Fostering Woodwork Technology in Tertiary Education: The Role of Computer Numerical Control (CNC)

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Abstract

In the context of modern education, the integration of technology plays a pivotal role in enhancing practical skills and knowledge acquisition. This paper delves into the significance of Computer Numerical Control (CNC) technology within the domain of woodwork technology at tertiary institutions using a quasi-experimental design involving 47 participants drawn from the National Institute of Construction Technology and Management, Uromi, Edo State, Nigeria. The study was structured as an educational design experiment using simulation modeling to teach woodwork concepts. An experiment of two equivalent groups was designed; one was the experimental group, and the other was the control group. The same project was given to the first (the experimental group) and second (the control group) groups using a simulation program and the traditional method. Simulation modeling proved to be an efficient method for enhancing woodwork skills. The results show that students used simulation programs to demonstrate more profound learning and understanding of the design concepts than the traditional method.

Keywords: simulation model, woodwork, CNC, students

Introduction

Within the context of higher education, the woodwork technology discipline, which is founded on craftsmanship and practical expertise, has undergone significant transformations. Woodworking technology comprises woodworking as both an art and a science. In the past, manual labor was necessary for tasks such as joinery, carving, and furniture construction. In the current educational setting, woodworking technology has progressed beyond the limitations imposed by traditional hand instruments. It integrates modern methodologies, apparatus, and digital technologies that enhance precision, efficiency, and innovation. Woodworking technology establishes a connection between innovation and tradition in higher education. It provides students with practical skills, critical reasoning, and adaptation. Even as digital tools and CNC technology continue to revolutionize the industry, woodworking education remains an enduring art form that adapts to the changing requirements of society. This study investigated the effects of CNC on the advancement of woodworking in tertiary education in Nigeria.

Woodwork Technology is integral to Nigeria's Technical and Vocational Education and Training (TVET) system (Ajie et al., 2022). It aims to help students become productive members who can boost the country's economy by teaching them the fundamentals of Woodworking. Research supports the idea that Woodworking is a course that helps students get ready for the workforce. Additionally, students must be prepared to handle the modern workforce by acquiring the abilities necessary to keep up with the fast-paced technological advancements. Therefore, to create a work-based economy and culture, colleges and universities that offer Woodworking as a major must rethink their course offerings to reflect modern workplace demands.

Woodwork technology, or Wood Technology, is a hands-on subject where you work with tools, machinery, and wood or plastic materials. It encompasses various aspects related to working with wood, including crafting wooden structures, furniture, and fixtures, creating strong joints and connections between wooden pieces, shaping wood into intricate designs and sculptures, and using a lathe to create cylindrical wooden objects like bowls and spindles. Indeed, constructing cabinets, cupboards, and storage units and enhancing the appearance and durability of wood through techniques like staining, varnishing, and painting and exploring methods to alter wood properties, such as thermal modification and pressure treatments.
In the ever-evolving world of woodworking, the seamless blend of tradition and technology is becoming more apparent and essential. Gone are the days when woodworking was solely about manual craftsmanship; today, it is also about harnessing the power of technology to create precise, efficient, and innovative woodwork projects. The contemporary woodworking field integrates timeless techniques and modern advancements.

Simulation plays a crucial role in Woodwork Technology, enhancing both efficiency and precision. Simulation modeling allows woodworkers to analyze and optimize various processes within woodworking production. They can experiment with different parameters, layouts, and workflows by creating digital representations of these processes. For example, simulating the assembly line in a furniture manufacturing plant helps identify bottlenecks, minimize waste, and improve overall productivity. The concept of a digital twin involves creating a virtual replica of a physical system (such as a woodworking enterprise). This twin mirrors the real-world processes, allowing experimentation and analysis without disrupting actual operations. Woodworking enterprises can use digital twins to simulate technological, auxiliary, and administrative processes. This aids in decision-making, resource allocation, and performance evaluation.

Computer-aided design (CAD) software integrates with simulation tools to assess woodwork quality. Dimension tools ensure precise measurements, while simulations predict how different design choices impact the final product. Additionally, simulation helps evaluate the efficiency of administrative processes, contributing to better management and resource utilization. Computer vision technology, a subset of artificial intelligence (AI), enables real-time quality control in the wood industry. These systems detect even subtle defects in wood that may go unnoticed by the human eye. By integrating AI-driven simulations, woodworkers can identify potential flaws early in production, leading to higher-quality finished products. Indeed, simulation modeling in education is well emphasized in the literature (Abdullah & Alnasheri, 2023; Bodine et al., 2020; Cudney et al., 2014; Hulme et al., 2021; Kezunovic et al., 2004; Litwin & Stadnicka, 2019; Magana & de Jong, 2018; Ogrizović et al., 2021; Omar et al., 2020; Psotka, 2013; Skafa et al., 2022).

The rise in simulation modeling for woodwork technology is attributed to the need to foster woodwork technology, which describes a paradigm shift in education (Mohd Adnan et al., 2019). Upskilling performance in digital competencies is essential and seems particularly important (Webb & Layton, 2023). Computer numerical control (CNC) is automation for operating, moving, and controlling machine tools using software embedded in microcomputer chips. It is used for many tools, such as CNC lathes, drills, CNC milling tools and milling machines, grinders, cutting tools, and other CNC machine tools, particularly high-speed ones. A CNC machine has automated controls that work through the software. It is used to machine materials into custom parts and designs. The CNC machines are utilized in the classroom to enhance the practical learning experience. The CNC simulation allows woodworkers to visualize and virtually understand the entire CNC process and provide a safe environment for learners to practice without risking damage to real materials or machinery.

The introduction of CNC systems has significantly affected the design of machine tools. The increased cost of machine tools requires higher utilization; for example, a CNC machine may be required to run continually for an extended period instead of a manual machine running for a single shift. The penalty for this is that the machine must be designed to withstand the extra wear and tear. CNC machines can reduce the non-productive time in the operating cycle through the application of automation, such as the loading and unloading parts and tool changes. In the context of modern education, the integration of technology plays a pivotal role in enhancing practical skills and knowledge acquisition. CNC technology empowers woodworkers to create remarkable designs, enhance productivity, and unlock the full potential of wood as an architectural resource. This paper delves into the significance of Computer Numerical Control (CNC) technology within the domain of woodwork technology.

Objective of the study

Simulation models represent real-world systems that enable explicit experimentation with system features such as process flows, inputs and outputs, and decision rules. A conceptual model (which can be an educational tool) is formed by representing a system as a set of interconnected variables and equations. It helps create models, drawings, and simulations quickly and easily. CNC simulation modeling fosters woodwork skills by providing a risk-free learning environment, optimizing processes, and enhancing overall craftsmanship. The study aims to evaluate the use of simulation modeling to foster woodwork technology in tertiary education.

Method

A quasi-experimental design was adopted. The participants comprised students attending Woodwork courses at the National Institute of Construction Technology and Management, Uromi, Edo State. The samples ($n = 47$) were randomly drawn from the Technical Department. The experimental processes were conducted in the laboratory, and skills in Woodwork technology were determined with a structured questionnaire. The students were assigned to groups (A and B). while the A group was labeled the experimental group, the B group was considered the control group. The students participated in a pre-experiment survey by completing a questionnaire. Students' Woodwork technology skills were evaluated in a preliminary test.

In the experiment, the experimental group was guided to use simulation modeling to create virtual components and assemblies in digital forms. Students grouped into small design teams could design and visualize their design options for evaluation. While creating virtual components, students could use the feature creation sequence to simulate the design process to visualize how to assemble the designed components. Students could assemble virtual components by the mating relations among components and understand how the components would be constructed for proper operation. On the other hand, group B represents the control condition, and mechanical design was taught using the traditional method. The post-test study was conducted similarly to the pre-test, except the questions were reshuffled. The data from the pre-test and post-test were subjected to data analysis.

Result

Table 1 shows the mean and standard deviation scores for the group.

Condition	Pre-Test Mean	Post-Test Mean	Mean Difference|
Experimental	43.17	50.19	7.02
Control	42.29	44.39	2.01

The pre-test mean difference between experimental and control conditions was 0.88, indicating no significant difference initially in participants' woodwork experience. However, after exposure to the CNC software, the experimental conditions showed a substantial improvement in mechanical design knowledge, as evidenced by the post-test mean difference of 5.08.

Table 2 shows a t-test comparison.

Condition	N	Mean	SD	df	*t*	Sig
Experimental	24	50.19	13.68			
Control	23	44.39	13.38	185	7.328	000

A t-test analysis was performed on the data to determine whether the simulation modeling would upskill students' woodwork experience. The study established a significant difference between the experimental and control conditions on woodwork skills (MD = 5.08, t (45) = 3.328, p = .000). Thus, the result suggests that the simulation software might be used to upskill students' woodwork experience.

Discussion

This study examined the impact of Computer Numerical Control (CNC) simulation modeling in fostering woodwork technology in tertiary education. The result showed a significant difference between the students taught Woodwork technology processes using simulation software and those prepared with conventional methods. For the pre-test and the post-test study conducted, the mean and standard deviation scores showed that exposing the students to simulation modeling significantly influenced their skills in the post-test study (M = 50.19, SD = 13.68) compared to the control group (M = 44.39, SD = 13.38). This result is likely attributable to the fact that simulation modeling facilitates the creation of a three-dimensional visual representation of the concept. The model is presented in a specific orientation and dimension. The drawing view may be annotated with notes, dimensions, geometric tolerances, and additional information to represent the model. Users are therefore able to generate assemblies and parts with precise component relationships, analyze the static, kinematic, and dynamic behavior of designs, and assess fatigue, thereby delivering responses that are among the best in their field.

Early integration of simulation exercises can greatly enhance skill and knowledge development. Simulation exercises can be a highly effective way to enhance student engagement and motivation. An issue frequently observed among woodwork instructors was the dearth of enthusiastic students in technology classes and decreased enrollment in subsequent courses. Students who engaged in the simulation exercises demonstrated a greater grasp of the subject matter and could achieve higher success in real-world scenarios. The rewards from gaining a deeper understanding and achieving success can greatly enhance a student's satisfaction, ultimately fostering greater interest and motivation in the subject matter.

Simulation exercises proved to be a highly effective approach for students to grasp the intricate relationship between cause and effect in the behavior of manufacturing processes. Online learning offers valuable advantages, such as enhancing students' technical abilities and providing opportunities for higher education advancement (Ibrahim et al., 2022). This knowledge is typically acquired during an apprenticeship phase and is crucial for problem-solving and decision-making. In general, it was observed that incorporating simulation exercises into pre-employment woodwork education proved to be successful in enhancing the depth and breadth of student knowledge and skills related to the trade.

Conclusion

Simulation modeling potentially facilitates 3D modeling, dynamically displaying the cutting process and generating virtual assembly and assembly exploded views. In Woodwork technology, some instances demonstrate how simulation models can dynamically present complex issues encountered in Woodworking design and drafting while establishing a fundamental volume model. These issues include an exploded view, plane intersections with the basic volume model, and assembly. The finding supports the significance of simulation modeling on the curriculum, students' aptitude for design and spatial imagination, their motivation to learn, and their capacity to recognize drawings. Simulation modeling in the classroom has been demonstrated to substantially reduce the challenge of teaching and learning, boost student motivation, and contribute to successful teaching outcomes. The finding suggests regularly educating Woodwork instructors in this area and integrating simulation modeling resources into the classroom.

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