

Analysis of Skills Needs for Future Architecture Graduates of Building Information Modelling (BIM) in Malaysia: A Thematic Review Paper

Nor Azida Ishak, Sharifah Fairuz Syed Fadzil, Nooriati Taib

School of Housing, Building and Planning, Universiti Sains Malaysia, 11800 USM, Pulau Pinang Malaysia

Email: eda_archi@yahoo.com, sfsf@usm.my, nooriati@usm.my

To Link this Article: <http://dx.doi.org/10.6007/IJARBSS/v11-i5/9937>

DOI:10.6007/IJARBSS/v11-i5/9937

Published Date: 29 May 2021

Abstract

Building Information Modelling (BIM) has become an essential tool for improving construction methods in delivering projects. Yet, much BIM-related expertise is needed to achieve the performance quality of the projects. The Malaysian Construction Industry Transformation Plan (CITP) 2016–2020 under the Construction Industry Development Board (CIDB) highlights that the government is beginning to follow the BIM for level 2 by 2020. The move was to improve the adoption and implementation of BIM among the practitioners in the construction industry. The government initiatives have raised the importance of BIM skills and knowledge among practitioners to facilitate successful implementation of BIM-related projects. This paper reports the findings of a thematic review analysis of skills that need to be harnessed from architecture graduates in preparing them to undertake BIM-related projects. Publications from 2010–2020 were analysed by means of a thematic review. Findings from the code-to-document review using ATLAS.ti 8 identified the BIM skills needed from an employee. This paper contributes to analysing the BIM skills indicated from the published papers hence the avenue for future studies on BIM graduates' preparation prior to entering the labour market in Malaysia.

Keywords: Building Information Modelling, Skills, Construction Industry, ATLAS.ti 8, Thematic Review

Introduction

Building information modelling (BIM) has been proven to deliver projects within cost, time, and quality. BIM is also currently known worldwide as an efficient and effective construction method within the architecture, engineering, and construction (AEC) industries. The AEC industry has used the method to ensure an effective integration, collaboration, and management process in a construction project (Ghosh, 2012). CIDB Malaysia defines BIM as a technology that involves modelling; the method includes producing, communicating, and interpreting digital knowledge models for the life cycle of a construction project.

With globalisation, Malaysia's construction industry has become more stable and continued to grow. New initiatives were proposed by the government to boost the construction industry towards the fourth revolution. The recent Malaysian Construction Industry Transformation Program 2016-2020 (CITP), mid-term review presented further efforts to align the construction industry's evolving technologies. One of the latest endeavours is to develop digital construction and industry 4.0 roadmap with the national agenda to guide the construction industry towards a digital future (CIDB, 2019). The Public Works Department (JKR) and the Construction Industry Development Board (CIDB) with MyBIM are organizations that focus on fulfilling the government missions. Implementing BIM in each organisation, firm, and construction in Malaysia is one of the measures to accelerate construction growth. One of the targets of CIDB is to use BIM Level 2 by Q4 2020 and for all public building projects above RM100 million (100%) (including hospitals and schools for JKR development projects) (CIDB, 2019).

The adoption of BIM in the future will pose many challenges with regard to the use of technology, processes, and people (Musa et al., 2018). The main challenges have also been identified with regard to people factor, particularly in terms of the shortage of professional and trained BIM workers, which has resulted in the high cost of implementing BIM (Jamal et al., 2019).

One of factors contributing to an architectural firm's challenges in implementing BIM is the shortage of technical expertise in BIM (Abd Hamid et al., 2020; Azmi et al., 2018). The lack of knowledge and readiness for change is one of the obstacles to successful implementation of BIM (Haron et al., 2017). Such loopholes necessitate further investigation on the BIM skills required from graduates. Hence, the objective of this paper is to explore the necessary BIM-related skills needed from future architecture graduates in order to enhance their employability in the constructions industry. The paper aims to answer the following question: R.Q.: What are the necessary BIM-related skills needed from future architecture graduates in Malaysia as discussed in the publications from 2010 to 2020?

Methodology

The literature review process followed the thematic review process proposed by Zairul (2020). A thematic analysis is defined by Clarke and Braun (2013) as the identification of pattern and construction of themes from thorough reading of a subject. In this study, the first step of the systematic review was to determine the current state of empirical knowledge on BIM skills. Articles published within the last ten years (2010–2020) were shortlisted for the review. The subsequent step was to determine the skills necessary for BIM-related projects, particularly from architecture graduates in Malaysia. The research tenets were to analyse and interpret the findings for future BIM research subjects.

SCOPUS and Mendeley were searched to extract the primary data sources. The publications were selected based on the following criteria: (1) published between 2010–2020, (2) possess keywords, (s) related to BIM or architecture or skills, and (3) focus on BIM skills. Table 1 shows the search string of the literature from the SCOPUS and Mendeley literature search.

Table 1. Search Strings from SCOPUS and Mendeley

SCOPUS	TITLE-ABS-KEY ("Building Information Modelling" AND Skills AND Architecture AND (LIMIT-TO (PUBYEAR, 2020) or (LIMIT-TO (PUBYEAR, 2019) or (LIMIT-TO (PUBYEAR, 2018) or (LIMIT-TO (PUBYEAR, 2017) or (LIMIT-TO (PUBYEAR, 2016) or (LIMIT-TO (PUBYEAR, 2015) or (LIMIT-TO (PUBYEAR, 2014) or (LIMIT-TO (PUBYEAR, 2013) or (LIMIT-TO (PUBYEAR, 2012) or (LIMIT-TO (PUBYEAR, 2011) or (LIMIT-TO (PUBYEAR, 2010)	58 results
Mendeley	"Building Information Modelling" = 1138 articles "Building Information Modelling" AND "skills" = 38 articles "Building Information Modelling" AND "skills" year: [2010 TO 2020]	37 results

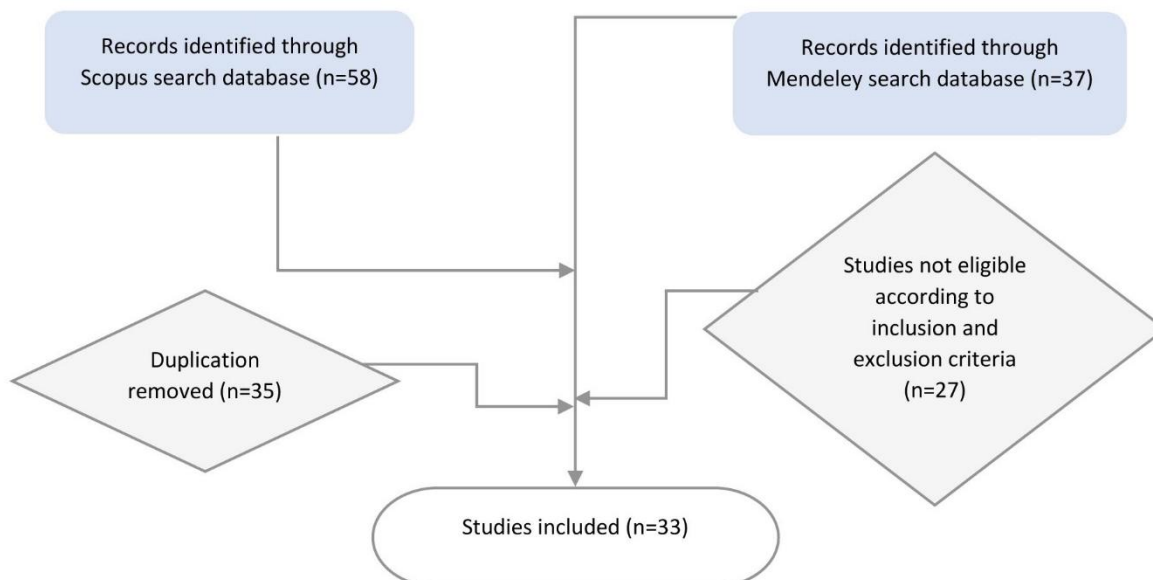


Figure 1. Inclusion and exclusion criteria for the thematic review

The published articles were extracted from SCOPUS using the following keyword TITLE-ABS-KEY ("Building Information Modelling" AND "Architecture" AND "Skills" AND (Limit -TO (PUBYEAR, 2020) or (LIMIT-TO (PUBYEAR, 2019) or (LIMIT-TO (PUBYEAR, 2018) or (LIMIT-TO (PUBYEAR, 2017) or (LIMIT-TO (PUBYEAR, 2016) or (LIMIT-TO (PUBYEAR, 2015) or (LIMIT-TO (PUBYEAR, 2014) or (LIMIT-TO (PUBYEAR, 2013) or (LIMIT-TO (PUBYEAR, 2012) or (LIMIT-TO (PUBYEAR, 2011) or (LIMIT-TO (PUBYEAR, 2010). The search generated 58 articles on BIM skills from 2010 to 2020. An initial search from the Mendeley database using the term "building information modelling" resulted in 1138 articles. The subsequent search using the terms "building information modelling" AND "architecture" AND "skills" (year 2010 to 2020) resulted in 37 articles.

The total number of articles retrieved from the SCOPUS and Mendeley search was 95. The initial search resulted in 58 and 37 articles, respectively. However, 60 articles were removed due to their premature results and anecdotes not concerning BIM skills issues. Some of the articles were also found to be incomplete; the full articles are not accessible, have a broken link, or overlapped. Therefore, the final number of articles to be reviewed was 33 (Figure 1). All the 33 articles were uploaded to ATLAS.ti 8 software. Several groups were initiated automatically in the code group from the metadata defined in Mendeley (Figure 2). The papers were then grouped according to (1) author, (2) number of issue, (3) periodical, (4) publisher, (5) volume, and (6) year of publication.

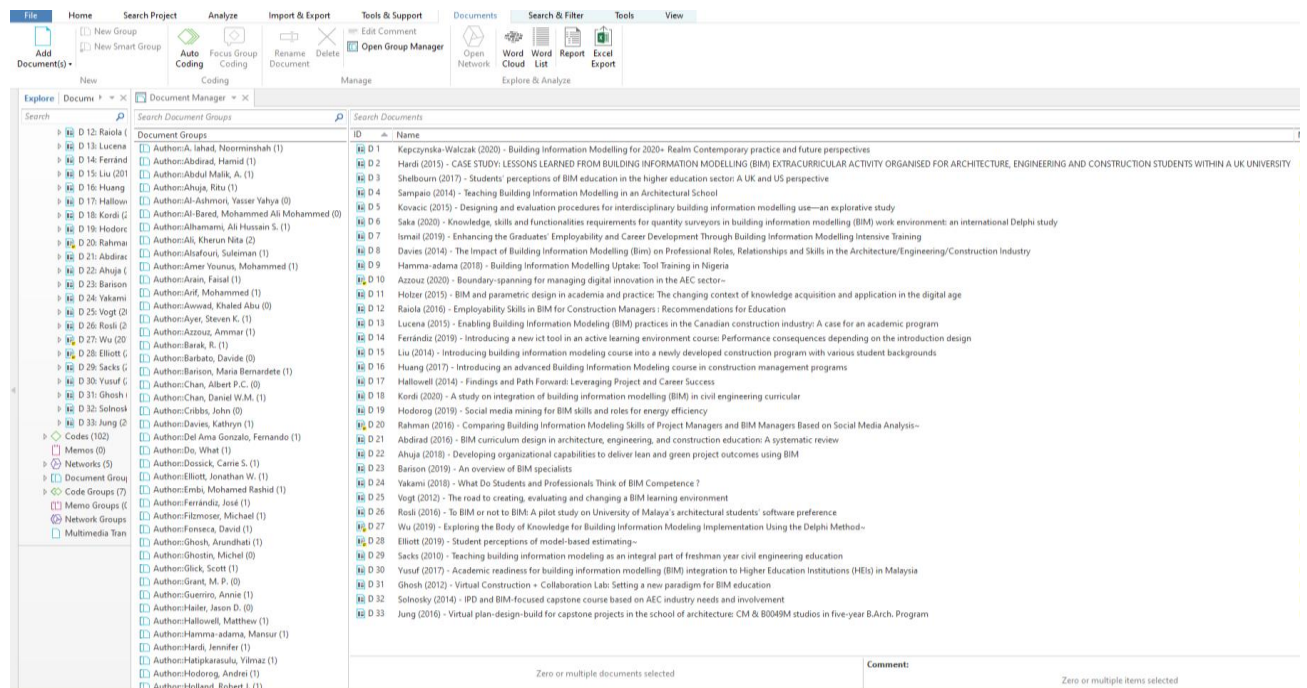


Figure 2. The code group established from Mendeley metadata

The publications could be easily grouped into year of publications and the frequency of paper review each year. The total number of articles analysed by ATLAS.ti 8 was 33 (Figure 3). As mentioned, the number of publications related to BIM skills has increased annually following the increased uptake of BIM in developed countries.

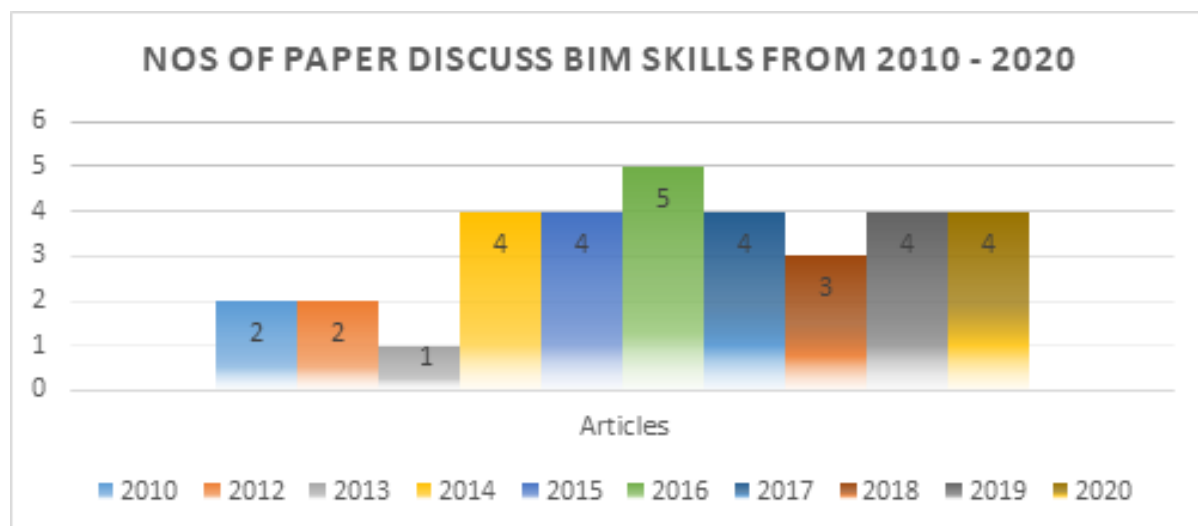


Figure 3. Paper breakdown according to the year of publication

A word cloud analysis review of the 33 documents captured the word *BIM* being used 4198 times; *construction*, 1559 times; and *skills*, 841 times (Figure 4). The thematic review and the frequency of sequence topic managed to identify the skills necessary from architecture graduates. The codes identified were then grouped into themes towards answering the question “what are the necessary BIM skills from future graduates discussed in the publication from 2010 to 2020?” The findings suggest the following two sets of skills: (1) technical skills and (2) nontechnical skills. The quantitative findings and the qualitative findings are discussed in the following section.



Figure 4. Word cloud generated from 33 articles

Results and Discussions

Quantitative Findings

The initial search uncovered that the database is static and that the phrases *BIM* and *building information modelling* are largely used within the scope of the construction industry. The

phrase *BIM skills*, however, is scarcely used. Review papers focus not only on the architectural industry but also in various fields.

Table 2 shows that among the 33 articles identified were those published in Architectural Engineering and Design Management Journal, ANZAScA, ASEE, and EG-ICE (Table 2). Some of the necessary BIM skills required from architecture graduates were identified by means of a critical review. Table 2 shows an increasing number of journal articles in BIM issues published between 2010 and 2020. While not many related works are published in 2010, the number of publications in BIM skills markedly increased from 2014 to 2020. The articles are related not only to architecture-related background but also to social sciences, engineering, education, information technology, and intelligent computing.

Table 2. Articles reviewed based on journals publications according to journal and year

	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020
Architectural Engineering and Design Management										2
ASA 2014 - 48th International Conference of the Architectural Science Association (ANZAScA)				1						
ASEE Annual Conference and Exposition, Conference Proceedings		2		1	1	1	1			
EG-ICE 2010 - 17th International Workshop on Intelligent Computing in Engineering	1									
Engineering Project Organization Journal					1					
Engineering, Construction and Architectural Management								1		
Industry and Higher Education							1			
International Conference on Research and Innovation in Information Systems, ICRIS							1			
International Journal of Architectural Computing					1					
International Journal of Built Environment and									1	
International Journal of Construction Education and									1	
International Journal of Engineering Education									1	
IOP Conference Series: Materials Science and Engineering										1
Journal of Asian Architecture and Building Engineering						1				
Journal of Design and Built Environment						1				
Journal of Information Technology in Construction						1				
Journal of Professional Issues in Engineering Education and Practice	1		1							
Open Science Journal								1		
Practice Periodical on Structural Design and Construction				1						
Procedia Engineering						1				
Proceedings - 2019 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2019									1	
Proceedings of the 4th New Zealand Built Environment Research Symposium (NZBERS). Auckland, New Zealand				1						
Rics Cobra Aubea 2015					1					

The publications regarding BIM skill sets mostly concern the practice in Malaysia, the UK, and the USA from 2016 to 2020. Not many researchers publications were noted from 2010 to 2012 (table 3). Studies on BIM skills also concern the practice in Arizona, Australia, Austria, Boulder, Canada, Hong Kong, India, Israel, Melbourne, New Zealand, Pennsylvania, Poland, South Dakota, South Korea, Texas, and UAE. The distribution of articles shows that the implementation and demands for BIM have increased in various countries. Such magnitude therefore necessitates the harnessing of appropriate skills among practitioners to facilitate successful implementation of such projects.

Table 3. Distribution of articles according to country

	2010	2012	2014	2015	2016	2017	2018	2019	2020	Total
Arizona		1								1
Australia				1						1
Austria				1						1
Boulder			1							1
Brazil										1
California										1
Canada				1						1
Hong Kong									1	1
India							1			1
Israel	1									1
Malaysia					1	1		1	1	4
Melbourne				1						1
New Zealand			1							1
Pennsylvania			1							1
POLAND									1	1
Portugal			1							1
South Dakota						1				1
South Korea					1					1
Texas			1							1
UAE								1		1
UK						1	1	1	1	4
USA					2			1		3

An iterative process involving similarities and disparities was conducted to ensure continuity in the resulting subcategories. Forty-two initial codings were derived from the review of the 33 articles. However, after several rounds of recoding and code merging in ATLAS.ti 8, the final skills were categorised into two main patterns, nontechnical skills and technical skills, as shown in Table 4. The main conclusions of the thematic review are reported in the next section.

Table 4. Thematic review of BIM publication from 2020 till 2020

	2010	2012	2014	2015	2016	2017	2018	2019	2020
NON-TECHNICAL SKILLS	1	0	1	4	3	2	1	3	3
TECHNICAL SKILLS	1	2	2	2	4	3	2	4	3

Qualitative Findings

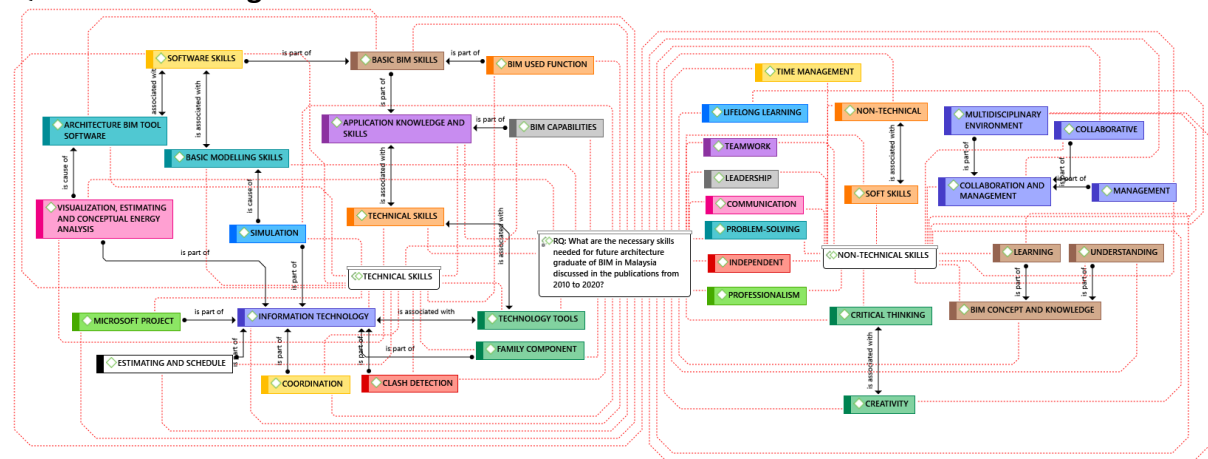


Figure 5. Overall network view of the thematic review answers the research question

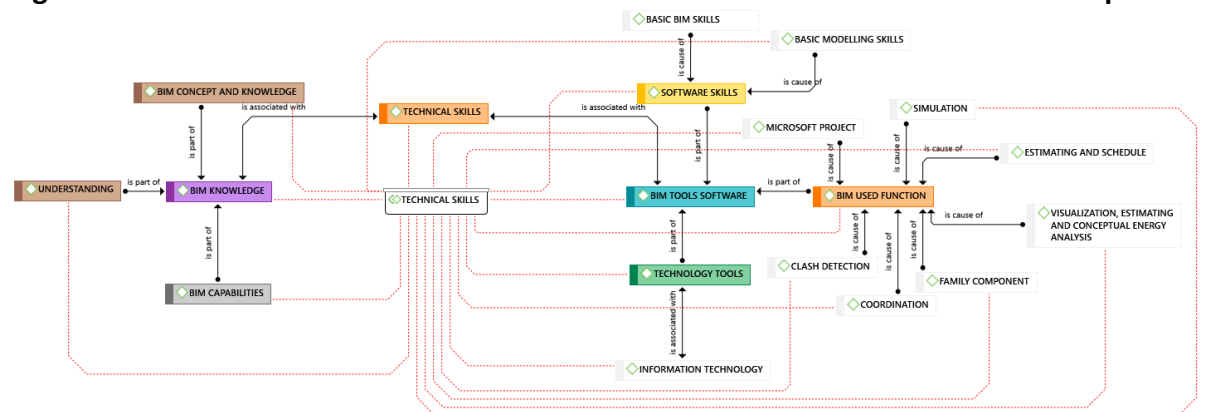


Figure 6. The tabulation of Technical BIM skills discuss by authors

Technical Skills

Technical skills refer to an individual’s (i) technical expertise to operate BIM software tools, as well as his/her (ii) knowledge of digital tools and BIM standards (Abdirad & Dossick, 2016; Azzouz & Papadonikolaki, 2020). The increasing uptake of BIM in the AEC industry necessitates construction players to have strong BIM expertise and knowledge in using specific software applications (Ismail et al., 2019). Specifically, the individuals involved need to improve their technical skills in using Autodesk Revit, AutoCAD, Naviswork Manage, and Microsoft Project.

a. BIM Knowledge

Knowledge in BIM is essential for practitioners and therefore can increase the employability of new graduates. Following the evolvement of the BIM technology, most employers expect recent graduates and employees to possess BIM knowledge before entering the industry.

According to Hodorog et al. (2019), the construction industry prefers to recruit future employees with intensive conceptual knowledge of BIM rather than those with mere BIM application skills. Therefore, the inclusion of intensive training in BIM in the university curriculum can provide graduates with better understanding of the BIM process hence improving their knowledge of the technology and processes (Ismail et al., 2019). The knowledge gained will lead them to better future career development in BIM construction. Nevertheless, technical knowledge remains critically important in BIM-related projects (Hallowell et al., 2014).

BIM modellers must be equipped with the knowledge of the design process because they must “design” using BIM technologies (Barison and Santos, 2019). Rosli et al (2016) highlighted that the future generation of architects needs to acquire knowledge of these technologies in their early educational years. Holzer (2015) maintained that BIM application skills are useful when applying for a job. Hence, the individuals involved must be able to apply both knowledge and technical knowledge (BIM software tools) in such projects.

b. BIM Software Tools

The literature also indicates software skills are the most preferred skills. Various softwares are used in BIM-related projects, such as Revit, ArchiCad, Naviswork (Kovacic & Filzmoser, 2015). These tools can provide various possibilities for exchange of data and collaboration in the construction industry (Hodorog et al., 2019). A study by Huang (2017) found that laser scanning, virtual reality, and mixed reality were also adopted in BIM-related projects in the AEC industry. These technologies upgrade the usage and function by the development of technology. In another study, Shelbourn et al (2017) highlight the importance of integrating BIM resources into all university curricula. To be more competitive in the future, architectural graduates need to acquire advanced skills in using the technologies related to BIM projects. Previous researchers have also raised the issue of lack of knowledge on BIM software tools among graduates. According to Ismail et al (2019), most graduates have low existing skills and knowledge in using BIM software tools applications, such as Autodesk Revit and Naviswork Manage Software. Graduates need to know the operational tools for creating a model and analysing the effective collaborative of BIM model (Sampaio, 2014). According to Hodorog et al (2019), BIM curriculum programmes should emphasise understanding computer application concepts and BIM processes. In the same vein, Shelbourn et al. (2017) maintained that university programmes should emphasise BIM tools in their curriculum. The programmes in the United States mostly focus on BIM to enhance their students’ basic or intermediate knowledge of BIM, the purpose being to facilitate their adaptability with the rapidly changing technologies in the industry (Hallowell et al., 2014). Elliott et al. (2019) note that partnering with the industry can provide the necessary skill sets and knowledge of the BIM manipulation model and benefit the graduates. Hence, a curricula programmes should enhance graduates’ relationship with the industry and allow them to harness their skills to undertake BIM-related projects.

Individuals entering the AEC workforce must also be skilled in operating related software tools application and BIM software tools. A study by Holzer (2015) identified skills in BIM Modelling, 3D Visualization, Parametric Modelling, and 2D Cad Drafting as the technical skills most demanded by employers. According to Wu & Issa (2014, as cited by Abdirad & Dossick, 2016), BIM software skills are rated by the industry as the most expected learning outcomes in BIM education at the university level. Similar issue is discussed by Raiola (2016), who advocated that individuals work competently with BIM software associates within the industry. In another study, Zhao et al. (2015), as cited by Elliott et al., (2019) found that the skills of

maneuvering BIM and related technology are the skill sets most expected by the industry. Another recent study by Ismail et al., (2019) also highlighted that graduates with good technical skills in using Autodesk Revit, AutoCAD, Naviswork Manage, and Microsoft Project could benefit from future employment. Nevertheless, the skills mentioned are still lacking among architectural graduates and particularly discussed scantily in the existing literature. More reviews are needed on the skills necessary for architectural graduates, specifically in BIM.

Nontechnical Skills

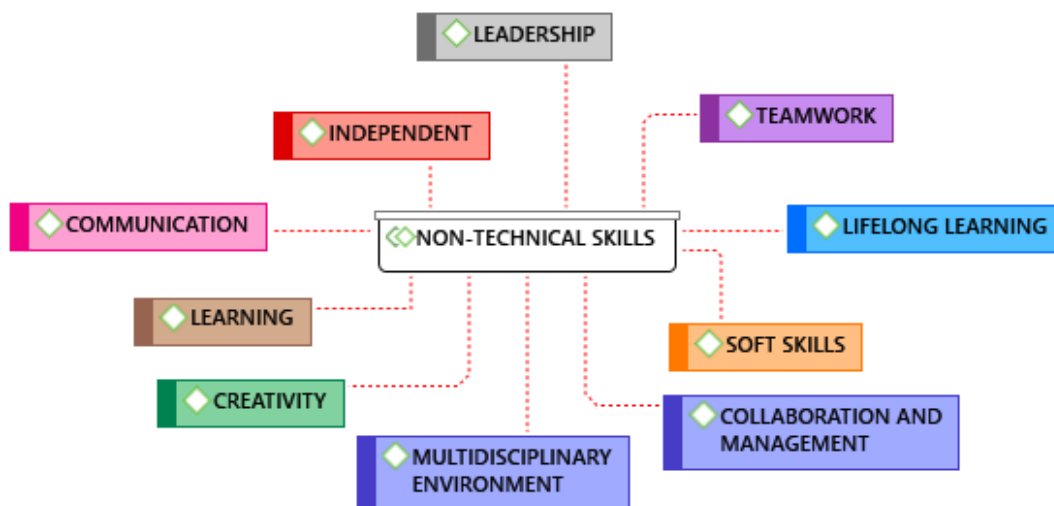


Figure 7. Tabulation of BIM nontechnical skills discussed by previous researchers

Previous researchers have referred to “nontechnical skills” using a myriad of terms hence the varying interpretations. Studies pertaining to “nontechnical skills” within the Malaysian context tend to revolve around the use soft skills, generic skills, and employability. Nontechnical skills (such as communication and organisation skills) are noted to be equally important as technical skills (such as the skill of using software tools and interoperability) (Kovacic & Filzmoser, 2015).

Various nontechnical skills were identified to be necessary for employability in firms undertaking BIM-related projects. BIM diffusion necessitates soft skills; Azzouz and Papadonikolaki (2020) confirmed the finding of Papadonikolaki and Oel (2016) that consultants have been perceiving their role to be more soft than hard due to the digital technologies involved. Another study by Solnosky, Parfitt & Holland (2014) found that the need to harness not only technical skill but also soft skills among graduates entering into the construction industry workforce.

Previous surveys also identified the importance of communication skills, teamwork, and analytical thinking in facilitating the use of BIM tools, BIM coordination, and BIM knowledge in workflow and standards (Abdirad & Dossick, 2016). Davies et al. (2015), cited by Yakami et al. [2018]) focused on soft skills like collaboration and communication, negotiation, teamwork, leadership, and conflict management. Whereas Barison & Santos (2011), as cited by Hodorog et al. [2019] and Yakami et al. [2018]) looked into individual competencies, including qualifications, knowledge and attitude, qualifications, and aptitude, as well as the professional needs for the position in terms of foundation and functionality ways. The key requirements for both BIM and parametric design, from practice to academic education, encourage students to (i) think critically, (ii) be responsive and alert to the new emerging

technologies, (iii) respond quickly to the evolving situations, (iv) communicate confidently, and (iv) manage information in a multidisciplinary (Holzer, 2015).

According to Raiola (2016), previous researchers have found that BIM requires new soft skills such as good written and verbal communication, interpersonal skills, leadership, and ethical skills. BIM requires efficient communication along with good soft skills. The final skill, written communication, is important because in construction projects, intents and requirements are communicated through writing. Graduates will improve their communication and team management skills with comprehensive and intensive BIM training prior to entering the industry (Ismail et al., 2019). According to Shelbourn et al. (2017), an individual should know how to interact with other BIM members in order to communicate their tasks more efficiently. Another empirical study by Kepczynska-Walczak (2020) found that communication and cooperation skills are important in work practices. Hence, to work effectively in a BIM-related project, communication skills are important as the ability enables cooperation with other team members.

The key feature of BIM is that it enables a multidisciplinary teamwork. Therefore, it is necessary that BIM applications be incorporated into an interdisciplinary context (Hardi, 2015). Teamwork is required in a BIM project, and therefore, ethics, interpersonal abilities, and verbal facility and leadership skills will be the essential BIM skills (Raiola, 2016). A BIM education programme should also aim to harness individual as well as team skills and competencies (Hodorog et al., 2019). Yakami et al. (2018) highlight the communication and teamwork skills required in the curricula. A study by Azzouz and Papadonikolaki (2020) corroborated Liu et al. (2011) that leadership is needed in the AEC sector for teamwork and collaboration to succeed.

Furthermore, BIM also encourages multidisciplinary team collaboration (Hardi, 2015). Yet, at most, there is a lack of practice in an interdisciplinary environment (Kepczynska-Walczak, 2020). According to Lucena et al. (2015), BIM optimises team collaboration, thus enabling project managers to communicate the project's intent to all stakeholders more reliably. The idea of collaborative design and the usefulness of BIM should be instilled in undergraduates prior to entering the workforce. The essential pedagogy must focus not only on design and detail but also on how to engage and lead others and collaborate with the professionals they will work with later (Shelbourn et al., 2017). In particular, individuals shall possess the following BIM-related skills to enhance their future employability: communication, teamwork, leadership, and collaboration. Future studies shall focus more on these skills to improve BIM implementation in the construction industry.

Conclusion and Future Studies

This article reviewed publications related to the skills required from architectural graduates necessary to undertake BIM-related projects. The findings from the code-to-document analysis in ATLAS.ti 8 indicated two types of BIM skills: technical and nontechnical skills. This paper has identified the thematic codes (with regard to the skills) within the previous studies published between 2010 and 2020. The technical skills necessary are knowledge of BIM technology and BIM software tools – this imply a deep understanding about BIM, its uses and software capabilities. The nontechnical skills necessary are communication and teamwork, especially when projects using BIM involves complex processes coming in various disciplines and professionals.

The findings presented a gap in the previous studies with regard to whether practical construction experience on-site is necessary as part of BIM skills needed among architectural

graduates. This was not touched by any researchers. Most of the publications focus on construction management, BIM managers, engineering, and quantity surveyor; and limited studies have identified the BIM-related skills required from architecture graduates. Yet, there is an increasing uptake of BIM projects in the Malaysian construction industry following the government's recommendations. However, implementing BIM requires technical skills among semi-skilled workers with the necessary technical and nontechnical skills in BIM. The findings, therefore, suggest that within Malaysian context, fresh graduates should possess BIM skills to support future construction industry development. Therefore, it is beneficial to study the necessary skills required in BIM demands to help academicians prepare graduates with the appropriate skills. More publications are needed to support BIM implementation in an effort to enhance the awareness of BIM skills necessary by architectural graduates on its benefit.

Contributions and Benefits of Study

This paper analyses BIM skills required from architectural graduates by extensively identifying the thematic codes within BIM publications from 2010 to 2020. The findings will benefit future research directions and identify the gaps in BIM studies in Malaysia, specifically for architectural graduates for employment.

Acknowledgements

The author would like to thank the *Hadiah Latihan Persekutuan* (HLP), Ministry of Higher Education, for supporting the carry-out project.

References

- Abd Hamid, A. B., Embi, M. R., Mohd Taib, M. Z., & Abdul Razak, A. H. N. (2020). Enhancing the Knowledge and Proficiency for Interior Designers in Malaysia through the Implementation Building Information Modelling. *IOP Conference Series: Materials Science and Engineering*, 713(1). <https://doi.org/10.1088/1757-899X/713/1/012047>
- Abdirad, H., & Dossick, C. S. (2016). BIM curriculum design in architecture, engineering, and construction education: A systematic review. *Journal of Information Technology in Construction*, 21(May), 250–271.
- Ahmad Jamal, K. A., Mohammad, M. F., Hashim, N., Mohamed, M. R., & Ramli, M. A. (2019). Challenges of Building Information Modelling (BIM) from the Malaysian Architect's Perspective. *MATEC Web of Conferences*, 266, 05003. <https://doi.org/10.1051/mateconf/201926605003>
- Azmi, N. F., Chai, C. S., & Chin, L. W. (2018). Building information modeling (BIM) in architecture, engineering and construction (AEC) industry: A case study in Malaysia. *Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate, 2016*, 209889, 401–421. https://doi.org/10.1007/978-981-10-6190-5_36
- Azzouz, A., & Papadonikolaki, E. (2020). Boundary-spanning for managing digital innovation in the AEC sector. *Architectural Engineering and Design Management*, 16(5), 356–373. <https://doi.org/10.1080/17452007.2020.1735293>
- Barison, M. B., & Santos, E. T. (2011). The Competencies of BIM Specialists: a Comparative Analysis of the Literature Review and Job Ad Descriptions. *Computing in Civil Engineering 2011*, 194–201.
- Barison, Maria Bernardete, & Santos, E. T. (2019). An overview of BIM specialists. *EG-ICE 2010*

- 17th International Workshop on Intelligent Computing in Engineering, January 2016.
- CIDB. (2019). The Construction Industry Transformation Program (CITP) 2016 – 2020 Mid-term. *Construction Industry Development Board Malaysia (CIDB), January 2019, 2016–2020.*
- Clarke, V., & Braun, V. (2013). Teaching thematic analysis : Overcoming challenges and developing strategies for effective learning Associate Professor in Sexuality Studies Department of Psychology Faculty of Health and Life Sciences University of the West of England Coldharbour Lane Br. *University of the West of England, 26, 120–123.*
- Davies, K., McMeel, D., & Wilkinson, S. (2015). Soft skill requirements in a BIM project team. *Proceedings of the 32nd International Conference of CIB W78, 108–117.* <http://itc.scix.net/data/works/att/w78-2015-paper-011.pdf>
- Elliott, J. W., Glick, S., & Valdes-Vasquez, R. (2019). Student perceptions of model-based estimating. *International Journal of Construction Education and Research, 15(2), 118–135.* <https://doi.org/10.1080/15578771.2018.1460642>
- Ghosh, A. (2012). Virtual Construction + Collaboration Lab : Setting a new paradigm for BIM education. *American Society for Engineering Education.* <https://doi.org/10.18260/1-2--22216>
- Hallowell, M., Tatum, C., & Rowings, J. (2014). Findings and Path Forward: Leveraging Project and Career Success. *Practice Periodical on Structural Design and Construction, 19(1), 142–147.* [https://doi.org/10.1061/\(asce\)sc.1943-5576.0000194](https://doi.org/10.1061/(asce)sc.1943-5576.0000194)
- Hardi, J. (2015). Case Study: Lessons Learned From Building Information Modelling (BIM) Extracurricular Activity Organised for Architecture, Engineering and Construction Students Within a Uk University. *Rics Cobra Aubea 2015, July, 12.*
- Haron, N. A., Raja Soh, R. P. Z. A., & Harun, A. N. (2017). Implementation of building information modelling (Bim) in malaysia: A review. *Pertanika Journal of Science and Technology, 25(3), 661–674.*
- Hodorog, A., Alhamami, A. H. S., Petri, I., Rezgui, Y., Kubicki, S., & Guerrero, A. (2019). Social media mining for BIM skills and roles for energy efficiency. *Proceedings - 2019 IEEE International Conference on Engineering, Technology and Innovation, ICE/ITMC 2019, 1–10.* <https://doi.org/10.1109/ICE.2019.8792571>
- Holzer, D. (2015). BIM and parametric design in academia and practice: The changing context of knowledge acquisition and application in the digital age. *International Journal of Architectural Computing, 13(1), 65–82.* <https://doi.org/10.1260/1478-0771.13.1.65>
- Huang, Y. (2017). Introducing an advanced Building Information Modeling course in construction management programs. *ASEE Annual Conference and Exposition, Conference Proceedings, 2017-June.* <https://doi.org/10.18260/1-2--28576>
- Ismail, A. S., Ali, K. N., Mustaffa, N. E., A. Iahad, N., & Yusuf, B. Y. (2019). Enhancing the Graduates' Employability and Career Development Through Building Information Modelling Intensive Training. *International Journal of Built Environment and Sustainability, 6(1–2), 91–99.* <https://doi.org/10.11113/ijbes.v6.n1-2.387>
- Kepczynska-Walczak, A. (2020). Building Information Modelling for 2020+ Realm Contemporary practice and future perspectives. *BIM | Concepts - Volume 1 - ECAADe 36, 1, 271–280.*
- Kovacic, I., & Filzmoser, M. (2015). Designing and evaluation procedures for interdisciplinary building information modelling use—an explorative study. *Engineering Project Organization Journal, 5(1), 14–21.* <https://doi.org/10.1080/21573727.2014.989426>
- Liu, J., Kramer, S., & Ph, D. (2011). East Meets West : Teaching BIM in a Study Abroad Class

- with Chinese & American University Students. *47th ASC Annual International Conference Proceedings*.
- Lucena, A., Mah, D., & Arain, F. (2015). Enabling Building Information Modeling (BIM) practices in the Canadian construction industry: A case for an academic program. *ASEE Annual Conference and Exposition, Conference Proceedings, 122nd ASEE(122nd ASEE Annual Conference and Exposition: Making Value for Society)*. <https://doi.org/10.18260/p.23934>
- Musa, S., Marshall-Ponting, A., Nifa, F. A. A., & Shahron, S. A. (2018). Building information modeling (BIM) in Malaysian construction industry: Benefits and future challenges. *AIP Conference Proceedings, 2016(September)*. <https://doi.org/10.1063/1.5055507>
- Raiola, J. A. I. I. I. (2016). Employability Skills in BIM for Construction Managers: Recommendations for Education. *ASEE Annual Conference and Exposition, Conference Proceedings*.
- Rosli, M. F., Razak, A. S., & Younus, A. M. (2016). To BIM or not to BIM: A pilot study on University of Malaya's architectural students' software preference. *Journal of Design and Built Environment, 16(1)*, 13–26. <https://doi.org/10.22452/jdbe.vol16no1.2>
- Sampaio, A. Z. (2014). Teaching Building Information Modelling in an Architectural School. *ASA 2014 - 48th International Conference of the Architectural Science Association (ANZAScA)*, 421–432.
- Shelbourn, M., Macdonald, J., McCuen, T., & Lee, S. (2017). Students' perceptions of BIM education in the higher education sector: A UK and US perspective. *Industry and Higher Education, 31(5)*, 293–304. <https://doi.org/10.1177/0950422217725962>
- Solnosky, R., Parfitt, M. K., & Holland, R. J. (2014). IPD and BIM-focused capstone course based on AEC industry needs and involvement. *Journal of Professional Issues in Engineering Education and Practice, 140(4)*, 1–11. [https://doi.org/10.1061/\(ASCE\)EI.1943-5541.0000157](https://doi.org/10.1061/(ASCE)EI.1943-5541.0000157)
- Wu, W., & Issa, R. R. A. A. (2014). Key Issues in Workforce Planning and Adaptation Strategies for BIM Implementation in Construction Industry. *Construction Research Congress 2014, 2008*, 140–149.
- Yakami, M., Singh, V., Suwal, S., Yakami, M., Singh, V., Suwal, S., Do, W., & Think, P. (2018). *What Do Students and Professionals Think of BIM Competence ?*
- Zairul, M. (2020). A thematic review on student-centred learning in the studio education. In *Journal of Critical Reviews (Vol. 7, Issue 2, pp. 504–511)*. <https://doi.org/10.31838/jcr.07.02.95>
- Zhao, D., McCoy, A. P., Bulbul, T., Fiori, C., & Nikkhoo, P. (2015). Building Collaborative Construction Skills through BIM-integrated Learning Environment. *International Journal of Construction Education and Research, 11(2)*, 97–120. <https://doi.org/10.1080/15578771.2014.986251>