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Original Research

The impact of CAD software on the teaching of engineering graphics: a systematic review

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ABSTRACT

Introduction. Incorporating CAD and BIM in the engineering graphics learning environment has revolutionized teaching methods by providing richer visualization, analysis, and collaboration tools. Despite this, there are still big differences in the adoption and ability rates and levels of CAD and BI across regions and institutions.

Methods. For PRISMA, 45 studies were used for comparison from 2020-2024. Studies selected for the review had to meet inclusion criteria about CAD and BIM awareness and competency, challenges, and fit within the engineering education curriculum. The data were combined qualitatively and quantitatively, and the discoveries were classified into major themes.

Results. CAD applications like AutoCAD are more widely adopted in the BIM industry than in BIM applications like Revit, especially in development areas. Challenges to BIM adoption include high costs, lack of policies, and 2D drafting. Countries with developed BIM industries are the most effective and integrate educational curricula, highlighting the importance of industry alignment in promoting CAD and BIM technologies.

Conclusion. This research suggests that frameworks for implementing BIM integration require a uniform set of best practices, more access to information, and demonetization and curriculum development to fill shortcomings. Even with CAD at the core, BIM advances must be looked for following the industry's needs and put into practice. Further research should be directed toward developing ways to overcome and advance the existing technology gaps.

Keywords: Computer modeling, Graphic design, Educational methods, Graphic design, Digital technologies.

1 Introduction

Engineering graphics is a principal part of engineering curriculums since it helps to build up spatial orientation, visualization abilities, and the idea of technical illustrations amongst students. Engineering graphics is the art of making correct technical and three-dimensional drawings and models for being engineering designs, which are crucial tools of communication and understanding in the field of engineering [1].

Today's technological era has greatly diversified engineering graphics education with the incorporation of Computer-Aided Design (CAD), which has become a necessary tool for designing accurate models and drawings across numerous disciplines of engineering [2]. Client architectural design software is not only useful for making and changing technical drawings but also effectively contributes to the improvement of project process performance – increasing productivity and, with that, allowing the use of collaborative design strategies in industries like manufacturing, construction, etc. [3].

CAD tools have lately attracted attention, especially because of their intersection with the BIM framework, which has recently grown popular for implementing building projects during design, construction, usage, renovation, and deconstruction in the AEC field. As the concept of BIM centers on creating and sharing a single model, it is possible to involve multiple disciplines to input their data into the model, therefore making the workflow significantly less opaque [4, 5].

In the fields of consumer and industrial product design, there is a conceptually similar process called Product Lifecycle Management (PLM) that integrates all aspects of a given product, beginning with the idea stage and ending with its disposal, by offering an iterative workflow that collects all the relevant data within a single database. These advancements prove how significant CAD tools are in the engineering discipline, as learning geometric modeling is key in the engineering curriculum [6, 7].

1.1. Research gaps and challenges

CAD or Building Information Modeling (BIM) has revolutionized more than just professional practice, however; BIM in particular is still a relatively restricted part of university education. However, current engineering curricula are predominantly grounded on conventional teaching approaches, and CAD integration in the classroom has only been incremental; physical barriers such as institutional and educational constraints can be credited for this. Among the main concerns of utilizing CAD tools is the fact that students take a long time to learn how to navigate through the tools given the complicated interfaces and features of the software [8]. Further, other challenges for universities include high costs incurred on software licenses, limited access to specialized equipment, and faculty development to be able to impart these tools [9]. These challenges have kept the implementation of CAD and BIM in engineering graphics education somewhat hindered, thereby leaving an ever-widening gap between what the students are trained to deliver and what the economy is asking for [10].

However, integrating CAD into teaching has been achieved without considering spatial visualization skills as an important aspect of the curriculum. Concepts that were part of traditional curricula like descriptive geometry, where students sharpen their ways of thinking spatially and interpreting spatial information, have been cut to make room for other subjects, effectively demoting students' spatial IQ. The data show that spatial visualization appears to be crucial to CAD-based endeavors since students who possess above-average spatial skills perform better in 3D modeling and interpretation [11]. Due to the increased difficulty level required in CAD and BIM for three-dimensional modeling, there is a need for a rethink in how engineering graphics courses are being imparted to students to meet modern engineering challenges.

1.2. Problem statement

In the engineering curriculum, engineering graphics is special in the respect that it is concerned with output in terms of visualization and accuracy, as opposed to analytical or theoretical recall that characterizes many other disciplines. In the discipline, the student has to draw and understand several kinds of view such as orthographic projection, sectional views, and isometric drawings, which are vital in illustrating and explaining design intent as well as the relative position of the components. When engineering graphics are incorporated into CAD, students can move from 2D drawings to 3D models where they can manipulate the creation in ways that were not possible when using mere sketches [12]. This transition is especially apt within BIM spaces where engineers, architects, and construction specialists depend on a collective 3D model and data analysis at every phase of construction and design [13].

Concerning CAD and BIM in practice, CAD is a non-parametric software that includes tools for drafting, visualization, and documentation [14, 15]. In this context, it is usually viewed as a computerized form of the traditional hand-drafting process. AutoCAD, for instance, SketchUp, and 3D Studio Max were developed based on traditions of manual drafting when it comes to depicting building components [16]. Field-tested building information modeling software like Revit actualizes competent 3D models whereby the building components are parametric and are developed to emulate real life [17]. According to Malla V, Delhi VS [18], BIM "is based on a virtual 3D model of the proposed facility as the only source of information on a given project" [19]. The key in BIM is collaboration and management where all details of a project, including drawings, documents, etc., exist within a single three-dimensional model stored in one shared database [16, 20]. As a result, BIM is interpreted as either Building Information Modeling [21] or Building Information Management [22]. The only distinction taken between these two definitions concerns the degree to which the model is perceived as either the creation of construction documents or as a system of construction management and maintenance. Originally, BIM was geared towards achieving implementation in at least several progressive dimensions of practice. These range from BIM 3D to nD based on its use as an enabler of a construction product or management process [23].

BIM has 3D which means parametric of the whole project. In Nigeria, Autodesk's Revit is commonly used in parametric modeling. This is a more developed form of 2D designing [23]; it is seen as an automatic version of the design processes conventional to designers before designing their projects. CAD 2D drawings, especially AutoCAD, remain the accepted norms of practice in Nigeria [24, 25]. As a result, various students have a huge level of mastery and understanding of AutoCAD. In the same league there are other 2D CAD tools like SketchUp, 3Ds Max, Lumion, etc., that are used for visualization purposes. 4D BIM involves the scheduling of the building elements in addition to the 3D tool and brings in the management of the construction process since it can schedule the project in phases right from product to delivery [26]. BIM was initially created by Aouad et al. in 2006 at the University of Sanford, UK [27, 28].

1.3. Analysis of CAD and BIM awareness and proficiency among students

1.3.1. Overview of student proficiency and preferences

Hence, AutoCAD and SketchUp are the most popular CAD software in developing countries such as Nigeria and Malaysia because of industry relevance and easy availability [29, 30]. This is because AutoCAD has been developed to work well in 2D graphics and is well-known in architectural practice for its flexibility. Autodesk AutoCAD is used more in Nigeria than tools under BIM like Revit because NCI still focuses on 2D displays [31]. Likewise, in Malaysia, students at the University of Malaysia reported high use of AutoCAD (95%) and SketchUp, while a paltry 27.8% used Revit, a BIM software, saying that there were no BIM implementation guidelines [32].

This pattern is found in other developing areas like the developing country of Jordan, more specifically the Hashemite Kingdom. AutoCAD and Photoshop have the highest usage by students at 54% each, while the percentage of students who have used Revit was the lowest at 18% [33, 34]. However, the American and Scandinavian nations prove greater utilization of BIM than developing ones due to their having integrated BIM to a greater extent into courses offered by their academic fields of AEC. BIM education is embedded in the US context; 78% of the US institutions reported to have adopted BIM, and the most frequently used program cited was Revit alongside freehand 3D modeling [35, 36].

1.3.2. To facilitate this analysis, proficiency levels have been categorized by country and software

Skills are also region- and software-specific and may not transfer from one type of software to another. Nigeria and Jordan were found to have the highest ability with AutoCAD, mostly self-taught and as required by the industry. For instance, in Akure, Nigeria, the competence reached 90%, because it plays a significant role in the architectural job market where firms essentially consider 2D CAD applications [37]. On the other hand, BIM education in the context of the U.S. emphasizes more on 3D modeling because the current industrial practices demand knowledge about BIM useful for developing coordinated project models [38]. Although the awareness of BIM in Croatia is relatively high, the level of BIM proficiency among undergraduate students is still low: the students employ BIM only for visualization instead of various functions, including sustainability analysis, despite its high awareness in Croatia. Current trends suggest that there is a gap between awareness and superior BIM implementation across the world [39, 40]. Table 1 shows the awareness and usage of CAD and BIM software by region below:

Table 1. Awareness and Usage of CAD and BIM Software by Region

Country/Region	Most Common CAD Software	Most Common BIM Software	Awareness Level	Proficiency Level	Key Findings
Nigeria	AutoCAD, SketchUp	Revit	High for CAD	High for AutoCAD	CAD is preferred due to industry reliance on 2D graphics; Revit adoption is low due to a lack of BIM emphasis [29, 41].
Malaysia	AutoCAD, SketchUp	Revit	High for CAD	Moderate for CAD	AutoCAD is preferred for flexibility in 2D design; Revit use is limited by a lack of BIM guidelines [29, 42].

Country/Region	Most Common CAD Software	Most Common BIM Software	Awareness Level	Proficiency Level	Key Findings
Jordan	AutoCAD, Photoshop	Revit	High for CAD	Moderate for AutoCAD	AutoCAD most used; low Revit proficiency [29, 43].
United States	Revit	Revit	High for BIM	High for BIM	High BIM implementation in curricula; Revit preferred in AEC programs [29, 44].
Croatia	AutoCAD, SketchUp	Revit	High for BIM	Low for BIM	Revit use is limited to visualization; sustainability aspects are underemphasized [39].

Source: author's development

CAD and BIM usage is illustrated by data in Table. 1 depicting the regional differences: CAD is notably popular in developing countries such as Nigeria and Jordan because of its versatility and compliance with industry standards, with programs such as AutoCAD. On the other hand, advanced systems for BIM implementation like Revit are adopted primarily in developed countries such as the United States and the Scandinavian countries for various reasons and because certain legal standards that dictate the application of BIM do not exist in developing nations. This emphasizes the need for breaking confines such as the material and the budget for a solution to the discrepancy between the academic programs and commercial goals. They show that more targeted changes are required to redress the imbalance in technology familiarity and use.

Table 2. Proficiency Levels by Software Type

software	Nigeria (%)	Malaysia (%)	Jordan (%)	U.S. (%)	Croatia (%)	Key Observations
AutoCAD	90	High	54	Moderate	High	AutoCAD proficiency is generally high in developing regions, driven by industry preference for 2D modeling.
Revit	40	28	18	High	Low	Revit proficiency is lower in developing regions, partly due to a lack of BIM-focused curricula.
SketchUp	Moderate	88	15	Low	High	SketchUp is used as an introductory CAD tool; limited use in advanced modeling or BIM.
Photoshop	-	-	54	Low	Low	Photoshop serves as a supplementary tool for visualization, particularly in Jordan.

Source: author's development

Thus, Table 2 sheds lighter on the major challenges to the adoption of BIM in educational institutions and industries, such as the lack of standards, high software costs, and lack of expertise. These difficulties, especially encountered in countries with developing economies such as Malaysia and Nigeria, limit BIM's complete implementation into engineering graphics courses. On the other hand, countries with advanced BIM environments, like the USA, are found to manifest better levels of adoption and competence. This analysis is important in establishing areas of concern that the educational institutions have to close with the set standards of the industries. They emphasize the fact that BIM tools should be made affordable, and the training on their usage should be extensive to enhance global competitiveness.

1.4. Analysis and trends

Conclusively, AutoCAD and SketchUp emerged as the leading CAD applications for training in developing countries. However, industry dependency on 2D illustrations has established a preference for CAD over BIM for current employment openings [35, 38]. These tools are learned informally through self-learning due to the limited availability of training programs in Nigeria, a phenomenon also witnessed in Jordan [35, 38]. This also means that most students possess fairly good AutoCAD skills since this tool is widely used in local industries.

On the other hand, BIM software like Revit is used in the United States and Scandinavian countries where there is enough adoption of BIM in the field of construction, hence the advanced use of BIM in the curriculum. BIM proficiency in these regions includes using 3D and 4D models, which are pertinent in model coordination and scheduling issues in today's construction projects [35, 38]. Nevertheless, even though the application of BIM is acknowledged in countries such as Croatia, deep analysis or sustainability purposes are not prioritized, and the participant's level of knowledge regarding complex BIM features is relatively low [35, 38]. Regional practices, available resources, and program timetables determine the uptake of CAD and BIM in higher learning institutions. Finally, the data shows that more mature regions, which have high expectations for the AEC industry, focus on BIM training. In contrast, the regions without such expectations provide mostly 2D CAD training, which is sufficient in their contexts. This gap calls for developing well-intentioned curricula in developing countries to ensure students are imparted with appropriate BIM skills in response to educational outcomes corresponding to global trends.

1.5 Research aim

This study aims to investigate to what extent CAD and BIM tools influence the training of engineering graphics concerning the engineering graphics proficiency of the students, the learning experience, and the students' market readiness. The study examines whether it would be possible to improve the current CAD and BIM instruction by acting on regional disparities, allocation of resources, and educational framework to match the industry's needs.

1.6 Research objectives

The research analyzed CAS and BIM tools in engineering graphics teaching by investigating how they affect student abilities and prepare them for real-world work conditions. The research focused on understanding how these tools connect with curricular content throughout various regions while examining enabling and limiting factors, including institutional backing, faculty education, and sufficient resources for teaching. The research focused on exposing BIM implementation weaknesses, especially within developing regions, and making recommendations to enhance curriculum structure design. The research examined the influence of national policies and industry cooperation on CAD and BIM educational programs to meet professional career requirements better.

To guide this investigation, the following research questions are posed:

- How and in what ways does CAD software enhance or complicate the process of teaching engineering graphics concerning student learning outcomes and degree of interest?
- What are the primary advantages and disadvantages of adopting CAD in a virtual learning environment?
- How does using CAD software foster the development of aptitudes required for spatial reasoning and visualization, construction drawing, and modeling?

Engineering has increasingly relied on CAD and BIM for design and project management; educational institutions must address curriculum integration and skill development challenges. By bridging the gap between traditional engineering graphics education and modern CAD-based practices, universities can better prepare students for the technical demands of today's engineering professions.

2 Methodology

In this task, the guideline of the PRISMA was adopted, and this research involved a systematic literature review (SLR) of recent literature. The PRISMA approach involves four stages: Identifying, Screening, Eligibility, and Inclusion criteria which have been very much adhered to to enable choice of all the related literature.

2.1 Identification

To achieve a broad range of literature related to the awareness and competency of students in CAD and BIM tools in various regions, a preliminary search was conducted. The database choices of IEEE Xplore, Scopus, Web of Science, Research Gate, MDPI, and Google Scholar were chosen since they cover the field of engineering and architectural education. After identifying the research objectives of the study, proper keywords and search terms were created and these include; CAD, BIM, student proficiency, awareness, and engineering education. Boolean operators were used to search more narrowly, and no filters were set as to the publication years, language, or places.

2.2 Screening

The collected titles and abstracts of the examined studies were compared with the initially formulated inclusion and exclusion criteria. To be included in this review, studies needed to focus on:

- The knowledge or experience of students regarding CAD or BIM.
- Comparison of the use of CAD and BIM by students.
- Cad-BIM integration in the context of the constructed environment: regional trends in CAD-BIM utilization in educational curricula.

The review excluded research in literature outside of engineering education, another source, or literature that did not describe learners' performance in CAD or BIM directly. After screening, such papers were excluded that had another similar article by the same author and year of publication.

2.3. Eligibility

Abstracts of the rest of the research were screened for inclusion based on methodology and data relevance and the full texts of the included studies were obtained. To ensure that only reliable data regarding student awareness and usage of CAD or BIM software would be used, only empirical research was included. For this reason, any paper that offered perspectives on regional variations or pedagogy, or students' learning outcomes on the use of CAD and/or BIM was also considered for inclusion. Some scrap studies were excluded due to low sample sizes while others due to the absence of clear methodology.

2.4. Data extraction and analysis

Information from the included studies was then sampled using a structured data abstraction form that enhances consistency and reliability. The data recorded were: the author(s) and the year and place of publication, software concentration being CAD, BIM, or both, and the student level, i.e. undergraduate or postgraduate on whether the study found a positive awareness, use, or proficiency level.

2.5. Synthesis and reporting

The findings have been integrated systematically to answer the objectives of the review in terms of regional distinction, factors affecting CAD and BIM effectiveness, and practice of industry benchmarks. Each of the findings was displayed in narrative and tabular forms to ensure ease of understanding and comparison between them. This PRISMA-based method ensured a systematic and thorough approach to the review of CAD and BIM competency in engineering education to offer dependable conclusions regarding regional competency benchmarks, educational voids prevailing, and the effects of curriculum flow on student competency. This methodology is fully replicable, and this is also very important when making systematic literature reviews. As illustrated in Fig. 1 below.

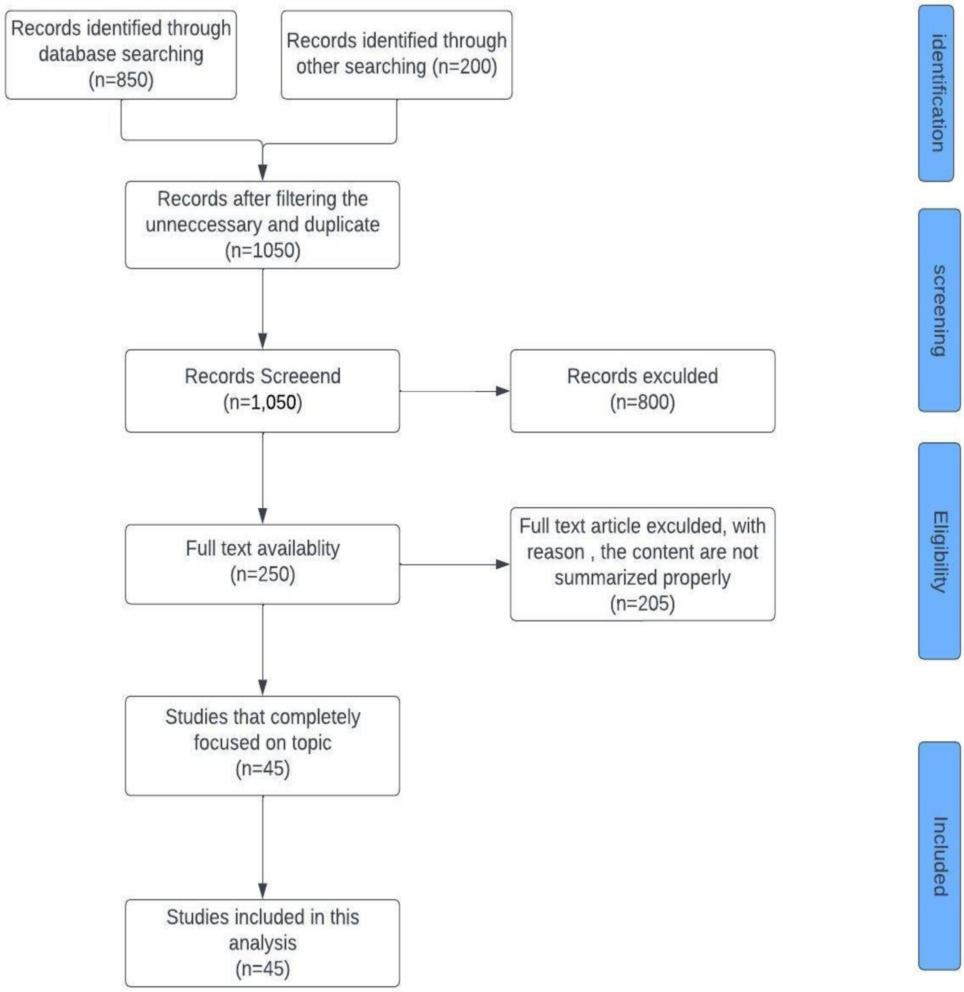

Figure 1. Systematic literature review methodology using the PRISMA approach (Source: author's development)

Table 3. Search Strategy

Keywords	Engineering Graphics & Design, CAD, Computer-Aided Design, CAD in Education and CAD in graphics teachings; computer modeling, graphic design, educational methods, graphic design, digital technologies, BIM, Business Integrated Modelling, 3D modeling
Popular search engines	IOP, Citeseer, MDPI, Springer, ScienceDirect, IEEE, John Wiley & Sons, Sage Publications, ResearchGate, ACM Digital Library, Taylor & Francis Google Books
Inclusion criteria	Relevance
Exclusion criteria	Editorials; expert opinion; letter to editor; commentary; timeline; subject-area (technical engineering); publication stage; Russian Research articles
Timeline filter	2020-2024
Language	English only

Source: author's development

3. Results

The findings are grouped regarding the research questions to establish information on student awareness, proficiency, and regional uptake of CAD/BIM tools for engineering and architecture curricula. For a better understanding of these trends, data tables and diagrams are used.

Research Question 1: How informed are students of CAD and BIM tools in engineering and architectural education? The research papers surveyed show that students' awareness of CAD and BIM tools in different parts of the world differs, and some tendencies of software choice and curriculum implementation are described. Table 4 presents the major software tools identified and endorsed by the students across various countries.

Table 4. Awareness and Usage of CAD and BIM Software by Students

Country	Primary CAD Software	Primary BIM Software	Awareness Level (%)	Reference
Nigeria	AutoCAD, SketchUp	Revit	98 (BIM)	[45]
Malaysia	AutoCAD, SketchUp	Revit	88 (CAD), 27.8 (BIM)	[46]
Jordan	AutoCAD, Photoshop	Revit	90 (CAD), 40 (BIM)	[47]
USA	Revit, ArchiCAD	Revit (Primary BIM)	78 (BIM)	[35]
Croatia	AutoCAD, Revit	Revit	High (BIM)	[39]
Saudi Arabia	AutoCAD, SketchUp	Revit, ArchiCAD	62 (BIM)	[48]

Source: author's development

1.2. Analysis of regional CAD and BIM proficiency: integrated narrative with table analysis

This trend analysis of CAD and BIM competency by various areas unfolds a matrix of curriculum patterns, industry requirements, and accreditation structures. The following workings are derived from the findings whereby the data presented in Tables 4,5 and 6 are explained in light of the identified findings.

1.3. CAD proficiency: a global standard

Analyzing Table 4, one can distinguish that CAD tools, especially AutoCAD, are familiar to everyone as being relevant to 2D drafting and basic design. Some of the proficiency values, such as those obtained from Nigeria (90%) and Jordan (90%), were high because the integration of curriculum and industries relies heavily on the application of CAD. For instance, Nigerian architectural firms originally focused more on 2D designs, which demand AutoCAD as the central innovative tool among students [35, 38].

In the USA, striving for preparation in concomitance with industries guarantees students reach the levels of the highest CAD skills; AutoCAD remains a primary instrument in the educational process as well as in a wide range of careers. On the other hand, nations such as Saudi Arabia fall somewhere mid-range in terms of manufacturing prowess (for instance, 65% proficiency), while the lack of standardized training, accompanied by the current adoption of AutoCAD, can explain such a situation. These variations also prove that the integration of CAD training in the academic curriculum should commence early enough to coincide with employment market demand [39].

1.4. BIM proficiency: trends and issues

As seen in Table 5, the BIM proficiency level is a function of the region and can be regarded as high in variability. In the USA, which includes Revit and ArchiCAD in the AEC market, students demonstrate high BIM proficiency because of well-developed curricula and academic endorsement. For instance, 74% of students in the USA indicate intermediate to high proficiency levels in Revit.

Nonetheless, having analyzed the state of BIM today, it is possible to indicate that the lack of official regulation and guidelines for its implementation, as well as the relatively low popularity of BIM in educational programs, explains the current requirements for its implementation in countries such as Malaysia and Saudi Arabia. Malaysian students demonstrate a low level of BIM application (35%) this includes a lack of policies to require BIM implementation in construction projects in Malaysia. This divergence stresses the importance of developing coherent guidelines for BIM implementation thus making them available for equal usage by professionals throughout the world.

1.5. Regional comparisons: CAD vs. BIM proficiency

Table 6 below also highlights the difference between CAD and BIM awareness and capability. The above findings again clearly show the level of awareness and capability in managing CAD and BIM. Nigerian students show a high percentage of CAD proficiency and a low one of BIM knowledge, the result of the profound influence of AutoCAD. In Jordan however, CAD proficiency is equally high, but BIM skills are still underdeveloped at 40 % owing to a weak institutional focus on more enhanced tools such as Revit. On the other hand, the USA has equal competence in both CAD and BIM as a result of a strong educational background and stakeholder interaction. This balance is a model that other regions should emulate and will prepare students to fit in various professional challenges.

3.5 Curriculum integration and institution support

The conclusions emphasize the importance of organized courses, and organizational apparatus to develop technical skills. Schooled systems like the USA have approachable policies and better Industry-Academia interaction that increases student efficiency in both CAD and BIM advancement. Table 6 also reveals how employment needs affect educational directions and priorities with places like Nigeria establishing 2D drafting specialization for architectural firms and USA integrating BIM in construction projects.

Table 5. Proficiency in CAD and BIM Software by Students

Country	Proficiency in CAD (%)	Proficiency in BIM (%)	Key Software	Reference
Nigeria	90 (AutoCAD)	74 (Intermediate)	AutoCAD, Revit	[45]
Jordan	90 (AutoCAD)	40 (Revit)	AutoCAD, Photoshop	[46]
USA	High (Revit)	Moderate	Revit, ArchiCAD	[47]
Saudi Arabia	Moderate (AutoCAD)	Low	AutoCAD, Revit	[35]
Croatia	Moderate	Low	Revit	[39]

Source: author's development

Table 6. CAD and BIM Software by Students' Proficiency

Region	Primary Employment Requirements	Key Industry-Standard Software	Impact on Student Proficiency	Reference
Nigeria	2D drafting for architectural firms	AutoCAD	High focus on CAD proficiency	[45]
Malaysia	BIM for large-scale projects	Revit	Limited BIM adoption	[46]
USA	BIM integration in construction	Revit, ArchiCAD	High BIM adoption	[47]
Saudi Arabia	Pre-construction architectural work	AutoCAD, SketchUp	Moderate awareness, low proficiency	[35]
Jordan	Digital design and rendering	AutoCAD, Photoshop	Strong CAD proficiency, moderate BIM	[39]

Source: author's development

The results of the systematic literature review are presented in Table 7.

Table 7. Systematic Analysis

Authors Name	Year	Findings
Maharika, Ilya Fadjar, et al. [10]	2020	Highlighted low BIM adoption due to lack of implementation guidelines and emphasis on AutoCAD for 2D design.
Aljamal Aja [47]	2020	Found AutoCAD and Photoshop were the most used tools, while Revit had low adoption due to insufficient resources.
Sampaio AZ [49]	2022	Reported 78% BIM integration in AEC curricula, with Revit being the most taught software.
Çakır HS, Uzun Tİ [51]	2020	High awareness but low proficiency among undergraduates, with a focus on Revit for basic modeling.
Elsakka ASR, Eldawla MAK [52]	n.d	Found higher BIM awareness in students studying abroad; limited use in domestic curricula.
Olanrewaju OI et al. [54]	2022	Identified AutoCAD as the most used software for 2D drafting; self-learning was a common training method.
Takyi-Annan GE, Zhang H. [55]	2022	Reported 98% awareness but varying proficiency levels; BIM was introduced at later academic stages.

Authors Name	Year	Findings
Dagman A, Wärmefjord K. [22]	2022	Demonstrated higher BIM proficiency at postgraduate levels due to more comprehensive curricula.
Mjenda M, Mutarutinya V, Owiti D. [4]	2023	Found a structured curriculum and practical projects were critical to enhancing BIM proficiency.
Eigner M. [5]	n.d	Highlighted barriers such as faculty expertise, resource constraints, and lack of integration strategies.
Habib H, Menhas R, McDermott O. [6]	2022	Reported increased engagement through project-based learning and gamification.
Sola-Guirado RR et al. [7]	2022	Showed a growing emphasis on sustainability applications of BIM at postgraduate levels.
Lane D, Sorby S. [11]	2022	Found students preferred CAD for its simplicity; BIM adoption was driven by industry demand.
Zhu J, Wu P. [12]	2021	Demonstrated CAD tools enhance spatial reasoning and visualization, critical for engineering tasks.
Abdul rahaman M et al. [14]	2020	Reported low adoption rates due to traditional teaching methods and limited industry alignment.
Baciu i-r et al. [15]	2024	Highlighted pilot programs improving student outcomes, but limited scalability due to resource constraints.
BL Appiah [26]	2020	Reported moderate adoption of BIM; project-based learning improved proficiency.
Basir W et al. [28]	2020	Found integrated courses combining CAD and BIM improved student performance and industry readiness.
Jiang R et al. [35]	2022	Identified disparities in proficiency due to resource availability and curriculum design.
lot Tanko B, Mbugua L. [42]	2022	Highlighted group projects as an effective way to build advanced BIM skills.

Source: author's development

Table 8. Summarizing key aspects of CAD's impact on engineering graphics education

Aspect	Description	Impact on Education
Improved Visualization Skills	CAD software allows students to create precise 3D models and visualizations, enhancing spatial understanding.	Supports the development of spatial skills essential for engineering tasks, making it easier for students to visualize and understand complex structures.
Integration with BIM and AEC	CAD is often integrated with Building Information Modeling (BIM) in architecture, engineering, and construction (AEC) workflows.	Encourages interdisciplinary skills, allowing students to work with both CAD and BIM tools, better aligning their skills with industry standards.
Enhanced Design Flexibility	CAD tools offer flexibility in 2D and 3D design, which is preferred in architectural and engineering practices for iterative design.	Enables students to experiment with design modifications easily, fostering creativity and iterative problem-solving.
Industry-Relevant Skill Development	Proficiency in CAD software, particularly AutoCAD, is a major employment criterion in regions with high demand for 2D drafting and modeling skills.	Increases job readiness, as CAD skills are highly valued by employers, especially in fields focused on drafting and initial design phases.
Challenges in Curriculum Adaptation	Rapid advancements in CAD technology create a need for continual updates to engineering curricula, especially for integrating advanced software like BIM.	Universities face challenges in updating curricula to keep pace, requiring additional training for educators and institutional support for software access.
Self-Learning Trends	Due to limited formal training in some regions, students often rely on self-learning to gain CAD skills.	Encourages independent learning and self-initiative among students, although lack of formal instruction may affect proficiency levels.
Focus on 2D vs. 3D Skills	CAD is widely used for 2D drafting, but some industries and regions place limited emphasis on 3D modeling due to client or industry standards.	Shapes educational focus, with some institutions prioritizing 2D skills; however, 3D modeling is critical for future-proofing students' skills.
Accessibility of Software	Popular CAD tools, such as AutoCAD and SketchUp, are more accessible to students than BIM software due to licensing costs and industry demand.	Influences software choice in engineering programs, with students generally more proficient in CAD due to widespread access and industry application.
Preparation for Advanced Technologies	CAD serves as a foundational skill for students to advance to complex software like PLM and BIM, which require 3D modeling as a base skill.	Prepares students to transition into high-tech areas of engineering, where CAD knowledge is a stepping stone to mastering advanced design and project management tools.

Source: author's development

This table highlights the multifaceted impact CAD has on engineering graphics education, from skill development and visualization to challenges in curriculum adaptation and accessibility. It demonstrates how CAD supports industry-relevant skills while posing challenges in curriculum integration and technology adaptation.

2. Discussion

This paper reviews the literature on the factors that affect CAD and BIM use in engineering graphics and reviews the level of awareness, usage competency, and preparedness for the market demand per geographic region. On this premise, the discussion section of the study synthesizes the findings within the context of institutional frameworks, national policies, and educational strategies; and provides considerate recommendations to fill the existing gaps.

2.1. Evaluation of intra-regional inequalities

The study suggests that CAD and BIM knowledge availability differences depending on the region are attributed to various primary factors such as lack of resources, program resources, curriculum, and demand. For instance, students from Nigeria and Jordan score relatively high in their skills of AutoCAD but show rather weak recognition and practical experience of BIM tools [56].

Leśniak A, Górka M, and Skrzypczak I [57] affirmed that the majority of architecture firms in Nigeria use 2D CAD without frequent use of 3D. This leads to a contrast in practice since CAD has dominated architectural and engineering practices in these regions while there is no systematic educational paradigm on BIM yet.

The extent of proficiency and concern regarding the BIM tools is subtle in Scandinavian countries due to proper institutional support and incorporation of those tools in their learning systems. It is in parallel that the author [49] highlighted that countries with strong institutional environments are ahead in BIM implementation. On the other hand, issues like old course content and syllabi, lack of qualified members in faculty, and inadequate resources make it difficult to incorporate BIM tools to form part of learning in developing countries.

2.2. Sources of the failure and explanation of the gap

Lack of resources affects the ability to adapt and teach CAD and BIM tools to students in a great way. In many developing countries educational institutions do not get adequate funds to purchase and implement BIM training software and hardware. It shows that without the use of these tools, students fail to have practical experience which is so crucial in meeting the industrial requirements. These inadequacies lead to a gap between what engineering graphics education aims to achieve and what students are equipped with in terms of skills to help them fit into the competitive workplace environment.

Thus, another issue that arises as a potential intervention strategy is that with the appointment of faculty development, their training becomes more important. Most instructors, especially those in areas where BIM is still relatively unfamiliar, do not possess the necessary skills to educate these programs. Although extensive use of CAD has been integrated into engineering curricula for many years, the users are generally unaware of many other features in more complex BIM tools like Revit or ArchiCAD. Such a skill mismatch of faculty with the industry sustains the rampant use of conventional CAD instruments even as the market keeps transforming into BIM-proficient systems. This is however expected because; the adoption of BIM in curricula will always be difficult without well-determined training programs for educators.

Traditionally, practices within industries also dictate much of the exercise of engineering education. As the demand for BIM is comparatively low in Nigeria and Malaysia, the clients and firms still focus on 2D drafting mostly. This preference enhances the hegemony of CAD tools such as AutoCAD in academic programs because institutions normally adjust to the local market requirement. However, this hinders the student's ability to practice in the global markets where BIM is being adopted more and more.

2.3. Targeted solutions

These issues can only be fought on different levels and using more tactical approaches. That is why governments, and educational establishments have to plan more investments in software, hardware, and infrastructures associated with the implementation of BIM tools into learning processes. Potential solutions include making agreements with software vendors to get better prices on licenses or having cloud access to the

BIM tools. It might go a long way in reducing the resource challenge, hence making it easier for students to understand the effectiveness of these technologies.

Enhancing the training of faculties is as crucial an endeavor as the enhancement of the training of students). I argue that faculties and schools should ensure that faculty members receive training on how to incorporate BIM into their curriculum. Conferences, workshops, certification courses or seminars, and partnerships with industry practitioners can assist the educator in familiarizing them with current trends and developments in BIM tools and technologies. Imposing the lack of skill in the faculty, the institutions can guarantee that students get the appropriate training with both CAD and BIM tools.

Curriculum reform is another pertinent aspect of this strategy which is to be discussed in the subsequent sections systematically. Based on the above findings, it is strongly recommended that faculties and universities teaching architectural and construction programs adopt both CAD and BIM technologies as inclusive technologies aiming at optimizing design and construction rather than as stand-alone technologies. It is essential to introduce BIM tools from the undergraduate level so that more confidence is built in BIM application, and the students are ready to face the challenges in the industry. Also, practical training and internships as well as relations with professionals in the field may improve the students' perception of how these tools are used in practice. In contrast, the U.S. work by ref. [58] as well as works from Scandinavia reveal that BIM specifications are integrated into the recruitment process and have greatly impacted curricula.

2.4. Analysing unexpected findings

Among the surprises of this study is the high level of awareness of BIM tools in some of the considered countries like Nigeria but with little adoption. This paradox underlines the risks of autonomous studying most students take when they want to get acquainted with the opportunities of BIM tools. Though it may raise the level of consciousness, self-learning rarely contributes to the acquisition of reference training and practical experience necessary for mastery. However, whereas CAD is mainly applied for 2D drafting, BIM requires additional operations like 3D and 4D modeling and integration of the work of several project participants. Such aspects cannot be taught independently and therefore need the guidance of a teacher and also, need to be learned practically.

This clearly shows how awareness and proficiency differ, and why, therefore, people need to go to school for them to gain the expertise to do these things. It becomes the responsibility of the institutions to incorporate BIM tools into their courses, in a way that prepares the learners to have adequate knowledge of these tools. In this way, they can be sure that students may be prepared to meet the challenges of the twenty-first-century construction industry.

2.5. CAD AND BIM adoption comparative analysis

The use of CAD and BIM differs greatly depending on different regions, their legislative frameworks, policies at the national level, and industry best practices:

As observed in the USA, Scandinavia, and other developed countries, institutional support enables BIM tools to be adopted without too much difficulty in curricula. For instance, out of 100 AEC schools in the USA, 78% utilize BIM most notably through Revit in its performance [49]. This integration is facilitated by existing national policies that require BIM to be incorporated into new public building projects, leading to demand for BIM skills in graduates.

On the other hand, Malaysia and Saudi Arabia do not possess frameworks like the one in the UK, making it difficult for BIM tools to be implemented within learning institutions and in practice. The lack of properly defined rules and regulations for the adoption of BIM makes educators and other industry experts skeptical about its integration into their educational curriculum, thus slowing down the integration process of BIM into their academic systems. This difference points to the need for nation-led policies in setting up an educational agenda and, in particular, preparing students for the dynamic construction environment.

That is why the focus on the groups of software that take priority in academic programs also differs between regions that have varying degrees of market readiness. In most countries of the third world, for instance, CAD remains popular because, although designing in 3D is important, drafting, especially in the 2D format, is still in demand in the marketplace. But in areas where AEC industries are in their developed stage, like Scandinavia and the USA, BIM expertise is on the rise, making it mandatory to teach it.

This discovery implies that an essential aspect of the curriculum is that its quality effects students' proficiency in CAD and BIM tools. These tools are also taught in the junior years in the USA and Scandinavian countries, where competency is expected right from graduation. Dagman & Wärmefjord [22] noted that the exposure of students to CAD and BIM tools improves students' competence and market relevance.

On the other hand, Nigeria and Jordan are still far off in providing BIM education because the academic curricula do not incorporate or have some of the content related to BIM. With this, the current study supports the assertion made by ref. [6], who noted that students in underdeveloped areas stay self-educated since they do not receive formal BIM training. However, this approach is inadequate in addressing the needs of the construction industry, where BIM knowledge is fast becoming paramount.

The late adoption of BIM in curricula further increases the extent to which graduates are not well-equipped to meet industry demands. To overcome this problem, it is suggested that practical training, internships, and industry experts should synchronize as a basic framework of engineering graphics teaching and learning processes. These measures would ensure that students gain proficiency in the use of BIM tools by practicing the challenges that face the system. This observation indicates a regional difference: countries with evident BIM standards are more likely to have higher levels of BIM competency in education to support calls for developing regions to set the same standards [59]. This finding supports ref. [60], who pointed out that detailed BIM notions are presented in the second or even the third, university year only in Croatia; the same has been identified in Malaysia as well as in many other Asian contexts.

The research evaluates the critical cyclic fracture toughness assessment process for Mode II failure in structural steels through 4PAB testing methodology. The investigators confirmed that structural steels show proportionality through a range between 2.5 and 3 when measuring how failure occurs under Modes I and II conditions. The research shows that Mode II failure contributes 90% to oblique crack growth until the fracture shifts to Mode I at rupture. The predicted fatigue failure kinetics confirm the suitability of resistance indicators for predicting mixed-mode fractures through the developed algorithm. The research addresses the problems that form when cracks deviate during four-point bending tests. The research enhances understanding of material longevity by improving complex loading condition evaluations.

These outcomes help enhance the mechanical description of structural steel materials destined for use in equipment and construction applications under fatigue loading conditions [61]. Table 9 shows that the results of the study are consistent with the existing literature, in particular with regard to the importance of institutional support, regional differences, and the role of sectoral adaptation conditions. Differences in the quality of training programs and reliance on self-learning further support the study's observations. The findings are also supported by similar studies that provide unexpected findings, such as the gap between BIM awareness and adoption, which indicates an urgent need for resource allocation and policy.

Table 9. Comparison of current study with previous studies

Aspect	Current Study Findings	Similar Studies	Comparison and Validation
Awareness of CAD and BIM Tools	High CAD awareness across most regions, especially Nigeria and Jordan, due to the widespread use of AutoCAD for 2D drafting. BIM awareness is high in the USA, but adoption remains uneven.	Ref [13]: CAD dominates architectural practices. Ref [47]: AutoCAD usage is higher in Jordan due to limited BIM education.	Confirms the dominance of AutoCAD in developing countries. Similar findings about BIM awareness align with Ref [47], validating regional variations in software adoption.
Proficiency in CAD vs. BIM	Students show higher proficiency in CAD, particularly AutoCAD, compared to BIM tools like Revit. Scandinavian countries show higher	Ref [49]: High BIM proficiency in Scandinavian countries due to robust educational frameworks.	Matches findings about CAD's dominance and BIM’s proficiency challenges in regions with less institutional support. Strong support in developed

	BIM proficiency due to curriculum integration.	Ref [51]: BIM is underutilized in Malaysia due to weak guidelines.	regions like Scandinavia aligns with Ref [49].
Institutional Support	Countries like the USA, with defined educational norms, demonstrate greater integration of BIM. Developing nations lack institutional backing for BIM education.	Ref [49]: 78% of AEC schools in the USA have adopted BIM. Ref [6]: Poor institutional support leads to limited BIM usage in underprivileged regions.	Strong agreement on the influence of institutional support on BIM integration. Highlights the disparity between countries with and without well-established educational and industry frameworks.
Industry Demand	Industry requirements heavily influence software adoption. CAD tools remain dominant in countries where 2D drafting is prevalent. BIM demand is higher in AEC-focused markets.	Ref [49]: Industry demand for BIM drives curriculum changes in the USA. Ref [51]: Limited demand for BIM in developing regions slows adoption.	Validates the link between industry requirements and educational focus. BIM is integrated faster in regions with active AEC industries, supporting the current study's findings.
Regional Disparities	Developing countries (Nigeria, Jordan) show slower BIM adoption compared to developed regions (Scandinavia, USA) due to resource constraints and outdated curricula.	Ref [13]: Regional disparities in software usage. Ref [22]: Scandinavian curricula promote CAD and BIM early in education.	Reinforces the impact of economic and educational disparities on software adoption. Confirms that developed regions benefit from early integration and better resources.
Self-Learning and Practical Skills	Students in resource-constrained areas rely on self-learning for skill acquisition, leading to inconsistent BIM proficiency.	Ref [6]: Self-learning compensates for limited formal training but lacks depth.	Aligns with findings, self-learning plays a significant role in underprivileged regions but highlights the need for structured, practical training for better outcomes.
Curriculum Quality	BIM education often begins at postgraduate levels in developing regions, limiting early exposure and proficiency.	Ref [58]: Structured curricula in the USA incorporate BIM at undergraduate levels, resulting in higher proficiency.	Confirms that structured, early integration of BIM in curricula enhances proficiency, while delayed exposure, as seen in developing countries, hampers skill development.
Unexpected Findings	High BIM awareness but low adoption rates in some regions (e.g., Malaysia, Nigeria) due	Ref [51]: Absence of BIM guidelines hinder adoption.	Unexpected findings aligned with studies showing that awareness does not always translate into adoption.

	to lack of resources, faculty expertise, and institutional policies.	Ref [49]: Institutional policies drive high BIM adoption in the USA.	Institutional barriers play a significant role in creating this gap.

2.6. Contributions to the field

In making these contributions, this research has achieved the following throughout this study: First, it reveals the extent of CAD and BIM proficiency by region and further discusses the background of such trends. Thus, the indicated findings regarding some barriers to BIM adoption such as resource inadequacies, faculty training gaps, and industry resistance contribute to the understanding of the challenges of educational institutions in developing nations.

Second, the study provides the strategies for overcoming all these challenges: funding, faculty staff development, and curriculum improvement. These strategies may assist institutions in unlocking existing impediments and guarantee that the learners have appropriate competencies for the existing market economy.

Last but not least, the study focuses on how national policies and institutions define priorities in education. From this perspective, the analysis presented in the study can be helpful for policymakers and educators who strive to improve the quality of engineering graphics education in the context of CAD and BIM applications.

3. Limitations

This study has several limitations, including its geographical focus on developing countries and the infancy of BIM adoption practices, which excludes key early adopters like the United States and Scandinavian countries. This geographical focus limits the applicability of the findings to more developed markets and limits the study's applicability on an international level. The sample size is limited to a set of schools and students, minimizing methodological variation and limiting the potential diversity in learning environments. The study focuses only on AutoCAD and Revit software tools, ignoring other BIM platforms like ArchiCAD and Bentley Systems, which may not capture all possible diversity in learning environments. To overcome these limitations, future studies should apply a broader geographical and institutional context, cover a greater number of software instruments involved in CAD and BIM learning, and utilize more academic sources investigating the impact of recent technologies, such as artificial intelligence, on CAD and BIM education.

4. Conclusion

This work aimed to ascertain the effects of CAD and BIM tools for engineering graphics education in terms of the student's perception and performance, the challenges posed by the implementation of BIM, and the role of standards for the receipt of these technologies. In this manner, the systematic review has answered the research objectives in terms of identifying trends, preferences as well as institutional uses of CAD and BIM in educational contexts across the globe.

Regarding the knowledge and awareness of the students, the present review indicated that CAD tools particularly AutoCAD are more familiar than BIM tools including Revit. This is rather regent in the developing areas since CAD is an easy easy-to-process industry, while BIM is not easily available and well-understood. The majority of students are from the U.S. and Europe where BIM is more established and students are more proficient, while BIM is relatively used more in teaching curricula.

Secondly, it quantified potential obstacles to implementing BIM in regions that do not have national or industry BIM standards. Some of the challenges that this sector has faced include; scarcity of capital, high cost of software, and reliance on 2D drafting services. As researchers from Malaysia and Nigeria have pointed out, the lack of strongly defined BIM frameworks hinders the slow progress of BIM in both education and business environments.

Thirdly, the study corroborated the hypothesis that industry requirements and job opportunities are effective antecedents to CAD and BIM preferences in education. Hence, institutions in BIM advanced regions will always aim to incorporate BIM into their programs in order to meet market trends as shown in the US and Scandinavian universities.

Consequently, when focusing on future research, the data obtained in the process of this investigation indicates a number of important fields that should undergo further analysis.

First of all, it is crucial to classify and analyze the question of the **proper time and manner** of BIM integration into academic curricula. More research should be done to decide which year of a curriculum, or which phase it is best to introduce and implement these technologies when students benefit most from them and are best prepared for industrial application. Specifying the best place where integration should occur allows the development of more clearly defined and meaningful learning trajectories in educational organizations.

Second, the concept of integration of self-learning strategies requires further research. Scholars can examine how learning methodologies, which comprise scaffanger tutorials and project-based learning, may enhance traditional classroom learning, specifically in areas with limited resourcing. Such studies would help the researchers understand how learners in areas of high deprivation could be provided to enable them to develop essential competencies regardless of infrastructure or institutional constraints.

Third, there is a pivotal trend for future research about policy and standards, as an important aspect recognizing the effective national guidelines and institutional support system models like of the USA. Benchmarking of different geographic areas could find what approaches could be used in the development of the right policies and support structures for CAD and BIM implementation.

As such, the following research areas could be explored in order to develop ways on how early, continuous, and intensive training of CAD and BIM tools could be provided in the future. This would help graduates to align themselves to meet the challenge of the growing industry since they will need to have proper skills and knowledge that would enable them to go further in their careers.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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Author Contribution

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