

## Challenges of BIM integration in construction education: The Ghanaian perspective

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ARTICLE INFO	ABSTRACT
<p><i>Article history:</i>            Received April 23, 2025            Received in revised form Oct. 10, 2025            Accepted November 11, 2025            Available online December 01, 2025</p> <p><i>Keywords:</i>            BIM            Construction education            Technical university            Technology adoption            Technology integration</p> <p><b>*Corresponding author:</b> Tutin Aryanti            Department of Architectural Education,            Universitas Pendidikan Indonesia            Email: <a href="mailto:tutin@upi.edu">tutin@upi.edu</a>            ORCID: <a href="https://orcid.org/0000-0001-6986-0680">https://orcid.org/0000-0001-6986-0680</a></p>	<p><i>Despite the global embrace of BIM as a form of digital transformation in the global construction sector, Ghana remains sluggish in its adoption of this technology, partly due to the scarcity of BIM-trained professionals. This study examines the integration of BIM within construction education curricula in Ghanaian technical universities and identifies the key challenges hindering its integration. A quantitative research methodology was employed, utilizing standardized questionnaires administered to academic staff from five Ghanaian technical universities running construction programs. A total of 59 valid responses were analyzed using SPSS 26 for descriptive statistics to examine the present state of BIM integration in academic curricula. Subsequently, Structural Equation Modeling (SEM) was employed in identifying and validating the critical challenges hindering BIM integration. The findings reveal that BIM integration into construction curricula remains limited, with BIM primarily taught through workshops or partially integrated into existing courses rather than being a standalone course. Key challenges include a lack of faculty expertise and training, limited educational resources, high training costs and inadequate IT infrastructure. SEM results confirmed the significance and interrelated nature of these challenges. Respondents emphasized the need for mandatory inclusion of BIM in curricula to align with global industry standards and to guarantee that graduates are well prepared for the digital challenges present in the construction industry. The study emphasizes importance of aligning educational programs with industry demands to mitigate the skills gap and facilitate the rapid digitalization of Ghana's construction industry.</i></p>

### Introduction

Recent technological advancements, such as Building Information Modeling (BIM), are strongly driving the digital revolution of the construction industry. The integration of BIM in the industry's workflow is well acknowledged to improve project design, construction and management. With the integration of BIM as a digital platform, construction projects become

more efficient, accurate, and sustainable (Ding et al. 2015; Sinenko et al. 2020).

Most developed countries are pushing for increased BIM adoption in their construction industries because of the potential benefits. With the support of policy frameworks, many higher education institutions have included BIM in construction education curricula to continuously produce skilled professionals for the sector (Amin, Mills, and Wilson 2023). However, there has been a slow rate of adoption in many



developing countries, which present a significant challenge for their industries.

These challenges are particularly evident in Sub-Saharan African countries like Ghana, where technology adoption is often not a priority. Currently, there is not enough BIM-skilled professionals in Ghana, which impedes the technology's widespread implementation (Acquah, Eyiah, and Oteng 2018; Leslie Appiah 2020; Bamfo-Agyei and Nani 2015). Central to this is the inadequate integration of BIM in construction education. It is anticipated that higher educational institutions align their curricula with current technological trends and industry demands by incorporating BIM (Babatunde and Ekundayo 2019). This has somehow been achieved in countries like the US, UK and Australia, where the educational curricula enable graduates to be trained to meet the construction industry's growing digital requirement (Adamu and Thorpe 2015).

The persistence inefficiencies evident in Ghana's construction industry show the urgency to align educational curricula with global trends. To improve construction project delivery in an increasingly digital global economy, educational materials need to reflect the global happenings in construction sector. construction industry. Failure to adequately integrate BIM in construction education curricula would create a digital skills gap and limit the industry's ability to overcome present challenges with project delivery.

BIM education has been widely researched in developed countries. However, less is known about the challenges to the integration of BIM in construction education curricula in developing countries such as Ghana (Kissi, Aigbavboa, and Kuoribo 2023). As such, this study examines the challenges hindering BIM integration in construction education curricula in Ghana's technical universities. It presents the current state of BIM integration and investigates the key challenges arising. It is expected that the study would provide key information for stakeholders to develop context-specific strategies for overcoming the challenges and contribute to the broader conversation on BIM education in developing economies.

## Literature review

### Global trends in BIM adoption

BIM has become an important technological tool in the global construction industry. It has

become the go-to digital platform that most industry professional rely to improve project workflow. Countries at the forefront of its adoption include Australia, the UK, the US, and Singapore. These countries have instituted national policies that require BIM use on public projects. To abide by the "Government Construction 2025" policy in the UK, all government projects needed to use collaborative BIM Level 2, greatly increasing BIM use across the industry (Awwad, Shibani, and Ghostin 2022; Burgess, Jones, and Muir 2018). Similarly, Singapore and South Korea required BIM for all publicly financed projects by 2015 and 2016, respectively, demonstrating their commitment to digital construction technology (Cheng and Lu 2015).

Although BIM adoption has greatly improved in developed countries, it is hardly used in many regions, including the Middle East and Africa. Adoption rates in these regions are generally low, because of technical, financial, and human resource issues, such as shortage of BIM-skilled professionals (Gerges et al. 2017; Zakeri et al. 2023). El Hajj, Martínez Montes, and Jawad (2023) identified the absence of standardization and inadequate training programs as the primary challenges to BIM adoption in Lebanon and other Middle Eastern countries. These challenges underscore the need for targeted educational programs that equips the potential workforce with the requisite BIM skill needed in regions with emerging construction markets.

### Challenges in developing economies: The case of Ghana

The construction industry in Ghana is beset with multiple challenges. These challenges which are frequently blamed on lack of stakeholder collaboration includes project delays, cost overruns, and substandard project outcomes (Ofori-Kuragu 2020). Although BIM has the potential to address these challenges, adoption has been slow due to several factors, primarily the low awareness and insufficient expertise among industry professionals (Acquah, Eyiah, and Oteng 2018; Bamfo-Agyei and Nani 2015). Acquah, Eyiah, and Oteng (2018) found that BIM use in Ghana's construction industry remains superficial, limited to basic tasks like 3D modelling and design visualization. According to Armah (2015) and Leslie Appiah (2020), insufficient understanding of BIM among smany industry professionals is a major obstacle to its widespread

adoption. The slow adoption rate is also due to the lack of BIM training programs, which worsens the skills gap within the industry (Leslie Appiah 2020; Oteng et al. 2018).

Although efforts have been made to integrate BIM into construction education curricula, the absence of policy framework for guidance has made the process slow (Bamfo-Agyei and Nani 2015). These challenges are not unique to Ghana. (Babatunde and Ekundayo 2019) reported similar problems in other developing nations such as Nigeria, where limited institutional support and inadequate educational resources are found to impede BIM adoption. In view of these many HEIs have recognized the necessity of integrating BIM into educational curricula to prepares students for the requirements of the evolving construction industry. A number of approaches have been adopted, including the introduction of independent BIM courses, cross-disciplinary integration, and BIM workshops (Huang 2016). These institutions aim to provide students with the requisite BIM design, scheduling, visualization, and coordination competencies (Singh 2025). In spite of these efforts, many educational institutions struggle to include BIM in the curricula due to the lack of faculty expertise and the absence of accreditation criteria (Ghosh, Parrish, and Chasey 2015). This highlights the growing necessity for context-specific approaches in the integration of BIM in educational curricula (Casasayas et al. 2021).

#### Bridging the gap in Ghana

To effectively implement BIM in Ghana's construction industry, the existing digital gap needs to be filled. A study by Leslie Appiah (2020) found a limited basic understanding of BIM concepts among Ghanaian construction professionals. He highlighted a significant knowledge deficit that slows down the adoption process. To overcome such knowledge deficit and encourage widespread use of BIM, educational initiatives that involve the incorporation of BIM competencies into higher education programs is strongly recommended (Adam et al. 2022; Telaga 2022; Zhang, Schmidt, and Li 2016). These authors call for better BIM training programs that are essential for preparing future workers to take the lead in applying BIM.

Improving BIM education in Ghana requires a multi-stakeholder collaboration between the construction industry, government and HEIs. Evidence from successful BIM education

initiatives have revealed how beneficial such collaboration in aligning BIM education with workforce needs (Panuwatwanich et al. 2013). Active government involvement, mainly through supportive policies and funding, has been shown to accelerate BIM integration. According to Jiang et al. (2022); Ismail, Chiozzi, and Drogemuller (2017), government mandate for BIM education in places like Hong Kong and Singapore have resulted in the creation of a highly skilled BIM workforce.

Likewise, in the context of Ghana, engagements by HEIs with industry stakeholders to co-develop BIM education curricula can be a vital step towards equipping graduates with the requisite digital competencies to succeed in an increasingly competitive and evolving construction sector. Technical universities in Ghana hold a pivotal role in this process due to their focus on providing practical training essential for developing a skilled workforce that meets the demands of the industry. Sam-Amoah, Frimpong, and Kumi (2020) indicate that these institutions are in a prime position to train students in the applied sciences and technology, which are important in the rapidly growing fields of engineering and construction, where BIM is making an impact. However, prior research has highlighted limited IT infrastructure, insufficient instructional resources, and a lack of faculty (Leslie Appiah 2020; Oteng et al. 2018).

**Table 1.** List of BIM integration challenges

Challenge	References
Lack of faculty expertise and training to teach BIM	(Ahmed 2018; El Hajj et al. 2021)
Limited BIM-related educational resources for students	(Aljarman et al. 2020; Silverio et al. 2023)
High cost of training lecturers	(Gamil and Rahman 2019)
Lack of IT infrastructure	(Ahmed 2018; Kassem et al. 2012)
Lack of government initiative to include BIM in education	(Jiang et al. 2022)
Lack of BIM teaching materials	(Bensalah, Elouadi, and Mharzi 2019)
Lack of qualified experts to advise on BIM curriculum	(Ahmed et al. 2013; Alreshidi et al. 2017)
Lack of university management support	(Doan et al. 2021)
Poor internet connectivity	(Silverio et al. 2021)
Lack of collaboration with industry	(El Hajj et al. 2021)
Lack of time and resources to develop a new course	(Kassem, Brogden, and Dawood 2012)

Challenge	References
Limited ICT skills of lecturers	(Gamil and Rahman 2019)
Lack of accreditation criteria to guide the integration	(Ahmed 2018)
Lack of understanding about BIM	(Aljarman et al. 2020)
Lack of student demand	(Silverio et al. 2023)
Hesitation to change or modify the current curriculum	(Doan et al. 2021)
Difficulty in selecting suitable BIM software	(Alreshidi et al. 2017)
Difficulty in incorporating BIM features into the curriculum	(Kassem, Brogden, and Dawood 2012)

## Methods

The study employs a quantitative methodology to collect and analyze data on the challenges of BIM integration within construction education curricula in Ghanaian Technical Universities. This approach complements existing qualitative research in BIM education by providing empirical insights into faculty perceptions, which are essential for understanding the scope and challenges of BIM integration in an academic context. The target population comprised academic staff from five (5) technical universities in Ghana offering accredited construction-related programs. These institutions have academic staff who teach architectural technology, building technology, civil engineering, and construction management programs. The structured questionnaire consisted of three main sections: (1) Demographic Information that collected information on academic qualifications, years of experience, and familiarity with BIM were collected; (2) Status of BIM in Current Curricula which collected information on how BIM is integrated into construction programs; and (3) Challenges to BIM Integration which collected data on challenges hindering effective BIM integration into construction curricula.

To verify the instrument's reliability and to refine the questions based on participant feedback, a pilot test was conducted. A Cronbach's alpha coefficient of 0,890 was obtained from a test using SPSS version 26. This indicates strong internal consistency of the Likert scale items, since values exceeding 0,7 are deemed acceptable (Hajjar 2018). A literature review and input from academic experts in BIM

and construction education were important in ensuring content validity. These steps ensured that the questionnaire accurately measured the intended constructs and reflected current trends in BIM education. The study comprised a sample size of 59 academic staff. The data gathered were analysed with the help of SPSS version 26. Descriptive statistics were used to capture the respondents' demographic characteristics and assess the status of BIM integration within construction education curricula. Factor analysis was used to aggregate related challenges into underlying constructs. Thereafter, Structural Equation Modeling (SEM) was utilised to validate and analyze the correlations among the identified challenges. This provided a robust statistical framework to determine their significance and inter-dependencies. The analysis made it possible to highlight and prioritize key challenges that needs to be addressed to ensure the effective integration of BIM in construction education curricula of Ghanaian technical universities.

## Results and discussion

### Demographics of respondents

The demographic features of the respondents surveyed offer a vital context for understanding their perspectives on BIM integration. As indicated in table 2, a significant 71,2% of the respondents hold a master's degree and 27,1% with a PhD. This high level of academic attainment suggests that the respondents have substantial knowledge and experience in their respective fields, which could influence their insights on BIM integration. Additionally, 45.8% of those surveyed reported having 6 to 10 years of teaching experience, which suggests a relatively experienced group of faculty members.

These demographic insights align with findings from similar studies conducted in other regions. For instance, research in Nigeria reported that most faculty members advocating for BIM integration had postgraduate qualifications and extensive teaching experience (Babatunde and Ekundayo 2019). This consistency suggests that experienced and well-qualified educators recognize the value of BIM in education and advocate for it to be integrated.

**Table 2.** Demographics of respondents

Profile of Respondents	Frequency	Percentage (%)
<i>Academic qualification</i>		
Bachelor's Degree	1	1,7
Master's Degree	42	71,2
Ph.D.	16	27,1
Total	59	100,0
<i>Years of Experience as academic staff</i>		
Less than 5 years	14	23,7
6 - 10 years	27	45,8
16 - 20 years	17	28,8
More than 20 years	1	1,7
Total	59	100,0

### BIM knowledge and experience

Regarding BIM knowledge, 52,5% of respondents reported having a fair understanding of BIM, while 33,9% indicated good knowledge. Only 8,5% of respondents reported poor knowledge, and 5,1% reported good understanding of BIM. This distribution points to a moderate degree of familiarity with BIM among academic staff. Furthermore, almost half of the respondents (47,5%) reported having 2 to 5 years of experience using BIM, while 32,2% had fewer than 2 years of experience. However, 3,4% of them had no experience with BIM, highlighting a gap in exposure that could limit the effectiveness of integration efforts.

These findings (table 3) are consistent with studies in other developing countries, such as Jordan, where a limited understanding of BIM among faculty has been identified as a significant challenge to integration (Matarneh and Hamed 2017). The moderate levels of BIM experience in this study suggest a need for targeted faculty development initiatives to build capacity and expertise.

**Table 3.** BIM knowledge and experience of academic staff

	Frequency	Percentage (%)
<i>Respondents' BIM knowledge</i>		
Poor	5	8,5
Fair	31	52,5
Good	20	33,9
Very Good	3	5,1
Total	59	100,0
<i>Respondents' years of BIM experience</i>		
No experience	2	3,4

	Frequency	Percentage (%)
Less Than 2 years	19	32,2
Between 2-5 years	28	47,5
More than 5 years	10	16,9
Total	59	100,0

### State of BIM in construction curricula

When asked about the current integration of BIM into construction programs, 21,3% of respondents indicated that their universities offer standalone BIM courses (table 4). However, most reported that BIM is integrated into existing courses (39,4%) or provided through workshops and training sessions (39,4%). This relatively low percentage of standalone courses raises concerns about whether students receive comprehensive BIM instruction. Standalone courses are critical for equipping students with dedicated and in-depth knowledge of BIM, a strategy successfully implemented in places like the UK and Australia (Adamu and Thorpe 2015).

The preference for integrating BIM into existing courses or offering workshops reflects a broader trend observed in other developing countries, where universities often face resource constraints in establishing full-fledged BIM courses (Panuwatwanich et al. 2013). This trend highlights the need for institutions in Ghana and similar contexts to invest in dedicated BIM programs to appropriately equip students are adequately prepared for the industry's digital demands.

**Table 4.** Current approach to BIM integration in the curriculum

BIM integration approach	Responses		Percent of Cases
	N	Percent	
Standalone course(s)	20	21,3%	33,9%
Integration into existing courses	37	39,4%	62,7%
Workshops and training sessions	37	39,4%	62,7%

### Course domains with BIM integration

The survey revealed that BIM is most commonly integrated into design-related courses (36,6%), followed by construction-related courses (31,7%). Project management and estimation courses were less likely to incorporate BIM, with only 18,8% and 12,9% integration, respectively. This disparity suggests that students may miss out on critical aspects of BIM's extensive applications in project management and cost estimation - skills vital for successful project delivery in the construction sector. Similar findings have been reported in other contexts,

such as the Middle East, where BIM integration primarily focuses on design and visualization, with limited emphasis on broader applications (Gerges et al. 2017). This indicates that the curricula design in Ghana aligns with global patterns but highlights the need for more holistic integration to cover all critical aspects of BIM.

**Table 5.** Course domains with dominant BIM integration

Courses in which BIM is mostly integrated	Responses		Percent of Cases
	N	Percent	
Design related courses	37	36,6%	64,9%
Construction related courses	32	31,7%	56,1%
Project management-related courses	19	18,8%	33,3%
Estimation related courses	13	12,9%	22,8%

#### Perception of BIM in construction education curricula

Academic staff generally recognized the importance of BIM in construction curricula (table 6), yielding a mean score of 4,02 (SD = 0.799). However, the frequency of BIM lessons was rated as only average (mean score 3,39, SD = 0,871), and respondents expressed dissatisfaction with the current level of integration (mean score 2,86). Notably, there was strong advocacy for making BIM mandatory, with a mean score of 4,39 (SD = 0,695).

These findings are consistent with studies in other developing countries, such as Nigeria and Jordan, where educators have called for the mandatory inclusion of BIM in construction curricula to better prepare students for industry requirements (Babatunde and Ekundayo 2019; Matarneh and Hamed 2017). The perceived importance of BIM, contrasted with the low frequency and satisfaction levels, highlights the necessity for more comprehensive and standardized BIM education.

**Table 6.** BIM and the construction curricula

BIM in the current construction curricula	Min	Max	Mean	SD
Importance of BIM in construction curricula	2	5	4,02	0,799
Frequency of BIM lessons	1	5	3,39	0,871
Satisfaction with the current level of BIM	1	5	2,86	1,058

BIM in the current construction curricula	Min	Max	Mean	SD
integration in the curricula				
Need for BIM to be a mandatory course in construction programs	1	5	4,39	0,695

#### BIM software preferences

Autodesk Revit Suite appeared as the most commonly used BIM tool in construction programs, with 86,0% of respondents indicating its use. Other popular software included Staad (31,6%) and Primavera P6 (33,3%). This focuses on industry-standard tools like Revit, which dominates the global BIM landscape. However, limited exposure to various BIM tools could constrain students' skill sets and adaptability in the job market.

This emphasis on Revit parallels findings in other regions, such as Singapore and the Middle East, where Revit is the dominant BIM tool used in academia and practice (Gerges et al. 2017). The reliance on a few essential software programs highlights the need for expanded training to include a broader range of tools.

**Table 7.** Common BIM software used for academic work

BIM software	Responses		Percent of Cases
	N	Percent	
Autodesk Revit Suite	49	39,2%	86,0%
ArchiCAD	10	8,0%	17,5%
Bentley BIM Suite	1	0,8%	1,8%
Staad	18	14,4%	31,6%
Ecotect	4	3,2%	7,0%
Navisworks	3	2,4%	5,3%
Robot Structures	6	4,8%	10,5%
BIM 360	7	5,6%	12,3%
Trimble Connect	1	0,8%	1,8%
Primavera P6	19	15,2%	33,3%
Prota Structure	7	5,6%	12,3%

#### Challenges in integrating BIM into curricula

The challenges associated with BIM integration in construction education are outlined in table 8, with the Mean, Standard Deviation (Std. Dev.), Relative Importance Index (RII), and Rank for each factor. The RII values, ranging from 0,502 to 0,856, offer insight into the relative significance of each challenge.

"Lack of faculty expertise and training to teach BIM" was ranked as the most critical challenge (RII = 0,856) per the result of the

analysis. This suggests that faculty currently lack the necessary skills or training in BIM, which undermines their ability to deliver BIM-related content. In view of this, an immediate need for educational institutions to prioritize investing in faculty development programs becomes paramount.

"Limited BIM-related educational resources for students" (RII = 0,800) was ranked 2nd. This highlights that student face difficulties in having access to the needed BIM resources such as manuals and tutorials.

The "High cost of training lecturers" (RII = 0.780) ranked 3rd, reflected a broader concern regarding the cost of equipping lecturers with the necessary BIM skills. Universities may therefore need to look for alternative funding sources or collaborate with industry partners who can support training programs.

"Lack of IT infrastructure" (RII = 0,772) and "Lack of government initiative to include BIM in education" (RII = 0,762) are additional noteworthy challenges. Given their significant influence on BIM integration into construction curriculum, these factors emphasize the need to investment in digital infrastructure and stronger government support for BIM education

Moreover, challenges such as "Lack of BIM teaching materials" (RII = 0,722), "Lack of qualified experts to advise on BIM curricula" (RII = 0,718), and "Lack of university management support" (RII = 0,712), underscore the need for universities to provide sufficient teaching materials, engage BIM experts, and secure top-level management support to facilitate BIM integration is further reinforced by On the other hand, factors such as "Poor internet connectivity" (RII = 0,694), "Lack of collaboration with industry" (RII = 0,674), and "Lack of time and resources to develop a new course" (RII = 0,674) are deemed important, but their impact is slightly lower. These factors underscore the importance of digital infrastructure and stronger academia-industry education.

The three items with the lowest RII and corresponding rankings were "Difficulty in incorporating BIM features into the curricula" (RII = 0,502), "Difficulty in selecting suitable BIM software" (RII = 0,552), and "Hesitation to change or modify the current curricula" (RII = 0,556). Although these factors present significant challenges, they are considered less critical than others. Which implies that institutions may focus

on overcoming more pressing challenges before addressing these ones.

**Table 8.** The challenges of BIM integration in construction education

Factor	Mean	Std. Dev.	RII	Rank
Lack of faculty expertise and training to teach BIM	4,14	0,776	0,856	1
Limited BIM-related educational resources for students	4,00	0,965	0,8	2
High cost of training lecturers	3,9	0,662	0,78	3
Lack of IT infrastructure	3,86	0,798	0,772	4
Lack of government initiative to include BIM in education	3,81	0,919	0,762	5
Lack of BIM teaching materials	3,61	1,017	0,722	6
Lack of qualified experts to advise on BIM curricula	3,59	1,116	0,718	7
Lack of university management support	3,56	1,087	0,712	8
Poor internet connectivity	3,47	1,455	0,694	9
Lack of collaboration with industry	3,37	1,258	0,674	10
Lack of time and resources to develop a new course	3,37	0,807	0,674	11
Limited ICT skills of lecturers	3,32	1,181	0,664	12
Lack of accreditation criteria to guide the integration	3,22	1,100	0,644	13
Lack of understanding about BIM	3,14	1,266	0,628	14
Lack of student demand	2,81	1,224	0,562	15
Hesitation to change or modify the current curricula	2,78	1,131	0,556	16
Difficulty in selecting suitable BIM software	2,76	1,023	0,552	17
Difficulty in incorporating BIM features into the curricula	2,51	1,251	0,502	18

Table 9 shows the outcomes of the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity, both

used to evaluate the suitability of conducting a factor analysis. The KMO value is 0,770, indicating a good sampling adequacy level. According to Kaiser's rule, values exceeding 0,7 are deemed suitable for factor analysis. A value of 0,770 indicate that the data is suitable for performing factor analysis, and the variables in the dataset have sufficient correlations to form meaningful factors.

The Approx. Chi-Square statistic is 621,251, with 153 degrees of freedom (df). The p-value (Sig.) is 0,000, which is highly significant ( $p < 0,05$ ). This result shows that the correlation matrix is not an identity matrix, meaning significant correlations exist between the variables. This is a requirement for conducting factor analysis, as it indicates that the variables have relationships strong enough to be grouped into factors.

**Table 9.** KMO and Bartlett's test

<b>Kaiser-Meyer-Olkin measure of sampling adequacy</b>		0,770
Bartlett's Test of Sphericity	Approx. Chi-Square	621,251
	Df	153
	Sig.	0,000

Table 10 presents the Total Variance Explained and Communalities from a factor analysis, showing the initial eigenvalues, the percentage of variance explained by each component, and the cumulative percentage of variance. This analysis provides insights into the factors underlying the data and their relative importance in explaining the variability of the observed variables. The eigenvalues represent the amount of variance explained by each factor. In the initial extraction, Component 1 has the highest

eigenvalue of 6,856, explaining 38,091% of the variance. Together, the first two components account for 51,640% of the total variance, and by the time we reach the fourth component, 66.983% of the variance is accounted for. By the fifth component, the cumulative variance explained increases to 73,146%, suggesting that these five components account for a substantial share of the total variability in the data.

After the fifth component, the percentage of variance explained begins to decrease, with subsequent components explaining smaller amounts of the total variance. For example, Component 6 explains only 5,300%, and by the time we reach Component 18, only 0,443% of the variance is explained. Despite these small contributions, these components still cumulatively account for the remaining 6.042% of variance.

The communalities represent the fraction of each variable's variance accounted for by the extracted factors. The communalities across the components are extracted from the factor analysis process, and these values can be interpreted as the degree to which each variable is represented by the extracted factors. For instance, Component 1 has the highest extracted communality value of 0,223, followed by Component 2 with 0,259, and Component 3 with 0,337, indicating that these components explain a higher proportion of the variables' variance. The communalities gradually decrease as we move to higher components. For example, Component 16 has an extracted communality of 0,635, suggesting that a significant portion of the variance for this component is explained. However, Component 18 only explains 0,566, reflecting less explained variance by this last factor.

**Table 10.** Total variance explained and communalities

Component	Initial eigenvalues			Initial	Extraction
	Total	% of variance	Cumulative %		
1	6,856	38,091	38,091	1,000	0,223
2	2,439	13,549	51,640	1,000	0,259
3	1,590	8,836	60,476	1,000	0,337
4	1,171	6,507	66,983	1,000	0,294
5	1,109	6,163	73,146	1,000	0,161
6	0,954	5,300	78,445	1,000	0,008
7	0,678	3,765	82,211	1,000	0,433
8	0,559	3,103	85,314	1,000	0,259
9	0,469	2,604	87,918	1,000	0,286
10	0,432	2,401	90,319	1,000	0,590
11	0,376	2,089	92,407	1,000	0,285
12	0,285	1,581	93,988	1,000	0,262
13	0,273	1,518	95,506	1,000	0,478
14	0,240	1,333	96,839	1,000	0,573

Component	Initial eigenvalues			Initial	Extraction
	Total	% of variance	Cumulative %		
15	0,209	1,159	97,998	1,000	0,580
16	0,180	1,002	99,000	1,000	0,635
17	0,100	0,557	99,557	1,000	0,627
18	0,080	0,443	100,000	1,000	0,566

The scree plot (figure 1) suggests that only one component ought to be kept, as it explains most of the variance (38,091%) in the dataset. The remaining components, while technically part of the factor analysis, contribute much less to

explaining the underlying patterns and can be discarded. This implies that a unidimensional structure is most appropriate for the data, where one main factor is driving the observed patterns.

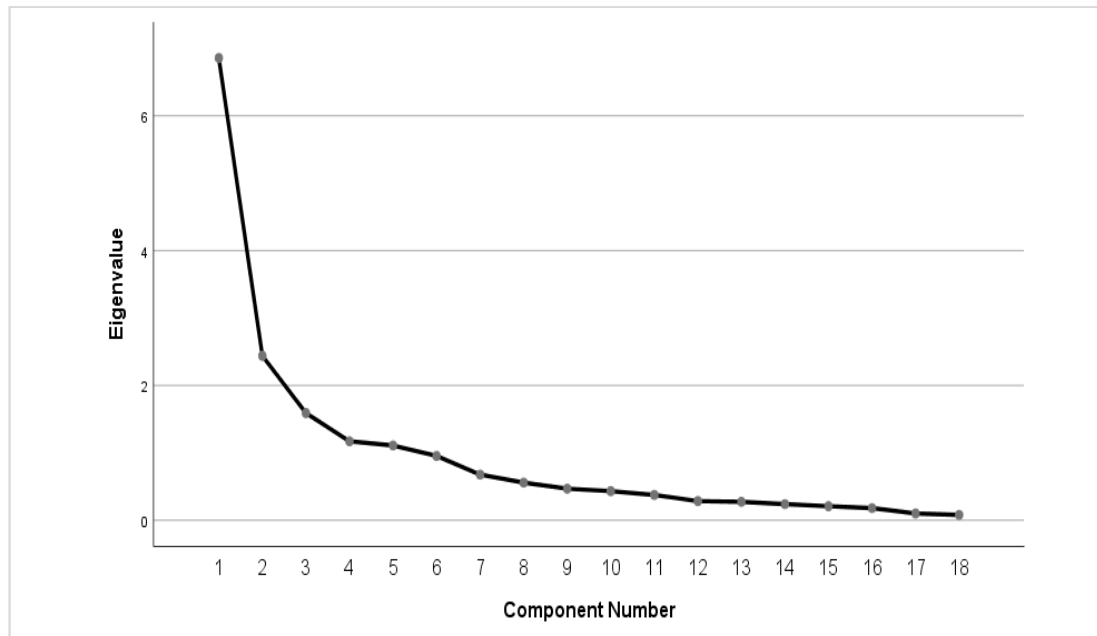


Figure 1. Scree plot for challenges of BIM integration

The dependability and unidimensionality of the Challenges of BIM Integration construct were assessed using the EFA. Extraction and rotation technique was Maximum Likelihood with Varimax rotation (ML Varimax). Measuring the Construct included eighteen (18) items. The Kaiser-Meyer-Olkin (KMO) of 0,911 along with Bartlett's test of sphericity of  $p < 0,000$  show concordance with the advised KMO threshold value of 0,70 by Hair et al. (2019). The findings showed that the data were appropriate for factor analysis. All eighteen items (C1 through C18), designed to assess the challenges of BIM integration, loaded onto a single component. Applying a factor loading threshold of 0,5 exceeding the minimum of 0,40 recommended by Field (2005); Hair et al. (2019) most items demonstrated strong loadings above this cutoff. However, three items "Lack of accreditation

criteria to guide the integration," "Lack of IT infrastructure," and "High cost of training lecturers" fell below the 0,5 threshold, indicating they were poor indicators of the underlying component.

For the component, fifteen (15) items exceeded a threshold of more than 0,5. These are "Lack of collaboration with industry", "Lack of university management support", "Lack of understanding about BIM", "Poor internet connectivity", "Limited ICT skills of lecturers", "Lack of government initiative to include BIM features into higher education curricula", "Lack of qualified experts to advise on the development of BIM curricula", "Lack of student demand", "Lack of faculty expertise and training to teach BIM", "Difficulty in selecting suitable BIM software", "Lack of time and resources to develop a new course", "Hesitation to change or modify the

current curricula", "Difficulty in incorporating BIM features into the present curricula", "Lack of BIM teaching materials", and "Limited BIM related educational resources for students". These items measure the Challenges of BIM Integration. Thus, they will be called the Challenges of BIM Integration.

After conducting Exploratory Factor Analysis (EFA) to identify the component, the adjusted

item-total correlations were evaluated using the recommended threshold of 0,30. The results showed that the items were valid indicators of the component, as the Cronbach's alpha value was 0,895 exceeding the acceptable benchmark of 0,800 thereby demonstrating good internal consistency (Marks et al. 2013).

**Table 11.** Unidimensionality and reliability test of the challenges of BIM integration

	C	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if Item deleted	Cronbach's alpha
Lack of collaboration with industry	0,797	0,414	0,602	0,894	0,895
Lack of university management support	0,792	0,430	0,665	0,893	
Lack of understanding of BIM	0,768	0,519	0,665	0,891	
Poor internet connectivity	0,762	0,477	0,578	0,891	
Limited ICT skills of lecturers	0,757	0,346	0,614	0,895	
Lack of government initiative to include BIM features in higher education curricula	0,752	-0,080	0,297	0,903	
Lack of qualified experts to advise on the development of BIM curricula	0,691	0,603	0,613	0,887	
Lack of student demand	0,658	0,433	0,804	0,893	
Lack of faculty expertise and training to teach BIM	0,581	0,486	0,611	0,891	
Difficulty in selecting suitable BIM software	0,542	0,719	0,668	0,883	
Lack of time and resources to develop a new course	0,535	0,480	0,547	0,892	
Hesitation to change or modify the current curricula	0,534	0,433	0,546	0,894	
Difficulty in incorporating BIM features into the present curricula	0,512	0,627	0,684	0,887	
Lack of BIM teaching materials	0,509	0,709	0,738	0,884	
Limited BIM-related educational resources for students	0,508	0,704	0,753	0,883	

Structural Equation Model (SEM) for the challenges of BIM integration construct

Following the constructs' demonstration of adequate unidimensionality and reliability using EFA, a CFA was then conducted. The goodness of fit analysis technique for the

After establishing unidimensionality and internal reliability of the constructs by Exploratory Factor Analysis (EFA), a Confirmatory Factor Analysis (CFA) was done. A good fit of the Challenges of BIM Integration model was evaluated based on three fit indices (Hu and Bentler 1999). The analysis provided the value of the Satorra-Bentler chi-square (S-B $\chi^2$ ) of 3,137 with 35 degrees of freedom and the significance value of  $p = 0,0000$ . Whilst this represents a statistically significant disparity between the proposed model and sample data, the chi-square test is notorious for its sensitivity to

sample size and is thus more readily interpreted as a descriptive fit statistic (Kline 2010).

The Comparative Fit Index (CFI) was also set at 0,973, which exceeded the suggested threshold of 0,90, and it showed that the model fit was excellent. Similarly, the Normed Fit Index (NFI) was 0,907, which also surpassed the acceptable value and supported the sufficiency of the model. On the other hand, the Parsimony Normed Fit Index (PNFI) equaled 0,550, which is lower than the recommended value of 0,80. Root Mean Square Residual (RMR) value was 0,011, much below the acceptable threshold of 0,05 and Goodness of Fit Index (GFI) value was 0,931, far above the 0,90 mark, on a positive note. Altogether, these indicators show that the suggested model of the interpretation of BIM integration issues suits the data quite well.

**Table 12.** Robust fit index for the challenges of BIM integration

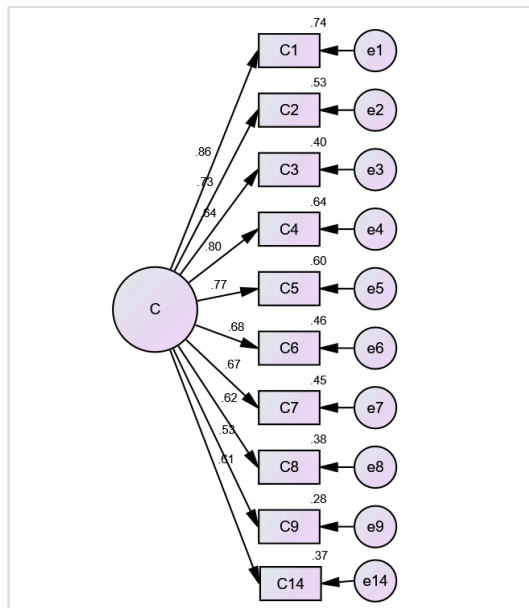
Fit index	Cut-off value	Estimate	Comment
$S - B\chi^2$	-	3,137	
$Df$	-	35	Acceptable
CFI	0,90 ≥ acceptable 0,95 ≥ good fit	0,973	Good fit
PCFI	Less than 0,80	0,601	Good fit
RMSEA	Less than 0,08	0,042	Acceptable
RMSEA 95% CI	0,00-0,08 "good fit"	0,000-0,019	Acceptable
NFI	Greater than 0,90 "good fit"	0,907	Good fit
IFI	Greater than 0,90 "good fit"	0,980	Good fit
PNFI	Less than 0,80	0,550	Good fit
RMR	Less than 0,05 "good fit"	0,011	Good fit
GFI	Greater than 0,90 "good fit"	0,931	Good fit

A Unidimensional model for the Challenges of BIM Integration features is presented (figure 2 and table 11). Of the fifteen (15) indicator variables, ten (10) were extracted and utilized in the final CFA analysis (Byrne 2013). From the 59

cases evaluated for this construct, ten (10) indicator variables made up of a component realized as C (C1, C2, C3, C4, C5, C6, C7, C8, C9 and C14).

**Table 13.** Final conceptual model indicator variables for the challenges of BIM integration

Latent component	Indicator variable	Measurement variable	Label
Challenges of BIM integration	C16	Lack of collaboration with industry	C1
	C17	Lack of university management support	C2
	C10	Lack of understanding about BIM	C3
	C15	Poor internet connectivity	C4
	C14	Limited ICT skills of lecturers	C5
	C18	Lack of government initiative to include BIM features into higher education curricula	C6
	C13	Lack of qualified experts to advise on the development of BIM curricula	C7
	C7	Lack of student demand	C8
	C3	Lack of faculty expertise and training to teach BIM	C9
	C8	Lack of BIM teaching materials	C14



**Figure 2.** CFA model for the challenges of BIM integration

Table 14 presents the factor loading and relevant statistical indicators for the proposed associations between the individual challenge items (C1 to C14) and the latent construct (C) representing Challenges in BIM (Building Information Modeling) integration. It includes both standardized and unstandardized factor coefficients ( $\lambda$ ), corresponding p-values, and R-square values, as well as an assessment of significance at the 5% level. Among the indicators, C1 exhibited the highest standardized loading, with a coefficient of 0.863.

Additionally, the R-square values were found to be near the optimal threshold of 1.00, suggesting that the latent construct explained a significant share of the variance in the observed variables. This outcome confirms that the indicators are strong and reliable measures of the underlying factor, with all variables demonstrating statistically significant relationships with the central construct of BIM integration challenges.

**Table 14.** Factor loading and P-value of the challenges of BIM integration

Hypothesized relationships (path)	Unstandardized coefficient ( $\lambda$ )	Standardized coefficient ( $\lambda$ )	P-value	R- Square	Significant at 5% level
C1 $\leftarrow$ C	1,000	0,863	0,00	0,744	Yes
C2 $\leftarrow$ C	0,732	0,731	0,00	0,535	Yes
C3 $\leftarrow$ C	0,741	0,635	0,00	0,403	Yes
C4 $\leftarrow$ C	1,073	0,801	0,00	0,641	Yes
C5 $\leftarrow$ C	0,842	0,774	0,00	0,599	Yes
C6 $\leftarrow$ C	0,577	0,681	0,00	0,464	Yes
C7 $\leftarrow$ C	0,689	0,670	0,00	0,448	Yes
C8 $\leftarrow$ C	0,700	0,620	0,00	0,385	Yes
C9 $\leftarrow$ C	0,379	0,530	0,00	0,281	Yes
C14 $\leftarrow$ C	0,572	0,610	0,00	0,372	Yes

## Discussion

The survey results indicate a promising level of BIM awareness among academic staff in Ghana, with 89,4% of respondents reporting fair, good, or very good knowledge of BIM. This level of awareness suggests that efforts to introduce BIM in higher education are gradually permeating academia. Additionally, almost half of the respondents (47,5%) stated having between 2 to 5 years of BIM experience. An indication that many faculty members have already embraced the technology. However, this awareness alone is insufficient; closing the gap between faculty knowledge and BIM integration into curricula is critical for preparing students to meet evolving requirements of the construction sector.

The results reveal that the integration of BIM in construction programs in Ghana remains limited. The predominant approach is integrating BIM topics into existing courses or offering workshops and training sessions rather than establishing dedicated BIM courses. This aligns with previous research, which identified four common approaches to BIM integration: standalone courses, cross-disciplinary courses, integration into existing courses, and workshops (Huang 2016). In Ghana, the focus is primarily on design-related courses, with less emphasis on project management and estimation courses, reflecting a partial approach to BIM education. In contrast, countries like the UK and Australia have successfully integrated BIM by offering dedicated courses supported by government initiatives to mandate BIM education (Cheng and Lu 2015; Succar and Kassem 2015). Establishing such courses has been pivotal in ensuring comprehensive training and competence development among graduates. Ghana could benefit from adopting a similar approach, advocating for government and industry partnerships to support the creation of dedicated BIM programs in higher education institutions.

This strategy could align curricula with industry demands and equip students with holistic BIM competencies.

Although academic staff recognize the importance of BIM (mean score 4,02), the frequency of BIM lessons remains average (mean score 3,39), and dissatisfaction with the current level of integration is evident (mean score 2,86). This gap between recognition and practical implementation is not unique to Ghana. Other developing countries also face similar challenges due to limited resources, faculty expertise, and infrastructure constraints (Sacks and Pikas 2013; Suwal, Jäväjä, and Salin 2014). Notably, 87% of respondents strongly advocated for making BIM a mandatory course, recognizing the increasing demand for graduates with BIM expertise. Countries like Singapore and South Korea have effectively addressed this gap by making BIM education mandatory for public construction projects, ensuring a steady supply of skilled professionals (Cheng and Lu 2015). Ghana government could adopt a similar model by collaborating with professional bodies and policymakers to mandate BIM education and provide funding and training resources to academic institutions. Such policy initiatives would enhance BIM integration and prepare the workforce for the digital demands of the construction industry.

The study identified numerous critical challenges in integrating BIM into construction curricula. The biggest challenge was the lack of faculty expertise and training to teach BIM (mean score of 4,14). This issue is not unique to Ghana; similar findings have been reported in other developing countries, where the lack of qualified faculty members was deemed critical as it directly affects the quality of instruction and student learning outcomes (Ahmed 2018) as well as contributed to the delayed adoption of BIM in educational institutions (El Hajj, Martínez

Montes, and Jawad 2021; Ghosh, Parrish, and Chasey 2015). This challenge could be addressed by investing in faculty development programs that provide specialized BIM training. Collaborative initiatives between universities, professional bodies, and software vendors, such as Autodesk, could offer academic staff certifications and professional development workshops. Limited access to BIM-related educational resources was the second most significant challenge (mean score of 4,00). The availability of educational resources is crucial for effective learning. Aljarman, Boussabaine, and Almarri (2020) highlights that many educational institutions lack sufficient BIM-related materials, which hampers students' ability to engage with technology effectively. Persistent challenges faced by students in accessing necessary BIM training materials may therefore complicate their learning experience.

Another significant barrier is the high cost of training lecturers and the lack of adequate IT infrastructure (mean scores 3,90 and 3,88, respectively). Radzi et al. (2019) points out that the financial burden involved in upskilling educators can deter institutions from investing in BIM education. It is therefore not surprising that in many developing countries such as Ghana, HEIs often lack the requisite hardware and reliable internet connectivity required to support BIM education (Leslie Appiah 2020). To overcome such challenges, public-private partnerships like those in the Netherlands and Finland could be explored, where construction firms collaborate with universities to sponsor BIM training and donate equipment (Chmelka et al. 2020). The lack of government initiatives to include BIM in higher education curricula also emerged as a critical challenge. Government support is essential for promoting BIM education. Countries like the UK and Singapore have successfully driven BIM adoption and education through government policies and standards (Awwad, Shibani, and Ghostin 2022). Without similar support from government in the form of policy frameworks that mandate BIM integration in construction education, technical Universities may struggle to access the necessary resources for comprehensive BIM education.

Finally, the lack of qualified experts to advise on developing BIM curricula (mean = 3,64) highlight the vital importance of academia-industry collaboration. Previous studies have highlighted lack of BIM-skilled professionals, while underscoring the need for expertise to guide

curricula development (Acquah, Eyiah, and Oteng 2018; Bamfo-Agyei and Nani 2015). A significant challenge has been the lack of industry professionals with the requisite expertise to guide the development of BIM curricula. According to Alreshidi, Mourshed, and Rezgui (2017), without inputs from industry experts, educational programs may fail to meet industry needs and result in skills gap among graduates. Succar and Kassem (2015) posit that Norway and Denmark have effectively overcome this challenge by instituting industry-academia partnerships that facilitate knowledge transfer and curricula development. Ghana might follow a similar model by setting up advisory boards to guide the integration of BIM into construction education curricula. This would guarantee that graduates leave school with practical BIM skills that align with the evolving industry needs.

The study underscores the need for a multi-stakeholder approach to address these issues. Successful examples from countries like the UK, Singapore, and Denmark suggest that collaborative partnerships between government, industry, and academia are critical for driving BIM integration in educational curricula.

## Conclusions

The study shed light on the current state and challenges of BIM integration in construction curricula within Ghanaian technical universities. Even though BIM knowledge and appreciation among academic staff was relatively high, a significant gap persists between such appreciation and actual integration of BIM into curriculum. There was a low level of satisfaction with the state BIM instructions, which suggests that the current practice which involves incorporating BIM into existing courses or providing workshops might not be enough to equip students with the scope of competencies needed to fit industry demands. A holistic integration of BIM as a comprehensive standalone course rather than relying on isolated workshops or partial course modules in existing courses as is the case presently is needed. This approach aligns with successful models observed in leading BIM integrated countries like the UK and Australia. It focuses on dedicated BIM training as essential component for developing industry ready graduates. Educational institutions need to broaden the scope of their curriculum

integration the full range of BIM competencies essential for present industry demands. This is because the prevalent emphasis on design-related aspects of BIM over broader applications such as project management and estimation might not adequately prepare graduates for the industry. Lack of faculty expertise, limited educational resources, high cost of training lecturers, and insufficient IT infrastructure were significant challenges highlighted by the study. Accordingly, there is the need for investments in faculty development programs and infrastructural upgrade. A general agreement among academic staff suggest that BIM should be made a mandatory component of construction education to close the skills gap. Essentially, this underscores the importance of policy frameworks mandating BIM education.

This would help align construction programs with global BIM trends and industry demands. As such, educational institutions could ease their resource constraints and create supportive ecosystem through the formation of public-private partnerships between governments and industry stakeholders.

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#### Author(s) contribution

**Daniel Ebo Hagan** contributed to the research concepts preparation, methodologies, investigations, data analysis, visualization, articles drafting and revisions.

**Tutin Aryanti** contribute to the research concepts preparation and literature reviews, data analysis, of article drafts preparation and validation.

**Ilhamdaniah** contribute to methodology, supervision, and validation.

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