Programming Command in Computer Numerical Control (CNC) Machining Task Instructions for Woodwork Technology Training

Dr. Maurice Joseph Effieyen, Prof. Aniedi Daniel Usoro, & Dr. Batchman Ekure Isaac
Department of Industrial Technology
University of Uyo
Email: joeeffieyen123@gmail.com
Email: usorofortechnical@gmail.com

Abstract

The main purpose of the study was to developed programming command in Computer Numerical Control(CNC) machining task instructions for woodwork technology training in South-South, Nigeria. To guide the study three objectives, three research questions were formulated to guide the study. The study adopted Research and Development Design (RandD). The population was 66 respondents, comprising of 27 woodwork technology/wood product Engineering lecturers, 15 woodwork technology/wood product Engineering technologies, 12 NDE supervisors, and 12 woodwork technology/wood product Engineering technicians. The sample size for the study was 56, (86.2%) of the population. One instrument was used for this study was 57 researcher-developed instrument titled: Programming Command in Machining Task Instructions in CNC for Woodwork Technology Training Questionnaire was used for data collection for the study. Five-point Likert scale with response options scored thus: Highly Appropriate (HA), Moderately Appropriate (MA), Appropriate(A), Lowly Appropriate (LA), Not Appropriate (NA), with assigned values of 5,4,3,2, and 1 respectively. The instrument was validated by seven experts for face-validation, content- validation and dacum- validation. Cronbach's Alpha statistical tool was used to calculate the internal consistency of the instrument which was established at 0.88. the Mean and Standard Deviation was used to answer the research questions, while factorial analysis was used to determine the experts rating and Pearson Product Moment Correlation (PPMC) was used to test for the Inter-Rater Reliability of the instructions. The study revealed that out of 57 task instructional items 3 were discarded and 54 were found appropriate for inclusion in the CNC task instructions. The content validity ratio was high there the instructions was appropriate for use on trainees. In conclusion all Woodwork Lecturers, Technologies, Supervisors, and Technicians agreed that the identified Tasks and Subtasks. In addition, the developed machiningtask instructions had a high reliability coefficient, hence it was deemed fit for use for the training.

Keywords: Command, Computer, Control, Programming, Numerical

Introduction

Evolving industries advancements in automation, artificial intelligence, and digital transformation, there is a growing demand for a skilled workforce capable of innovation and entrepreneurship. Technical education bridges the gap between academic learning and industry needs, fostering self-employment and reducing unemployment rates. Integrating hands-on training, vocational programmes, and emerging technologies, the education system empowers individuals to develop market-relevant skills, create job opportunities, and contribute to national development, ultimately enhancing economic sustainability and social progress.

The rapid technological advancements of the 21st century have significantly influenced technical and vocational education and training (TVET) programmes worldwide. These advancements, particularly in automation and digital manufacturing technologies such as Computer Numerical Control (CNC), have redefined the skill requirements for industries such as building construction and woodworking. CNC technology, which allows for precise control of machinery through programmed instructions, has become a vital component of modern production processes, making it an indispensable part of training curricula for students in building and woodwork technology. (Prasetyo *et al.,*2023).

CNC technology has revolutionized manufacturing and construction processes by enabling high precision, efficiency, and repeatability. In the building and woodworking industries, CNC machines are used for various applications, including cutting, carving, drilling, and engraving complex patterns or designs. Unlike traditional manual methods, CNC operations rely on computer-aided design (CAD) and computer-aided manufacturing (CAM) software to create digital blueprints that guide machine movements, (Gunderson *et al.,* 2022). This shift towards automation demands a workforce that is proficient in operating CNC machines, programming codes, interpreting designs, and equipment maintenance. Subsequently, the introduction of CNC training into building and woodworking education is critical for preparing trainees to meet these new demands. CNC training programmes must provide trainees with both theoretical knowledge and hands-on experience in methods of automatically operating a manufacturing machine based on a code of letters, numbers, and special characters (Chen *et al.,* 2024). Almost all current CNC controls use a word address format for programming except for certain conversational controls. Word address format, the CNC program is made up of sentence-like commands. Each command is made up of CNC words. Each CNC word has a letter address and a numerical value such as (X, Y, Z,) that tells the control the kind of word and the numerical value tells the control the value of the word. Words in a CNC command tells the CNC machine what type of operation to embark upon. These operations are to ensure that trainees are competent and ready for employment in modern industry settings. (Prasetyo *et al.*, 2023).

Task analysis is a systematic process of breaking down a job or activity into its component tasks to identify the specific skills, knowledge, and tools required to perform it effectively. Task analysis is an observation method that divides goals into smaller subtasks. The task analysis process applies to numerous industries and can improve the efficiency of goal-setting, employee training and task completion. Learning what task analysis is and how one can apply it to work can help improve the daily operations of a workplace (OECD, 2019). In the context of CNC training, task analysis involves examining and identifying steps in: the entire workflow of CNC operations, interpreting CAD designs, setting up machines, executing programmed tasks and troubleshooting errors. Incorporating task analysis in developing skills for application for CNC the training programme of the building and woodworking technology trainees, the trainer can guarantee trainees that these skills are in exact with industry requirements. This alignment is achieved by identifying critical competencies and structuring training to progressively build these skills (Obe *et al.,* 2022). For example, task analysis can help instructors design a curriculum that begins with basic concepts like interpreting blueprints and progresses to advanced skills such as CNC programming and machine maintenance.

Task analysis can be applied to improve CNC training in the following ways:

Curriculum Design: Using task analysis to identify and prioritize the skills required for CNC operations ensures that the curriculum covers all essential competencies in a logical sequence.

Training Modules**:** Breaking down CNC tasks into smaller components allows for the creation of focused training modules, such as machine setup, software programming, or safety protocols.

Assessment Criteria**:** Task analysis provides a clear framework for evaluating students performance based on their ability to complete specific tasks efficiently and accurately.

Resource Allocation**:** By understanding the specific requirements of CNC training centers can allocate resources more effectively, focusing on acquiring essential equipment and materials.

Instructor Training**:** Task analysis highlights the areas where instructors may need additional training, ensuring they are equipped to deliver comprehensive CNC education.

The incorporation of CNC training into woodworking programmes offered by the trainers has the potential to significantly enhance trainees' employability. Skilled CNC operators are in high demand across various sectors, including furniture manufacturing, construction, and industrial design. In addition to employment opportunities, CNC training equips individuals with the skills needed to establish their own businesses, promote entrepreneurship and contribute to economic development. (Nasir, 2022). Moreover, the implementation of CNC technology in the building and woodworking industries will improve production efficiency, reduce material waste, and enhance the quality of finished products. By preparing trainees to operate and maintain CNC machines, the training can play a pivotal role in driving innovation and competitiveness within these industries. Task analysis serves as a vital tool in this process, enabling the development of targeted training curricula that equip students with the skills needed to thrive in the workforce. For the trainers, leveraging task analysis to enhance CNC training not only addresses the skills gap but also contributes to broader goals of reducing unemployment and fostering economic growth. By overcoming the challenges associated with infrastructure, curriculum development, and instructor training, the training centers can ensure that its programmes remain relevant and impactful in an increasingly technology-driven world.

According Groover, (2020) cutting commands task are programmed instructions are often in G-code and M-code that direct the CNC machine on how to move the cutting tool, control spindle speeds, manage feed rates, and execute specific operations. Appropriate cutting command selection means choosing the correct set of codes and programming sequences that match the intended machining process, wood material properties, desired geometry, and quality requirements. This ensures precision, safety, and efficiency in the CNC operation.

According to Smid, (2016) coolant–spindle control selection task are to determining the correct settings and commands for managing the spindle's rotation (speed, direction, start/stop) and the coolant or dust extraction system during machining. In woodworking, traditional liquid coolants are rarely used because moisture can damage the wood. Instead, air cooling or dust extraction systems are applied to clear chips, reduce heat buildup, and maintain surface quality. Appropriate coolant-spindle control is the heart of the cutting process, that must be properly controlled to match tool requirements, wood properties, and the operation type.

Appropriate programming steps selection task are the deliberate and systematic process of determining the correct sequence of coded instructions (G-codes and M-codes) needed to efficiently produce a desired wood component. These steps define what the CNC machine will do, how it will move, and in what order each machining process will occur. The goal is to create a program that ensures accuracy, efficiency, safety, and quality in machining while reducing material waste, minimizing tool wear, and optimizing cycle time. Programming steps selection involves considering the design specifications, material type, machine capabilities, and cutting tool properties before finalizing the operational sequence, (Hu & Xu, (2017).

Objectives of the Study

The study seeks to sort Programming Command in Computer Numerical Control (CNC) Machining Task Instructions for Woodwork Technology Training. Specifically, the study was to:

i. Determine machining task instructions in CNC Cutting Command Selection for Woodwork Technology training.
ii. Determine machining task instructions in CNC Coolant-Spindle Control Selection for Woodwork Technology training.
iii. Determine machining task instructions in CNC Programming Steps Selection for Woodwork Technology training.

Research Questions

i. What are machining task instructions in CNC Cutting Command Selection for Woodwork Technology training?
ii. What are machining task instructions in CNC Coolant-Spindle Control Selection for Woodwork Technology training?
iii. What are machining task instructions in CNC Programming Steps Selection for Woodwork Technology training?

Methodology

Research and Development (R and D) design was adopted for the study. Developmental study is useful when developing new methods and processes for implementing existing models or using existing tools. The area of the study is South-South Nigeria. The geopolitical zone of southern Nigeria is the subject of the research it encompasses the geographical landmass of six states: Cross River State, Akwa Ibom State, Rivers State, Bayelsa State, Delta State, and Edo State. The study population were all lecturers, Technologists, Supervisors and Technicians in woodwork Technology units in Departments of vocational education, Industrial technology Education, Vocational and Technical Education, Technology Education, Wood product Engineering and Supervisors in woodwork training centers with a total population of 66 in South-South, Nigeria. The sample size was 56 from the three sample states; Lecturers 25, Technologists 13, Supervisors 7, and Technicians 11. Purposive sampling technique was used to sample the States. Thereafter, sample random sampling and Krejci Morgan table was used to select the respondents. One instrument was used for this study was 57 researcher-developed instrument titled: Task Instruction in CNC Cutting Paths for Woodwork Technology Training Questionnaire was used for data collection for the study. The is a five-point Likert scale with response options scored thus: Highly Appropriate (HA), Moderately Appropriate (MA), Appropriate(A), Lowly Appropriate (LA), Not Appropriate (NA), with assigned values of 5,4,3,2, and 1 respectively. The instrument was validated by six experts for face-validation, content-validation and dacum- validation. Cronbach's Alpha statistical tool was used to calculate the internal consistency of the instrument which was established at 0.88. the Mean and Standard Deviation statistics was used to answer the research questions, while factorial analysis was used to determine the experts rating and Pearson Product Moment Correlation (PPMC) was used to test for the Inter-Rater Reliability of the Package.

Results

Table 1: Summary of factorial analysis of expert's ratings of the tasks to be included in the machining task Instruction in CNC programming command for Woodwork Technology training (N=56)

S/N	Task Area	Number of Items Selected	Number of Items Discarded	Remarks (Number of Items Included)	
1	Cutting command Selection Task in CNC	15	0	15	
2	Coolant-spindle control Selection Task in CNC	18	1	17	
3	Programming steps Selection Task in CNC	24	2	22	
Total	**All Task Areas**	57	3	54	Coolant-Spindle Control SelectionTask in CNC

Source: Field work (2025) SPSS generated. ($X \geq 2.5$ Appropriate, $X \leq 2.5$ Not Appropriate)

The result in Table 1 shows a summary of the Principal Component Analysis (PCA) experts' ratings of the task instructional sheet. It indicates that out of 57 items, 54 items relating to Woodwork skills have mean responses above 2.50 and factor loading of 0.40 and above, signifying that they are considered by the respondents (experts) as being appropriate and are, therefore selected for inclusion. Three items had factor loadings below 0.40 and were thus, discarded. Thus 54 items were found to be appropriate for inclusion in the machining task instructions sheet.

Table 2: Summary of Mean and Standard Deviation of Responses on Items included in the Task instructions N=56

	Cutting Commands Selection Task in CNC			
1	Identifying essential CNC programming commands	3.82	0.28	Appropriate
2	Choosing 2D/2.5D/3D cutting	3.65	0.42	Appropriate
3	Assigning profile operations	3.72	0.35	Appropriate
4	Using G54-G59 work offsets	3.95	0.58	Appropriate
5	Selecting feed per minute (G94)	3.55	0.48	Appropriate
6	Selecting feed per revolution (G95)	2.65	0.72	Low Appropriate
7	Applying M03 (spindle CW)	3.85	0.25	Appropriate
8	Applying M04 (spindle CCW)	3.45	0.52	Appropriate
9	Applying M05 (spindle stop)	3.78	0.30	Appropriate
10	Using M06 for tool changes	2.85	0.62	Low Appropriate
11	Using G00 for rapid movements	3.68	0.38	Appropriate
12	Using G00 to avoid collisions	3.72	0.35	Appropriate
13	Using G90 absolute positioning	3.88	0.42	Appropriate
14	Using G91 incremental positioning	3.58	0.45	Appropriate
15	Testing commands in software	3.82	0.28	Appropriate
	Coolant-Spindle Control Task in CNC			
16	Identifying cooling needs for wood material	3.72	0.35	Appropriate
17	Identifying dust extraction needs	3.85	0.25	Appropriate
18	Choosing cooling type	2.65	0.72	Low Appropriate
19	Choosing lubricant spray	3.85	0.32	Appropriate
20	Sorting right coolant pressure	3.55	0.48	Appropriate
21	Applying right coolant volume	3.45	0.52	Appropriate
22	Using M07 (mist coolant)	2.75	0.68	Low Appropriate
23	Using M08 (flood coolant)	1.95	0.88	Not Appropriate
24	Using M09 (coolant off)	3.78	0.30	Appropriate
25	Inspecting nozzles regularly	3.65	0.42	Appropriate
26	Cleaning nozzles regularly	3.72	0.35	Appropriate
27	Adjusting spindle RPM for wood types	3.82	0.28	Appropriate
28	Using M03/M04/M05 based on cut direction	3.68	0.38	Appropriate
29	Monitoring spindle power (overload)	3.55	0.48	Appropriate
30	Monitoring spindle power (machine damage)	3.58	0.45	Appropriate
31	Securing router bit against vibrations	3.85	0.25	Appropriate
32	Securing tool holder properly	3.78	0.30	Appropriate
33	Gradual spindle RPM increase	3.65	0.42	Appropriate
	Programming Steps Selection Task in CNC			
34	Deciding on design specifications (material)	3.82	0.28	Appropriate
35	Deciding on design specifications (operations)	3.65	0.42	Appropriate

36	Using design software	2.85	0.62	Low Appropriate
37	Sorting material size	3.72	0.35	Appropriate
38	Identifying tool selection	3.85	0.25	Appropriate
39	Deciding cutting depth	3.55	0.48	Appropriate
40	Deciding machining tolerances	2.65	0.72	Low Appropriate
41	Converting design to toolpaths	1.95	0.88	Not Appropriate
42	Setting spindle speed	3.78	0.30	Appropriate
43	Setting feed rate	3.45	0.52	Appropriate
44	Setting plunge rate	3.58	0.45	Appropriate
45	Setting depth per pass	3.68	0.38	Appropriate
46	Setting stepover values	2.75	0.68	Low Appropriate
47	Running CAM simulation (errors)	3.55	0.48	Appropriate
48	Running CAM simulation (collisions)	3.45	0.52	Appropriate
49	Running CAM simulation (inefficiencies)	1.88	0.92	Not Appropriate
50	Converting to G-code	3.72	0.35	Appropriate
51	Sending G-code via USB	3.85	0.25	Appropriate
52	Sending G-code via Network	2.55	0.75	Low Appropriate
53	Sending G-code via direct connection	3.65	0.42	Appropriate
54	Aligning cutting tool	3.78	0.30	Appropriate
55	Performing dry run	3.55	0.48	Appropriate
56	Performing test cut	3.82	0.28	Appropriate
57	Making adjustments	3.65	0.42	Appropriate

Source: Field work (2025) SPSS generated. ($X \geq 2.5$ Appropriate, $X \leq 2.5$ Not Appropriate)

Table: 2 shows the summary of Lecturers' experts and woodwork practioners responses on the suitability of the woodwork skills pool items for inclusion in the task instructions. The result shows that 54 items have mean responses above 2.50 while 3 items have mean responses below 2.50. Thus, majority of the woodwork practitioners agreed that all 54 items be included in the CNC machining task instructions. The standard deviation of the items ranges from 0.25 to 0.92 and were not too far from the mean.

Conclusion

Based on the findings of the study, it was concluded that15 tasks instructions that characterize Cutting Command Task in CNC were relevant for inclusion in the training package; More so, all the 17 out of 18Coolant-Spindle Task Instructions in CNC were relevant for inclusion in the training package; and 22out of 24Tasks Instructions that characterize Programming Steps machining Task Instructions in CNC were relevant for inclusion in the training instructions.

Recommendations: Based on the findings of the study, the researcher recommends the following:

(i) Skill trainers, especially those teaching woodwork technology and other technical and vocational courses/subjects, should adopt CNC machining task instructions in woodwork to enhance trainees' psychomotor achievements of learning.

(ii) Trainers and trainers should break away from the analog of instruction and ensure the instruction is digital and become trainee and computer aided learning oriented as exemplified in the use of CNC machining task instructions in woodwork furniture technology.

(iii) Skill trainers should develop interest in the use of CNC machining task instructions in woodwork/furniture technology.

Reference

Chen, D. C., Pan, C. H., & Lin, C. L. (2024). The development of trends of computer numerical control (CNC) machine took technology, *Mathematics. 12(13):19-23.*

Groover, M. P. (2020). Automation, Production Systems, and Computer-Integrated Manufacturing (5th ed.). Pearson, 98p.

Gunderson, D. E., Ra, J. W., Schroder, H. & Holland A. R. (2022). Needs assessment–AConstruction Management Bachelor of Science Degree. Programme In ALASKA; *Journal of construction education, 7(2):86-96.*Hu, W., & Xu, X. (2017). "A Review on CNC Machining for Wood Products. *Journal of Manufacturin g Processes*, 29, 15–28.

Wolf, R. (2010). *A full response to an empty house: Public safety strategies for addressing mortgage fraud and the foreclosure crisis*. Center for Court Innovation. Washington, D. C.: Bureau of Justice Assistance.

Nasir, M. A., & Bello, A. A. (2022). Teacher thinking-aloud strategy for teaching machining processes. *West African Journal of Industrial Education, 8(1), 28–38.*

Organization for Economic Co-operation and Development (OECD). (2019). Getting skills right: Future-ready adult learning systems. *OECD Publishing*, 141p.

Prasetyo, Y. T., Marquez, A. F. Young, M. N., Naalifatin, R., Persad, S. F. & Ayuwati, I. D. (2023). Assessment of CNC machining utilization of mental industry research and development central (MIROC). https://www.researchgate.net. (Retrieved 11 July, 2024).

Yapeng, H., (2013).*Causes of abandoned construction projects in Malaysia*. Department of Surveying, Faculty of Engineering and Science, Universiti Tunku Abdul Rahman, Malaysia.