The Virtual Constructor: AI-Powered Simulation for Enhancing Experiential Learning in Building Technology Education

Yuel Okey Kalu, PhD[1], Cornelius Ekene Odoh, PhD[2], Sunday Uta Kalu[3]*, Chukwuemeka Kalu Ukoji[4] & Samuel Ajah Okorie[3]

[1]Civil Engineering Department, University of Nigeria, Nsukka-Enugu state, Nigeria

[2]Department of Science Education, National Open University of Nigeria, Abuja, Nigeria

[4]Department of Computer & Robotics Edu., University of Nigeria, Nsukka-Enugu state, Nigeria

[3]Physics Department, AE-Ekweme Federal University, Ndufu-Alike Ikwo, Ebonyi State Nigeria

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ABSTRACT

The study investigated the integration of virtual constructor technologies as pedagogical tools for enhancing experiential learning among building technology students in Nigerian tertiary institutions. The research pursued three objectives: identifying the major software applications necessary for experiential learning, determining effective strategies for their acquisition and implementation, and examining their impact on student learning outcomes. A survey research design was employed. The study population comprised 65 building technology lecturers from federal polytechnics in Nigeria. A structured questionnaire, developed from a literature review and validated by experts, was administered to the respondents. The instrument achieved a Cronbach's alpha reliability coefficient of 0.86. Data analysis utilized mean ratings for research questions and a t-test for hypothesis testing at the 0.05 significance level. The study identified a hierarchical taxonomy of software essential for comprehensive experiential learning, including Autodesk Revit with BIM 360 integration and ArchiCAD /SimPro software for design, Navisworks Manage for 4D sequencing, and Synchro Pro and Revizto for time-based construction planning. The study reveals that effective acquisition of this software requires strategic institutional investment in hardware, adoption of cloud-based educational licensing and open sourcing of hardware by students, and structured curriculum integration. The findings further confirmed that these virtual constructor technologies significantly enhance students' practical comprehension and industry preparedness compared to traditional methods. The study recommended that the National Board for Technical Education (NBTE) revise the building technology curriculum benchmarks to mandate the integration of these software applications, specifying minimum competencies for programme accreditation to ensure graduates meet contemporary industry demands.

Keywords: Virtual constructor, artificial intelligence, building simulation, experiential learning, building technology

INTRODUCTION

The landscape of building technology education stands at a transformative crossroads, where traditional pedagogical methods increasingly struggle to prepare students for the complexities of modern construction practice. For decades, building technology programmes have relied heavily on lectures, case studies, and site visits to convey the dynamic processes inherent in building construction. While valuable, these approaches are often constrained by logistical challenges, safety concerns, and the impossibility of compressing construction timelines to allow students to witness sequential project stages within a single academic session. As building projects grow exponentially more complex, demanding stricter cost control, accelerated timelines, enhanced quality assurance, and rigorous sustainability compliance, the gap between classroom instruction and workplace reality widens, thus creating a pressing need for artificial intelligence (AI) assistance.

In response to this widening gap, the concept of the virtual constructor emerged. This concept integrates artificial intelligence, building simulation technologies, and experiential learning principles to revolutionize how building technology students acquire professional competence. The term "virtual constructor" encompasses both a technological framework and a pedagogical approach. Technologically, it refers to AI-powered simulation environments that replicate construction processes, allowing students to plan, execute, and manage virtual building projects. Pedagogically, it represents a fundamental shift from passive knowledge reception to active knowledge construction through immersive, problem-based learning experiences (Ayar & Yalvac, 2025). This convergence of artificial intelligence and building simulation creates “experiential simulation environments," a digital space where students make decisions, witness consequences, and develop the intuitive judgment that characterizes expert practitioners. Similarly, Tayeh and Bademosi (2025) demonstrated through their five-year Delphi study of industry and academic expectations that a widening chasm exists between the competencies graduates possess and those the construction industry demands. The study reveals that while academic programmes emphasize foundational knowledge, industry employers increasingly prioritize advanced technical proficiency in emerging technologies, particularly artificial intelligence, generative design, and immersive simulation tools. This skill gap threatens both graduate employability and industry innovation capacity, creating an urgent imperative for educational transformation.

Furthermore**,** experiential learning theory provides the pedagogical foundation for these virtual constructor approaches. The theory argues that authentic understanding emerges from concrete experience; experiential learning posits that students construct knowledge most effectively when they actively engage with realistic problems, reflect on outcomes, and apply lessons to new situations (Kolb, 1984). Virtual constructor environments operationalize this theory by creating what Yanatchkova (2025) describes as "narrative and immersive learning spaces,”; a digital context where students co-construct understanding through collaborative problem-solving and iterative design. The addition of artificial intelligence magnifies this effect, enabling adaptive learning pathways, intelligent tutoring through AI-powered avatars, and real-time feedback that mirrors professional mentorship. Recent technological advances have dramatically expanded the possibilities for virtual constructor implementation (California Digital Library, 2025). The MIT-Tec de Monterrey VR FrED Laboratory exemplifies cutting-edge applications, combining virtual reality, artificial intelligence, and gamification strategies to create immersive manufacturing environments (Jaafari, Manivong, & Chaaya, 2001). Within these simulated industrial plants, students interact with AI-powered expert avatars; virtual mentors representing technical specialists, project managers, and even CEOs who evaluate student proposals with business-savvy discernment. This integration of large language models enables natural, contextualized feedback that adapts to individual student learning profiles and communication styles, personalizing education at scale (Kolb & Kolb, 2017).

Similarly, building simulation technologies have evolved from simple three-dimensional visualizations to comprehensive virtual construction platforms. Early systems like Virtual Construction (VIRCON), according to Nikolic, Lee, Messner, & Anumba (2010), demonstrated the feasibility of combining construction planning with 3D/4D models, integrating cost planning, scheduling, and cross-impact analysis within object-oriented programming environments. Subsequent developments, including the Virtual Construction Simulator (VCS), advanced this work by creating interactive simulation games where students plan construction schedules, allocate resources, and witness how decisions about methods, sequencing, and productivity affect as-built outcomes. These platforms transform abstract scheduling concepts into tangible experiences, helping students internalize the dynamic relationships between planning assumptions and construction realities. Building on this technological evolution, the concept of the "virtual constructor" emerges from this technological convergence: an AI-enhanced professional entity that guides students through construction complexities. Unlike traditional computer-aided instruction, which presents predetermined content, AI-powered virtualconstructoradapt to student actions, diagnose misconceptions, and scaffold increasingly sophisticated understanding (Tayeh & Bademosi, 2025). These systems incorporate domain-specific knowledge spanning control engineering, mechanics, digital systems, and business strategy, enabling them to serve as credible mentors across the full spectrum of building technology competencies. Students’ progress from understanding how individual building systems function to integrating multiple systems within complex projects, consulting virtual experts at each stage before ultimately defending their proposals to AI-powered executive avatars. The educational imperative for such technologies grows more pressing as construction projects accelerate in complexity. Nikolic et al. (2010)

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observed that construction education faces inherent challenges in exposing students to the full range of construction stages, the variability of site conditions, and the consequences of management decisions. Virtual constructor environments address these limitations by compressing time, enabling safe exploration of dangerous scenarios, and making visible the invisible factors such as weather impacts, productivity variations, and supply chain disruptions that shape construction outcomes. Students develop not only technical competence but also problem-solving orientation and decision-making confidence essential for professional practice. Consequently, building technology educators increasingly recognize that preparing students for twenty-first-century construction careers requires more than technical skill transmission (Trevino, 2025). The integration of virtual constructor approaches into building technology curricula represents a fundamental reimagining of educational purposes, which is to move from knowledge transmission to capability development, from passive reception to active construction, from classroom abstraction to professional simulation. Therefore, the study investigates how such integration can be optimized, what software tools prove most effective, what acquisition strategies enable successful implementation, and what benefits accrue to students who learn through virtual constructor methodologies.

Statement of the Problem

Building technology education in Nigeria faces a widening relevance crisis. Despite curriculum reforms, a significant disconnect persists between graduate competencies and industry demands. Employers consistently report on graduates' lack of proficiency in modern construction technologies, exhibition of poor problem-solving skills on dynamic sites, and the need for extensive retraining. This skill gap undermines employability, stifles industry innovation, and leaves Nigerian construction practices stagnant. This problem is fundamentally pedagogical. Programmes remain anchored in lecture-based instruction and textbook learning methods inadequate for developing the experiential knowledge required in construction. Students learn principles in abstraction without confronting the complexities of real projects, rendering the construction site a described concept rather than a tangible experience. Emerging technologies offer transformative solutions. Virtual constructor platforms integrating AI and building simulation can create immersive environments where students develop professional judgment through simulated real-world decisions. However, Nigerian programmes have scarcely explored these possibilities. No research has identified which virtual constructor applications align with Nigerian curricula and industry contexts. No systematic investigation has determined how resource-constrained institutions can implement these technologies sustainably. Critically, no empirical evidence exists regarding their impact on Nigerian students' learning outcomes. Without integrating virtual constructor technologies, Nigerian graduates will remain disadvantaged in a competitive labor market, the industry will struggle to modernize, and students will be denied transformative learning experiences essential for professional development. Thus, the study sought to investigate how virtual constructor technologies could be strategically integrated into building technology education curricula to bridge this pedagogical-industrial divide.

Purpose of the Study

This study investigates the integration of virtual constructor technologies, specifically, AI-powered building simulation platforms as pedagogical tools for enhancing experiential learning among building technology education students in Nigerian tertiary institutions. This overarching purpose was operationalized through three specific research objectives:

1. To identify the major virtual constructor software applications needed to enhance experiential learning by building technology education students that align with industry practice standards.

2. To determine effective strategies for the acquisition of virtual constructor software within building technology programmes.

3. To examine the significance of virtual constructor technologies to building technology students' learning outcomes, and their transition to construction industry employment.

Research Questions

Three research questions that guided the study were as follows:

1. What are the major virtual constructor software applications required to enhance experiential learning in building technology education?

2. What strategies are most effective for the acquisition of virtual constructor software in building technology programmes?

3. What are the significance of virtual constructor technologies to building technology students' development of professional competencies, problem-solving abilities, and industry readiness?

Hypotheses

The following null hypotheses (H_0) were formulated and tested at a 0.05 level of significance:

H_{01}: There is no significant difference in the mean ratings of TVET-Building technology lecturers regarding the major virtual constructor software applications needed to enhance experiential learning.

H_{02}: There is no significant difference in the mean ratings of TVET-building technology lecturers regarding effective strategies for acquiring virtual constructor software.

H_{03}: There is no significant difference in the mean ratings of TVET-building technology lecturers regarding the significance of virtual constructor technologies to student learning outcomes, based on their prior exposure to virtual design and construction tools.

METHODOLOGY

The study adopted a survey research design to investigate the integration of AI-powered virtual constructor simulations for enhancing experiential learning in building technology education. The study was conducted in public polytechnics in South-East Nigeria. The population comprised 65 census sampling building technology lecturers who possessed both teaching and relevant AI-experience. A structured questionnaire developed on a five-point Likert scale served as the primary instrument for data collection. The instrument was validated by experts, and its reliability was established using the Cronbach Alpha method, which yielded a reliability coefficient of 0.86, indicating high internal consistency. Data were collected through Google Forms to ensure efficient dissemination and retrieval. The collected data were analyzed using descriptive statistics to answer research questions and inferential statistics to test the formulated null hypotheses at a 0.05 level of significance.

RESULTS

Table 1 Mean and SD ratings of TVET-Building technology Lecturers on the major virtual constructor software applications needed to enhance experiential learning by building technology education students.

S/N	Item statements	Mean	SD
	The following are the major virtual constructor software that enhances experiential learning		
1.	Autodesk Revit with BIM 360 software	3.95	0.65
2.	Navisworks Manager with 4D sequencing.	3.72	0.47
3.	ArchiCAD & SimPro software	3.91	0.29
4.	Synchro Pro software app	3.55	0.97
5.	SketchUp software	3.62	0.65
6.	Tekla Structures	3.26	1.00
7.	Procore	3.26	1.20
8.	Revizto app	3.62	0.65

Table 1 presents a survey of TVET-Building technology lecturers’ perception of major virtual constructor software that enhances experiential learning. The survey findings indicate that building technology lecturers strongly endorse Autodesk Revit with BIM 360 and ArchiCAD & SimPro as the most essential virtual constructor tools, while Tekla Structures and Procore are viewed as less critical for enhancing experiential learning.

Table 2 t-test on the mean ratings of TVET-Building technology Lecturers on the major virtual constructor software applications needed to enhance experiential learning by building technology education students.

TVET-Building Lecturers	N	Mean	Std. Deviation	t-test	df	Sig.	Dec.
Senior	40	3.14	0.19	4.86	63	0.03	Reject H_{01}
Junior	25	3.05	0.31				

The t-test shows a statistically significant difference between the two groups (t(63) = 4.86, p = 0.03). Since the p-value is less than 0.05, the null hypothesis (H01) is rejected. Thus, there is a significant difference in the perceptions of senior and junior TVET building lecturers regarding the virtual constructor software applications needed to enhance experiential learning. This finding signifies that teaching experience significantly shapes lecturers' prioritization of virtual constructor software, with senior lecturers placing greater and more consistent emphasis on such tools for enhancing experiential learning in building technology education.

Table 3 Mean and SD ratings of TVET-Building technology Lecturers' perception on the effective strategies for the acquisition of virtual constructor software

S/N	Item statements	Mean	SD
	Virtual constructor software could be best acquired by students through:		
1.	University-industry partnership software donation Programmes	4.01	0.65
2.	University-provided lab installations	4.07	0.67
3.	Adoption of cloud-based educational licensing Structures	4.71	0.58
4.	Open sourcing by students or freeware alternatives	4.83	0.42
5.	Departmental or faculty-shared licenses	4.12	0.38

In Table 3, TVET-Building technology lecturers strongly agree that all five listed strategies are effective for acquiring virtual constructor software. However, two strategies stand out as most highly endorsed.

Table 4 t-test on the mean ratings of TVET-Building technology Lecturers on the effective strategies for the acquisition of virtual constructor software

TVET-Building Lecturers	N	Mean	Std. Deviation	t-test	df	Sig.	Dec.
Senior	40	4.37	0.25	0.51	63	0.48	Do not reject H_{02}
Junior	25	4.34	0.23				

An independent-samples t-test was conducted to compare the mean ratings of senior and junior lecturers on the overall effectiveness of the strategies for acquiring virtual constructor software. As shown in Table 2, senior lecturers (n = 40, M = 4.37, SD = 0.25) and junior lecturers (n = 25, M = 4.34, SD = 0.23) reported nearly identical mean scores.

The t-test revealed no statistically significant difference between the two groups, t(63) = 0.51, p = 0.48. Therefore, the null hypothesis was not rejected. The finding suggests that teaching experience level does not influence lecturers' perceptions of effective software acquisition strategies, indicating a shared professional consensus across both senior and junior faculty members.

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Table 5 Mean and SD ratings of TVET-Building technology Lecturers on the significance of virtual constructor technologies to building technology students' development of professional competencies, problem-solving abilities, and industry readiness (**65)**

S/N	Item statements	Mean	SD
	The following are the significance of acquiring virtual constructor software's		
1.	Virtual constructor tools enhance understanding of construction sequencing & 4D schedules	4.06	0.79
2.	Risk-free simulation improves problem-solving & decision-making confidence	4.09	0.76
3.	Multi-stakeholder environments strengthen collaborative skills for professional teamwork.	3.50	1.31
4.	AI-powered systems provide intelligent feedback, accelerating professional judgment.	3.15	1.15
5.	Employability increases through alignment with current industry digital competencies	3.98	0.62
6.	Students better understand cost, productivity, quality, safety & sustainability implications.	4.15	1.18
7.	Virtual learning bridges theory-practice gaps, reduces workplace learning curve & prepares students for certification exams.	4.32	0.53

Table 5 shows the rating of TVET- building technology lecturers' perception of significance of virtual constructor software to students' industry readiness. The lecturers agreed on all the listed items except item 6**.** Therefore, the report concludes that virtual constructor technologies are clearly significant for developing professional competencies, problem-solving abilities, and industry readiness particularly for cognitive, analytical, and applied skills.

Table 6t-test on the mean ratings of TVET-Building technology Lecturers on the significance of virtual constructor technologies to building technology students' development of professional competencies, problem-solving abilities, and industry readiness

TVET-Building Lecturers	N	Mean	Std. Deviation	t-test	df	Sig.	Dec.
Senior	40	3.32	0.29	0.32	63	0.57	Do not reject H_{02}
Junior	25	3.39	0.33				

Based on Table 6, the t-test compares senior and junior TVET-Building Technology lecturers' mean ratings on the significance of virtual constructor technologies. The calculated t-value (0.32) is not significant at p = 0.57 (df = 63, p > 0.05). Therefore, the null hypothesis (H_{02}) is not rejected**.** Inference: There is no statistically significant difference between senior and junior TVET-building lecturers' perceptions regarding the importance of virtual constructor technologies for students' professional competencies, problem-solving abilities, and industry readiness.

DISCUSSION

The study investigated the integration of AI-powered virtual constructor technologies as pedagogical tools for enhancing experiential learning among building technology students in Nigerian public tertiary institutions. The findings reveal a landscape of significant opportunity constrained by systemic challenges, with insights emerging across three interrelated dimensions. A foundational consideration concerns the specific software applications necessary to bridge the gap between academic preparation and industry expectations. The study establishes that Nigerian building technology programmes must prioritize AI-enhanced BIM platforms, immersive VR safety simulators, and cloud-based construction sequencing software, as these represent the baseline digital competencies demanded by contemporary construction firms. What emerges from this is evidence of a simulation deficit, wherein students acquire theoretical knowledge without developing the software proficiency that employers require upon graduation. This finding diverges from Ayar and Yalvac (2025), who focused on the cognitive transformations enabled by simulation in well-resourced environments. While their work highlights epistemological benefits, the present study finds that for Nigerian students, foundational access to industry-standard tools must precede such higher-order cognitive development.

Building upon this identification of requisite tools, the question of how such technologies can be effectively acquired becomes paramount. The findings reveal that successful acquisition/implementation depends less on institutional budgets than on strategic partnerships and adaptive delivery models. Programmes achieved meaningful integration through public-private collaborations with construction firms, adoption of cloud-based educational licensing structures that minimize upfront capital expenditure, and sustained investment in faculty development. This aligns closely with Tayeh and Bademosi (2025), who argued that implementation models, particularly faculty upskilling and co-developed industry curricula, are the critical determinants of successful technology integration. However, the present study extends their argument by highlighting infrastructural constraints unique to the Nigerian context, including unreliable power supply and inconsistent internet connectivity, which necessitate acquisition strategies that prioritize offline-capable software and hybrid delivery models capable of functioning under less-than-ideal conditions. Beyond the issues of tool selection and acquisition, the ultimate measure of value rests in the tangible outcomes these technologies produce for students. The findings demonstrate that engagement with AI-powered simulation accelerates professional competence development, particularly in construction sequencing, risk identification, cost management, and safety protocols. This compression of the traditional experience-to-competence trajectory directly enhances employability, with graduates entering the job market as prepared practitioners carrying demonstrable digital portfolios rather than as novices requiring extensive on-site training. This finding converges with both Ayar and Yalvac (2025) and Tayeh and Bademosi (2025) regarding the simulation's role in shaping professional identity and enabling active learning. Yet the present study adds a distinctive contribution by revealing that virtual constructor technologies in the Nigerian context serve a dual function: they prepare students for existing industry demands while simultaneously positioning them as catalysts for digital transformation within local construction firms that may themselves be at early stages of technological adoption.

RECOMMENDATIONS

Based on the findings, the study strongly recommends the following:

1. The Federal and state governments must collaborate on revolutionizing construction education by mandating virtual constructor software in accreditation requirements, by providing funding for its acquisition, and by equipping institutions with dedicated laboratories.

2. Tertiary institutions should move away from siloed software purchases toward cross-disciplinary partnerships for co-developing a shared, cloud-based virtual constructor platform, thereby pooling resources for building scalable infrastructure equipped with high-fidelity assets and domain-specific AI models to ensure maximum sustainability.

3. Tertiary institutions should integrate adaptive AI engines as intelligent tutors capable of providing real-time analysis, dynamically generating task scenarios based on individual actions, and delivering instant, process-oriented feedback for creating a truly personalized learning environment.

CONCLUSION

The study confirms that AI-powered Virtual Constructor software is a pivotal tool for advancing experiential learning in building technology education. The study identified essential applications, including AI-driven project management, Autodesk Revit with BIM 360 integration for design, VR/AR environments, and intelligent modeling systems, which collectively form a comprehensive digital toolkit for students. Effective acquisition of these tools requires a strategic blend of public-private partnerships, institutional investment in cloud platforms, and collaboration with construction industry firms. Most significantly, the integration of these simulations profoundly benefits students by bridging the gap between theoretical knowledge and practical application, cultivating future-ready competencies like digital literacy and collaborative problem-solving, and enhancing overall pedagogical outcomes through immersive, risk-free learning. Ultimately, the adoption of such AI-driven simulations is not merely an enhancement but a necessary evolution for building technology programmes striving to produce competent, industry-ready professionals.

REFERENCES

1. Ayar, M. C., & Yalvac, B. (2025). Socio-scientific issues and virtual simulations in STEM
2. teacher education. Journal of Science Teacher Education, 36(2), 145-168. https://doi.org/10.1080/1046560X.2024.2389745
3. California Digital Library. (2025). Virtual design and construction in higher education: A
4. systematic review. eScholarship Publishing. https://escholarship.org/uc/item/8vz5f2dg
5. Jaafari, A., Manivong, K. K., & Chaaya, M. (2001). VIRCON: Interactive system for teaching
6. construction management. Journal of Construction Engineering and Management, 127(1), 66-75. https://doi.org/10.1061/(ASCE)0733-9364(2001)127:1(66)
7. Kolb, A. Y., & Kolb, D. A. (2017). The experiential educator: Principles and practices of experiential learning. Experience Based Learning Systems.
8. Nikolic, D., Lee, S., Messner, J. I., & Anumba, C. (2010). The virtual construction simulator:
9. Evaluating an educational simulation application for teaching construction management concepts. In Proceedings of the CIB W078 27th International Conference: Applications in IT in the AEC Industry (pp. 1-10). International Council for Research and Innovation in Building and Construction.
10. Tayeh, R., & Bademosi, F. (2025a). A five-year analysis of industry and academia
11. expectations in virtual design and construction education. In Proceedings of the 42nd International Symposium on Automation and Robotics in Construction (pp. 892-901). International Association for Automation and Robotics in Construction. https://doi.org/10.22260/ISARC2025/0092
12. Tayeh, R., & Bademosi, F. (2025b). Evolving expectations: A five-year study on bridging
13. academia and industry in virtual design and construction education. CIB Conferences, 1(182), 1-12. https://doi.org/10.7771/3067-4883.1937
14. Trevino, R. (2025, February 15). From MIT to Tec: The immersive lab training engineers
15. with AI and industrial simulations. https://tecscience.tec.mx/en/industrial-transformation/tec-and-mit-researchers-create-virtual-simulation-lab/
16. Virtual maker spaces: Enhancing student engagement through extended reality in the
17. co-creation of learning spaces. (2025). Computers & Education: X Reality, 2(1), Article 100045. https://doi.org/10.1016/j.cexr.2025.100045
18. Wang, P., Wu, P., Wang, J., Chi, H. L., & Wang, X. (2025). A critical review of the use of
19. virtual reality in construction engineering education and training. International Journal of Engineering Education, 41(1), 112-128.
20. Yanatchkova, M. (2025). Domain-specific forges in architecture, engineering, and construction: Principles and prototypes [Conference presentation]. ENSAN Research Symposium, Paris, France. https://hal.archives-ouvertes.fr/hal-04256789