jobs (Kolaric et al., 2019). Because of BIM education, BIM-oriented graduates will emerge. Technical competency in BIM is a core competence that all graduates must learn, not an optional skill that adds value to a career.

Through BIM education, students can improve their learning experiences by visualizing BIM models. The dynamic 3D BIM model generates a visualization that correctly depicts the reality of the complete building and environment, providing for a better understanding of the project's architectural design (Witt and Kahkonen, 2019). The fundamentals of BIM will be covered, as well as the ideas that underpin it. Because BIM simplifies difficult design procedures, students will be able to boost their productivity by finishing all assignments on time (Doan et al., 2020; Haron et al., 2017).

Incorporating BIM projects into the curriculum would also help students communicate and cooperate better (Jin et al., 2017). To develop a thorough BIM model, students will need to collaborate to accomplish all design tasks.

2.3 BIM Software and Skillsets

The Higher education is incorporating BIM education in order for a large number of students to develop BIM skills and competence in order to fulfill industry demands. Most universities, according to Aziz et al. (2019), employ BIM software such as Autodesk Revit, Naviswork, Cubit software, Glodan Cubicost, and Cost – X. The most often used BIM software at Malaysian higher education institutions are Autodesk Revit (Architecture, Structural, MEP-Mechanical, Electrical, and Plumbing), Autodesk Navisworks, Graphisoft ArchiCAD, and TEKLA Structures (Hedayati et al., 2015).

Autodesk Revit, Graphisoft ArchiCAD, and TEKLA Structures are some of the design authoring software utilized to produce the 3D model. Autodesk Navisworks is a 3D coordination application for 4D scheduling and conflict detection. Cubit software, Glodan Cubicost, and Cost X are used to estimate costs. Students in higher education institutions must have the necessary BIM abilities for a variety of BIM applications at various phases of the project. Table 1 displays various uses of BIM and their definitions at different BIM stages.

A BIM project execution planning guide has been created, which comprises a list of main BIM applications during the lifecycle of the facility or building. BIM is used at numerous stages, including preparation, design, construction, and operation. BIM uses in the planning stage include condition modeling, cost calculation, phase planning, site analysis, and design reviews. The design stage includes plan authoring, design / engineering analysis, and 3D coordination. For site use preparation, 3D monitoring and planning, and record modeling, BIM is used during the construction stage. During the building's operating stage, BIM software is utilized for maintenance and scheduling, as well as building system analysis Kjartansdottir et al. (2017). Kjartansdottir et al. (2017) discovered that existing conditions modeling, cost estimates, phase planning, site utilization planning, 3D coordination, construction system design, digital fabrication, record modelling and 3D control and planning are among the most common BIM applications. Similarly, Existing conditions modelling, cost estimation, site analysis, cost analysis, phase planning/scheduling, design authoring, constructability reviews, design/engineering analysis, programming/space validation program, 3D coordination, digital fabrication, construction system design, record modelling, and a host of other BIM applications for oil and gas projects were identified by Lee et al. (2018).

Table 1 Definition of BIM Uses at Different Stages of the BIM Process

BIM Uses	Definition	Authors
Cost Estimation	Establishing an accurate cost estimation and trace the cost effects on design changes. Quantity take-off is extracted.	Kjartansdottir et al., 2017; Lee et al., 2018; PSU, 2011
Existing conditions modelling	3D models are developed based on the existing site conditions or a specific area within a building or facility. The efficiency and accuracy of the existing site conditions is enhanced.	PSU, 2011; Kjartansdottir et al., 2017; Lee et al., 2018
Cost Analysis (5D modelling)	4D BIM model is linked with the cost data, forming the 5D BIM model that is used to carry out cost analysis.	Lee et al., 2018
Phase planning /Scheduling (4D modelling)	3D model is linked with a programme consisting of project timeframe and schedule for the phased occupancy planning to show the construction process sequences and the space requirements on site.	PSU, 2011; Kjartansdottir et al., 2017; Lee et al., 2018
Programming (Space validation program)	The area and the information of the program is obtained from BIM to access and review the space design which allows the tracking of gross area, rentable area and usable area.	PSU, 2011; Lee et al., 2018
Site Analysis	The use of BIM tools or GIS tools to carry out site location evaluation to decide a location that is appropriate for the future project use and to carry out analysis on the volumes, orientation and position of the facility.	Lee et al., 2018

Design Review	3D model is being reviewed by the project stakeholders to obtain different feedback on validation of design aspects to ensure the design constructability. Besides, it involves the selection of design from various options prepared by BIM, design communication though the process of visualization and virtual digital mock-ups.	PSU, 2011; Lee et al., 2018
Design Authoring	The use of design authoring BIM software to develop BIM model consisting of building properties, quantities, costs, schedule, mean and methods.	Lee et al., 2018
Design /engineering analysis	BIM models are simulated to carry out analysis on the energy, structural, mechanical, electrical, lighting, sustainability and code validation aspects.	PSU, 2011; Lee et al., 2018
3D coordination (Clash detection)	Clash detection is undertaken to examine the physical interferences between the building components within the building system.	PSU, 2011; Kjartansdottir et al., 2017; Lee et al., 2018
Site utilization planning	A process whereby the detailed information of the logistics objects are inserted into the BIM model and link with the 4D scheduling of the project for both temporary and permanent on-site facilities	PSU, 2011; Kjartansdottir et al., 2017; Lee et al., 2018
Digital fabrication	The geometry of the building element is obtained from the BIM model to generate the shop drawings which is then sent to the computerised numerical control equipment for building element prefabrication and assembled on site efficiently.	Kjartansdottir et al., 2017; Lee et al., 2018
Construction System Design	Complex construction system can be modelled for improvement in construction productivity, planning process and safety.	Kjartansdottir et al., 2017; Lee et al., 2018
3D control and planning	Detailed layout points that are taken from BIM will be loaded into the total stations for the assembly of facilities layout to automatically control the movement of construction equipment and location.	PSU, 2011; Kjartansdottir et al., 2017; Lee et al., 2018
Record modelling	Depicting accurate physical representation of the facility's conditions, environment, and assets. Linking of data of operation, maintenance and asset to an As-built model in order to deliver the record model to the employer.	PSU, 2011; Kjartansdottir et al., 2017; Lee et al., 2018
Maintenance and scheduling	Planning and managing the maintenance of the project, building equipment and fabric throughout the facility operational life.	PSU, 2011; Lee et al., 2018
Building System Analysis	Comparing the performance of the building with the specified design.	PSU, 2011

3. Methodology

3.1 Scientometric-Based Review

A scientometric analysis method was used to assess the current domain of BIM education. This allows for a statistical analysis and graphical display of the synthesised network based on scientific articles to depict the conceptual, analytical, and social context of the scientific field (Zheng et al., 2020). The analysis includes selecting tools, gathering, transforming, analyzing, visualizing, reading, displaying, and discussing data. Using keyword co-occurrence analysis, document co-citation analysis and cluster identification analysis with the first step being the creation of networks (Xiao et al., 2019), and utilising quality indexes and extensive bibliographic data, this method offers a quantitative approach that visualizes, plots, and connects research progress in order to analyze the evolution of a study field (Mansuri et al., 2019). With so many scientific papers, it is imperative to know which databases are the most dependable for generating materials. Therefore, this paper made use of the Scopus Analyzer and VOSviewer software. While the Scopus was used to search the literature databases because it is a more broad-based site of more existing journals (Darko et al. 2020, Shukra et al. 2020, Saka and Chan 2019) the VOSviewer was used to create and analyse bibliometric maps (Babalola et al. 2021, Adegoriola et al. 2021, Darko et al. 2020). Unlike other bibliometric mapping applications, VOSviewer pays special attention to the graphic representation of bibliometric maps. The data mining features of VOSviewer are particularly beneficial for swiftly presenting large bibliometric maps (Zakka et al., 2021). Clusters and relationships between keywords, researchers, journals, and institutions were investigated using science mapping. Researchers' data and keywords provide a timeline of the most recent academic developments in the field of BIM education around the world. The research procedure of the study is illustrated in Figure 1. A case study was added to provide a more concrete image of how far BIM education has spread in Malaysia.

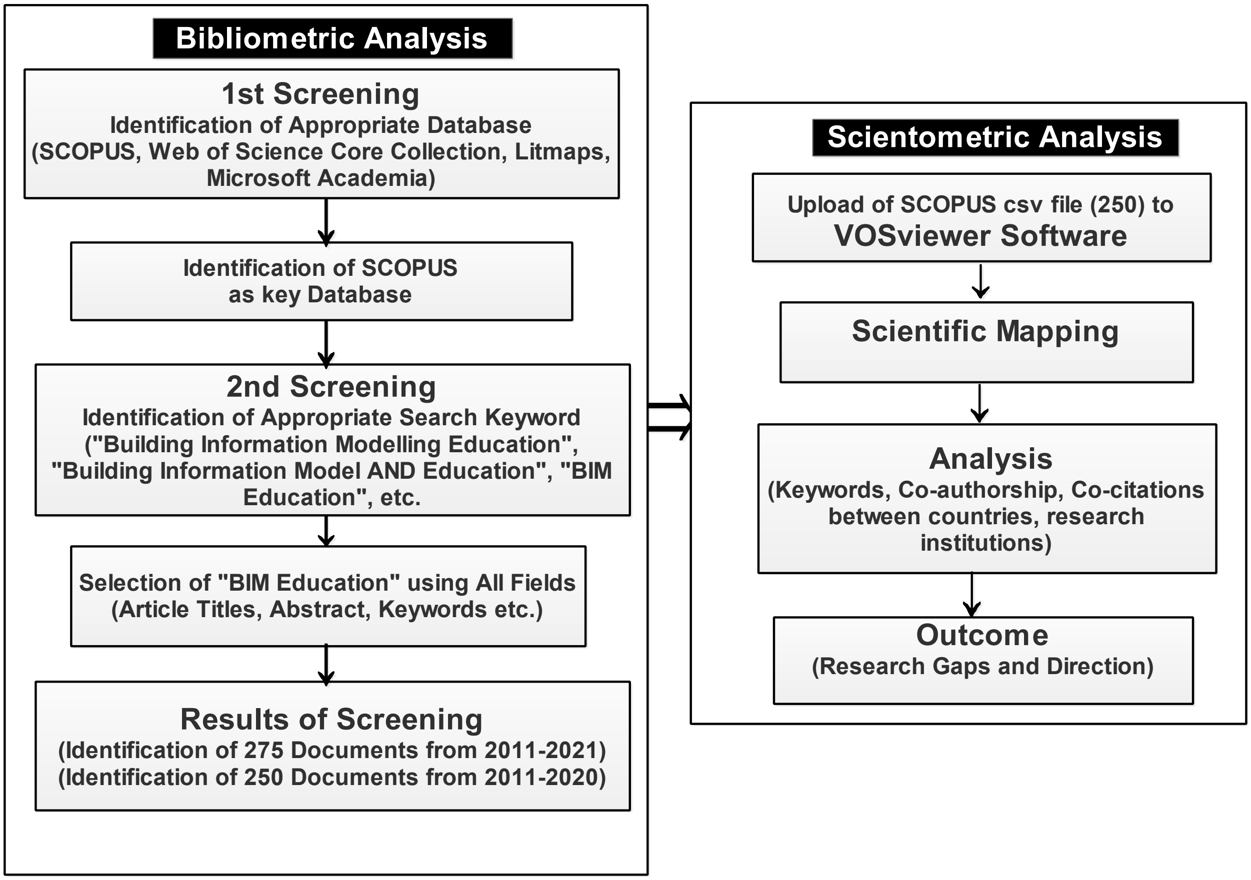

Figure 1 Research procedure of the study

3.2 Quantitative Research Design

Since the research involves the exploration of BIM education in Malaysia, descriptive research was used to specifically respond to the research question and examine the results. Descriptive analysis usually employs questionnaires to explain the difference in various phenomena, whereas the 'observed phenomena' in this study is BIM education in Malaysian higher learning institutions.

343 questionnaires were distributed to a targeted sample size of Year 2 and Year 3 built environment students from two public institutions (University of Malaya and University of Technology Malaysia) and two private institutions (University of Reading Malaysia and INTI International University) in Malaysia using the "simple stratified sampling" process. Students majoring in architecture, quantity surveying, building surveying, construction management, urban and regional planning, and landscape architecture made up the majority of the built environment students. Opinion-based questions on a 5-Likert scale were examined using cross-tabulation in SPSS software, which documented the frequencies of respondents with unique characteristics and analyzed the relationship between different disciplines (Tanko, 2018). The relative importance index (RII) was used to rank the variables and classify the most significant factors.

4. Results and Discussions

4.1 Scientometric Analysis

A total of 250 papers were found in the Scopus database during the literature review. Over a decade of research into BIM education, the initiative has stepped up a notch, according to the literature samples from 2011 to 2020. However, in contrast to other nations, Malaysian BIM education studies are still in their infancy, and many policy decisions have been taken in anticipation of its full adoption. The total sample of literature, source of publication, research keywords, most cited publications, partnering countries, and institutions that are actively engaged in BIM education studies were all examined using the Scientometric method. The types of documents contained in the Scopus database; journal articles and conference papers account for 50.8% and 38.4 %, respectively on global BIM education studies. Since journal articles and conference papers account for nearly 90% of the results, the review focuses on them as the primary source of information. The number of documents provided by authors in relation to BIM education is analysed. The most documents belong to Wu, W (15 documents), Jin, R. (9 documents), and Issa, R.R.A., Li, H. and Zhang, J. having 7 documents respectively (Figure 2).

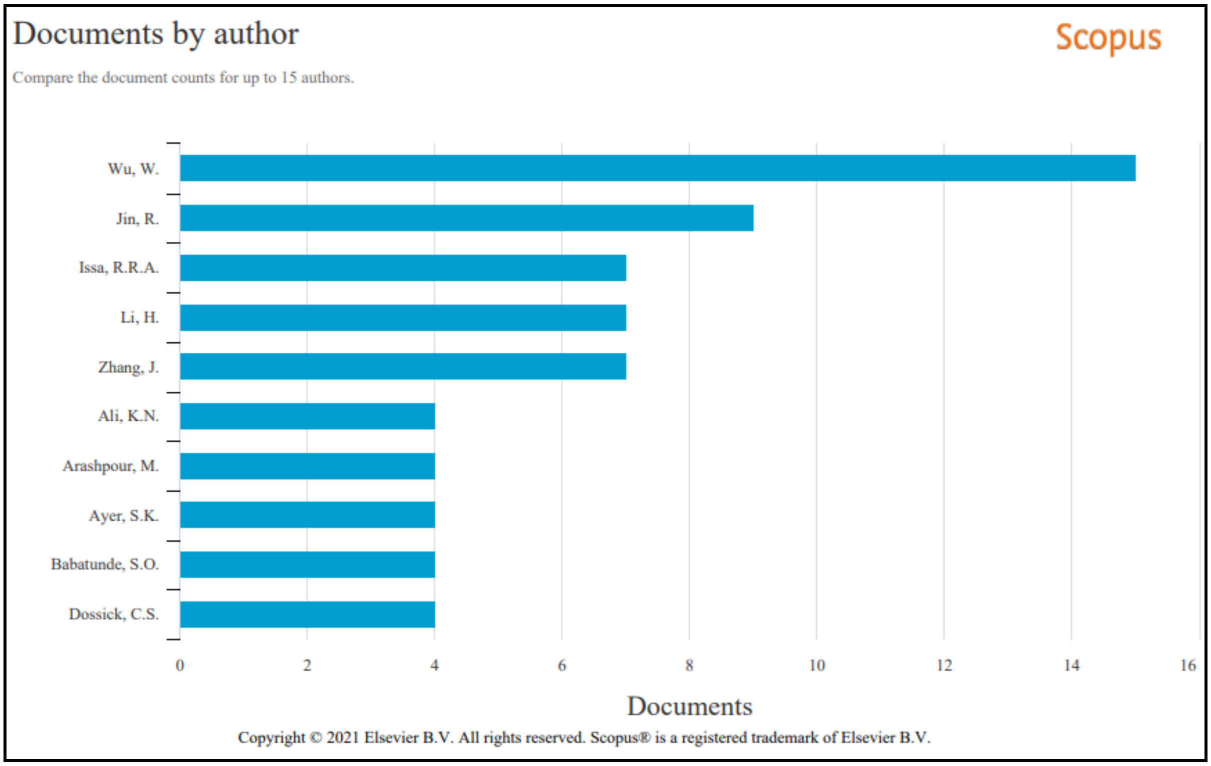

Figure 2 Number of Document by Top Authors

4.1.1 Literature sample and keywords

Figure 3 depicts a compilation of BIM education literature from 2011 to 2020. According to the trend, research into BIM education prior to 2011 was largely unknown. However, since 2011, the number of publications in the field of BIM education has increased. The evolution of BIM education research may be separated into two phases based on the annual publication volume: initiation and development. The annual publication volume during the initial period (2011–2012) was only four articles, which is quite low. During the development phase (2011–2020), the annual publication amount of QS research increased, ranging from 10-45 papers per year. Since 2011, scholarly interest in BIM education has grown, and the annual publication volume has increased in a quasilinear fashion.

BIM education has centred on different aspects of learning from 2011-2020. Ghosh (2012) advocated the setting up of a virtual lab for BIM education. In 2013, Miller et al. developed a BIM framework for the tertiary educational sector in New Zealand and Rosli et al. (2016) explored the preference of BIM software among University of Malaya's architectural students. Boton et al. (2018) developed a framework BIM implementation in engineering education, while Barison et al. (2019) documented an overview of BIM teaching strategies. In 2020, Olowa et al. conceptualized BIM for construction education. As the world moves towards digitalization and smart construction, it is predicted that BIM adoption in higher learning institutions will reach a highpoint in the coming years because of the increasing global interest in BIM education.

Keywords play an important role in scientometric science. Keywords provide an overview of the current research domain in a subject area and serve as a foundation for locating studies in that field. The VOSviewer program is used to visualize keywords in Figure 4. The visualization portrays a timeline of when these keywords were most widely used in BIM education studies. The circles show the degree of keyword co-occurrence, with the larger cycles reflecting the most prevalent topics of research. The closeness of the link between the various keywords is also indicated by the thickness of the lines linking them. The closer two points are to each other, the closer they are connected (Van Eck and Waltman, 2010). The analysis revealed several keywords, along with their frequency and link strength. Based on the keyword analysis, the research gaps are in the areas of BIM Education (Figure 5) with only 5 occurrences and 13 total link strength, followed by architectural education (5 occurrences, 17 total link strength), e-learning (5 occurrences, 34 total link strength), curriculum (7 occurrences, 35 total link strength), and information management (9 occurrences, 66 total link strength).

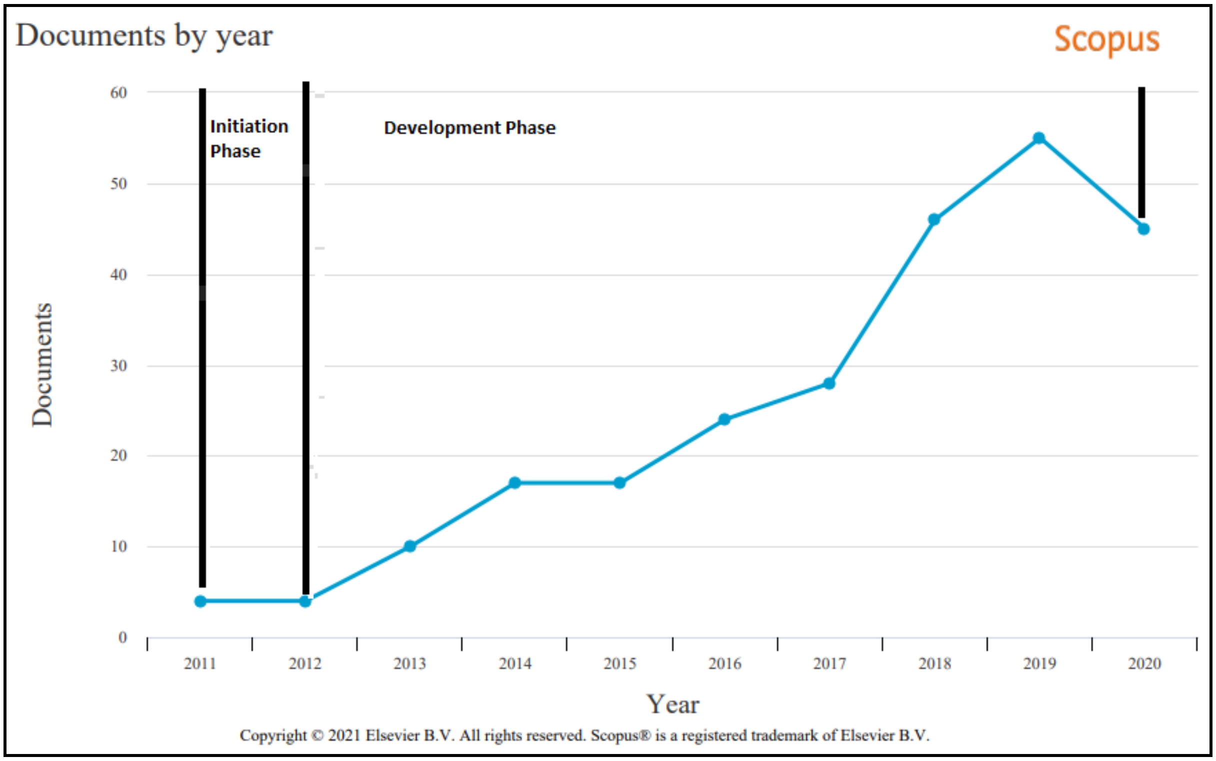

Figure 3 Literature sample and year of Publication

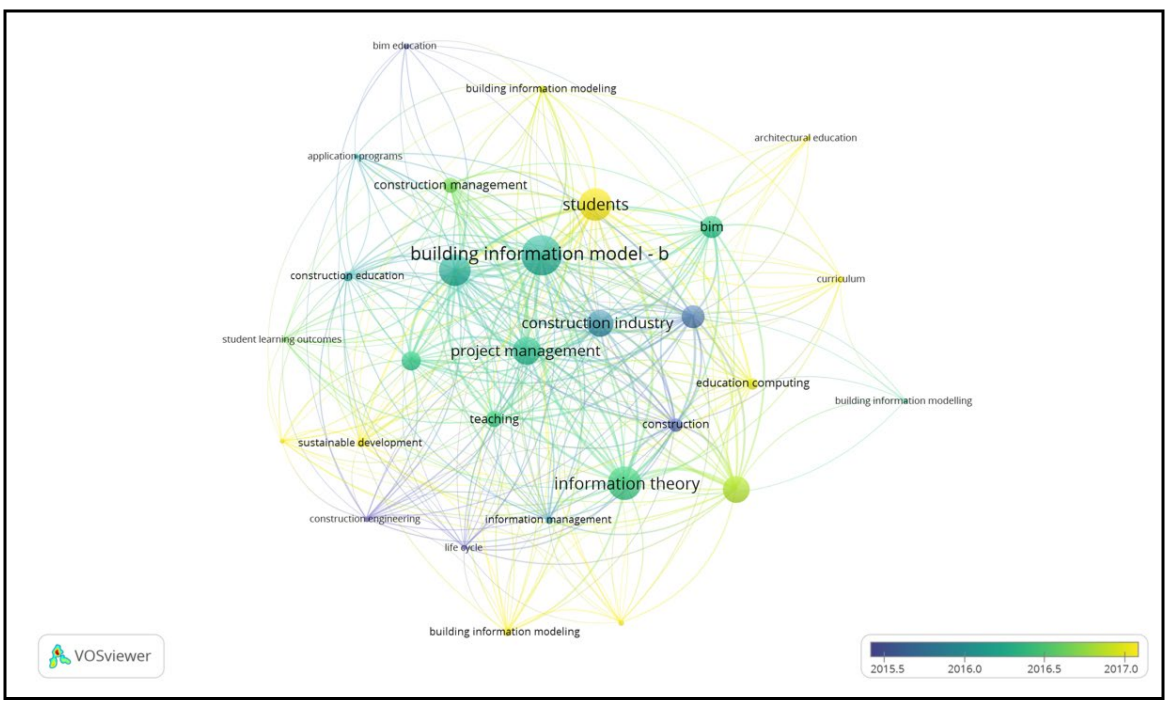

Figure 4 Visualization of Keywords

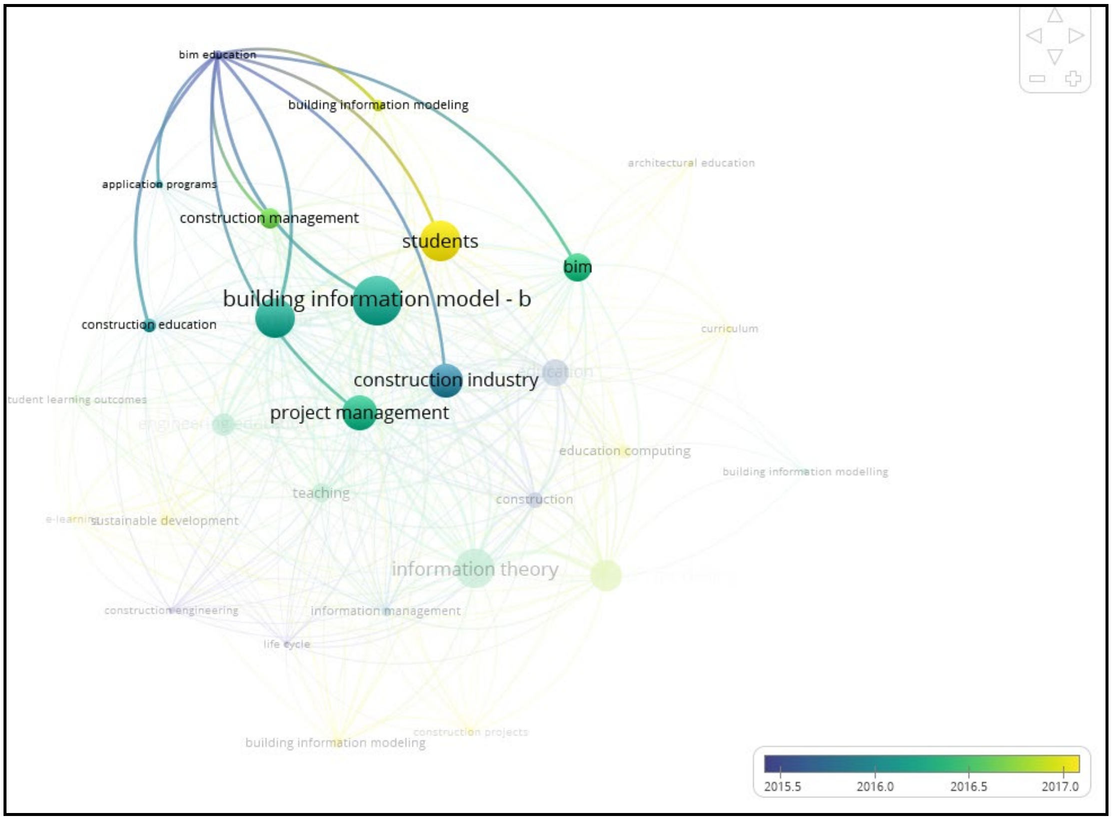

Figure 5 Visualization of BIM Education

4.1.2 Sources of Documents and Impact of Countries

The top 10 institutions involved in the study of BIM education are analyze. The California State University, Fresno has the most studies on BIM education (14), followed by Arizona State University (9) and University of Florida (8). The University of Salford, Deakin University, Universiti Teknologi Malaysia, and Chang'an University have 7 documents respectively. Although there is widespread interest in BIM education, adoption remains poor, as evidenced by the number of documents produced.

The bibliometric analysis and visualization of co-citation between studies in different countries are shown in Figure 6 and Figure 7 respectively. The analysis reveals that the country with the most total link strength, documents, and co-citations is the United States, which has 12 total link strength, 50 documents with a total of 571 citations. Australia in second place, with 10 link strength, 29 documents and 703 citations, and United Kingdom in third place, with 7 link strength, 13 documents and 256 citations. China is fourth with 6 link strength, 8 documents and 37 citations, while Malaysia is fifth with 4 total link strength, 15 documents and 48 citations. The volume of documents indicates that that there is still a global outlook that is deficient in BIM education studies around the world.

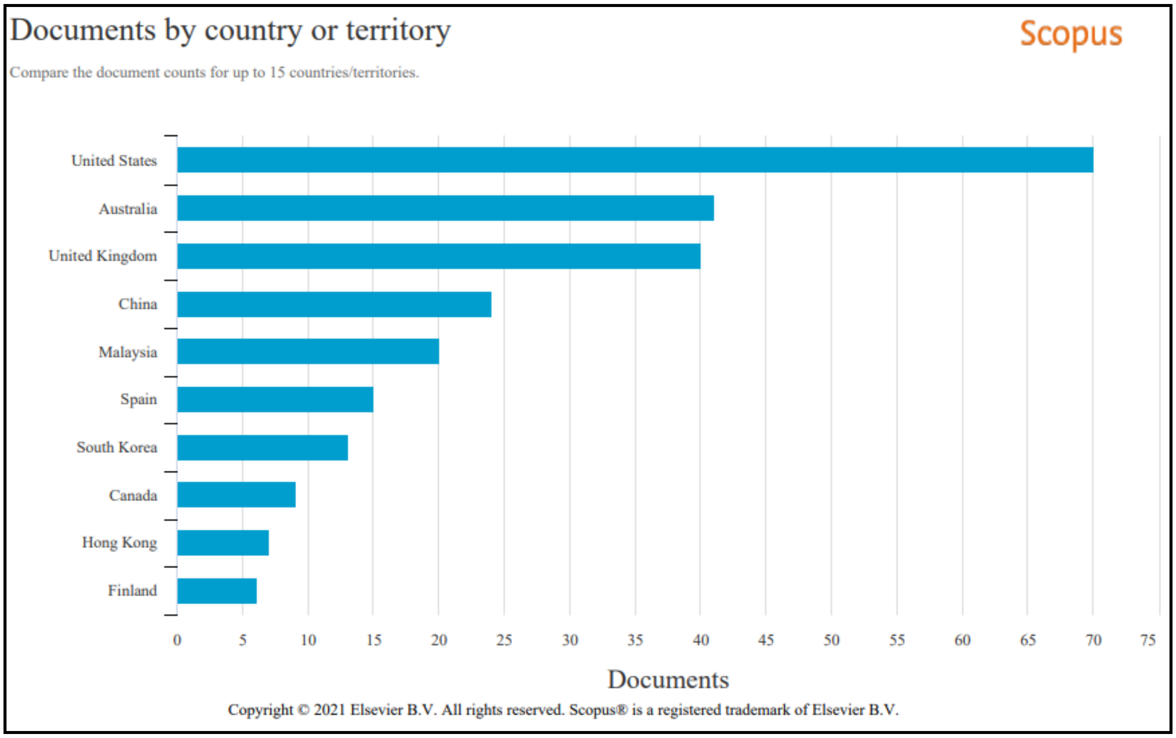

Figure 6 Number of Document by Top Countries

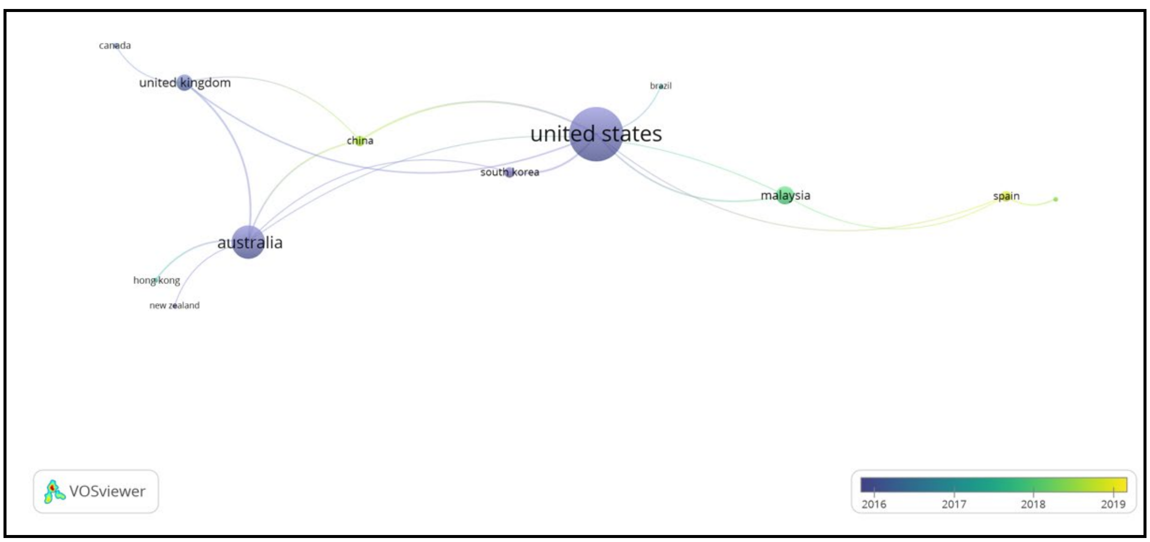

Figure 7 Visualization of Documents by Top Countries

4.2 Quantitative Analysis

This case study focuses on Built Environment students at two private universities in Malaysia (University of Reading Malaysia - UoRM and INTI International University) as well as two public universities (University of Technology Malaysia - UTM and University of Malaya - UM) who use BIM in their learning. From a total sample size of 343, 106 people responded to the survey questionnaire. The overall number of respondents from private institutions is 59 (56 percent), while the number of respondents from public institutions is 47 (46 percent). The UoRM has 32 (30%) students, UTM has 29 (27%) students, INTI International University has 27 (26%) students, and UM has 18 (17%) students. In addition, 78 (73%) students are from quantity surveying discipline, 18 (17%) from architecture, 6 (6%) from landscape architecture and construction management, and 4 (4%) from urban and regional planning and building surveying. The targeted respondents were mainly year 2 (45%) and year 3 (51%) students. Year 1 entry students were not considered in this study while Year 4 students were undertaking internships. However, the study had 4 (4%) students from Year 4. The findings of the case study are highlighted in Sections 4.2.1 and 4.2.2.

4.2.1 BIM Education Practices and Skillsets among Built Environment Students

BIM applications used by built environment students at public and private universities are depicted in Figure 8. Most of the students utilise more than one BIM software in their learning. Except for AutoCAD and Sketchup, the BIM tools in Figure 8 are used to create building information models. Revit software (51 students), Cost X (49 students), and Glodon Cubicost (45 students) were found to be the most widely used BIM tools in the study. Since quantity surveying students make up 73 percent of the respondents, Cost X and Glodon Cubicost tend to be mostly used. Navisworks comes in fourth place with 10 students, followed by Solibri Model Checker (8 students), Recap Pro for laser scanning (7 students), GIS (Geographic Information System) (5 students), and Rhino 3D (1 student).

The skillsets of built environment students are shown in Figure 9. It can be deduced from the figure that design authoring (62 students), existing condition modelling (61 respondents), and cost estimation (46 respondents) are ranked 1st, 2nd and 3rd skillsets among higher education students. Design review had 35 students, while 3D coordination, phase planning (4D scheduling), site analysis, and programming (site validation program) had 13, 9, 6 and 5 students, respectively. Lee et al. (2018) and Kjartansdottir et al. (2017) support these findings. However, no student had skills in building system analysis, maintenance, and scheduling, record modeling, construction system design, design fabrication, site utilization, logistic planning, 3D control and planning (Digital layout) and cost analysis (5D), as shown in the figure.

4.2.2 BIM Level among Built Environment Students

Figure 10 depicts the BIM education levels available in both public and private universities. It is crucial to briefly describe the various levels of BIM education in this paper. Level 0 refers to 2D design software such as manual sketching and AutoCAD. Stage 1 refers to 3D modelling using 3D parametric modelling or software (Kjartansdottir et al., 2015). Stage 2 refers to 3D modelling and information sharing among disciplines using a cloud-based platform (Hasni et al., 2019) while Stage 3 refers to the development of a single integrated model where designs and information can be updated in a cloud-based system. Based on the results, no public or private university student is in BIM stage 0. Private higher learning institutions have a higher mean score of 0.97 for BIM stage 1 than their public counterparts (0.85). Public institutions, on the other hand, outperformed private universities in BIM Stage 2 (0.15). Unfortunately, no higher education institutions have reached BIM Stage 3. At BIM Stage 1, both public and private higher education students mainly build 3D models using parametric 3D software, according to the overall findings.

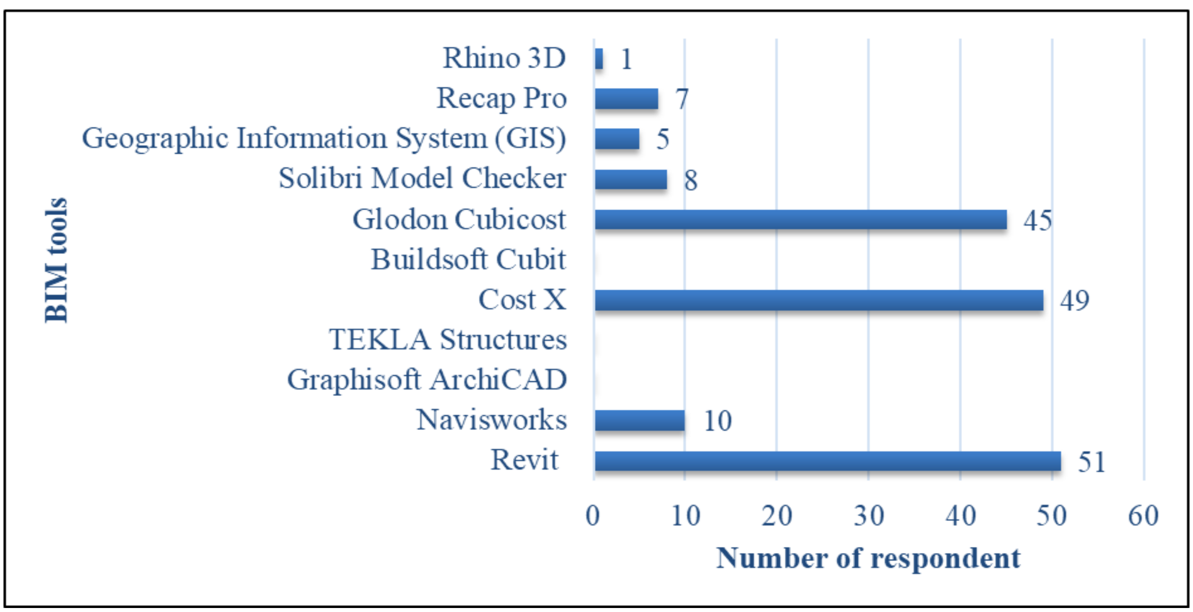

Figure 8 BIM Applications Used by Built Environment Students

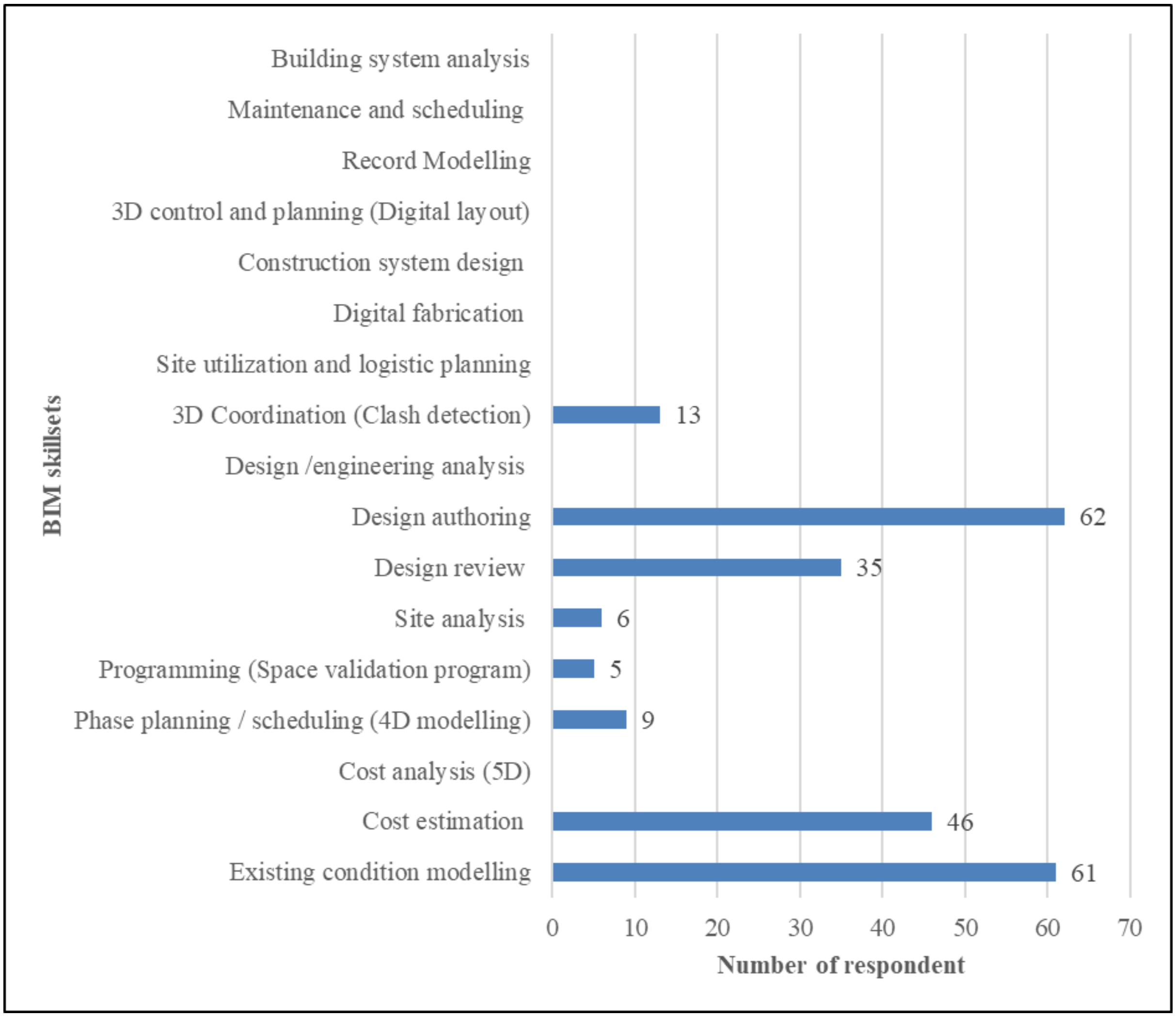

Figure 9 BIM Education Practices among Built Environment Students

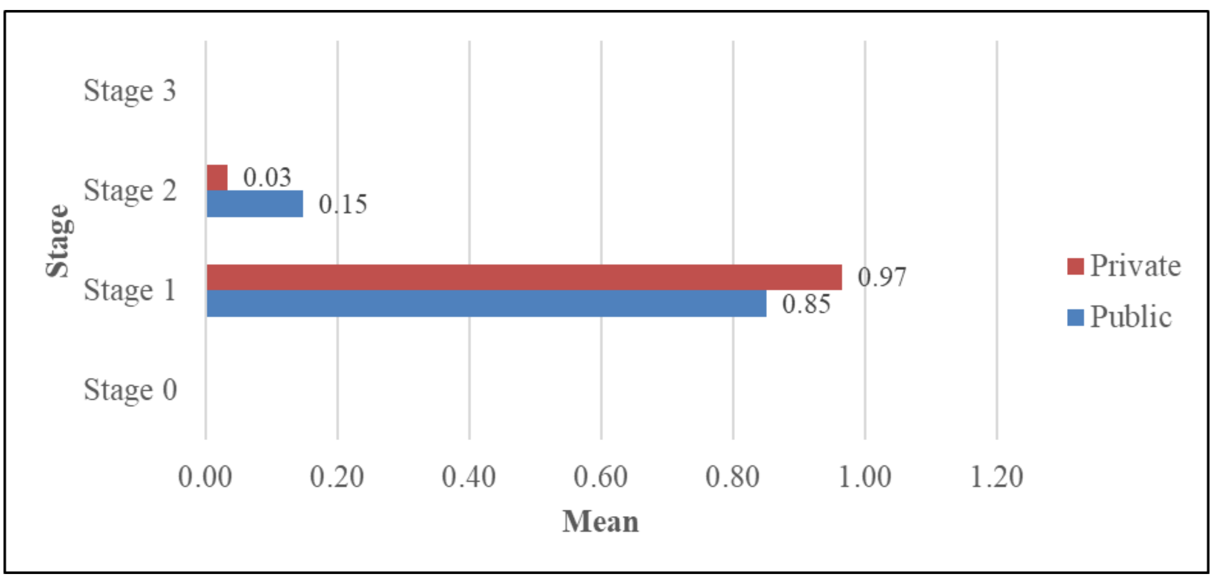

Figure 10 BIM levels among Built Environment Students

5. Conclusion and Recommendations

The status of global BIM education practices was determined using science mapping and scientometric analysis in this study. The study identified the research trend from 2011 to 2020, as well as the publications in various countries, and revealed two stages of BIM education research: initiation and development phases. The scientometric analysis found five (5) research gaps in BIM education, architectural education, e-learning, curriculum and information management. On a national basis, the United States, Australia, United Kingdom, China, and Malaysia are the most influential countries in BIM education research. Therefore, the practical implication is concerned with the possibility of establishing existing research directions to provide avenues for developing new research questions and, thus making, theoretical contributions. This could be used by policymakers and construction stakeholders as a starting point for identifying major issues in BIM education for further research in policymaking dialogue. The study goes on to investigate BIM education further by identifying BIM practices, skillsets, and BIM level. The most used BIM applications among built environment students are Revit, Cost X, and the Glodon Cubicost software, with design authoring, modeling, and cost estimation as major skillsets. The study also revealed that at BIM level 1, both public and private university students are primarily engaged in designing 3D models. The study advises institutions and education stakeholders to provide continuous BIM training, acquire BIM software, and integrate BIM implementation framework into the higher learning institutions' curricula.

Acknowledgements

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