WIP: Impacts of BIM Instruction on Civil Engineering Student Learning, Workforce Readiness, and Equity in HBCU

Adeyemi Jerry Ibiyemi, Morgan State University

I am a civil engineer with expertise in pavement construction, materials testing, and safety management. From 2016 to 2020, I managed engineering projects for Aniyikaye General Contractor with Nigeria Breweries, ensuring timely delivery and strict safety compliance. From 2021 to 2025, I worked in quality assurance and engineering roles at Craneburg Construction. Currently, I am pursuing advanced civil engineering studies at Morgan State University with a focus on transportation and structures. I hold safety certifications and am a member of ASCE and ASEE.

Julius Ogaga Etuke, Morgan State University

Julius Ogaga Etuke is a seasoned civil engineer and Ph.D. Candidate in Civil Engineering at Morgan State University, where his research focuses on sustainable and resilient infrastructure engineering. With over 15 years of consulting and project leadership experience, primarily in Nigeria's infrastructure landscape, he brings a robust, practical perspective to academic inquiry. His doctoral research is at the cutting edge of transportation resilience, integrating virtual and augmented reality (VR/AR), climate adaptation modeling, and data-driven solutions to improve disaster preparedness and risk mitigation in complex transportation systems. As a COREN-registered engineer and member of the Nigerian Society of Engineers, his work emphasizes impactful research and consultancy that bridges structural design principles with urgent sustainability and resilience challenges.

Adeolu Victor Banjo, Morgan State University

Banjo Adeolu Victor is a doctoral student and research assistant in the Department of Civil Engineering at Morgan State University, Baltimore, Maryland. With Bachelor's and Master's degrees in Architecture and years of professional practice in the architecture and construction industry, he combines academic teaching experience with industry expertise. His research explores the integration of Virtual Reality (VR), Augmented Reality (AR), and Building Information Modeling (BIM) to advance sustainable infrastructure engineering. Passionate about innovation and education, he has participated in several conferences and workshops, contributing to immersive learning, sustainable construction, and infrastructure resilience initiatives.

Dr. Oludare Adegbola Owolabi P.E., Morgan State University

Dr. Oludare Owolabi, a professional engineer in Maryland, joined the Morgan State University faculty in 2010. He is the director of the Sustainable Infrastructure Development, Smart Innovation and Resilient Engineering Research Lab, Department of Civil Engineering at Morgan State University

Taiwo O Ogunlade, Morgan State University

Taiwo O. Ogunlade is a Structural and Bridge Engineer at Century Engineering, a Kleinfelder Company, in Hunt Valley, Maryland, specializing in the design, inspection, and rehabilitation of highway bridge structures across Maryland, Delaware, and Pennsylvania. He holds a Master of Engineering (MEng) in Civil Engineering from Morgan State University Maryland and is currently pursuing a doctoral degree at the same institution, with research focused on infrastructure performance, sustainable materials, and applications of machine learning in Bridge Inspections.

With over eight years of engineering experience including four years in residential and highway infrastructure construction in Nigeria and four years in bridge design in the United States, Ogunlade brings a strong integration of field construction knowledge and structural engineering expertise. At Kleinfelder, he has contributed to significant regional bridge projects involving structural analysis, QA/QC oversight, and CADD-based design. Alongside his practice, he is actively engaged in doctoral research, including journal writing and reflecting his commitment to advancing civil and structural engineering through both professional practice and scholarly contribution.

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Abstract

Rapid digitization of civil engineering practice through the inclusion and teaching of BIM data-oriented designs highlights persistent skill gaps in many Historically Black colleges and universities (HBCU) of learning. Not having access to advanced software coaching in a well arranged curricula manner which constrains student's performance, employability and engineering equity in an educational setting. This study research work in progress focuses on the importance of empirical evidence linking to digital inclusion programs which helps to measure the learning skill and work gain outcome. Its aim to evaluate the effectiveness of Civil Engineering focused on digital training integrating BIM Data skill literacy on Engineering student competency, capstone performance and after graduation employability among HBCU. The Unified Theory of Acceptance and Use of Technology (UTAUT) framework underpins this research because it systematically captures the determinants of technology adoption and performance expectancy, social influence, and facilitating conditions in educational settings. The framework which captures institutional acceptances, perceived importance and ease of use which influence training success and sustained digital engagement. A quasi experimental mixed method framework will compare intervention and control in HBCU using standard skill test, employment tracking, and survey data to analyze through regression-based and structural modeling techniques to examine relationships among BIM instruction and student outcomes. The study is expected to provide preliminary evidence regarding potential improvements in digital competency, internship readiness, and equitable access to BIM-related skills among participating students. This study anticipates in producing an adaptable implementation toolkit with evidence based guidance for synergizing digital training in an HBCU civil engineering curriculum, promoting educational equity and workforce readiness in the US infrastructural sector**.** *This paper reports a work-in-progress study, presenting the research framework, methodology, and preliminary observations, with full results forthcoming.*

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INTRODUCTION

The architecture, engineering, and construction (AEC) industry is undergoing a paradigm shift driven by digital transformation. Building Information Modelling (BIM) has become the standard for planning, design, construction, and lifecycle management of built infrastructure due to its capacity to enable collaborative workflows, reduce errors, and integrate data-rich modelling across disciplines [1-2]. For civil engineering students, proficiency in BIM and associated data-skills is increasingly a de facto requirement for industry readiness and competitiveness. However, as BIM becomes ubiquitous in professional practice, a persistent challenge remains: many academic institutions, especially under-resourced institutions such as Historically Black Colleges and Universities (HBCUs), struggle to integrate BIM instruction effectively into civil engineering curricula. Reviews of BIM education highlight barriers including, lack of resources, absence of trained instructors, and difficulty in restructuring curricula to incorporate BIM without diluting core civil engineering fundamentals [3-4]. These constraints may contribute to inequities in workforce readiness and limit the ability of graduates from such institutions to compete on equal footing. Thus, there is a critical need for empirical evidence assessing whether structured BIM instruction at HBCUs can close this skills gap, improve student performance and employability, and promote equity in civil engineering education and career outcomes.

Aim of the Study

This study aims to empirically examine whether structured BIM and data-skills instruction produces measurable improvements in civil engineering student learning, capstone performance, workforce readiness, and educational equity at HBCUs, relative to traditional civil engineering curricula without BIM integration, and to identify the individual and institutional factors that shape the effectiveness of such instruction.

Objectives of the Study

1 Compare changes in learning and design skill gains between HBCU civil engineering students with and without BIM instruction.

2 Evaluate whether BIM-integrated instruction improves capstone project quality and effective collaborative design workflows relative to traditional curricula experiences.

3 Examine differences in workforce readiness and job placement between BIM-trained and non-BIM-trained graduates.

4 Assess how technology acceptance and institutional support influence the effectiveness of BIM instruction and continued skill use.

Research Questions

i. How does BIM instruction influence civil engineering students' technical competency, capstone project performance (including collaboration), and workforce readiness (internship placement and early employment) in HBCUs?

ii. What individual and institutional factors, such as technology acceptance, social influence, and facilitating conditions, moderate the effectiveness of BIM instruction and shape students' sustained use of digital skills in HBCUs?

Expected Outcomes

The study is expected to provide preliminary evidence regarding the following potential outcomes:

1. Potential improvement in student digital competency and civil engineering design skills following BIM instruction.
2. Indications of enhanced capstone project quality, collaboration, and digital workflow integration.
3. Potential increases in internship and early employment placement rates among trainees, compared with the control group.
4. Identification of key institutional and social factors (from UTAUT constructs) that influence effective adoption and sustained use of BIM skills, leading to a proposed and to be validated model for BIM curriculum implementation.

Literature Review

Overview of BIM and Digital Transformation in Civil Engineering Education.

The civil engineering profession has undergone significant transformation due to the integration of digital technologies, particularly Building Information Modeling (BIM). BIM is defined as a process that facilitates the generation and management of digital representations of physical and functional characteristics of infrastructure across its lifecycle [9]. Unlike traditional CAD-based approaches, BIM supports data-rich modeling, interdisciplinary coordination, visualization, and simulation, thereby enhancing design accuracy and project efficiency [10]. As a result, BIM has become a core competency expected of entry-level civil engineers in the architecture, engineering, and construction (AEC) industry [11].

Consequently, higher education institutions are increasingly pressured to align civil engineering curricula with industry needs by incorporating BIM and data-oriented design tools. Studies have shown that BIM-integrated instruction improves students' spatial reasoning, design comprehension, and collaborative problem-solving skills [12]. However, the extent and effectiveness of BIM adoption in engineering education vary significantly across institutions, often reflecting disparities in funding, infrastructure, and institutional support [13].

BIM Instruction and Student Learning Outcomes

A growing body of research has examined the pedagogical impact of BIM instruction on student learning. Researchers have reported that students exposed to BIM demonstrate improved understanding of construction sequencing, structural systems, and interdisciplinary coordination compared to those trained using conventional 2D methods [14]. BIM-based learning environments also promote active learning by enabling students to visualize complex engineering concepts and test design alternatives in real time [15].

Despite these advantages, several studies caution that BIM instruction alone does not guarantee improved learning outcomes. Effective implementation depends on curriculum design, instructor competency, and integration with core engineering concepts rather than isolated software training [16]. Poorly structured BIM instruction may overwhelm students cognitively, particularly when introduced without adequate scaffolding or alignment with learning objectives [17]. This highlights the need for empirical evaluation of structured BIM curricula that balance technical rigor with pedagogical clarity.

Workforce Readiness and Industry Expectations

Workforce readiness has become a central metric for evaluating the effectiveness of engineering education. Employers increasingly expect civil engineering graduates to possess not only theoretical knowledge but also practical digital skills, including BIM proficiency, data management, and collaborative workflow experience [18]. Industry surveys consistently rank BIM competency among the top employability skills for civil engineering and construction management graduates [19].

Several studies have established a positive correlation between BIM exposure during undergraduate education and improved internship performance, job placement rates, and early-career productivity [20]. Graduates with BIM experience are often perceived as more adaptable and capable of contributing to multidisciplinary teams[21].

However, these findings are predominantly based on studies conducted at well-resourced institutions, leaving a gap in understanding how BIM instruction influences workforce readiness in underrepresented or resource-constrained educational environments such as HBCUs.

Digital Equity and BIM Education in HBCUs

Historically Black Colleges and Universities play a critical role in producing a significant share of African American engineers in the United States. Despite this contribution, HBCUs have historically faced systemic underfunding, which has limited their ability to invest in advanced laboratories, software licenses, and high-performance computing infrastructure [22]. These constraints directly affect students' access to BIM tools and digital learning opportunities.

Research on digital equity in STEM education indicates that disparities in access to technology contribute to differences in academic performance, confidence, and career outcomes [23]. In the context of BIM education, students who lack early exposure to digital tools may experience steeper learning curves and reduced self-efficacy [24].

Targeted digital inclusion initiatives, such as structured BIM instruction and institutional support programs, have been proposed as mechanisms to mitigate these inequities; however, empirical evidence evaluating their effectiveness within HBCUs remains limited [25].

Technology Acceptance and BIM Adoption in Education

Understanding how students adopt and engage with BIM tools requires a theoretical lens that accounts for both individual and institutional factors. The Unified Theory of Acceptance and Use of Technology (UTAUT) has been widely applied to study technology adoption across various domains, including education and construction [26]. UTAUT posits that technology use is influenced by performance expectancy, effort expectancy, social influence, and facilitating conditions.

Several studies have applied UTAUT to examine BIM adoption among professionals, revealing that perceived usefulness and organizational support are key predictors of sustained BIM use [27]. More recent studies have extended UTAUT to educational settings, demonstrating that students' intention to use BIM is strongly influenced by perceived learning benefits, ease of use, and instructor encouragement [28]. These findings suggest that successful BIM instruction requires not only access to software but also supportive institutional environments and positive social norms. However, limited research has applied UTAUT specifically to civil engineering students in HBCUs. Given the unique institutional contexts and equity considerations associated with HBCUs, applying UTAUT in this setting provides an opportunity to identify distinct adoption barriers and facilitators that may not be evident in predominantly white or well-funded institutions.

Gaps in Existing Literature

Although literature demonstrates the educational and professional value of BIM, several critical gaps remain. First, few studies employ quasi-experimental designs that compare BIM-integrated instruction with traditional curricula while controlling for institutional and demographic variables [29]. Second, there is limited empirical research linking BIM instruction directly to workforce outcomes such as internship acquisition and job placement, particularly within HBCUs [30]. Third, existing studies rarely address equity explicitly, despite widespread recognition of digital divides in engineering education.

Furthermore, the absence of scalable, evidence-based frameworks for integrating BIM across under-resourced institutions limits the transferability of successful practices.

Addressing these gaps requires a comprehensive approach that combines learning assessment, workforce metrics, and technology acceptance theory.

Methodology

A quasi-experimental mixed-methods research design will be employed: Population & Sample: Civil engineering students from at least two HBCU institutions; one institution will represent the intervention group (BIM + data-skills instruction integrated into curriculum), the other a control group (standard curriculum without BIM integration).

I Quantitative Components: Pre and post-instruction skills assessments will measure BIM proficiency and civil engineering design competence for both intervention and control groups.

II Capstone project evaluation: Use standard rubric to assess design quality, collaboration, constructability, and digital workflow integration. Workforce readiness and placement tracking: Internship offers, job placement rate within 6–12 months of post graduation.

III Survey instrument: UTAUT-based questionnaire to assess acceptance, facilitating conditions, social influence, effort expectancy, and behavioral intention. Quantitative data will be analyzed using appropriate regression-based and structural modeling techniques to examine relationships among BIM instruction, student outcomes, and technology acceptance factors. Where necessary, institutional differences will be examined using covariate controls.

IV Qualitative Components: Semi-structured interviews and focus groups with students, faculty, and administrators to identify institutional barriers/facilitators, student perceptions, and equity-related experiences. Thematic analysis will complement quantitative results, providing contextual understanding. Implementation Timeline: Over two academic semesters (one for instruction and data collection, another for follow-up employment tracking). Because the comparison spans multiple institutions, baseline demographic and academic covariates will be collected and included in the analysis to reduce potential institutional confounding.

Theoretical Framework

This study is grounded in the Unified Theory of Acceptance and Use of Technology (UTAUT) [6]. UTAUT provides a robust, empirically validated framework to assess how factors such as performance expectancy, effort expectancy, social influence, and facilitating conditions influence individuals' behavioral intention and actual use of a technology. In this study, UTAUT is adapted rather than directly adopted, as its core constructs are used to explain variation in the effectiveness of BIM instruction and sustained digital skill use, rather than solely to predict initial technology adoption. In the context of BIM instruction at HBCUs, UTAUT is especially appropriate because it links technology adoption (BIM/software) to both individual attitudes and institutional environment key determinants for effective curriculum integration and student adoption. Prior research has successfully applied UTAUT (and its extensions) to BIM adoption in industry settings [5], and to assess students' BIM learning attitudes and behaviors in academic contexts [7-8]. Thus, UTAUT will not only help explain acceptance and usage behavior among students but also provide insight into institutional enablers or barriers informing scalable strategies for curriculum design and resource.

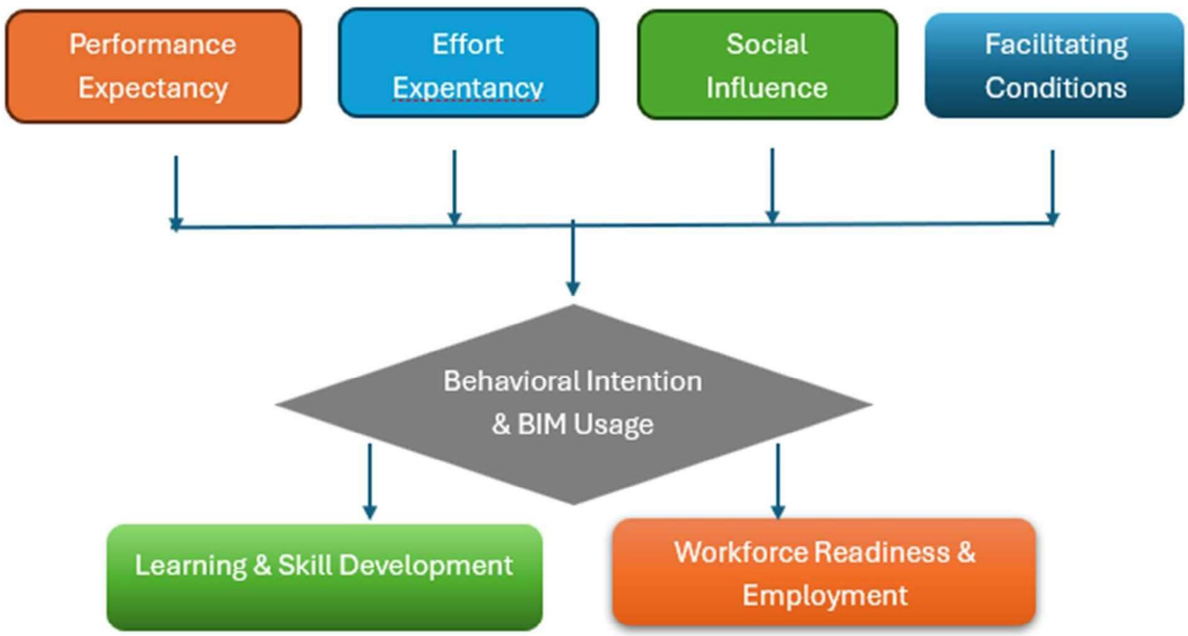

Figure 1. Adapted UTAUT framework illustrating BIM instructional pathway and expected outcomes in HBCU civil engineering programs.

Scalability Across Other Engineering Curricula

The proposed BIM based curriculum model is inherently scalable and will be transferable. The same conceptual structure integrating digital skills training with core disciplinary courses, supported by institutional facilitation and acceptance assessment, could be adapted for other engineering disciplines (structural engineering, environmental engineering, transportation engineering) by customizing software tools (SAP2000, GIS, data-analysis tools) and aligning them with respective capstone or core courses. The use of UTAUT enables the evaluation of adoption behavior and institutional readiness regardless of discipline, facilitating cross-disciplinary implementation. Moreover, the mixed-methods design and toolkit resulting from this study will serve as a template for other engineering departments seeking to integrate digital tools equitably and systematically, thereby promoting broader workforce readiness and reducing inequities across STEM education.

Results

Preliminary Results and Ongoing Analysis

This study is currently in the data collection phase at the time of submission, preliminary descriptive results and planned analytical procedures are reported to demonstrate the feasibility and rigor of the research design. Full inferential results will be reported upon completion of data collection.

Participant Overview

Initial participation includes civil engineering students from HBCU institutions, representing an intervention group exposed to structured BIM instruction and a control group following a traditional curriculum. Demographic and academic background data are being collected to support comparative analysis.

Planned Quantitative Analysis

Upon completion of data collection, for both intervention and control groups instruction assessments will be analyzed using paired statistical tests to evaluate changes in technical competency. Capstone project outcomes will be evaluated using standardized rubrics

Planned Qualitative Analysis

Qualitative interview and focus group data will be analyzed thematically to identify institutional barriers, student perceptions, and equity-related experiences that contextualize quantitative findings.

Expected Contributions

The final results are expected to provide empirical evidence on the effectiveness of BIM instruction in improving learning outcomes, workforce readiness, and equity in HBCU civil engineering programs.

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