Journal of Technical and Vocational Education and Training (JTVET) Vol 1. Issue 1, 2025
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INTEGRATING DIGITAL SKILLS AND ARTIFICIAL INTELLIGENCE IN METALWORK EDUCATION

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Abstract

The demand for industry-relevant skills in the 21st century has highlighted the urgency of integrating digital competencies and artificial intelligence (AI) into technical education. However, in many Nigerian technical colleges, including those in Kwara State, the curriculum remains largely outdated, lacking alignment with technological advancements such as CNC (Computer Numerical Control) machines and digital fabrication tools. This study investigated the integration of digital skills and AI in metalwork education, focusing on its impact on students' competency and instructional delivery in public technical colleges. The study adopted a descriptive survey design, guided by three research hypotheses. The population of the study comprises 15 instructors and 519 students making a total of 534 from which a sample of 236 respondents comprising instructors and final-year metalwork students across five public technical colleges in Kwara State. Purposive sampling technique was used to select 10 instructors and 226 students. Data were collected using structured questionnaires and analyzed using linear regression. Findings revealed a significant relationship between digital skills integration and students' competency in metalwork ($B = 0.563$, $p < .05$, $R^2 = 0.375$). Similarly, the availability and use of AI tools significantly influenced instructional quality ($B = 0.485$, $p < .05$, $R^2 = 0.353$). Instructors' competence in digital and AI tools also had a strong effect on instructional effectiveness ($B = 0.531$, $p < .05$, $R^2 = 0.387$). The study concluded that digital and AI integration is critical to improving the relevance and effectiveness of metalwork education. It recommended curriculum reform, investment in AI-enabled equipment, and capacity building for instructors to bridge the technological gap and enhance students' readiness for modern industry.

Keywords: Artificial Intelligence, Digital skills, Educational technology, Instructional effectiveness, Metalwork education

Introduction

In the context of the Fourth Industrial Revolution (4IR), digital skills and artificial intelligence (AI) have become critical drivers of educational transformation, particularly within technical and vocational education and training (TVET). Globally, AI-powered technologies are reshaping the teaching and learning of practical subjects like metalwork. Tools such as Computer Numerical Control (CNC) machines now play a central role in training students on precision manufacturing, digital design interpretation, and automated control systems (UNESCO, 2021). Countries at the forefront of technological advancement, including Germany, South Korea, and China, have embedded AI tools, simulation software, and digital fabrication technologies into their vocational education curricula to prepare learners for intelligent manufacturing environments (OECD, 2022).

In Nigeria, the Federal Government recognises the importance of developing digital and AI competencies as outlined in the National Digital Economy Policy and Strategy (2020–2030), which identifies automation, robotics, and machine learning as critical to national development (Federal Ministry of Communications and Digital Economy, 2020). Despite these policy frameworks, the integration of such competencies into TVET, especially in metalwork, remains limited. Research indicates that many technical institutions still rely on outdated curricula and lack sufficient exposure to advanced digital tools like CNC machines (Adedeji & Salami, 2022; Udo & Adebayo, 2021), making it difficult to equip students with the skills needed for modern manufacturing systems.

At the local level in Kwara State, efforts have been made to improve technical education through equipment upgrades and public-private partnerships. However, the incorporation of AI and digital training into metalwork education is still in its early stages. Some schools have received modern equipment, a 2023 report from the Kwara State Ministry of Education and Human Capital Development shows that AI tools like CNC machines are not yet widely used in classroom instruction, and most instructors lack formal training in digital machining and AI applications. This skills gap threatens the ability of students to compete effectively in a digitally driven global economy.

Given this context, the present study investigated the integration of digital skills and AI in metalwork education in Kwara State. Specifically, it assessed the extent of digital skill inclusion in the metalwork curriculum, examine the availability and use of AI-enabled

technologies like CNC machines in teaching, and evaluate the digital and AI competence of metalwork instructors in public technical colleges across the state.

Statement of the Problem

The rapid advancement of digital technologies and artificial intelligence (AI) has transformed global industrial practices and reshaped the nature of technical education. The metalwork industry, in particular, has experienced a significant shift with the adoption of AI-powered tools such as Computer Numerical Control (CNC) machines, which require advanced digital proficiency for effective use.

Despite the formulation of national policies aimed at aligning Technical and Vocational Education and Training (TVET) with global technological trends, there seems to be a noticeable gap between policy intentions and classroom implementation, particularly within the metalwork subsector. Many technical colleges still depend on outdated teaching methods and manual tools, with limited use of AI technologies such as CNC machines. Even where these tools exist, they appear to be underutilized due to infrastructural limitations or a lack of instructor competence. In Kwara State, some reforms have been initiated, including equipment upgrades and the recruitment of technical teachers. Nonetheless, the integration of digital skills and AI in metalwork education remains inadequate. Many instructors lack proper training, and students frequently graduate without practical experience using intelligent machines. This situation raises critical concerns about the industry readiness of graduates in a digital economy. Therefore, it is essential to investigate the extent to which digital skills and AI technologies are integrated into metalwork education in Kwara State.

Research Hypotheses

H01: There is no significant relationship between the integration of digital skills in the curriculum and students' competency in metalwork in technical colleges in Kwara State.

H02: The availability and utilisation of AI-enabled technologies such as CNC machines do not significantly influence the quality of metalwork instruction in technical colleges in Kwara State.

H03: Metalwork instructors' competence in digital tools and AI-based systems has no significant effect on the effectiveness of instructional delivery in technical colleges in Kwara State.

Research Method

This study adopted a descriptive survey research design to investigate the integration of digital skills and artificial intelligence in metalwork education in technical colleges across Kwara State, Nigeria. The descriptive survey design is suitable for this research because it enabled the collection of factual data from a specific population to describe the current state of instructional practices, availability of technological resources, and instructors' competencies in the use of AI-enabled tools such as CNC machines. The design also allowed for the identification of existing gaps and patterns related to the study variables without manipulating the environment.

The population of the study comprised 15 metalwork instructors and 519 final year students in the five public technical colleges offering metalwork in Kwara State. These respondents are considered relevant because they are directly involved in the teaching and learning processes and are most likely to provide accurate information on curriculum content, equipment utilisation, and skill application.

A multistage sampling technique was employed. First, purposive sampling was used to select two technical colleges that offer metalwork as a course of study. A sample size of 236 respondents (comprising 10 instructors and 226 students) were drawn to ensure statistical validity and generalisability of findings using Taro Yamane formula for sample size. Structured questionnaire was the primary instrument used for data collection. The questionnaire consisted of closed-ended items measured using a 4-point modified Likert scale and was divided into sections addressing each of the research objectives: curriculum integration of digital skills, availability and usage of AI tools such as CNC machines, and instructor competencies in digital and AI applications. The instrument was validated by experts in educational technology and technical education, and a pilot study was conducted. A coefficient of 0.69 was obtained for the instrument reliability using Cronbach's alpha. Data collected were analysed using Pearson Product-Moment Correlation and linear regression analysis, to test the formulated hypotheses and determine the strength and nature of the relationships among the variables. The ethical standards of research were upheld. Participation was made voluntary, and respondents were assured of the confidentiality and anonymity of their responses. Consent was obtained from school authorities before administering the instrument.

Concept of Digital Skills

Digital skills encompass the range of abilities required to effectively operate digital devices, utilize communication applications, and navigate networks for accessing, managing, and creating information. These skills extend from basic tasks such as operating a computer and using productivity software, to more advanced competencies like data analysis, coding, cybersecurity, and proficiency in emerging technologies such as artificial intelligence (AI) and machine learning. As digital transformation accelerates across all sectors, these skills have become indispensable for personal development, employability, innovation, and full economic participation (UNESCO, 2021).

In technical and vocational education, digital skills are particularly vital, including the ability to operate Computer Numerical Control (CNC) machines, work with Computer-Aided Design (CAD) software, and analyze production data using digital tools (OECD, 2021). The European Commission (2020) classifies digital competencies into five core areas: information and data literacy, communication and collaboration, digital content creation, safety, and problem-solving, emphasising that digital literacy requires both technical expertise and critical thinking.

Globally, digital skills are recognised as essential for preparing youth for the Fourth Industrial Revolution, where automation and AI are reshaping work and learning (World Economic Forum, 2020). In Nigeria, the National Digital Economy Policy and Strategy (2020–2030) positions digital literacy as foundational for national growth and competitiveness (Federal Ministry of Communications and Digital Economy, 2020). However, a persistent skills gap exists, especially among students and instructors in technical education, undermining efforts to modernize education and workforce readiness.

In metalwork education, digital skills are crucial for operating AI-enabled tools like CNC machines. The absence of such competencies hampers instructional delivery and limits both student adaptability and employability. Therefore, integrating digital skills into educational curricula is not only essential but urgent for sustainable national development and global relevance.

Integration of Artificial Intelligence in Metalwork Education

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are programmed to think, learn, and act autonomously or semi-autonomously. In the context of education, AI encompasses systems and technologies that support teaching and learning processes through intelligent automation, data-driven personalisation, and smart content delivery (UNESCO, 2021). As AI continues to transform various sectors, its

application in technical and vocational education, especially in metalwork, has become increasingly vital for aligning educational outcomes with the demands of Industry 4.0. In metalwork education, AI plays a transformative role in modernising instructional methods, automating practical tasks, and enhancing the precision of training tools. A key example is the use of Computer Numerical Control (CNC) machines, which operate based on programmed instructions and intelligent feedback systems. These machines rely on AI algorithms to interpret complex designs, optimize cutting paths, and minimise human error (Choi et al., 2020). By integrating AI-enabled CNC machines into metalwork classrooms, students acquire hands-on experience with industry-standard equipment, thus improving their employability and technological competence.

Moreover, AI facilitates adaptive learning environments in metalwork training. Through intelligent tutoring systems, learners can receive personalised instruction based on their skill levels, learning speed, and performance data. This reduces the inefficiency of one-size-fits-all approaches in technical education and ensures that each student attains mastery at their own pace. AI also supports the use of virtual simulations and digital twins, technologies that replicate physical environments digitally, allowing students to practice metalwork operations safely and repeatedly before working on real materials (Ali et al., 2021). Instructors also benefit from AI by gaining access to automated assessment tools and real-time analytics that track student performance and suggest instructional adjustments. AI-driven platforms can provide immediate feedback on students' machine handling, safety compliance, and design interpretation, thereby enhancing the overall teaching process and reducing the cognitive load on educators (Alkhatlan & Kalita, 2021).

However, despite the immense potential, the integration of AI in metalwork education, particularly in developing countries such as Nigeria, faces challenges. These include limited access to modern AI-driven equipment, inadequate infrastructure, and a shortage of instructors trained in AI technologies (Okonkwo & Adepoju, 2022). In many public technical colleges, the curriculum still emphasizes manual metalworking techniques, with little or no exposure to CNC programming, AI-based diagnostics, or predictive maintenance tools. This gap highlights a critical need for educational reform, targeted training for teachers, and increased investment in AI-enabled learning environments. Recognising these needs, global and national policy frameworks have started to emphasize AI's role in transforming vocational education. For instance, the Federal Government of Nigeria’s National Digital Economy Policy and Strategy (2020–2030) advocates for the integration of AI and emerging technologies in education to

prepare the workforce for the digital economy (Federal Ministry of Communications and Digital Economy, 2020). Similarly, UNESCO (2021) recommends the incorporation of AI in technical education as a key strategy for building resilience, innovation, and competitiveness in low- and middle-income countries.

Data Analysis

H01: There is no significant relationship between the integration of digital skills in the curriculum and students' competency in metalwork in technical colleges in Kwara State.

Table 1: Linear Regression Analysis on Digital Skills Integration and Students' Competency in Metalwork (N = 236)

Model	Unstandardized Coefficients (B)	Std. Error	Standardised Coefficients (Beta)	t	Sig. (p-value)
(Constant)	1.742	0.213	–	8.180	.000
Digital Skills Integration	0.563	0.067	0.612	8.403	.000

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.612	0.375	0.372	0.561

Table 1 shows the result of the linear regression analysis. The table reveals a statistically significant relationship between the integration of digital skills in the curriculum and students' competency in metalwork in technical colleges in Kwara State. The regression coefficient (B = 0.563) indicates that for every one-unit increase in the level of digital skills integration within the curriculum, there is a corresponding increase of 0.563 unit in students' competency in metalwork. This positive relationship suggests that greater emphasis on digital skill inclusion contributes meaningfully to students' practical abilities and performance in the field. Furthermore, the R-value of 0.612 implies a moderately strong positive correlation between the two variables. The R-squared value of 0.375 indicates that approximately 37.5% of the variation in students' metalwork competency can be explained by the integration of digital skills in the curriculum. This means that digital skills are a notable predictor of student performance and competence in metalwork education. The significance level (p = .000) is less than the standard threshold of 0.05, confirming that the relationship is statistically significant.

Therefore, the null hypothesis (H01), which stated that there is no significant relationship between digital skills integration and students' competency, is rejected.

Therefore, the findings affirm that embedding digital skills into the curriculum plays a critical role in enhancing students' competence in metalwork. This supports the need for policy makers and educational stakeholders to prioritize digital literacy and technological tools in technical education as a means of producing industry-ready graduates in Kwara State and beyond.

H02: The availability and utilisation of AI-enabled technologies such as CNC machines do not significantly influence the quality of metalwork instruction in technical colleges in Kwara State.

Table 2: Linear Regression Analysis on Availability and Utilisation of AI-Enabled Technologies and Quality of Metalwork Instruction (N = 236)

Model	Unstandardised Coefficients (B)	Std. Error	Standardised Coefficients (Beta)	t	Sig. (p-value)
(Constant)	2.014	0.198	–	10.172	.000
Availability and Utilisation of AI Tools	0.485	0.063	0.594	7.698	.000

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.594	0.353	0.350	0.579

Table 2 indicates a statistically significant relationship between the availability and utilisation of AI-enabled technologies, such as CNC machines, and the quality of metalwork instruction in technical colleges in Kwara State. The regression coefficient (B = 0.485) implies that a one-unit increase in the availability and use of AI tools results in a 0.485-unit improvement in the quality of metalwork instruction. This demonstrates a positive influence of AI technologies on teaching effectiveness, instructional delivery, and student engagement in metalwork education. The R value (0.594) shows a moderately strong positive correlation between the variables, while the R-squared value (0.353) reveals that approximately 35.3% of the variance in instructional quality can be explained by the extent to which AI technologies are available and utilized. This highlights the importance of technological integration in enhancing the relevance and standard of metalwork education. Moreover, the p-value (.000) is below the significance threshold of 0.05, indicating that the observed relationship is statistically

significant. Consequently, the null hypothesis (H02), which posited that AI-enabled technologies do not significantly influence metalwork instruction, is rejected.

In essence, the findings validate that increasing the availability and use of AI tools such as CNC machines directly contributes to the quality modernity of metalwork instruction. This underscores the need for sustained investment in digital infrastructure and training within technical colleges to ensure that graduates are equipped with cutting-edge skills demanded by today's industries.

H03: Metalwork instructors' competence in digital tools and AI-based systems has no significant effect on the effectiveness of instructional delivery in technical colleges in Kwara State.

Table 3: Linear Regression Analysis on Instructors' Digital/AI Competence and Effectiveness of Instructional Delivery (N = 236)

Model	Unstandardised Coefficients (B)	Std. Error	Standardised Coefficients (Beta)	t	Sig. (p-value)
(Constant)	1.968	0.209	–	9.415	.000
Instructors' Digital/AI Competence	0.531	0.061	0.622	8.705	.000

Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.622	0.387	0.384	0.553

The results of the regression analysis in Table 3 reveal a statistically significant and positive relationship between metalwork instructors' competence in digital tools and AI-based systems and the effectiveness of instructional delivery in technical colleges across Kwara State. The unstandardized regression coefficient (B = 0.531) suggests that a one-unit increase in instructors' digital/AI competence leads to an approximate 0.531-unit improvement in instructional effectiveness. This means that more technologically competent instructors are likely to deliver metalwork lessons more effectively, likely due to better engagement, demonstration accuracy, and integration of advanced tools. The R-value of 0.622 indicates a moderately strong correlation between the two variables. Additionally, the R-squared value of 0.387 implies that 38.7% of the variation in instructional delivery effectiveness can be explained by instructors' competence in digital and AI systems. This proportion reflects a meaningful influence, particularly in the context of technical and vocational education where practical skills and equipment handling are central. Importantly, the p-value (.000) is less than the standard threshold of 0.05, which confirms that the relationship is statistically significant.

Therefore, the null hypothesis (H03), which states that instructors' competence has no significant effect on instructional delivery, is rejected.

Therefore, the analysis affirms that enhancing instructors' digital literacy and AI-related competencies is crucial for improving the effectiveness of metalwork education. These findings call for continuous professional development programs, policy support, and institutional investments to upgrade teachers' capacity for 21st-century technical instruction.

Conclusion

The findings of this study affirmed that the integration of digital skills into the metalwork curriculum, the availability and utilisation of AI-enabled technologies like CNC machines, and instructors' competence in digital tools all significantly influence the quality and effectiveness of instructional delivery. Students exposed to digitally enriched learning environments demonstrated greater competency in practical metalwork, while AI-equipped workshops enhance teaching relevance and modernity. Moreover, instructors' digital proficiency strongly predicts instructional success, highlighting the critical role of teacher preparedness in achieving desired learning outcomes. These results emphasised the need for deliberate policy interventions to modernize technical education through infrastructure upgrades, curriculum reforms, and continuous professional development for instructors. Without these efforts, technical education risks becoming obsolete, leaving graduates unfit for the demands of the digital economy. Therefore, integrating digital competencies and AI in metalwork education is a strategic necessity for building a skilled, future-ready workforce and positioning Nigeria's technical colleges for industrial innovation and competitiveness.

Recommendations

In light of the findings, several strategic recommendations are proposed to strengthen metalwork education in technical colleges across Kwara State.

i. The Kwara State Ministry of Education and curriculum development agencies should urgently revise the metalwork curriculum to incorporate essential digital competencies such as Computer-Aided Design (CAD), basic programming, and digital simulation tools to ensure students are equipped with both traditional and modern manufacturing skills.

ii. Kwara State government should prioritise the acquisition and deployment of smart, AI-compatible tools in public technical colleges and upgrade existing workshops or establish new one to facilitate hands-on training.

iii. Targeted professional development programmes should be introduced for metalwork to encourage practical training in AI applications, digital teaching methods, and equipment handling

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