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Critical Factors for Effective BIM-Enabled Education: An Adaptive Structuration Theory Perspective

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Abstract: Educational systems of the 21st century require agility and flexibility for construction graduates to have the skills, knowledge, and abilities required for effective performance in the construction industry, especially with the global digitalization of the industry. With reference to adaptive structuration theory (AST) as a theoretical lens and a survey research design, this research examined the relationship between building information modeling (BIM) as an advanced information technology and educators' attitudes toward implementing BIM for construction education to prepare local graduates for global relevance and employment. Data collected were analyzed using Statistical Package for the Social Sciences (SPSS Ver 25). The findings of the study showed that group internal system, structure of BIM, and task and organizational environment play important roles in implementing BIM for construction education in the architecture, engineering, construction, and facilities management (AEC/FM) disciplines. It was recommended that policymakers, academics, and curriculum developers pay attention to these factors for rapid development in the realm of BIM education. The development of a robust BIM education framework that considers these factors should also be studied.

Keywords: BIM; building information modeling; adaptive structuration theory; construction education; BIM-enabled learning; AEC/FM

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1. Introduction

Sustaining the motivation to learn has never been more challenging, especially in the face of information overload, combined with innovations, improvements, and changes in norms resulting from the digitalization of the construction sector [1]. Today's learners can no longer derive satisfactory learning experiences from yesterday's teaching methods [2]. These issues have been the focus of academics and industry researchers for more than two decades, and construction management education is in crisis [3]. For instance, the pathways and competencies outlined by the Royal Institute of Chartered Surveyors (RICS) specify the necessary knowledge, skills, experience, and competence for achieving chartered surveyor status [4]. According to these, applicants are required to fulfill a specific set of criteria and competencies, which include technical and professional practice, business, interpersonal, and management abilities. Much like engineering education in general, there are conflicting demands for graduates to be specialists with mastery of a growing range of technologies while, at the same time, there are also requirements for them to be generalists in terms of having system-building, teamwork, entrepreneurial, communication, and managerial skills [5]. Universities have come under fire for stressing the teaching of theory above the foundations for practice due to a claimed divergence between university education and industry needs (e.g., [6]). According to Crawley et al. [5], there are continuous efforts to restructure construction management education to address this claim. Building information modeling (BIM) can provide opportunities for construction-related education to address many of these problems. BIM can enable construction activity prototyping that encourages immersive learning of core concepts as well as system building and practice abilities by utilizing its virtual environment as a learning platform [7]. This virtual prototyping and simulation can also provide continuity between formal degree courses and continuous professional development.

BIM plays a crucial role in the digitization of the construction sector, and it presents multiple possibilities for teaching practice improvements just as it does to the industry workflow [8]. BIM is a collaborative construction system that allows stakeholders to interact with a virtual depiction of the tangible and operational characteristics/specifications of construction assets [8]. It also ensures that project data are comprehensive, organized, and easily available and serves as a maintained source of information for the duration of the design process and beyond [8]. Much of this information is directly linked to architectural and engineering items (claddings, structural elements of buildings, windows, doors, ground and suspended slabs, services pipes, and so on). It involves a 3D virtual model illustrating both the physical and functional attributes of a structure, allowing for straightforward examination and comprehension [8]. Consequently, BIM facilitates the simulation of complex real-world project scenarios in an educational setting, enhancing students' comprehension efficiently. Additionally, it fosters students' acclimatization to BIM workflows and technology.

Despite the growing awareness [9] and increasing advantages of utilizing BIM in the construction sector, academia has yet to fully leverage BIM for educational purposes in construction. The inability to embrace BIM for construction education has made it difficult to innovate and enhance the quality of teaching and learning scholarship among academics in AEC-FM. Recent research findings indicate how integrating technology into teaching methods can improve learning and raise students' enthusiasm for lifelong learning [10–12]. Likewise, evidence abounds that accidents and other fatal incidences can be reduced on construction sites with BIM for construction education [13–16]. For example, BIM-based instructional training that involves risky jobs (like crane assembly and operation, scaffolding mounting and dismantling) can now be achieved through BIM-based simulation either through virtual (VR), augmented (AR), mixed (MR), or extended (XR) realities [13–16].

Pedagogical and organizational changes brought about by technology are complex [17]. When advanced information technologies like BIM are adopted (for industrial or pedagogical purposes), people adapt them to their specific needs, leading to wide variations in outcomes [18].

The complexity of the relationships between BIM technology and organizations can be shown by capturing the processes of BIM in construction education within academic circles and tracking their effects. In doing so, we can learn more about how to use and engage BIM technologies for construction education, and we might also be able to create better pedagogical designs or educational initiatives that promote the teaching of construction engineering concepts in ways that sustain students' motivation for continuous learning.

The adaptive structuration theory (AST) proposed by DeSanctis and Poole [19] provides a framework to study organizational change as advanced information technologies are used. AST acknowledges the recursive interrelationships between the embedded structures in advanced technologies and the structures that emerge in human action when people use these technologies, and it offers us a theoretical lens through which to investigate the interaction between sophisticated information technologies, social frameworks, and human engagement [19].

The purpose of this quantitative non-experimental correlational research is to investigate the interrelationships between three classes of variables that relate to sources of structure:

1. Structure of BIM (the structural features embedded within this technology as well as the general intentions, values, etc. underlying the structural features);
2. Task and organizational environment (structures of the pedagogical tasks that are to be undertaken with the aid of BIM and of the educational organization);
3. Group's internal system (such as hierarchical and procedural structures that may affect the adoption of BIM);

and the degree to which they explain:

4. The behavioral intention to adopt BIM for construction education.

In this research, we address the question, "To what extent do structures of BIM, task and organizational environment, and the group's internal system predict the behavioral intention to adopt BIM-enabled education?" This study is motivated by the potential for a new, BIM-enabled educational approach that moves away from dividing projects between specialist areas toward integrative work and information flows for whole projects [20] and embraces the opportunities of big data with BIM's ability to make it useful through logical arrangement, presentation and accessibility [21]. This offers solutions to the perceived mismatch between graduate competencies and their professional roles in the industry [22], the need to integrate students' learning in the context of real projects [23], and, in doing so, to promote experiential, student-centered learning methods [24–26]. Therefore, the outcome of the study would facilitate a better understanding of BIM for construction education acceptance factors, providing needed insight into decision making and BIM-enabled education's global adoption.

The next section of this paper describes the AST variables relevant to this study. This is followed by a description of the quantitative research methodology applied and then of the case context in which it was applied. The findings and discussions of their implications for educational practice were presented before conclusions were finally drawn.

2. Literature Review

2.1. BIM in Construction Education

BIM is increasingly being integrated into construction education, with a focus on its role as a tool and method in both education and industry [27]. It has been found to be effective in teaching construction details and material quantity take-offs [28] and has been used to develop interactive educational modules that enhance spatial understanding, interoperability, and communication [29]. The majority of architecture and construction schools in the U.S. have either implemented or expressed interest in implementing BIM into their curriculum, with a particular emphasis on its importance to the industry [30].

The integration of BIM in construction education is a critical need, with universities worldwide lacking a clear strategy for its implementation [31]. Perceptions of BIM practice and application vary across different institutions, with factors such as pedagogical assessment approach and individual disciplines influencing these perceptions [32]. Several authors have tried to identify practical challenges in BIM education [33–39] with the hope of bringing BIM into the classroom at par with the industry BIM. Despite these efforts, BIM education still seriously lags behind industry adoption [40], probably because none of the extant studies have considered these challenges from the adaptive structuration point of view. The AST helps us to understand the dynamics at play between the different structures (technological and social) and how these, in turn, birth new structures that can impact the implementation of BIM-enabled education. This study is, therefore, intended to fill this gap. Expert analysis of the groups' dynamic internal systems through structuration theory can offer valuable insights into how to navigate complex social dynamics within different organizational settings relating to BIM education.

2.2. BIM and Its Structure

The confusion surrounding what BIM stands for is not as prevalent today as it was four to five decades ago [41]. At first, the idea of BIM was very unclear among professionals, vendors, and academia [41]. The initial influence of BIM was predominantly experienced in the design domain, enabling architects to envision and plan projects in innovative and compelling manners [42]. The use of custom parametric objects enables the modeling of intricate geometries that were formerly difficult or unfeasible to represent [41]. Other key stakeholders in the construction industry have also acknowledged the advantages of BIM. For instance, contractors are progressively utilizing BIM to enhance the accuracy of project estimates, streamline scheduling, and improve overall construction execution [42]. As such, BIM is continuously becoming a powerful educational resource due to its repository (database) ability for both parametric and non-parametric representation of construction information and other big data through the Internet of Things (IoT).

Figure 1 shows a high-level overview of the structures that are inherent in BIM. The central component is the BIM application (e.g., Autodesk Revit), which is used for creating and editing BIM models. BIM project files, in various formats like .rvt or .ifc, store project-specific data. A BIM collaboration platform, such as BIM 360 or Aconex, facilitates collaboration among project stakeholders. The BIM server or cloud hosts the central project data, and a common data environment manages project information. The BIM database/repository stores the BIM models and associated data. BIM model components refer to the elements and families within the BIM model. Integration modules link the BIM system with other software applications. External applications, like analysis or rendering tools, can interact with the BIM system for extended functionalities.

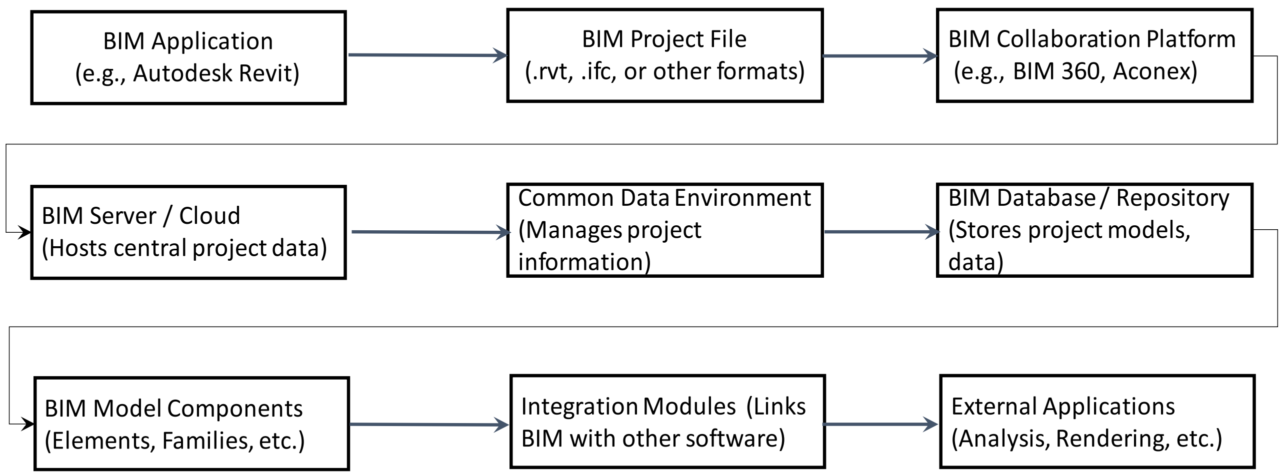

Figure 1. High-level overview of the structures of BIM.

According to Heidegger, technology is not devoid of values; instead, it harbors inherent potential that awaits discovery by those who engage with it [43]. Feenberg termed this as the under-determination and contingent nature of technology [44], which means that the effectiveness of any technology cannot be deemed absolute, given the numerous potential contextual factors. According to DeSanctis and Poole [19], understanding the effect of technology on group outcomes requires the appreciation of the structural ability of the technology, how technology and other structures (such as work tasks and the larger organizational environment, etc.) are appropriated by the group. Hence, the manner in which a technology is employed relies on the user, and the user bears moral responsibility for its consequences. Hence, BIM, being an advanced information technology, is not a neutral tool; rather, it exerts a deterministic influence on the way humans relate to objects or to each other. It possesses a capacity to shape our society and culture, including teaching and learning. This research is based on the idea that while BIM is intended for specific industry applications, it acknowledges the potential for its utilization in academia for other "beneficial" purposes, fostering active and lifelong learning in construction education.

2.3. Task and Organizational Environment

Tasks are performed in conformity with organizations' values and culture. Educational institutions with a preference for face-to-face learning will have low incentives, investment policies, and budgets for technologies required for virtual training and instructions. Enthusiastic academics willing to change the norm might be challenged with euphemism folklore such as "this is how we do our things". Figure 2 shows a representation of the relationships between the organizational environment, external factors, cultural values, and task performance. It visually communicates how changes in the organizational environment and cultural values can influence and shape the way tasks are carried out within the organization.

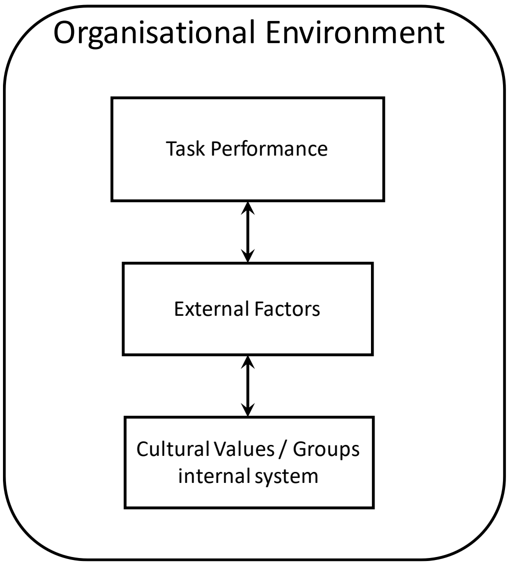

Figure 2. Relationships between the organizational environment, external factors, cultural values, and task performance.

For things to be performed in certain ways foretells that structures exist for specific tasks to be executed. The prevailing conditions would also influence the way such tasks are executed. De Sanctis and Poole [19] depict task and organizational environment as one of the major determinants for decision making. Later studies have expanded this model [45,46]. Majchrzak et al. [46] examined the adaptation of collaborative technology for decision making within an inter-organizational virtual team. They illustrate how appropriation actions impact decision processes and results. Huang et al. [45] demonstrate that a group support system (GSS) can be employed to facilitate the building of virtual teams. Apparently, the organizational environment influences where, when, and how tasks are performed. In fact, Akram and his colleagues posit that BIM has suffered a setback as a core decision support system due to the lack of an enabling organizational environment [47]. They stated further that developing countries have a greater share of this setback because of higher poverty levels and generally low interest in technology adoption due to their low level of awareness, etc. [47].

2.4. Group's Internal System

According to the British sociologist's structuration theory [48], which was further elaborated by DeSanctis and Poole's adaptive structuration theory [19], groups are conceptualized as social structures that are created and sustained through the actions of their members. These actions are defined by Homans [49] as the process of forming activities, interactions, and feelings directed at formal tasks or responsibilities in a group. The internal system of a group is constituted by the rules, norms, values, and beliefs that shape members' behavior and interaction. This system is not static but perpetually changing as members engage in ongoing negotiation and renegotiation of meaning. Structuration theory posits that this process of internal transformation is crucial to the survival and viability of groups. Furthermore, groups' internal systems are shaped by external factors such as institutional norms or laws [19,49,50]. Thus, understanding a group's internal system requires exploring how its members define themselves in relation to these external factors while constantly negotiating their identity internally. An expert analysis of groups' internal systems in structuration theory can offer valuable insights into how to navigate complex social dynamics within different organizational settings.

2.5. Behavioral Intention to Adopt BIM

Behavioral intention to adopt refers to an individual's willingness or readiness to adopt a new behavior or technology [51]—BIM for construction education in this case. In the context of construction education management, this concept enables policymakers to understand how AEC-FM academics may respond to changes in policies or practices. Factors that influence behavioral intentions may include perceived usefulness, ease of use, and social norms [52]. For instance, if employees perceive a new software as easy to use and beneficial for their work, they are more likely to adopt it. Additionally, social norms such as peer pressure or leadership support can affect behavioral intentions, as individuals often model the behaviors of those around them [50]. Understanding behavioral intentions is crucial for the successful adoption of new technologies and practices within organizations, as it helps identify potential barriers and develop strategies for effective implementation.

3. Materials and Methods

The aim of the study was to determine the extent to which structures of BIM, task and organizational environment, and group internal system predict the behavioral intention as the decision outcome to use BIM for construction education using a non-experimental quantitative research design approach as no intervention was needed [53]. Structures of BIM (operationalized as SB), task and organizational environment (operationalized as TOE), and group's internal system (operationalized as GIS) were used as predictors to explain the behavioral intention (operationalized as BP) as decision outcomes to adopt BIM for construction education (Figure 3). The concepts and their relationships with the decision outcome to adopt BIM for construction education informed the further decomposition of the main research question into the following three sub-research questions: (a) To what extent does SB predict behavioral intention (BP) to adopt BIM for construction education?; (b) To what extent does TOE predict BP to adopt BIM for construction education?; and (c) To what extent does GIS predict BP to adopt BIM for construction education?

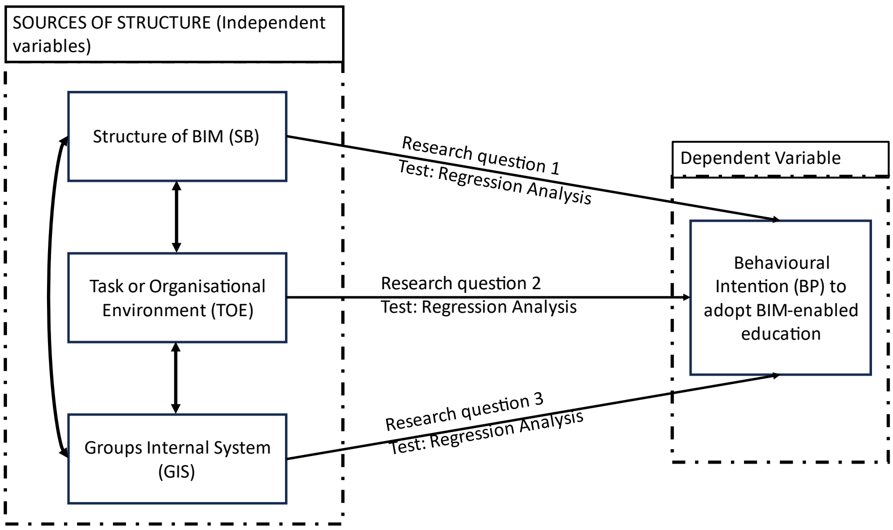

Figure 3. Relationship between concepts and analysis method.

3.1. Population

The sampling and distribution of the questionnaires took place in two different phases. The first set of questionnaires, which contained 15 major questions, were distributed among academics in the built environment using purposive sampling. Three federal universities were selected, viz the University of Ilorin, Federal University of Technology Minna, and Obafemi Awolowo University. A total of 45 questionnaires were sent to each university with the intention of sampling the opinion of 5 respondents each from the departments of architecture, building, civil engineering, electrical engineering, estate management, facility management, project management, quantity surveying, and mechanical engineering. A total of 29 questionnaires were returned completed from the first 135 questionnaires distributed, which represented a 21.48% response rate. These responses were used to analyze the perceived BIM benefits (BB), future plans to include BIM in teaching (BP), and BIM aspects in teaching (BA), which are reported in another study.

The second phase was necessitated by the insufficient data points required to determine the behavioral intention to adopt BIM for construction education using regression analysis. In the second phase, only 7 questions were asked. These were required to answer the research questions. The first four questions were demographic information for respondents' categorization. The questions included current job title, highest academic qualification, discipline, and years of teaching experience. They were all close-ended questions. The other three questions had two close-ended and one open-ended question. They included the level of influence by peers, views on fourteen indicators of BIM usage, and one open-ended question on benefits derived/derivable from the use of BIM in teaching AEC-FM concepts.

The respondents were purposively selected among quantity surveying academics in the built environment. This method of recruitment is also common with the adaptive structuration theoretical model [54]. Some of the authors belonged to a WhatsApp group called "QS educators forum". This group was created for quantity surveying academics in Nigeria with no age, cadre (academic level), experience, gender, or any other restrictions—it was intended to promote camaraderie and scaffolding. Instead of sampling, which could reduce the number of respondents, the total census of the sample frame was used to identify all 225 academic quantity surveyors that were in that forum. The forum members belonged to different institutions from all over Nigeria but had no means of associating participants in the group with their institutions. Each member of the group was contacted individually via WhatsApp messaging app after harvesting their contact numbers. All the questions were set to "required", and 48 respondents filled and submitted their responses, making a response rate of 21.33%.

3.2. Instrument

The survey instrument contained the questions that represented indicators underlying the scales for the study. Measurement of SB and BP was carried out on the basis of one indicator each (Table 1). Evaluation of GIS involved the use of seven indicators and, for TOE, six indicators. All variables (i.e., GIS, SB, TOE, and BP) used a dichotomous 5-point Likert scale. The questionnaire was designed using the Microsoft online questionnaire form. The questionnaire leveraged the diachronic analysis model for a given group [19] to collect the data for SB, TOE, and GIS, adapted based on the instrument designed by Simonova [55]. The scale for each variable consisted of index questions using a Likert scale from 1 to 5, and participants were asked to select the option that best described their experience. The administration and collection were performed online before exporting to SPSS [56] for analysis.

Table 1. Variables and indicators.

Question	Indicator	Variable
What is the level of influence by your peer or senior colleagues in the teaching of BIM skills or incorporating BIM in your teaching?	GIS1	GIS
I face administrative or technical issues/conflicts in my teaching task(s).	GIS2	GIS
My teaching task(s) is clearly defined.	GIS3	GIS
There are standing rules/guidelines in my department or faculty on how to teach BIM or use BIM for teaching.	GIS4	GIS
There is information on areas of BIM to teach students in the curriculum.	GIS5	GIS
I am usually guided by the curriculum in preparing my lesson notes.	GIS6	GIS
I teach or use BIM because of peer influence/pressure.	GIS7	GIS
My institution supports the use of BIM.	TOE1	TOE
I have the resources necessary to use BIM.	TOE2	TOE
I have the knowledge necessary to use BIM.	TOE3	TOE
I plan to use BIM in my teaching in the future.	TOE4	TOE
What I teach is not complex enough to engage BIM in it.	TOE5	TOE
BIM could be useful in my teaching job.	TOE6	TOE
There is a limit to which I can use BIM because it is not compatible with other software that I use in my teaching.	SB1	SB
How likely do you plan to include BIM in your teaching in the future?	BI1	BI

3.3. Data Analysis

Kolmogorov–Smirnov tests of normality were carried out on each of the variables to identify any violations of assumptions of normality through a combined assessment of the distribution of the histogram and boxplots. This check informed the choice of analysis adopted in testing the formulated hypothesis in terms of parametric or non-parametric analyses. Table 2 shows the descriptive statistics for the variables in this study.

Table 2. Descriptive statistics.

Variable	N Statistic	Minimum Statistic	Maximum Statistic	Mean Statistic	Standard Deviation	Kurtosis	Skewness
TOE1	77	1	5	4.08	1.11	0.05	−0.99
TOE2	77	1	5	3.25	1.27	−0.99	−0.04
TOE3	77	1	5	2.62	1.30	−0.95	0.33
TOE4	77	1	5	3.18	1.27	−0.90	−0.19
TOE5	77	1	5	4.03	1.16	0.83	−1.20
TOE6	77	1	5	2.39	1.23	−0.53	0.53
SB	77	1	5	2.96	1.27	−0.88	0.07
GIS1	77	1	4	2.53	1.01	−1.04	−0.13
GIS2	77	1	5	2.62	1.36	−1.00	0.33
GIS3	77	1	5	3.92	1.25	−0.66	−0.79
GIS4	77	1	5	1.96	1.31	0.61	1.33
GIS5	77	1	5	2.91	1.42	−1.20	0.16
GIS6	77	1	5	4.22	1.13	0.55	−1.29
GIS7	77	1	5	2.03	1.26	−0.19	1.01
BP	77	1	5	2.86	1.62	−1.59	0.20
Valid N (listwise)	77						

Note. N represents the number of participants, minimum and maximum indicate the range of responses, mean reflects the average score, standard deviation represents the spread of scores, kurtosis measures the peakedness of the distribution, and skewness indicates the symmetry of the distribution. All values are reported to two decimal places.

The result of the normal probability curve in Figure 4 shows that the data plot is normal. It shows a well bell-shaped curve.

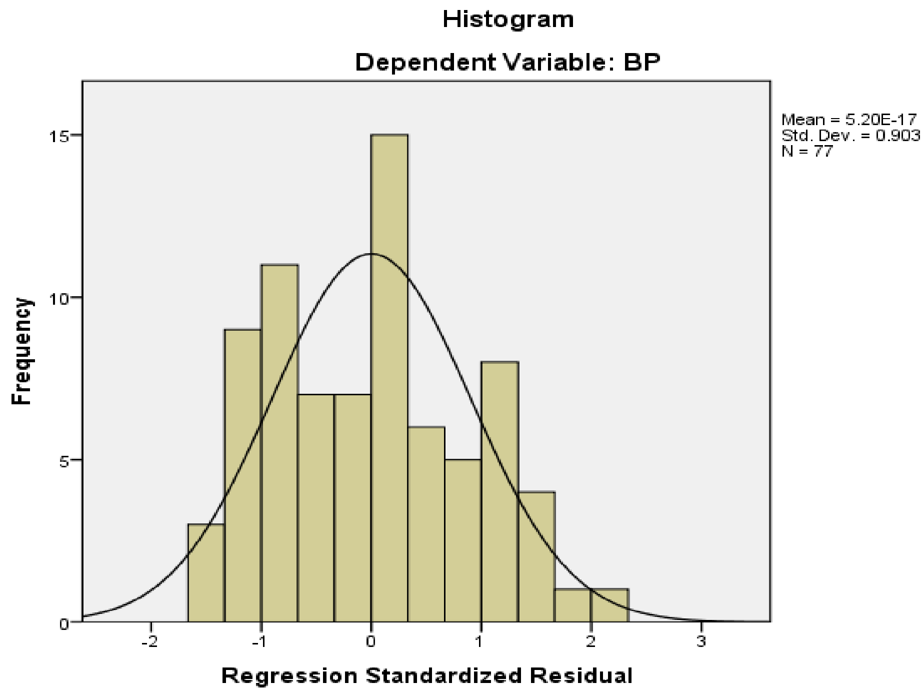

Figure 4. The normal probability curve.

The normal P-P plot in Figure 5 shows that the variables considered are significant since most of the plotted points are not far away from the trend line. The result of the chart in Figures 4 and 5 shows normality in the dataset.

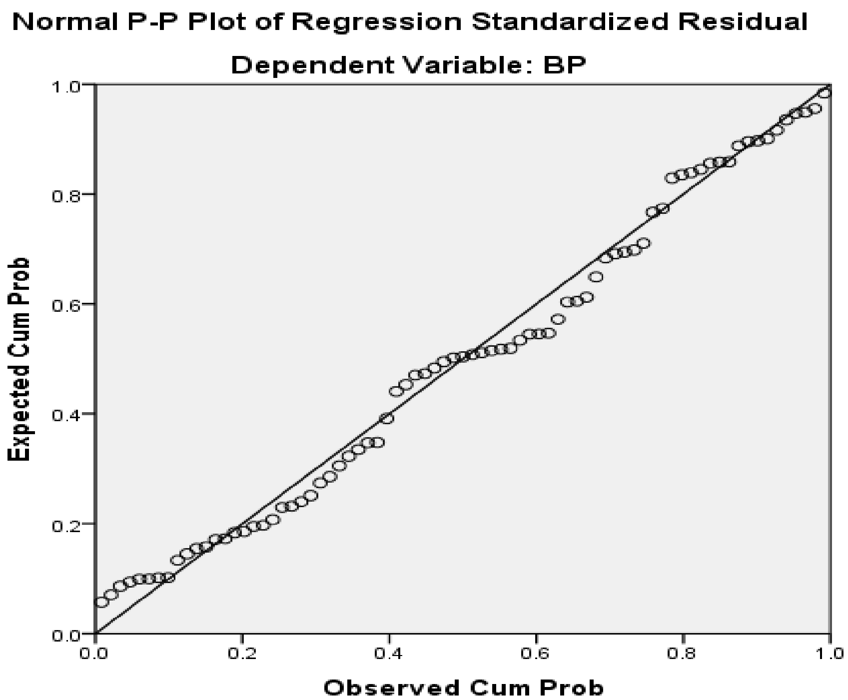

Figure 5. Normal P-P regression plot.

4. Results and Discussions

4.1. Regression Analysis

The value of the adjusted R square of 0.155 in Table 3 reveals the existence of a relationship between the variables considered. The value of R square (0.311)—representing the large size of the predicted effect [57]—shows that 31.1% of the probability of adopting BIM for construction education (dependent variable) is explained by the independent variables (i.e., structure of BIM, task and organization environment, and group's internal system). According to Kroll and Song [58], small R squares are consistent with smaller sample sizes. However, this phenomenon has been found to be predominant in social or behavioral sciences irrespective of sample size since all the social factors and predictors affecting an outcome variable cannot be adequately represented in a model [59]. Mood and Morrow [59] further suggest that larger sample sizes only decrease the sample variances but have no effect on the expectation of the R square and that a low R square could be significantly different from zero, thereby having a high explanatory power of a model.

Table 3. Model summary [b].

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin–Watson
1	0.558 [a]	0.311	0.155	1.489	1.798

[a] Predictors: (Constant), SB, TOE1, TOE2, TOE3, TOE4, TOE5, TOE6, GIS1, GIS2, GIS3, GIS4, GIS5, GIS6, GIS7.
[b] Dependent variable: BP.

The value of R (0.558) shows a positive relationship between the variables. The Durbin–Watson statistic is performed for independence error to make sure that one of the main assumptions of multiple regression is not violated [59]. The result of the Durbin–Watson statistic (1.798) also indicates an autocorrection that is between 1.5 and 2.5, which is considered relatively normal. Overall, the presented data indicated linearity and a relationship between the variables, which is signified by the regression line.

The findings obtained from the ANOVA results in Table 4 reveal that there exists a significant relationship between the variables selected since its *p*-value of 0.033 is less than a 0.05 level of significance. This implies that the model obtained is significant and can be used for further analysis.

Table 4. ANOVA [a].

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	61.995	14	4.428	1.998	0.033 [b]
	Residual	137.434	62	2.217		
	Total	199.429	76			

[a] Dependent variable: BP; [b] Predictors: (Constant), SB, TOE1, TOE2, TOE3, TOE4, TOE5, TOE6, GIS1, GIS2, GIS3, GIS4, GIS5, GIS6, GIS7.

The tolerance and variance inflation factor (VIF) in Table 5 indicates that there exists no presence of negative impact of multicollinearity in the dataset since the values of VIF are all less than 10 [59] and the TOL values are all greater than 0.2. However, the constant terms TOE2, TOE3, GIS1, GIS4, and GIS6 are found significant with *p*-values less than 0.05 level of significance, while other variables are found insignificant as their *p*-values are greater than 0.05 level of significance.

Table 5. Coefficients [a].

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	3.963	1.046		3.789	0.000		
	TOE1	0.095	0.216	0.065	0.442	0.660	0.509	1.966
	TOE2	0.451	0.198	0.353	2.280	0.026	0.463	2.158
	TOE3	−0.434	0.214	−0.348	−2.028	0.047	0.378	2.647
	TOE4	0.174	0.215	0.137	0.809	0.421	0.390	2.565
	TOE5	0.002	0.220	0.001	0.007	0.994	0.450	2.223
	TOE6	0.151	0.169	0.114	0.895	0.374	0.680	1.470
	SB	−0.084	0.162	−0.066	−0.522	0.603	0.691	1.447
	GIS1	−0.463	0.190	−0.288	−2.435	0.018	0.795	1.258
	GIS2	−0.042	0.137	−0.035	−0.308	0.759	0.842	1.188
	GIS3	−0.076	0.169	−0.059	−0.449	0.655	0.646	1.548
	GIS4	0.492	0.171	0.399	2.876	0.006	0.579	1.729
	GIS5	0.070	0.155	0.061	0.453	0.652	0.608	1.644
	GIS6	−0.468	0.197	−0.327	−2.375	0.021	0.587	1.702
	GIS7	−0.051	0.168	−0.039	−0.303	0.763	0.657	1.522

[a] Dependent variable: BI.

4.2. BIM Structure and BIM-Enabled Education

Table 6 shows the regression statistics between the structure of BIM and behavioral intention to adopt BIM for construction education.

Table 6. Regression statistics of the structure of BIM and intention to use BIM for education.

Multiple R	0.029201969
R Square	0.000852755
Adjusted R Square	−0.012469208
Standard Error	1.629963221
Observations	77

One surprising variable that was found not to be significantly associated with the behavioral intention to use BIM for education in Table 5 was the structure of BIM at p = 0.603. Building information modeling has become a popular technology for construction and engineering projects globally [60], and the predominant teaching methods in AEC/FM are generally considered to not be supportive of the demands of both academia and the industry [61]. The structure of BIM, which is based on interconnected data exchange and intelligent 3D models, has a direct impact on the way it could be used for teaching and learning. BIM education should be structured to provide students with real-world skills and knowledge that they can utilize in the workplace. One would expect the structure of BIM to affect BIM education in a number of ways. Firstly, the teaching method should be tailored to cater to different learning styles. Since BIM involves multiple disciplines, such as architecture, engineering, construction, and facilities management, the instructor must be able to communicate the subject matter effectively. Secondly, the curriculum should be designed to provide students with hands-on experience with BIM software. This will help students develop practical skills using these tools and methodologies. Finally, BIM education should focus on the management aspect since BIM is not just software but a process that involves teamwork and collaboration. Overall, BIM is a complex technology that requires a structured approach to education. By providing students with hands-on experience and focusing on the management aspects of BIM, students can prepare themselves to become proficient in the technology. The structure of BIM education should provide students with an understanding of not only the software but also how to integrate BIM processes with other engineering and construction processes. By doing so, they will become successful BIM and construction management professionals in the future. However, this finding could be less of a surprise as Onososen and Adeyemo [62] observed that BIM training was non-existent in almost all the institutions of learning in Nigeria, with just a university offering an introductory course to BIM, unlike the United States, where there are more than 120 universities that are fully accredited to offer degree programs that include BIM courses in the curriculum [63].

The structure of BIM was assessed based on two variables. First was whether "BIM could be useful in my teaching job", and the second was whether "There is a limit to which I can use BIM because it is not compatible with other software that I use in my teaching." The result indicates that many academics found BIM to be irrelevant in their teaching. This, however, calls for concern. And yet, there is hope. It is worthy of note that some of these concerns are currently being addressed through the introduction of core curriculum and minimum academic standards (CCMAS) for the Nigerian Universities System [64]. The ninth unique feature, as encapsulated by the document, is that "the discipline gives emphasis to the acquisition of sound knowledge of Computer-Aided Design and information technology skills needed in the 21st century". The tenth unique feature states that "…spaces and facilities are adequate and not compromised so that graduates produced can be sufficiently equipped for professional practice". This CCMAS also allows each institution to include its peculiarities, which constitute 30% of the curriculum content. With this opportunity, interested academics can now fully incorporate BIM into their curriculum. The execution of the new curriculum is expected to take effect from the 2023/2024 academic session. This effort is highly commendable; however, very little impact would be felt if professional institutions did not also revise their professional examination curricula. This is necessary to aid the smooth transition of graduates into the industry. While there are no empirical data yet, it is only left to the imagination what the likely performance would be of a digitally compliant graduate who eventually ends up writing an "analogue" professional exam.

4.3. Task and Organizational Environment and BIM-Enabled Education

Task and organizational environment were measured using six variables (Table 5). TOE2 (p = 0.026) and TOE3 (0.047)—i.e., required resources and knowledge, respectively—were found to have significant values on the effect of task and organizational environment on the intention to adopt BIM for construction education in AEC-FM education among academics. The growth of the building information modeling (BIM) sector has been remarkable in recent years, and it requires a skilled workforce that can navigate the complexities of the technology effectively [65]. BIM education plays a crucial role in equipping students with the skills and knowledge required to successfully navigate the organizational environment and handle complex BIM tasks [66].

However, the effectiveness of BIM education is significantly influenced by the task and organizational environment [67]. Firstly, the task environment plays an essential role in shaping BIM education. The task environment involves the specific characteristics of the BIM project and the skills required to execute it successfully [7]. When designing the curriculum for BIM education, the task environment should be taken into account to ensure students are equipped with the necessary skills, knowledge, and tools to handle complex projects [68]. Additionally, the task environment can influence the adoption of new technologies, and as such, BIM education should incorporate the latest trends in the sector, including digital twins, machine learning, big data, and artificial intelligence. Secondly, the organizational environment is an essential factor that can impact BIM education. The organizational environment comprises the policies, practices, and culture within a company, which can have a significant effect on how BIM is used and taught. The adoption of BIM in different organizations and sectors varies, and this informs the kind of knowledge, skills, and tools required by BIM professionals. BIM education should aim to raise awareness of the varying organizational environments and how to navigate them to achieve better project outcomes.

4.4. Group's Internal System and BIM-Enabled Education

The group's internal system was measured using seven indicators (Table 5). GIS1 ($p = 0.018$), GIS4 (0.006), and GIS6 (0.021)—i.e., level of group influence, departmental guidelines for BIM-enabled teaching and learning, and curriculum-guided lessons, respectively—were found to have significant values on the effect of the group's internal system on the intention to adopt BIM for construction education in AEC-FM education among academics.

The internal system of a group is composed of the rules, norms, values, and beliefs that influence how members behave and interact. This system is not fixed but constantly challenged as members engage in ongoing negotiation and renegotiation of meaning. BIM-enabled education requires a new way of thinking, creating and ensuring a new set of beliefs within the group. Institutional norms and values through existing outdated curricula could slow down the uptake of revolutionary technologies in the academic environment. Efforts by individuals to introduce new rules are likely to be met with contestations if not properly handled [69].

Collaboration is an essential part of BIM technology, especially through a common data environment (CDE), where a single source of truth is available to stakeholders and model integrity is maintained. The successful implementation of BIM education should recognize this. To achieve this, academics and trainers should encourage interdisciplinary academic projects that promote teamwork and enhance learners' understanding of the different roles and responsibilities of construction professionals within a project. This will help bridge the knowledge gap between construction professionals and other team members, promoting effective communication and collaboration.

It could be argued that implementing BIM-enabled education is not only an academic or institutional activity but also a socio-cultural endeavor. Some academics have expressed the fear of quacks taking over the industry if the knowledge of BIM is widespread [70]. The literature is awash with several evidence-based reports on the importance of promoting formal training in BIM education. As such, this fear should not outweigh the recognized benefits of BIM-enabled teaching and learning in higher education institutions [71,72].

5. Conclusions

The purpose of this study was to investigate how the adaptive structuration theoretical (AST) model could explain the relationship between structures of BIM, task and organizational environment, the group's internal system, and the behavioral intention to implement BIM for construction education.

The model generated was able to explain the intention to adopt BIM for construction education by structure of BIM, task and organization environment, and group's internal system. BIM education has a crucial role to play in developing the next generation of BIM and construction professionals. To effectively deploy BIM for construction education, curriculum developers, academics, and policymakers must take into account the structure of BIM, the group's internal system, and the task and organizational environment.

Our research results indicate several significant correlations that can guide interventions aimed at increasing the adoption of BIM in construction education. Specifically, we found that departmental guidelines for BIM-enabled teaching and learning, the level of group influence, curriculum-guided lessons, required resources, and required knowledge all have a strong relationship with the behavioral intention of adopting BIM in the context of construction education. These findings suggest that focusing on these factors can be instrumental in promoting the intention to use BIM for educational purposes in the construction industry globally.

To elaborate further on these correlations, it is essential to understand their implications for enhancing BIM adoption in construction education, first, on departmental guidelines. When educational departments establish clear guidelines for integrating BIM into teaching and learning, it significantly influences the intention to adopt BIM. This suggests that institutions should prioritize the development and implementation of such guidelines to promote BIM-enabled learning. Secondly, with group influence, the level of influence from peer groups plays a crucial role in shaping the intention to adopt BIM. Collaborative efforts, group discussions, and peer support can be leveraged to encourage BIM-enabled learning among educators. Considering the third factor, curriculum-guided lessons, when BIM is integrated into the curriculum and lessons, it positively impacts the intention to adopt it. Institutions should consider revising their curriculum to include BIM-related content and ensure that lessons are aligned with BIM principles. The fourth is required resources. Having the necessary resources for BIM adoption, such as software, hardware, and training, is essential. Institutions should invest in providing these resources to facilitate the smooth transition to BIM-enabled education. Lastly, required knowledge involves ensuring that faculty and students have the knowledge and skills required to effectively use BIM, which is critical. This highlights the importance of educational institutions providing training and skill development opportunities related to BIM processes and technology.

In summary, these correlations underscore the importance of a holistic approach to BIM-enabled teaching and learning in construction education. Institutions should establish clear guidelines, promote group influence and collaboration, integrate BIM into the curriculum, provide the necessary resources, and offer training and knowledge development. By addressing these factors, educational institutions can enhance the behavioral intention to adopt BIM, ultimately benefiting the construction education sector globally.

Staying mindful of evolving trends in the industry, curricula must be designed to facilitate effective collaboration between multidisciplinary teams. The task of developing a BIM curriculum is an ongoing challenge. As the sector evolves, so must the methods employed in BIM education to ensure that students are equipped to meet the ever-changing requirements of the industry. Furthermore, academics and researchers should design BIM for construction education curricula to provide students with a deep understanding of how BIM technology fits into the architectural, engineering, and construction industries. Such an understanding will equip students to handle real-life scenarios where they need to adapt to quickly changing environments.

Based on the findings and discussions presented in this paper, the following are some novel findings that we believe can contribute valuable insights to the field of BIM-enabled education and guide future research and educational practices. First is the impact of the BIM structure on education. Despite the widespread recognition of BIM in the construction industry, the study revealed a surprising lack of significant association between the structure of BIM and the intention to use BIM for education among academics. This finding challenges conventional assumptions about the direct applicability of BIM structure to educational settings, signaling a need for a nuanced understanding of how BIM's structural elements align with teaching and learning methodologies. Second is task and organizational environment influence. The study underscores the critical role of the task and organizational environment in shaping BIM-enabled education. It identifies specific variables within the task and organizational environment (e.g., required resources and knowledge) that significantly impact the intention to adopt BIM for construction education. Third is the group's internal system dynamics. The internal dynamics of academic groups, including levels of influence, departmental guidelines, and curriculum-guided lessons, emerged as crucial factors influencing the intention to adopt BIM in education. Recognizing the socio-cultural dimensions, the study suggests that successful BIM-enabled education requires a cultural shift within academic groups to accommodate the revolutionary changes brought about by BIM technology.

Therefore, the following recommendations are suggested for the universal adoption of BIM-enabled education.

1. Curriculum Integration and Skill Development

Educational institutions that are yet to integrate BIM-enabled education into their curricula should revisit and refine their curricula to integrate BIM-related content, focusing on real-world skill development for students. Emphasis should be placed on interdisciplinary projects that simulate teamwork and collaboration, essential elements in BIM projects.

2. Strategic Planning for BIM Adoption

Institutions should strategically plan for the adoption of BIM-enabled education by considering the specific task and organizational environment, ensuring that educational programs align with industry demands. This includes incorporating the latest trends in the BIM sector, such as digital twins, machine learning, big data, and artificial intelligence, into the curriculum.

3. Cultural Shift and Collaboration

To facilitate a smooth transition to BIM-enabled education, academic groups need to undergo a cultural shift. Encouraging collaboration through interdisciplinary projects, creating a supportive internal system, and addressing concerns about the widespread adoption of BIM are crucial steps.

4. Policy Advocacy and Professional Examinations

Advocacy for the inclusion of BIM-related content in educational policies is essential for widespread adoption. Professional institutions should revise their examination curricula to reflect the evolving industry standards, ensuring that graduates are well-prepared for the demands of BIM in professional practice.

There are limitations in this study. One is the adaptation of the AST. There are other intervening structures in the AST theory that were not considered in this study. Such structures include other emergent sources of structures and new social structures. Future research will be geared toward developing a BIM education framework that adequately addresses both the groups' internal system and task and organizational environment in higher institutions, including the emergent and new social structures that may develop as a result of adopting BIM-enabled learning. In addition, as most professional examinations are still largely paper based, a correlational study to investigate the relationship between BIM-enabled education and performance outcomes in professional competence examinations will also be carried out. And lastly, to aid research on the BIM education framework, a global comparative contextual study to understand the nuanced influences of task and organization environment and the group's internal system on BIM-enabled learning will be conducted.

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