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Original Article

Exploring BIM Implementation in Architectural, Engineering and Construction (AEC) Education in Uganda

Suubi Lubanga Arthur[1*], *Chris Bic Byaruhanga*[1] *& Joel Mubiru*[1]

[1] Kyambogo University, P. O. Box 1, Kyambogo, Uganda.
[*] Author for Correspondence ORCID ID; https://orcid.org/0009-0008-8532-0105; Email: artwrld626@gmail.com

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ABSTRACT

Building Information Modelling (BIM) is increasingly recognised as a transformative technology in the global construction industry. While developed nations have advanced in integrating BIM into practice and higher education curricula, BIM adoption in Africa, particularly Uganda, remains limited. This study explored the extent of BIM implementation in Architectural, Engineering and Construction (AEC) education in Uganda. Using a cross-sectional survey design, data were collected from 372 respondents, including 31 academic staff (purposively sampled) and 341 students (randomly sampled) across three universities. Questionnaires and interviews were used to collect data, while Pearson's correlation coefficient was applied in the analysis. Findings revealed that BIM adoption in AEC education is still in its infancy, with limited curriculum integration and reliance on BIM primarily for 3D modelling rather than collaborative functions. Barriers included high software licensing costs, insufficient infrastructure, inadequate faculty training, and curriculum gaps. Correlation results indicated a 22.5% association between adoption and barriers, and a stronger 47.3% correlation between adoption and strategies. Strategies such as experiential project-based learning, vertical integration pedagogy, and Green BIM models were identified but remain underutilised. The study concludes that while awareness of BIM exists, full pedagogical and institutional adoption is constrained by systemic challenges. It recommends targeted investment in infrastructure, curriculum reforms, faculty capacity building, and stronger institutional support to accelerate BIM integration in Uganda's AEC education.

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INTRODUCTION

Globally, Building Information Modelling (BIM) has revolutionised the construction sector, offering advanced tools for visualisation, coordination, cost management, and lifecycle facility management. Countries such as the United Kingdom, the United States, and Australia have mandated BIM for public projects, with higher education institutions integrating BIM into curricula to equip graduates with industry-relevant skills.

In Africa, BIM adoption has been slow. Although South Africa, Nigeria, and Algeria have initiated BIM use in practice, academic integration remains fragmented and under-researched. Uganda, despite hosting a rapidly growing construction sector, exhibits very low adoption of innovative technologies such as BIM. Studies indicate that while professionals employ BIM for basic modelling, its collaborative, analytical, and lifecycle management functions are rarely applied.

Problem Statement: Even with significant commercial interest in BIM methodology, academic communities in several countries, including Uganda, have been slower in adopting it within AEC education (Adamu & Thorpe, 2015). Given BIM's capacity as a suite of tools and methods to optimise the construction process (Elinwa & Agboola, 2013), it is timely to address aspects of BIM adoption that are just as crucial as educational integration (Barison & Santos, 2015). The growing need for modern construction technologies within Uganda's AEC environment is at a high rate. Existing research shows that while BIM has been introduced in professional practice, it is often restricted to 3D modelling and lacks integration in University curricula. Universities face challenges such as high software costs, inadequate ICT infrastructure, insufficiently trained faculty, and curriculum gaps. Without addressing these constraints, graduates risk entering the industry without the necessary competencies for modern construction demands.

Main Objective: The main objective of this study is to explore BIM implementation in Architectural, Engineering, and Construction (AEC) education in Uganda.

Specific Objectives: This study specifically sought to:

- Identify the extent to which BIM is currently adopted in AEC education in Uganda.
- Determine the barriers hindering BIM implementation in AEC education.
- Examine the strategies currently being used to enhance BIM adoption.
- Assess how the barriers and strategies collectively influence the adoption rate of BIM in higher education.

This study, therefore, fills a critical gap by examining the status of BIM integration in Uganda's higher education, identifying barriers, and

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assessing strategies currently used to promote BIM in AEC education.

LITERATURE REVIEW

Building Information Modelling (BIM) is widely defined as an intelligent model-based process that creates and manages digital representations of the physical and functional characteristics of buildings and infrastructure (Naamaneb, 2015). It goes beyond simple drafting to provide a collaborative platform that integrates multiple project dimensions, including design, scheduling, cost estimation, and facility management. Unlike traditional Computer-Aided Design (CAD), which produces 2D or 3D graphical representations, BIM utilises parametric objects and centralised databases that are dynamically linked. This integration reduces data redundancy, minimises design errors, and enhances communication among stakeholders across the entire project lifecycle (Agoras, 2018; Smith, 2014).

BIM's collaborative potential has been recognised globally, particularly in developed countries where governments and institutions have mandated its use on public projects (HM Government, 2012). Scholars argue that BIM facilitates greater efficiency in construction processes by improving visualisation, clash detection, and information management (Romero et al., 2020). These benefits have influenced the push to incorporate BIM not only in professional practice but also within higher education curricula, ensuring graduates acquire competencies aligned with industry demands (Wu & Issa, 2014).

The theoretical framework that guided this study was the Technology Acceptance Model (TAM), developed by Davis (1989). TAM posits that technology adoption is shaped by two main constructs: perceived usefulness and perceived ease of use**.** When individuals perceive a technology as beneficial and relatively easy to use, the likelihood of adoption increases. However, numerous studies applying TAM in educational settings reveal that contextual factors such as inadequate training, insufficient infrastructure, or lack of institutional support can significantly moderate adoption outcomes (Shroff et al., 2011; Surendran, 2012). In the case of BIM, while students and faculty may recognise its potential usefulness, challenges such as high software costs, hardware limitations, and absence of structured curricula often undermine its ease of use, thereby constraining adoption (Babatunde et al., 2020).

Empirical evidence reveals a significant variation in BIM adoption across different regions. In North America and Europe, universities have increasingly embedded BIM into construction management and architecture programs, either through dedicated BIM courses or integrated modules (McGraw-Hill Construction, 2014). In Asia, countries like Singapore and China have advanced BIM adoption by linking government mandates with academic training programs (Jin et al., 2019). By contrast, many African countries remain in the early stages of adoption. Studies in South Africa and Nigeria highlight recurring obstacles such as a lack of trained instructors, insufficient funding, limited institutional awareness, and the absence of national BIM education standards (Oyewole & Dada, 2019; Olanrewaju et al., 2020).

In Uganda, the limited research conducted on BIM has primarily examined its application within professional practice, where adoption is often restricted to 3D modelling without full exploitation of collaborative and analytical functions (Acheng et al., 2022). Very little scholarly work has investigated BIM integration within higher education, despite its potential to prepare students for the evolving demands of the construction industry. This gap underscores the importance of exploring BIM adoption in Uganda's AEC education, focusing on the barriers that hinder implementation and the strategies that can facilitate meaningful integration.

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METHODOLOGY

This study adopted a cross-sectional survey design to examine the extent of BIM adoption in AEC education, identify barriers to its implementation, and assess strategies for enhancing integration. The cross-sectional approach was appropriate because it enabled the collection of data at a single point in time from multiple respondents, thereby providing a snapshot of the current state of BIM adoption across selected universities in Uganda.

Study Population and Sampling

The target population comprised academic staff and students enrolled in AEC-related programs at three universities: Kyambogo University, Makerere University, and the International University of East Africa (IUEA). These institutions were selected because they represent some of the leading providers of architecture, engineering, and construction education in Uganda.

A total of 372 respondents participated in the study. This included 31 academic staff, who were purposively sampled due to their direct involvement in curriculum development and delivery of AEC courses. Staff members were selected across different departments to capture diverse perspectives on BIM integration. In addition, 341 students were selected using simple random sampling to ensure fair representation of the student body across year levels and disciplines. This mixed sampling approach allowed the study to capture both institutional (staff) and learner (student) perspectives on BIM adoption.

Data Collection Instruments

Two main instruments were employed:

- Structured questionnaires were administered to students. The questionnaire was divided into sections that captured demographic information, level of BIM exposure, perceptions of BIM usefulness, perceived barriers, and views on strategies for adoption. Closed-ended questions with Likert-scale responses facilitated quantitative analysis, while a few open-ended questions allowed students to provide more detailed perspectives.

- Interview guides were used with academic staff. The interviews provided deeper insights into curriculum design, faculty capacity, and institutional challenges in adopting BIM. The qualitative data obtained from these interviews complemented the survey findings by offering contextual explanations.

Data Collection Procedure

Permission to conduct the study was obtained from relevant university authorities, and ethical clearance was sought to ensure compliance with research standards. Respondents were assured of confidentiality, and informed consent was obtained before participation. Data collection took place within university premises, with questionnaires distributed in lecture rooms and interviews conducted at times convenient for academic staff.

Data Analysis

Quantitative data from the questionnaires were coded and entered into the Statistical Package for Social Sciences (SPSS) for analysis. Descriptive statistics such as frequencies and percentages were used to summarise adoption levels and barriers. Inferential statistics, specifically Pearson's correlation coefficient, were employed to establish the relationships between BIM adoption, barriers, and strategies.

Qualitative data from interviews were analysed thematically. Responses were transcribed, categorised, and coded into themes such as curriculum gaps, infrastructural limitations, and potential strategies for adoption. These thematic insights were integrated with quantitative findings to provide a comprehensive understanding of the research problem.

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Validity and Reliability

To enhance validity, the research instruments were pre-tested with a small sample of students and staff not included in the main study, and necessary adjustments were made to improve clarity and relevance. Reliability of the questionnaire was tested using Cronbach's alpha, which confirmed acceptable internal consistency of the scales measuring adoption, barriers, and strategies.

RESULTS

Survey findings revealed mixed levels of BIM adoption within AEC education in Uganda. While a small proportion of staff members had made efforts to introduce BIM-related concepts in their teaching, the majority continued to rely on conventional approaches such as manual drafting and basic CAD applications. Interviews with lecturers indicated that although there was awareness of BIM's importance in preparing students for modern industry demands, many lacked the technical skills or institutional support necessary to integrate BIM fully into their courses.

From the academic staff responses (n=31), findings showed that BIM adoption is very limited across all objectives. Regarding Objective 1 (extent of adoption), most staff acknowledged only partial exposure to BIM, mainly through isolated modules or optional sessions, while full curricular integration was almost non-existent. For Objective 2 (barriers), staff consistently highlighted high software licensing costs, lack of adequate ICT laboratories, and limited institutional prioritisation of BIM. Objective 3 (strategies) revealed that while a few lecturers had introduced experiential learning methods and encouraged students to use software such as Revit and ArchiCAD, these strategies remained isolated and under-supported. Finally, in relation to Objective 4 (interaction between barriers and strategies), staff emphasised that even when strategies such as project-based learning were attempted, they were undermined by systemic constraints, particularly curriculum gaps and insufficient faculty training. These staff perspectives corroborate the quantitative student data, reinforcing that BIM integration in Uganda's AEC education remains fragmented and at a preliminary stage.

Students' responses further highlighted the limited exposure to BIM. Most reported that their engagement was confined to introductory modelling exercises, often using software like Revit or ArchiCAD, without access to the full suite of collaborative, analytical, or lifecycle management functions that characterise advanced BIM use. This suggests that while awareness of BIM exists at the student level, practical implementation remains narrow and underdeveloped.

Table 1: Extent of BIM Adoption in AEC Education (Students' Responses, n=341)

Adoption Level	Frequency (n)	Percentage
Fully integrated	41	12%
Partially integrated	123	36%
Not integrated	177	52%

As shown in Table 1, only 12% of respondents indicated that BIM had been fully integrated into their coursework. The majority (52%) reported no integration, while 36% had partial exposure. These figures illustrate the early and fragmented stage of BIM adoption in Ugandan higher education institutions.

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Table 2: Key Barriers to BIM Implementation in AEC Education

Barrier	Rank	Frequency (n)
High software costs	1	210
Inadequate facilities	2	180
Lack of trained staff	3	165
Curriculum gaps	4	150
Limited management support	5	120

When asked about the barriers to implementation, respondents consistently cited challenges that align with broader African experiences. The most pressing constraint was the high cost of software licenses, which universities found unsustainable without government or industry support. This was followed by inadequate computer laboratories and poor ICT infrastructure, which limited the capacity for practical training. A further barrier was the lack of adequately trained staff, many of whom had not received formal training in BIM. Curriculum gaps also emerged as a key issue, with most programs still structured around traditional CAD and engineering design methods. Finally, limited management support and prioritisation of BIM by institutional leadership exacerbated these challenges.

Correlation analysis provided further insight into the relationships between adoption, barriers, and strategies. A modest 22.5% correlation between adoption and barriers suggested that while barriers play a significant role in constraining BIM use, they are not the sole determinant of adoption levels. A stronger 47.3% correlation between adoption and strategies indicated that well-designed institutional and pedagogical strategies have a more substantial effect on BIM uptake. Conversely, only a 7% correlation between barriers and strategies was recorded, implying that although strategies are being attempted, they are often not sufficient to overcome the systemic barriers identified.

Technology Acceptance Model (TAM) Summary Findings:

- **Perceived Usefulness:** Both staff and students recognised BIM as a valuable tool for improving design accuracy, collaboration, and alignment with global industry practices. This recognition shows strong potential for adoption if institutional and infrastructural barriers are addressed.
- **Perceived Ease of Use:** Respondents, especially staff, emphasised that BIM was difficult to integrate due to inadequate training, lack of institutional support, and limited access to software and hardware. This reduced the ease of use dimension and negatively influenced adoption rates.
- **Overall Acceptance:** The imbalance between perceived usefulness (high) and perceived ease of use (low) explains the current low levels of adoption despite strong awareness. **This indicates that improving infrastructure, training, and curriculum support could significantly shift BIM adoption in line with TAM predictions.**

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Table 3: Comparative Results: Students vs. Academic Staff

Objective	Students' Findings	Academic Staff Findings
Extent of Adoption	The majority (52%) reported no integration; only 12% reported full integration.	44.4% had partially integrated BIM in some teaching; 55.6% had not integrated at all.
Barriers	High software costs, poor ICT infrastructure, curriculum gaps, lack of trained staff.	The same barriers echoed, with stronger emphasis on the lack of training and institutional prioritisation.
Strategies	Students are exposed mainly to isolated modelling exercises.	Some lecturers attempted experiential/project-based learning, but efforts were under-supported.
Adoption Interaction	Students are unsure about institutional commitment and ease of use.	Staff highlighted that strategies fail due to systemic barriers such as curriculum gaps and limited support.

Students vs. Academic Staff

Overall, the results from academic staff strongly align with those of students, confirming that systemic barriers, particularly cost, infrastructure, and faculty training, are the main hindrances, while strategies remain fragmented and underfunded. This combined evidence from staff and students provides a holistic picture of BIM adoption in Ugandan AEC education and highlights the urgent need for coordinated institutional reforms.

Correlation analysis provided further insight into the relationships between adoption, barriers, and strategies. Table 4 presents the correlation coefficients obtained from the analysis.

Table 4: Correlation Analysis of Adoption, Barriers, and Strategies

Variables Compared	Correlation Coefficient (r)	Interpretation
Adoption vs. Barriers	0.225	Weak positive correlation
Adoption vs. Strategies	0.473	Moderate positive correlation
Barriers vs. Strategies	0.070	Very weak correlation

The results indicate that barriers alone explain only a small proportion of the adoption variance (22.5%), suggesting that while constraints are significant, they do not completely prevent adoption. Strategies, however, showed a stronger correlation with adoption (47.3%), meaning that well-structured institutional and pedagogical approaches can considerably enhance BIM uptake. The minimal correlation (7%) between barriers and strategies suggests that although strategies are being attempted, they are often insufficient to fully counter systemic challenges.

Overall, this analysis reinforces that BIM adoption in Ugandan AEC education is influenced more by the presence or absence of deliberate strategies than by barriers alone. Without proactive institutional reforms and resource investments, adoption is likely to remain limited.

DISCUSSIONS

The results of this study affirm that Uganda's AEC education sector is still in the initiation stage of BIM adoption, a pattern consistent with findings from other developing countries such as Nigeria, Kenya, and South Africa (Babatunde et al., 2020; Oyewole & Dada, 2019). The limited levels of integration reported by both staff and students indicate that while awareness of BIM exists, practical implementation remains shallow and fragmented.

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This suggests that Uganda is yet to transition from exploratory use of BIM to a more institutionalised and curriculum-driven adoption phase.

The correlation analysis provides important insights into the dynamics of adoption. The relatively strong 47.3% correlation between adoption and strategies underscores the critical role of deliberate pedagogical and institutional interventions in shaping outcomes. Strategies such as project-based learning, vertical integration of BIM concepts across courses, and collaborative projects with industry partners appear to significantly enhance students' exposure and engagement with BIM. This finding resonates with earlier studies in developed contexts, where well-structured curricular strategies have been instrumental in mainstreaming BIM education (Wu & Issa, 2014; Romero et al., 2020).

On the other hand, the 22.5% correlation between adoption and barriers shows that while constraints such as cost, lack of infrastructure, and inadequate training are important, they do not completely prevent adoption when proactive strategies are in place. However, the persistence of systemic challenges, including limited institutional investment and curriculum gaps, continues to slow down the pace of adoption. These findings highlight the paradox in which universities acknowledge the importance of BIM but fail to commit sufficient resources to address the practical obstacles to implementation.

The comparative analysis between students and academic staff further strengthens this argument. Both groups consistently identified high software costs, poor ICT infrastructure, and inadequate training as key barriers, though staff placed greater emphasis on institutional prioritisation and curriculum gaps. While students mainly experienced BIM as fragmented exposure through modelling exercises, staff revealed that their attempts to introduce experiential learning and project-based strategies were often undercut by systemic barriers. This dual perspective demonstrates that adoption challenges are not isolated at the learner level but deeply embedded in institutional structures.

The findings also align with the Technology Acceptance Model (TAM) framework. According to TAM, user acceptance is shaped by perceived usefulness and perceived ease of use (Davis, 1989). In Uganda, students and faculty appear to recognise the usefulness of BIM in enhancing design accuracy, improving collaboration, and aligning with industry demands. Nevertheless, the ease of use dimension remains constrained by infrastructural and institutional shortcomings, including poor computer facilities, limited software access, and inadequate training opportunities. This imbalance between perceived usefulness and ease of use explains the low adoption rates despite relatively high awareness. The TAM findings therefore confirm that BIM adoption is not hindered by a lack of recognition of its benefits, but by insufficient conditions that support ease of use. Addressing training gaps, improving ICT infrastructure, and lowering software costs would directly improve the ease of use construct and enhance adoption.

Furthermore, the weak 7% correlation between barriers and strategies suggests that the strategies currently being applied are insufficiently robust to counter the systemic barriers identified. For example, while some lecturers attempt to introduce BIM concepts in isolated modules, these efforts are undermined by the lack of institutional support and standardised curricula. This indicates that adoption cannot rely on individual faculty initiatives alone but requires coordinated, top-down policy reforms at both institutional and national levels. Taken together, the correlation analysis and TAM application demonstrate that adoption outcomes are more strongly shaped by the presence of enabling strategies than by the magnitude of barriers alone. This suggests that institutions can overcome

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persistent constraints through well-structured reforms, provided these strategies are adequately resourced and institutionalised.

Overall, the discussion reveals that Uganda's path toward meaningful BIM adoption in AEC education requires a dual approach: (i) addressing systemic challenges through targeted investment, faculty training, and curriculum reform, and (ii) scaling up effective pedagogical strategies that enhance students' hands-on engagement with BIM tools and concepts. Without simultaneous action on both fronts, BIM adoption is likely to remain at the exploratory stage, limiting the competitiveness of Ugandan graduates in the regional and global construction markets.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study set out to explore the extent of BIM adoption in Uganda's AEC education sector, the barriers hindering its implementation, and the strategies being employed to facilitate integration. The findings indicate that BIM adoption remains limited, with most institutions either partially integrating BIM concepts or not integrating them at all. Only a small proportion of students and staff reported meaningful engagement with BIM beyond basic modelling, underscoring the early stage of adoption.

The study identified several barriers, including the high cost of software licenses, inadequate ICT infrastructure, lack of adequately trained faculty, curriculum deficiencies, and limited institutional commitment. These challenges mirror those reported in other developing countries and reinforce the systemic nature of BIM adoption constraints in low-resource contexts.

The comparative analysis between students and academic staff highlighted that both groups face similar challenges, though staff emphasised institutional prioritisation and curriculum gaps more strongly, while students noted fragmented exposure to BIM through modelling exercises. These complementary perspectives underline the need for holistic reforms that address both learner experiences and staff capacity.

Despite these challenges, the study revealed that targeted strategies such as experiential learning, vertical integration of BIM across courses, and curriculum reforms hold strong potential to enhance adoption. The correlation results showed that adoption is more strongly associated with strategies (47.3%) than with barriers (22.5%), indicating that deliberate institutional reforms and pedagogical strategies have the power to accelerate BIM uptake even in the presence of systemic challenges.

Furthermore, the application of the Technology Acceptance Model (TAM) confirmed that while perceived usefulness of BIM is high, perceived ease of use remains low due to insufficient training, poor ICT infrastructure, and limited access to licensed software. This imbalance explains the current low adoption levels despite growing awareness. Improving ease of use through capacity building and infrastructural investment is, therefore, key to improving acceptance.

Overall, the study concludes that the future of BIM adoption in Uganda's AEC education lies in tackling systemic barriers while simultaneously scaling up effective strategies. Institutional commitment, curriculum reform, and faculty development will be essential if Uganda is to move beyond exploratory adoption and prepare graduates with globally competitive digital construction skills.

Recommendations

1. **Universities:**

Incorporate BIM into core curricula across all AEC programs rather than offering it as an elective or supplementary module. Institutions should also prioritise investment in ICT infrastructure,

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including computer laboratories and licensed software, to support effective BIM training. In addition, universities should institutionalise project-based and experiential learning approaches identified in this study as effective strategies for enhancing adoption.

2. Government:

Provide subsidies or negotiate educational licensing agreements that incorporate all the software capabilities with software providers to reduce costs for universities. National policy directives mandating or encouraging BIM integration in higher education would further accelerate adoption. Government ministries responsible for works, housing, and education should jointly develop a national BIM education strategy to standardise and guide integration across universities.

3. Faculty Development;

Establish continuous professional development programs to train academic staff in BIM. Partnerships with professional associations, industry stakeholders, and international institutions could help strengthen faculty capacity and foster knowledge transfer. Training should focus not only on technical BIM use but also on innovative teaching to improve students' perceived ease of use, as highlighted by TAM findings.

4. Collaboration with Industry;

Promote partnerships between universities and construction industry stakeholders. Such collaborations would provide students with hands-on exposure to BIM-enabled projects, bridging the gap between theory and practice while ensuring that academic training remains aligned with industry needs. Industry involvement would also help universities update curricula and adopt tools that reflect real-world practices.

5. **Curriculum Reform:**

Develop and adopt national BIM education guidelines or frameworks to standardise BIM integration across Ugandan universities. A harmonised approach would ensure consistency in training, promote best practices, and enhance the competitiveness of graduates both regionally and internationally. Curriculum reform should specifically address the gaps highlighted by academic staff, including fragmented exposure, outdated teaching methods, and weak institutional prioritisation of BIM.

FURTHER RESEARCH RECOMMENDATIONS

There is a need to conduct a longitudinal study to track the progression of BIM implementation in AEC education over time. This would allow researchers to observe changes in adoption rates, barriers, and strategies over an extended period, providing valuable insights into the dynamics of BIM integration in higher institutions of learning in Uganda.

There is a need to assess the impact of BIM implementation on student learning outcomes, industry readiness, and job market competitiveness. Evaluate the effectiveness of BIM education in preparing students for careers in the construction industry and examine the benefits and challenges of incorporating BIM into the curriculum.

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