Available online on: http://ejournal.undip.ac.id/index.php/teknik
TEKNIK, 46 (3), 2025, 255-269

Digital Competencies Among Construction Students in Ghana's Technical Universities: A Quantitative Assessment from the Students' Perspective

Daniel Ebo Hagan[1, 2] *, Tutin Aryanti[1], Ilhamdaniah Ilhamdaniah[1]

[1] *Faculty of Technology and Vocational Education Universitas Pendidikan Indonesia, Jalan Dr. Setiabudhi No. 229 Bandung 40154, Indonesia*
[2] *Department of Construction Technology and Management, Cape Coast Technical University, Cape Coast, Ghana*

Submitted: May 15th, 2025; Revised: July 20th, 2025; Accepted: July 28th, 2025; Available online: July 30th, 2025
DOI: 10.14710/teknik.v46i3.68645

Abstract

The construction industry's digital transformation demands professionals with advanced digital skills. This study assesses the digital competencies of construction students at Ghana's technical universities, focusing on self-reported proficiency and perceived job readiness. Based on data from 271 final-year students across six institutions, the study employs a data-driven quantitative approach using a structured questionnaire and analyses through descriptive statistics, correlation, and regression. Findings reveal moderate proficiency in foundational skills like digital literacy and communication, but significant gaps in advanced areas such as cloud computing, 3D modelling, and coding. While students report high access to general digital tools, training in emerging technologies remains limited. Regression results indicate that digital literacy, planning and estimation skills, and access to training resources are key predictors of job readiness. The study highlights the need for curriculum reforms that incorporate a wider range of digital competencies aligned with Construction 4.0. It recommends enhancing hands-on learning, improving institutional support systems, and encouraging self-directed skill development. These interventions are crucial to bridging the gap between academic preparation and industry expectations, equipping graduates with the capabilities required for a digitally evolving construction sector in Ghana.

Keywords: Digital Competencies, Construction Education, Quantitative Survey, Job Market Readiness, Construction Industry

1. Introduction

The fourth industrial revolution, known as Industry 4.0, has brought a wave of digital advancement that demands a new set of skills from current and future employees across all sectors of the global economy, including construction. This transformation is evident in the shift from manual design to computer-aided design (CAD) and, more recently, Building Information Modeling (BIM), where automation, digitilization, and networked systems are at the forefront. Building on this shift, technologies such as the Internet of Things (IoT), robotics, Artificial Intelligence (AI), BIM, and big data analytics are becoming fundamental to the architectural, engineering, and construction (AEC) industry. These advancements illustrate the application of Industry 4.0 principles in the construction industry – often termed "Construction 4.0." Such innovations hold the potential to improve project performance and drive sustainability significantly (Karmakar & Delhi, 2021; Siddiqui et al., 2023; Zizic et al., 2022). Moreover, the past decade has witnessed the emergence of various skilled technical roles in the construction industry, along with increased demand for digital skills in the AEC job market (Chandramohan et al., 2022). As a result, skills once limited to information and communication technology (ICT) tools, techniques, and practices have become vital (Sawhney et al., 2020). According to Balogun et al. (2023) and Soltani et al. (2023), the widespread adoption of digital technologies - and, more broadly, the shift towards Industry 4.0 - is hindered by deficits in the required digital skills, knowledge, expertise, and experience among industry professionals. Consequently, digital competencies - the knowledge and skills needed to utilize digital tools and technologies – have become

*) Corresponding Author
E-mail: *danielebohagan@upi.edu*

critical across a wide range of roles in the AEC industry (Djumalieva & Sleeman, 2018).

Previous studies, including those by Sherratt et al. (2020) and Casini (2021), have emphasized integrating digital skills training into construction education to prepare students for the demands of Construction 4.0. A study by Hwang et al. (2022) highlights the persistent challenges of digital skills gaps, particularly in developing contexts where access to advanced tools and training resources is limited. While some efforts have been made to explore digital competencies and their influence on employability, most studies, like those by Buscemi et al. (2022) and Mansour et al. (2023), focus predominantly on developed nations, leaving a significant gap in understanding these dynamics in developing countries like Ghana.

This study addresses this gap by evaluating the digital competencies, access to training resources, and job market readiness of construction students in Ghana's technical universities. As core institutions for shaping the future workforce of Ghana's construction industry, Technical Universities must prepare middle and upper-level professionals by aligning their curricula and teaching methods with the industry's evolving digital demands (Sam-Amoah & Frimpong, 2020). By examining the current state of digital competence among construction students, this study aims to support the transition to Construction 4.0 by addressing the fundamental issue of digital readiness among future professionals. It seeks to equip academic institutions with critical insights to enhance curricula and better prepare students for a technology-driven construction industry. As the global construction industry shifts toward digitalization, bridging this skills gap will enable more significant benefits from greater efficiency, cost savings, and innovation in construction projects in developing countries (Weber-Lewerenz & Traverso, 2023).

2. Literature Review

2.1 Construction 4.0 and Digital Competencies

Construction 4.0 represents the application of Industry 4.0 principles within the construction sector, leveraging advanced digital technologies to drive efficiency, productivity, and sustainability. Key technologies in this paradigm include BIM, IoT, robotics, drones, AI, and big data analytics, enabling a shift from traditional practices to integrated and automated systems. This transition reduces human error, enhances design accuracy, and optimizes project management processes, as highlighted by Zheng et al. (2023). According to Sawhney et al. (2020), Construction 4.0 modernizes workflows and fosters a digitally mature construction ecosystem.

The effective adoption of Construction 4.0 technologies necessitates a workforce equipped with robust digital competencies. Proficiency in digital design, project management, and analytics tools has become essential for construction professionals to fully leverage these advancements (Casini, 2021). However, a significant digital skills gap persists, impeding the widespread adoption of these technologies. Many professionals lack the competencies to utilize digital tools effectively. This skills disparity is a barrier to the construction industry's digital transformation (Sherratt et al., 2020). A Digital Construction Competency Framework has been proposed to identify and develop the essential skills required for digitalization, accelerating the industry's progression toward digital maturity (Siddiqui et al., 2023).

A recurring discussion focuses on the readiness of the current workforce and new graduates to embrace Construction 4.0 technologies (Mansour et al., 2023). This readiness is especially pertinent given the rapid technological advancements that demand adaptable, digitally skilled professionals. Some researchers emphasize aligning digital competency development with industry needs, particularly within academic settings. Universities are responding by adapting curricula to include training in BIM, IoT, and other digital tools, ensuring that graduates are equipped with relevant digital skills for their careers (Li, 2022). Despite these efforts, many programs lack hands-on experience with emerging technologies, limiting students' readiness to contribute effectively to the industry's digital evolution (Buscemi et al., 2022).

Targeted upskilling efforts are essential to bridge this divide and ensure that all segments of the construction workforce can participate in and benefit from the digital transformation. Furthermore, the successful integration of digital technologies in construction projects requires technical skills, an understanding of workflow adjustments, and collaboration across project stakeholders (X. Chen et al., 2024). This holistic approach to digital competency development is necessary to harness the full potential of Construction 4.0.

A digital competency framework delineates the vital skills and knowledge necessary for emerging professionals, encompassing digital literacy, expertise in BIM, data management, and the utilization of digital collaboration platforms (Bolpagni et al., 2022). Numerous educational institutions, particularly in developed countries, have incorporated digital competency frameworks into their curricula to guarantee that students are proficient in the technologies that form the foundation of Construction 4.0 (González-Pérez & Ramírez-Montoya, 2022; Gupta et al., 2024). Such frameworks prioritize technical competencies and interpersonal skills, including digital collaboration and project management, to prepare students for effective

doi: 10.14710/teknik.v46i3.68645

participation in multidisciplinary and digital contexts (García-Pérez et al., 2021).

Siddiqui et al. (2022) proposed an extensive framework that classified digital competencies needed by the construction sector, particularly in era of Construction 4.0. Their categorization includes fundamental digital literacy, technical abilities, strategic competencies relevant to digital transformation and the engineering and design of nano-enhanced materials for sustainable and efficient construction. This study utilized a questionnaire adapted from the framework to evaluate digital competencies among construction students, assuring its relevance to the Ghanaian educational context.

Table 1 outlines the modified classification of digital abilities tailored to the context of Ghana and the particular requirements of construction-related fields. This classification corresponds with current literature and guarantees that the competencies assessed are indicative of the contemporary digital environment in the construction industry, particularly in developing economies such as Ghana, where deficiencies in digital skills pose a significant obstacle to the adoption of Construction 4.0 (Bitegeko et al., 2024; Gbadebo, 2024).

A significant challenge in this context is the insufficient resources and infrastructure necessary to facilitate the incorporation of digital technologies within the educational framework. Ebekozien et al. (2023) emphasizes that numerous African universities face challenges due to outdated curricula that do not align with the contemporary dynamics of the digital construction environment.

2.2 Challenges in Accessing Digital Training Resources

The availability of digital tools and sufficient training continues to pose a significant challenge for implementing Construction 4.0 technologies, especially in developing regions such as Sub-Saharan Africa (Mhlongo et al., 2023). Various studies have underscored the differences between developed and developing countries regarding the incorporation of advanced digital technologies, such as BIM, IoT, and AI, within construction education (Wang, Guo, Zhang, Hao, et al., 2022). This disparity results from inadequate infrastructure, insufficient funding, and a lack of experienced instructors. The high cost of acquiring and maintaining digital tools is a significant barrier to their accessibility in construction education. Consequently, students frequently depend on theoretical understanding, lacking the practical experience to cultivate the digital skills imperative in today's construction industry. Most faculty members possess limited familiarity with these technologies.

Consequently, they face challenges in effectively training students regarding their application (Gbadebo, 2024). The availability of digital tools does not compensate for the lack of experienced educators, which diminishes their effectiveness, as students lack the essential guidance needed to utilize these resources proficiently. In most developing countries, educational programs persist in emphasizing conventional construction techniques, resulting in a workforce inadequately equipped for the demands of a digitalized construction sector. Most of these countries lack the initiative to integrate digital tools into their construction education curricula, worsening the growing digital competency divide in the region. The deficiency in technological infrastructure significantly impacts students' educational experiences and diminishes their competitiveness in the global job market, where proficiency in digital skills is becoming an essential requirement (Goulart et al., 2022).

Table 1. Categorization of digital skills of Ghana's Tehcnical Universities adapted from Siddiqui et al. (2022).

Category	Skills
Digital Literacy	Computational tools, computer skills, Microsoft Office, construction software usage, knowledge of current construction technologies
Automation & Robotics	3D printing, autonomous construction equipment, digital fabrication, Drones for construction purposes, offsite construction and manufacturing, Robotics
Coding and Programming	AI, computer programming, machine learning
Design & Drafting	AutoCAD, Nanotechnologies, structural design
Communication	IoT, Smart sensors, IT/ICT/computer information systems, Smart wearables
Cloud Computing and Data Management	Big data, blockchain, cloud computing and collaboration, data analytics, data-driven digitalization, GIS, Laser scanning, Lider survey scanner
3D Modeling, Virtualisation and Simulation	BIM design and modeling, Digital twin, Mixed reality, virtual reality, augmented reality, Revit, Simulation
Planning and Estimation	Productivity planning software, scheduling, and cost estimating/management via technology and software, e.g., Navisworks

doi: 10.14710/teknik.v46i3.68645

2.3 Digital Competencies and Industry Readiness

The significance of digital competencies is becoming more pronounced as they serve as a vital connection between construction education and the industry's readiness in the context of Construction 4.0. With the increasing reliance on digital technologies within the construction industry, students' proficiency in these technologies is a decisive factor influencing their employability and potential for success in their professional careers. A significant body of research indicates a robust relationship between levels of digital competency and readiness for the industry. Students with advanced digital skills demonstrate greater readiness for the work environment and navigate the sophistication of contemporary construction projects (Siddiqui et al., 2023; Souza & Debs, 2023). A significant issue in construction education is the increasing disparity between the curriculum offered by universities and the skill sets demanded by the construction sector. The disparity is particularly evident in areas where integrating digital tools such as BIM, AI, and data analytics into construction education has progressed sluggishly. In advanced economies, incorporating digital tools into standard educational curricula has resulted in students acquiring a solid understanding of these technologies. Consequently, they are better equipped to oversee digital construction projects and deploy automated systems (Wang, Guo, Zhang, & Schaefer, 2022).

In contrast, students in developing countries frequently complete their studies with minimal familiarity with these tools. The skills gap presents considerable challenges for their industry readiness, as construction firms are progressively searching for graduates who can effectively engage in the industry's digital transformation. A survey conducted among construction firms in developing regions indicated that the insufficient digital proficiency of graduates was a significant factor hindering the effective implementation of technologies such as BIM and AI (Souza & Debs, 2023). The disparity between academic training and the requirements of the construction industry has prompted a demand for educational institutions to better align their curricula with industry standards and integrate more practical experience with digital tools (Ebekozien & Aigbavboa, 2024). Engaging in practical projects and utilizing digital tools within a professional environment enables students to acquire the necessary experience for a seamless transition into the workforce (Samuelson & Stehn, 2023).

3. Research Methods

This study adopts a quantitative research design to evaluate the digital competencies of construction students at Ghana's technical universities and their readiness for the evolving demands of Construction 4.0. The quantitative approach was selected to systematically collect and analyze data from a broad population, providing insights into students' self-reported competencies, access to digital tools, and perceived job market readiness. A flow chart of the research design is shown in Figure 1.

The target population for this study consisted of construction students from selected technical universities in Ghana, estimated to be around 900 students according to the universities' HR/planning and quality assurance departments. The sample was drawn from six major technical universities that offer AEC-related programs.

These institutions were chosen due to their central role in training middle-level construction professionals. Their curricula for construction programs are structured to ensure students first acquire core knowledge in areas such as engineering drawing, structural analysis, construction materials and mechanics before progressing to digital tools. Foundational mathematics, physics and technical communication courses further support students' ability to interpret and apply data in digital environments. This sequencing ensures that digital competency is not treated as a standalone skill but as an applied extension of theoretical learning.

Using standard sample size determination formulas for a finate population, with a 95% confidence level and 5% margin of error, the minimum required sample size was calculated to be approximately 270 students. Accordingly, a stratified random sampling technique was used to select 271 final-year students across various levels of study (Diploma, Higher National Diploma, and Bachelor's degree). The study purposefully combined respondents from these levels to provide a comprehensive understanding of digital competencies among construction students. They represent the progressive academic structure within Ghana's technical universities, where students across all these tiers are trained for middle-level roles in the construction sector. Despite differences in curriculum depth and specialization, students at each level engage with core digital tools and foundational concepts related to Construction 4.0, albeit with varying intensity. Integrating these groups into a singular analysis was crucial for capturing a broader view of digital readiness across the full spectrum of technical university training for the middle-level workforce. This approach enabled the identification of systemic trends, common challenges, and shared opportunities for curriculum enhancement rather than isolating insights to one academic level. This inclusive strategy enhances the generalizability of the findings and supports holistic policy recommendations aimed at improving digital competency development across all levels of technical construction education.

The primary data collection instrument was a structured questionnaire designed using Google Forms.

doi: 10.14710/teknik.v46i3.68645

The questionnaire consisted of closed-ended questions and Likert-scale items, allowing students to rate their digital competencies, access to digital tools, and training experiences on a scale from 1 to 5. The questionnaire was divided into three main sections: Demographic information, Students' self-assessment of their digital competencies, and Access to Training Resources.

To ensure the reliability and validity of the data collection instrument, a multi-step validation process was undertaken. First, the questionnaire items were developed based on a comprehensive review of existing literature on digital competencies in the context of Construction 4.0, drawing on frameworks and empirical studies by Siddiqui et al. (2023), Casini (2021), and Souza and Debs (2023). The draft questionnaire was then subjected to content validation by three academic experts in construction education and digital learning. Their feedback was used to refine item clarity, relevance, and alignment with the study objectives. Subsequently, a pilot test was conducted with a sample of 30 final-year construction students from one of the participating technical universities. This helped assess the clarity of the items and identify any ambiguities. Following the pilot, minor revisions were made to improve readability and item precision.

To evaluate internal consistency, Cronbach's alpha was computed for the major constructs in the questionnaire. All constructs achieved acceptable reliability levels, with Cronbach's alpha values ranging from 0.72 to 0.84 ($\alpha = 0.72$-0.84), indicating satisfactory internal consistency. These steps collectively ensured that the instrument was both reliable and suitable for capturing data on digital competencies and job readiness among construction students.

While the study offers critical insights into Ghana's technical university system, the external validity is limited. The findings may not be entirely generalizable beyond Ghana due to differences in technological infrastructure, policy environments, and digital education frameworks. However, similar patterns have been observed in other developing countries, such as Tanzania (Bitegeko et al., 2024) and Nigeria (Gbadebo, 2024), where foundational digital skills are more developed than advanced competencies due to infrastructural and training limitations. This alignment suggests that the recommendations offered may be applicable across similar contexts in Sub-Saharan Africa and other developing economies.

Data collection was conducted over a four-week period during the second semester of the 2023/2024 academic year. Participation in the survey was voluntary, and confidentiality was maintained by ensuring that respondents did not provide identifying information. The data collection resulted in 271 fully completed questionnaires suitable for analysis. The data collected through the structured questionnaire were analyzed using

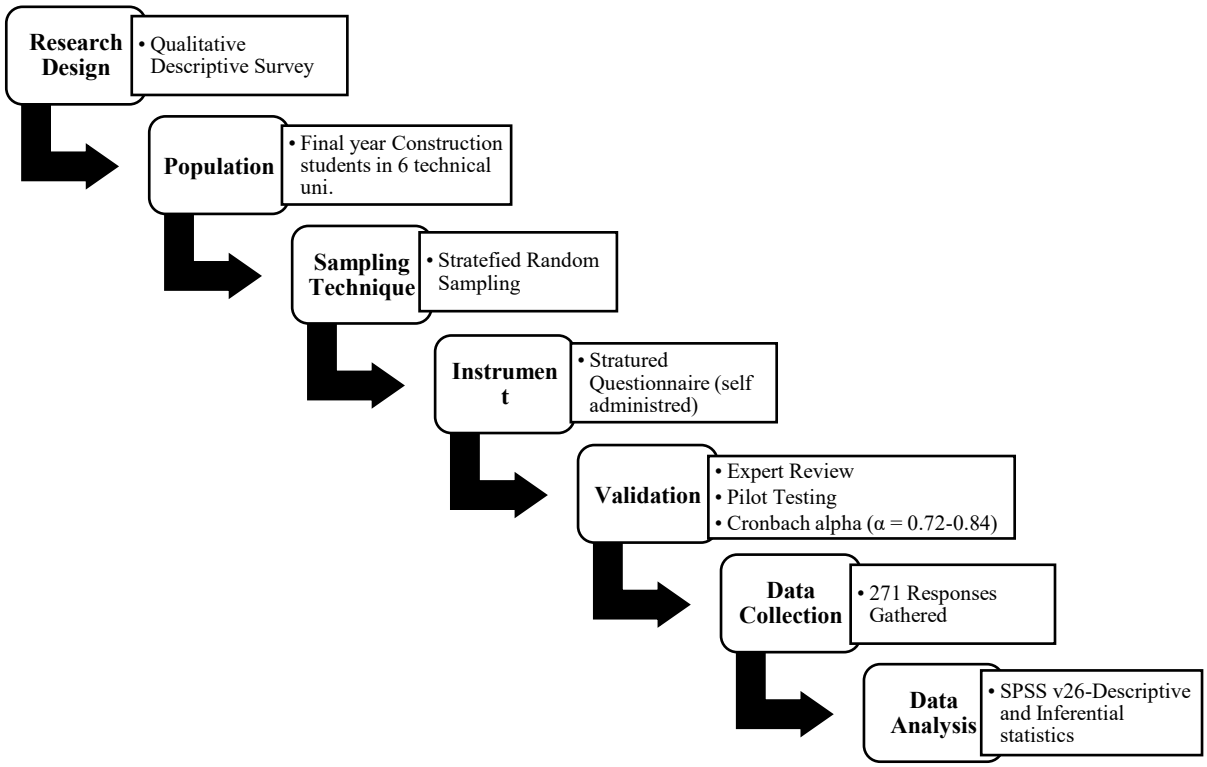

Figure 1. Flow chart of the research design.

doi: 10.14710/teknik.v46i3.68645

Statistical Package for the Social Sciences (SPSS) version 26. A combination of descriptive and inferential statistical techniques was employed to address the study objectives. Descriptive statistics (means, standard deviations, and frequencies) were used to summarise students' demographic characteristics, self-reported digital competencies, access to training resources, and perceived job market readiness. To examine relationships among key variables, Pearson correlation analysis was conducted, exploring associations between digital competencies, access to training resources, and job readiness.

Further, multiple linear regression analysis was performed to identify significant predictors of students' perceived readiness for the construction job market. Specifically, regression models were used to assess the joint and individual contributions of digital competencies and access to training resources in explaining job readiness, as well as the relative influence of different digital skill categories on employability outcomes.

4. Results

4.1 Demographic Characteristics

The demographic profile of the respondents as listed in Table 2 shows that the majority of respondents (89.7%) were male, with the remaining 10.3% being female, reflecting the male-dominated nature of construction-related fields in the study. Most students (69.4%) were aged between 20 and 29 years, indicating that they are early-career professionals, with a smaller representation of individuals below 20 years (8.5%). The least represented age groups were 40-49 years (2.2%) and 50 years or older (1.8%). In terms of field of study, Building Technology (42.8%) was the most represented program, followed by Construction Technology/Management (25.1%). The rest were distributed across Quantity Surveying (15.1%), Civil Engineering (10.7%), and Estate Management (3.3%), with Architectural Technology having the least representation (3.0%). A significant proportion (40.6%) of the respondents were pursuing Bachelor's degrees. Higher National Diploma (HND) students comprised 39.1%, while Diploma students comprised 19.2%. Only a small fraction of respondents were pursuing a Master's degree (1.1%).

Regarding digital tool usage for construction-related tasks or assignments, most respondents reported frequent use, with 41.0% using them weekly and 26.9% using them daily. However, a notable portion (12.2%) reported rare usage, and 6.3% indicated no use of digital tools for construction tasks, highlighting a potential gap in practical digital exposure.

Table 2. Demographic characteristics of the respondents.

Demographic Characteristics		Freq.	Percent (%)
Gender	Male	243	89.7
	Female	28	10.3
Age	Below 20 years	23	8.5
	20-29 years	188	69.4
	30-39 years	49	18.1
	40-49 years	6	2.2
	Above 50 years	5	1.8
Field of Study	Architectural Technology	8	3.0
	Building Technology	116	42.8
	Civil Engineering	29	10.7
	Construction Technology/Management	68	25.1
	Quantity Surveying	41	15.1
	Estate Management	9	3.3
Level of Study	Diploma	52	19.2
	Higher National Diploma	106	39.1
	Bachelor Degree	110	40.6
	Master's Degree	3	1.1
Frequency of digital tool usage tasks or assignments	Daily	73	26.9
	Weekly	111	41.0
	Monthly	37	13.7
	Rarely	33	12.2
	Never	17	6.3
Total		271	100.0

doi: 10.14710/teknik.v46i3.68645

4.2 Digital Competencies of students

The descriptive statistics in Table 3 indicate the self-reported digital competencies of construction students across eight key skill areas. The mean scores suggest a moderate level of proficiency with the highest competency reported in "Digital Literacy" (Mean = 3.7435, Std. Dev. = 0.825). This indicates that students generally perceive themselves as competent in foundational digital skills, which form the basis for navigating more specialized tools and technological processes. The relatively high score and moderate variability suggest that digital literacy is well-established among the respondents. "Communication" also shows a relatively high mean score (Mean = 3.6229, Std. Dev. = 0.769), which suggests that students are well-prepared for digital communication. Communication is critical in a collaborative industry like construction, where digital tools are increasingly used for information sharing, project updates, and stakeholder engagement. "Design & Drafting" (Mean = 3.5461, Std. Dev. = 0.841) and "Planning & Estimation" (Mean = 3.3699, Std. Dev. = 0.840) show moderate proficiency, with variability in confidence levels. These skills are more specialized, which may explain the slightly lower scores than those in basic digital literacy and communication. Proficiency in design, drafting, planning and estimation forms a core foundation for effective project execution in Construction 4.0. The moderate competency levels in these areas suggest that while students have a reasonable grasp, additional training is needed to deepen their skills, particularly in advanced digital tools. "Automation & Robotics" (Mean = 3.378, Std. Dev. = 0.747) and "Coding and Programming" (Mean = 3.413, Std. Dev. = 0.810) also had moderate mean scores. However, the latter displayed more variation in skill levels, possibly due to differing exposure and experience with these technologies. Stronger coding and programming skills would allow students to leverage most Construction 4.0 technologies more effectively by enabling data analysis, custom digital tool development, and data-driven decision-making. The lowest mean scores were exhibited in "Cloud Computing" and "Data Management" (Mean = 3.2149, Std. Dev. = 0.880) and "3D Modelling, Virtualization, and Simulation" (Mean = 3.2177, Std. Dev. = 0.865), suggesting lower confidence and more significant variability in these advanced skill areas. This signals gaps in training related to advanced technologies, indicating that students may not feel fully prepared to utilize these advanced technologies essential for virtual project representation and testing, effective project management, collaboration, and pre-construction planning in Construction 4.0. Strengthening competencies in these areas would better prepare students to meet the demands of a digitally-driven construction environment, fostering the ability to collaborate effectively, manage data securely, and apply advanced visualization techniques to improve planning and execution in the industry.

4.3 Access to Training Resources The findings from Table 4 provide an overview of the access to training resources for construction students at Ghana's technical universities. Overall, the results suggest a moderate level of satisfaction among students, with varying degrees of confidence in specific areas.

The highest mean score was recorded for access to Microsoft Office tools (Mean = 3.68, Std. Dev. = 0.949), indicating that students are well-equipped with essential tools needed for construction-related assignments. While this is a positive outcome, it highlights the need to shift focus toward integrating more specialized software, such as BIM and other advanced technologies, to align students' skills with the demands of Construction 4.0. Similarly, access to comprehensive training materials was rated moderately high (Mean = 3.61, Std. Dev. = 0.896), suggesting that students perceive the provided resources as helpful for their learning. However, continuous improvement in the quality and clarity of these materials could further enhance learning outcomes.

The provided training's coverage of emerging digital skills was also rated favourably (Mean = 3.55, Std. Dev. = 0.850), reflecting a reasonable level of adequacy. Nevertheless, expanding the curriculum to incorporate more advanced competencies in emerging technologies

Table 3. Construction students' self-reported digital competencies.

Competence Area	Mean	Std. Dev.
Automation & Robotics	3.378	0.747
Coding and Programming	3.413	0.810
Communication	3.6229	0.769
Design & Drafting	3.5461	0.841
Cloud Computing and Data Management	3.2149	0.880
3D Modelling, Virtualization and Simulation	3.2177	0.865
Planning & Estimation	3.3699	0.840
Digital Literacy	3.7435	0.825

doi: 10.14710/teknik.v46i3.68645

would better prepare students for the evolving construction industry. Students also reported moderate access to current construction technologies for learning purposes (Mean = 3.51, Std. Dev. = 0.938) and software tools that align with industry demands (Mean = 3.50, Std. Dev. = 0.918). While these scores indicate satisfactory alignment, there is an opportunity to enhance students' exposure to cutting-edge technologies, bridging the gap between academic training and industry practice.

Access to general digital tools, including hardware and software, scored a mean of 3.48 (Std. Dev. = 0.973), suggesting that while tools are generally available, there is room for improvement. Enhanced access to these tools could significantly support students in developing critical digital competencies. The frequency of training sessions provided to students (Mean = 3.41, Std. Dev. = 1.003) shows some variability in students' experiences. Increasing the regularity and variety of these sessions could improve skill development and ensure a more consistent learning experience. Training and guidance on using computational tools received a slightly lower score (Mean = 3.39, Std. Dev. = 0.994), reflecting a need for more comprehensive and practical training. Providing hands-on sessions and improved guidance could better equip students to apply digital tools effectively in construction tasks. Independent learning resources scored lower still (Mean = 3.30, Std. Dev. = 1.058), indicating that students may lack sufficient resources to develop their digital skills outside of structured classes. Access to additional tools, software licenses, and online learning platforms could empower students to independently enhance their competencies.

The lowest-rated aspect was the availability of support services for students facing challenges in using digital tools for construction tasks (Mean = 3.25, Std. Dev. = 1.065). This finding highlights a significant gap in institutional support. Strengthening support systems, such as tutoring programs and help desks, could help students overcome challenges and build their confidence in using advanced digital tools.

4.4 Readiness for the Job Market

Table 5 shows construction students' self-reported readiness for the industry/job market, specicifically in relation to their digital competencies. The highest mean score was recorded for students' active efforts to stay updated on advancements in digital technologies in construction (Mean = 3.88, Std. Dev. = 0.817). This reflects a proactive attitude among students, suggesting they recognize the importance of keeping pace with technological advancements. This eagerness to stay informed indicates their adaptability and commitment to personal and professional growth. However, ensuring they have access to reliable resources and training opportunities to support this drive will be crucial. Students also expressed high confidence in their ability to adapt to changes brought about by digital technologies in the construction industry (Mean = 3.81, Std. Dev. = 0.876). This readiness to embrace change highlights a strong foundation for transitioning into the evolving Construction 4.0 environment.

Similarly, students reported feeling prepared to collaborate effectively through the use of digital tools and technologies for construction projects (Mean = 3.79, Std. Dev. = 0.880), indicating they are comfortable working together in teams within digitally enabled construction project environments. These findings suggest that students are well-positioned to contribute to modern construction practices that rely heavily on teamwork and digital tools. Nevertheless, fostering more opportunities for hands-on collaboration in academic settings could further strengthen these skills.

Students' comfort with adapting to the changing technological landscape of the construction industry was also rated highly (Mean = 3.73, Std. Dev. = 0.842). This underscores their ability to navigate the dynamic nature of technological advancements, a critical competency for thriving in Construction 4.0. Additionally, students believe that their digital competency aligns with the requirements of the digital construction era (Mean = 3.62,

Table 4. Access to training resources.

Training Resources	Mean	Std. Dev.
Ease of access to general digital tools	3.48	0.973
Microsoft Office tools availability	3.68	0.949
Access to current construction technologies for learning	3.51	0.938
Alignment of digital tools for coursework with industry demands	3.50	0.918
Sufficient training in computational tools	3.39	0.994
Adequate training in emerging digital skills	3.55	0.850
Comprehensive training materials	3.61	0.896
Regular digital tool training sessions	3.41	1.003
Independent computational resources	3.30	1.058
Support for digital tool challenges	3.25	1.065

doi: 10.14710/teknik.v46i3.68645

Std. Dev. = 0.889). While this is a positive indicator of their self-assessed preparedness, it also suggests an opportunity for institutions to ensure that this alignment is validated through practical and industry-relevant training.

Confidence in digital skills meeting employer expectations received a slightly lower score (Mean = 3.56, Std. Dev. = 0.964). This finding points to a potential gap between students' perceptions of their skills and the actual demands of the job market. Addressing this gap may require academic institutions to enhance their curricula with more industry-specific training and exposure to real-world applications of digital tools. Similarly, students' confidence in their ability to use digital tools and technologies scored a mean of 3.70 (Std. Dev. = 0.917), reflecting moderate confidence but highlighting the need for further training to deepen their proficiency in critical digital competencies. These findings indicate that while construction students demonstrate a positive attitude and moderate confidence in their readiness for the industry, there are opportunities to strengthen their preparedness further.

A Pearson correlation analysis was conducted to examine the relationships between Digital Competencies, Access to Training Resources, and Readiness for the Industry/Job Market to understand how enhanced digital skills and access to training resources impact students' readiness for careers in the construction industry (see Table 6). All the relationships between these variables are statistically significant ($p<0.01$), demonstrating strong positive correlations. Access to training resources strongly correlates with Readiness for the Industry/Job Market ($r = 0.646$, $p = 0.000$), indicating that students who report greater access to digital tools and training also tend to feel more prepared for the job market. This suggests that access to training opportunities is crucial in boosting students' confidence and readiness for industry demands. The correlation between Access to Training Resources and Digital Competencies is even stronger ($r = 0.748$, $p = 0.000$), emphasizing that improved access to digital tools and training significantly enhances students' digital competencies. This further highlights the importance of providing resources and training opportunities that develop digital skills, as these are foundational for modern construction industry requirements.

Additionally, Digital Competencies show a robust positive correlation with Readiness for the Industry/Job Market ($r = 0.731$, $p = 0.000$). This finding suggests that a higher level of digital competence is closely linked to students' perceptions of their job market readiness. Developing digital skills benefits technical competency and enhances students' readiness for professional roles in a technologically advancing construction sector. These insights underscore the importance of integrating accessible digital training into educational curricula to cultivate a workforce equipped for Construction 4.0.

Table 5. Students' readiness for industry/ job market.

Students' Readiness	Mean	Std. Dev.
Confidence in using digital tools	3.70	0.917
Digital skills meet Employer expectations	3.56	0.964
Adaptability to evolving technology	3.73	0.842
Collaboration with digital tools	3.79	0.880
Digital readiness for the demands of the industry	3.62	0.889
Adaptation to digital transformation	3.81	0.876
Active efforts to stay updated on advancements in digital technologies	3.88	0.817

Table 6. The relationships between Digital Competencies, Access to Training Resources, and Readiness for the Industry/ Job Market.

Items		Access to Training Resource	Readiness for Industry/Job Market	Digital Competencies among Construction Students
Access to Training Resource	Pearson Correlation	1		
	Sig. (2-tailed)			
Readiness for Industry/Job Market	Pearson Correlation	.646**	1	
	Sig. (2-tailed)	0.000		
Digital Competencies among Construction Students	Pearson Correlation	.748**	.731**	1
	Sig. (2-tailed)	0.000	0.000	

**. Correlation is significant at the 0.01 level

4.5 Impact of Digital Competencies and Access to Training Resources on Job Market Readiness

Regression analysis was used to provide critical insights into the relationship between digital competencies, access to training resources, and students' readiness for the job market in the construction industry. These two factors emerged in literature and initial exploratory analysis as the strongest predictors of job readiness, particularly in this era of digital transformation. The results from this study further reinforce their significant role in preparing students for a rapidly evolving, digitally-driven construction sector.

As shown in Table 7, the model summary reveals that “digital competencies” and “access to training resources” collectively explain 58.1% of the variance in job market readiness (R Square = 0.581, Adjusted R Square = 0.578). This indicates a strong relationship between the independent variables and students' perceived readiness for the construction industry. The relatively low standard error of the estimate (0.48285) suggests that the model is a reliable fit, further emphasizing the importance of these predictors in shaping students' preparedness.

The ANOVA results presented in Table 8 demonstrate the overall significance of the regression model ($F = 185.829$, $p < 0.001$). This indicates that digital competencies and access to training resources, as a combined set of predictors, significantly impact students' readiness for the job market. The low residual mean square (0.233) reinforces the model's robustness, suggesting that the predictors strongly account for the variability in the dependent variable.

The coefficients as shown in Table 9 provides a deeper understanding of the individual contributions of each predictor. Digital competencies ($B = 0.622$, Beta = 0.563, $t = 9.170$, $p < 0.001$) emerge as the most significant predictor, contributing more intensely to job market readiness than access to training resources. This finding underscores the critical importance of equipping students with robust digital skills to prepare them for the demands of Construction 4.0. Students with higher digital competencies are more likely to feel confident and ready to engage with advanced construction technologies, improving their employability and potential contribution to the industry. While less impactful than digital competencies, access to training resources ($B = 0.210$, Beta = 0.225, $t = 3.659$, $p < 0.001$) still plays a significant role in influencing job market readiness. Adequate access to training resources, including digital tools, software, and instructional materials, supports students in building their competencies and applying their skills in practical settings. This highlights the need for institutions to invest in modern training facilities and resources to enhance students' learning experiences.

4.6 Key Competencies Influencing Students' Perceived Job Readiness

The regression analysis presented in Table 10 provides insights into the key digital competencies influencing students' perceived readiness for the construction job market. The coefficients indicate the relative importance of various competencies in predicting students' readiness to meet industry demands.

Communication skills positively influenced job readiness ($B = 0.209$, Beta = 0.232, $t = 4.596$, $p < 0.001$). This finding underscores the importance of effective communication in a digitally integrated construction environment, where collaboration across multidisciplinary teams and the ability to convey information are critical for project success. Students who excel in communication are better equipped to navigate the collaborative challenges of modern construction practices. Planning and Estimation skills strongly

Table 7. Model summary for the impact of digital competencies and access to training resources on students' job market readiness.

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.762	0.581	0.578	0.48285

Predictors: (Constant), Digital Competencies among Construction Students, Access to Training Resources.

Table 8. ANOVA results for the regression model on job market readiness.

	Sum of Squares	df	Mean Square	F	Sig.
Regression	86.651	2	43.325	185.829	0.000
Residual	62.483	268	0.233		
Total	149.134	270			

Dependent Variable: Readiness for Industry/Job Market

Predictors: (Constant), Digital Competencies among Construction Students, Access to Training Resources.

doi: 10.14710/teknik.v46i3.68645

impacted job readiness (B = 0.280, Beta = 0.339, t = 4.923, p < 0.001). This highlights the vital role of these skills in budgeting, scheduling, and resource management, which are essential for ensuring project efficiency. Students with strong planning and estimation abilities are more likely to meet the expectations of employers in an industry increasingly reliant on data-driven decision-making.

Digital Literacy also emerged as a significant predictor of job readiness (B = 0.277, Beta = 0.330, t = 5.607, p < 0.001). As the foundation for engaging with advanced digital tools and technologies, digital literacy enables students to adapt to technological advancements and effectively leverage digital resources. The significance of this competency emphasizes the need for institutions to ensure that all students possess strong foundational digital skills to remain competitive in a rapidly evolving construction landscape. 3D Modelling, virtualization, and simulation skills were another significant positive predictor of job readiness (B = 0.124, Beta = 0.155, t = 2.223, p < 0.05). These competencies are essential for creating realistic project representations, virtual testing, and improving design visualization. As construction projects increasingly rely on virtual and augmented reality tools, students proficient in 3D modelling and simulation will be better positioned to contribute effectively to project success.

In contrast, Automation and Robotics, Coding and Programming, Design and Drafting, and Cloud Computing and Data Management were not statistically significant predictors of job readiness. Although these competencies are essential for Construction 4.0, their lack of significance in this model suggests that broader, foundational skills influence students' readiness for the job market more than these advanced, specialized areas. For instance, Automation & Robotics (B = 0.013, Beta = 0.014, t = 0.283, p = 0.777) and Cloud Computing & Data Management (B = -0.061, Beta = -0.077, t = -1.330, p = 0.185) show limited impact, indicating that these skills may not yet be as critical for entry-level job readiness or are areas where students may lack sufficient exposure to demonstrate readiness.

5. Discussion

The findings of this study provide valuable insights into the digital competencies, access to training resources, and job market readiness of construction students in Ghana's technical universities. The results highlight strengths and gaps in students' preparation for a digitalized construction industry, reflecting broader challenges in aligning education with the technological demands of Construction 4.0. The findings align with recent literature, emphasizing the importance of foundational skills and the need for greater emphasis on advanced digital tools and technologies. Students

Table 9. Coefficients of predictors for job market readiness.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.862	0.159		5.419	0.000
Access to Training Resource	0.210	0.057	0.225	3.659	0.000
Digital Competencies among Construction Students	0.622	0.068	0.563	9.170	0.000

Table 10. Coefficients of key competencies influence students' perceived job readiness.

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.922	0.158		5.842	0.000
Automation & Robotics	0.013	0.046	0.014	0.283	0.777
Coding and Programming	-0.039	0.047	-0.045	-0.828	0.409
Communication	0.209	0.045	0.232	4.596	0.000
Design and Drafting	-0.013	0.046	-0.016	-0.291	0.772
Cloud Computing and Data Management	-0.061	0.046	-0.077	-1.330	0.185
3D Modelling, Virtualization and Simulation	0.124	0.056	0.155	2.223	0.007
Planning & Estimation	0.280	0.057	0.339	4.923	0.000
Digital Literacy	0.277	0.049	0.330	5.607	0.000

Dependent Variable: Readiness for Industry/Job Market

doi: 10.14710/teknik.v46i3.68645

reported strong foundational competencies, particularly in digital literacy, communication, and planning and estimation, which are crucial for collaboration and project management in the construction industry. These findings are consistent with Casini (2021), who identifies digital literacy and communication as essential for effective teamwork and information sharing in digitally-enabled environments. However, the lower competency levels in advanced areas, such as cloud computing, 3D modelling, and automation, reflect gaps in training that are critical for meeting the demands of Construction 4.0. Similar gaps have been reported in other developing contexts, where inadequate infrastructure and limited access to modern tools hinder students' exposure to cutting-edge technologies (Z.-S. Chen et al., 2024; Sherratt et al., 2020). Addressing these gaps is vital to preparing students for a construction industry increasingly shaped by automation, data-driven decision-making, and virtual simulation.

The correlation and regression analyses further underscore the significance of digital competencies and access to training resources in shaping students' job market readiness. Digital competencies emerged as the strongest predictor, reflecting their central role in equipping students to navigate the technological landscape of modern construction. This aligns with the findings of Mansour et al. (2023), who emphasize the importance of digital skills in enhancing employability and adaptability in a rapidly evolving industry. While foundational competencies like communication, planning, and digital literacy were critical predictors of readiness, advanced coding, cloud computing, and robotics skills were less significant for entry-level roles. This suggests that students' immediate readiness is more closely tied to practical, foundational skills, whereas advanced competencies may become more relevant as they progress in their careers. Such findings echo the work of Buscemi et al. (2022), who argue that the integration of advanced digital skills should be phased to match students' career trajectories. Access to training resources also significantly influences students' perceived readiness, as highlighted by its strong correlation with digital competencies and job market preparedness. Consistent with Martiniuk et al. (2022), this underscores the importance of providing students with adequate access to modern tools, comprehensive training materials, and practical learning opportunities. The variability in students' experiences with training resources, particularly in support services and independent learning tools, reflects broader systemic challenges. Institutions must invest in digital infrastructure, provide consistent access to advanced tools like BIM, and create support systems to effectively address students' challenges in applying these tools.

These findings have practical implications for educational institutions, policymakers, and industry practitioners. The results highlight that educational institutions need to revise curricula to include more hands-on training in advanced digital technologies, ensuring alignment with industry requirements. Training programs should incorporate emerging tools like cloud computing, robotics, and virtual simulation to close the competency gap. Additionally, institutions should strengthen support services and provide resources for independent learning, empowering students to develop their skills beyond structured classes. Policymakers must prioritize funding for digital infrastructure and incentivize collaborations between academia and industry to bridge the gap between theoretical learning and practical application. These partnerships could facilitate internships, industry-driven training, and access to state-of-the-art tools, as Monteiro and Leite (2021) advocated. From an industry perspective, employers should offer structured internships and mentorship programs to expose students to real-world applications of digital tools. Such initiatives would help align students' academic training with the skills required in the field, enhancing their readiness to contribute to Construction 4.0 projects. Additionally, addressing gender disparities in the construction field, as indicated by the predominantly male student population, is essential for creating a more inclusive workforce. Targeted programs and outreach efforts can encourage greater participation of women in construction-related disciplines, tapping into a broader talent pool and fostering diversity in the sector.

In a broader context, the findings have significant implications for Ghana's construction industry and its role in the global digital transformation of construction practices. The sector can achieve greater efficiency, innovation, and competitiveness by equipping students with the necessary digital skills. The proactive attitude demonstrated by students in staying updated with technological advancements is a positive sign of their adaptability, which, if supported by appropriate training and resources, can accelerate the industry's transition to digitalized practices. Furthermore, strengthening foundational and advanced digital competencies in construction education can enhance overall productivity and sustainability, contributing to national economic growth.

6. Conclusion

This study provides a comprehensive evaluation of the digital competencies of construction students at Ghana's technical universities, revealing a moderate level of proficiency with significant gaps in advanced digital skills. While students are confident in their basic digital literacy, their readiness to meet industry demands is compromised by limited access to cutting-edge

doi: 10.14710/teknik.v46i3.68645

technologies and insufficient training. Addressing these challenges will require collaborative efforts between educational institutions, policymakers, and industry stakeholders. By revising curricula to incorporate advanced digital tools such as Automation, 3D Modeling, and Cloud Computing, universities can better equip students for the demands of Construction 4.0. Additionally, enhancing access to these tools and creating stronger ties with the industry through internships and hands-on training will be crucial for bridging the skills gap. This study recommends that educational institutions revise construction curricula to include a broader range of digital competencies, emphasizing automation, robotics, coding, and advanced software relevant to the industry. Additionally, partnerships with industry stakeholders should be established to facilitate practical training and internships. At the same time, access to essential digital tools and resources, such as software licenses and updated hardware, should be improved. Digital competencies should be integrated into assessment criteria to ensure students are evaluated on both theoretical knowledge and practical application, and awareness campaigns should promote the importance of these skills in the construction industry. Future research should focus on assessing the effectiveness of digital competency frameworks and training models in improving job readiness, particularly in developing countries. These findings provide valuable insights for educators and policymakers to align construction education with the digital transformation of the industry. In addition to institutional reforms, it is important to empower students to take proactive steps in developing their own digital competencies. Students are encouraged to pursue self-directed learning through freely accessible online platforms which offer relevant courses in Construction 4.0 technologies. Participation in digital innovation clubs, tech-focused student associations, and extracurricular workshops can also provide valuable exposure to practical applications. Moreover, students should seek internships, volunteer opportunities, or industry-led competitions that allow them to apply digital skills in real-world contexts. These self-initiated efforts complement formal education and foster a mindset of continuous learning.

7. Limitations

This study provides valuable insights into the digital competencies of construction students in Ghana's technical universities, however a number of limitations are acknowledged. First, the study relied on self-reported data, which may be subject to response bias or overestimation of actual competencies. Students may have rated themselves more favourably due to social desirability or limited awareness of their own skill gaps. Secondly, although a stratified sampling technique was used to ensure representation across academic levels and departments, the sample was limited to final-year students from six technical universities. As such, the findings may not be generalizable to all construction students across Ghana or to professionals already in the workforce. Third, while the study employed robust quantitative techniques, including correlation and regression analysis, unmeasured variables such as prior digital exposure, institutional digital infrastructure, and individual motivation were not accounted for and could influence digital competency and job readiness. Furthermore, although statistical relationships were reported, including correlation coefficients and p-values, it is important to note that these do not imply causation. The interpretations were therefore framed cautiously to avoid overgeneralization, especially regarding national-level implications drawn from student-level data.

8. Reference

Balogun, T. B., Awonuga, O. O., & Abowen-Dake, R. (2023). Investigating digital technological competencies amongst black Asian minority ethnic construction students in the UK. *Journal of Engineering, Design and Technology*, *21*(6), 1857-1882.

Bitegeko, R. M., Lawrent, G., & Cosmas, J. (2024). Applying the UNESCO ICT competency framework to evaluate digital competencies among undergraduate students in teacher education in Tanzania. *Educational Technology Quarterly*, *2024*(3), 298-318.

Bolpagni, M., Gavina, R., Ribeiro, D., & Arnal, I. P. (2022). Shaping the future of construction professionals. *Industry 4.0 for the Built Environment: Methodologies, Technologies and Skills*, 1-26.

Buscemi, L., Debs, L., & Zimpfer, M. (2022). WIP: Teaching of emerging technology in construction workforce development programs. 2022 IEEE Frontiers in Education Conference (FIE),

Casini, M. (2021). *Construction 4.0: Advanced Technology, Tools and Materials for the Digital Transformation of the Construction Industry*. Woodhead Publishing.

Chandramohan, A., Perera, B., & Dewagoda, K. (2022). Diversification of professional quantity surveyors' roles in the construction industry: the skills and competencies required. *International Journal of Construction Management*, *22*(7), 1374-1381.

Chen, X., Chang-Richards, A., Ling, F. Y. Y., Yiu, T. W., Pelosi, A., & Yang, N. (2024). Digital technologies in the AEC sector: a comparative study of digital competence among industry

practitioners. *International Journal of Construction Management*, 1-14.

Chen, Z.-S., Lu, J.-Y., Wang, X.-J., & Pedrycz, W. (2024). Identifying digital transformation barriers in small and medium-sized construction enterprises: A multi-criteria perspective. *Journal of the Knowledge Economy*, 1-37.

Djumalieva, J., & Sleeman, C. (2018). Which digital skills do you really need. *London. Recuperado de https://www. nesta. org. uk/report/which-digital-skills-do-you-really-need*.

Ebekozien, A., Aigbavboa, C., & Aliu, J. (2023). Built environment academics for 21st-century world of teaching: stakeholders' perspective. *International Journal of Building Pathology and Adaptation*, *41*(6), 119-138.

Ebekozien, A., & Aigbavboa, C. O. (2024). Improving quantity surveying education through continually updating curriculum digitalization to meet industry requirements. *Journal of Engineering, Design and Technology*, *22*(5), 1523-1543.

García-Pérez, L., García-Garnica, M., & Olmedo-Moreno, E. M. (2021). Skills for a working future: How to bring about professional success from the educational setting. *Education sciences*, *11*(1), 27.

Gbadebo, A. D. (2024). Digital Transformation for Educational Development in Sub-Saharan Africa. *International Journal of Social Science and Religion (IJSSR)*, 397-418.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. *Sustainability*, *14*(3), 1493.

Goulart, V. G., Liboni, L. B., & Cezarino, L. O. (2022). Balancing skills in the digital transformation era: The future of jobs and the role of higher education. *Industry and Higher Education*, *36*(2), 118-127.

Gupta, A. K., Aggarwal, V., Sharma, V., & Naved, M. (2024). Framework to Integrate Education 4.0 to Enhance the E-Learning Model for Industry 4.0 and Society 5.0. In *The Role of Sustainability and Artificial Intelligence in Education Improvement* (pp. 151-167). Chapman and Hall/CRC.

Hwang, B.-G., Ngo, J., & Teo, J. Z. K. (2022). Challenges and strategies for the adoption of smart technologies in the construction industry: The case of Singapore. *Journal of Management in Engineering*, *38*(1), 05021014.

Karmakar, A., & Delhi, V. S. K. (2021). Construction 4.0: what we know and where we are headed? *Journal of Information Technology in Construction*, *26*.

Li, L. (2022). Reskilling and upskilling the future-ready workforce for industry 4.0 and beyond. *Information Systems Frontiers*, 1-16.

Mansour, H., Aminudin, E., & Mansour, T. (2023). Implementing industry 4.0 in the construction industry-strategic readiness perspective. *International Journal of Construction Management*, *23*(9), 1457-1470.

Martiniuk, A., Challinor, J., Arora, R. S., Handayani, S. A., & Lam, C. (2022). Digital solutions to facilitate education, training and professional support for paediatric oncology and other health professionals in rural and other low-resource settings. *Health Education*, *122*(2), 232-259.

Mhlongo, S., Mbatha, K., Ramatsetse, B., & Dlamini, R. (2023). Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative review. *Heliyon*, *9*(6).

Monteiro, A., & Leite, C. (2021). Digital literacies in higher education: Skills, uses, opportunities and obstacles to digital transformation. *Revista de Educación a Distancia (RED)*, *21*(65).

Sam-Amoah, L., & Frimpong, K. A. (2020). Role of higher education and science, technology and innovation in capacity development in Ghana.

Samuelson, O., & Stehn, L. (2023). Digital transformation in construction–a review. *Journal of Information Technology in Construction (ITcon)*, *28*, 385-404.

Sawhney, A., Riley, M., Irizarry, J., & Riley, M. (2020). Construction 4.0. *Sawhney, A., Riley, M., Irizarry, J., Eds*.

Sherratt, F., Dowsett, R., & Sherratt, S. (2020). Construction 4.0 and its potential impact on people working in the construction industry. *Proceedings of the Institution of Civil Engineers-Management, Procurement and Law*, *173*(4), 145-152.

Siddiqui, F. H., Abdekhodaee, A., & Thaheem, M. J. (2022). Taxonomy of Digital Skills Needed in the Construction Industry: A Literature Review. Proceedings of the 45th AUBEA Conference, Sydney, Australia,

Siddiqui, F. H., Thaheem, M. J., & Abdekhodaee, A. (2023). A Review of the Digital Skills Needed in the Construction Industry: Towards a Taxonomy of Skills. *Buildings*, *13*(11), 2711.

Soltani, S., Maxwell, D., & Rashidi, A. (2023). The State of Industry 4.0 in the Australian Construction Industry: An Examination of Industry and Academic Point of View. *Buildings*, *13*(9), 2324.

Souza, A. S. C. d., & Debs, L. (2023). Identifying Emerging Technologies and Skills Required for Construction 4.0. *Buildings*, *13*(10), 2535.

Wang, K., Guo, F., Zhang, C., Hao, J., & Schaefer, D. (2022). Digital Technology in Architecture, Engineering, and Construction (AEC) Industry: Research Trends and Practical Status toward Construction 4.0. Construction Research Congress 2022,

Wang, K., Guo, F., Zhang, C., & Schaefer, D. (2022). From Industry 4.0 to Construction 4.0: Barriers to the digital transformation of engineering and construction sectors. *Engineering, construction and architectural management*(ahead-of-print).

Weber-Lewerenz, B., & Traverso, M. (2023). Best Practices in Construction 4.0–Catalysts of digital innovations (Part I). *Journal of Architectural Environment & Structural Engineering Research*, *6*(1).

Zheng, Z., Wang, F., Gong, G., Yang, H., & Han, D. (2023). Intelligent technologies for construction machinery using data-driven methods. *Automation in Construction*, *147*, 104711.

Zizic, M. C., Mladineo, M., Gjeldum, N., & Celent, L. (2022). From industry 4.0 towards industry 5.0: A review and analysis of paradigm shift for the people, organization and technology. *Energies*, *15*(14), 5221.

doi: 10.14710/teknik.v46i3.68645