Exploring the Design and testing of an off - screen Educational Robotics curriculum for early Childhood STEM Teachers in Plateau State

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Abstract

An experimental research design was used to design and test Educational Robotics (ER) curriculum for pre-service teachers in Federal College of Education Pankshin. The population for the study consisted of all NCE one students in the department of early childhood offering the course Science Technology Engineering and Mathematics STEM (ECE 124) in the 2023/2024 session. A Sample of 60 Pre service NCE teachers were selected. A robot car was constructed low cost kits in the robot design stages. The instruments used were the Robot Parts test (which will assess robotics knowledge) and secondly the Solve-Its tasks (which will assess robots design competence). Treatment lasted for 4 weeks. Data was collected and analysed using descriptive and inferential statistics. Results indicated that 50% of our participants did greatly in identification, 10% had never seen some of the components and a 55% has ever use the components in this project exercise. This implies that pre-service teachers are novice to robot part and use Also, participants were very competent in robot design process activities and robot base cutting. Participants also showed average competence in Robot stage cutting, construction of rollers and fixing of robot parts. They however showed only fair competence in coupling of robots parts. Findings indicate that the teachers designed robots have high educational value and are age appropriate. The robots are averagely complete in form, ease of use motion and durability. The designs however have low compliance to safety. It was recommended amongst other that Teacher training colleges should organised in-service training to improve teacher competent in handling engineering and technology parts and programming of STEM robots.

Key Words: STEM Educational Robotics curriculum, Robots Design, Robots Testing

Introduction

The problem of neglect of the T and E aspects of Science Technology and Engineering (STEM) at the early childhood levels of education in African countries and especially Nigeria due to teachers' low capacity to engage lower level learners with the engineering and technology aspects of the STEM curriculum is worrisome. Also, innovative and play based technology materials and curriculum seems not to have been given the right place in Nigerian early Childhood STEM teaching and learning (Katniyon, *et al,* 2023). As discovered by Cirfat, et al. (2022) this situation is further compounded by lack of electricity and power in rural and urban schools for on screen educational robotics learning in Nigeria. One tangible innovation and play based way that children can engage with both T and E concepts of STEM during the early childhood years especially in countries that have electricity challenges like Nigeria is through off- screen educational robotics.

According to Lerch (2018), educational robotics are programmable machines or gadgets that are used in performing a range of tasks by executing input commands. The advantage that educational robotics especially (off- screen robotics) offers is that it engages children in hands- on- minds on approach, it is age appropriate and does not require electricity and thus compatible to Nigeria rural school environment. They are programmed to move, make noise, light up, and follow instructions as directed. Sullivan and Bers (2015), emphasizes that educational robotics is designed to make learners to advance their ability to think, design and build robots that perform a variety of task in a developmentally appropriate way. This innovation has provided opportunity for play -based hands-on learning of technology and engineering to young children in a developmentally appropriate way. Despite the advantage that educational robotics seems to provide, most of them requires electricity to operate. Hence the need for an off-screen approach.

Off-screen Robotics education such as KIBO robotics facilitates playful experiences while learning basic engineering concepts, such as programming skills, electronics, gearing and gear ratios, relative speed, direction of turning gears, torque and acceleration, loops, forks, subroutines, logic, the use of light/ultrasonic/infrared sensors, buoyancy, propulsion, balance, laws of motion, and physical processes (Elkin, et al 2016). If utilized in early childhood school setting, educational robots can enhance children's computational thinking, problem-solving, creative thinking, and a healthy sense of competition that drives innovation by learners hence, learners need to be expose to robotics through the off-screen option where there is no electricity and computers. Another reason why the off-screen educational robotics is important is because it is an interesting way to bring STEM to life for young children. This is because it encourages experimentation, teamwork, problem-solving and knowledge application and tech use in the simplest possible form (Khodabandeh, 2022).

Recently, there has been significant growth in interest and acquisition of technology related skills a critical demand of the twenty-first century work environments. Consequently, children have become technologically engaged daily in areas such as gaming, play toys, phones, laptops and computers, television, and videos at home and outside the home (Khodabandeh, 2022). Cirfat *et al.*, (2022) posits that commonly used digital technologies in early childhood programme include computers, educational robots, mobile devices like smart phones and tablets, smart boards, the internet, cameras, iPhones, iPads, digital cameras and many types of assistive technology. These devices have been progressively applied in early childhood classroom learning in developed nations such as USA and Europe. As observed by National Commission for Colleges of Education (NCCE, 2020) if Nigerian children must catch up with the increasing roles of digital technologies required in this fourth industrial revolution which is significantly becoming part of culture of the home, school, and in their immediate environment, digital learning should be made an integral part of learning in the early childhood Science Technology Engineering and Mathematics (STEM) curriculum and teacher training programmes.

Educational robotics and coding are among the 21st century innovations and skills being sort after globally by educational institutions and industry. Unfortunately Nigeria seems to lack behind both in teacher preparation and curriculum design that incorporates future oriented innovations such as coding, machine learning and Educational robotics as topics to be taught (Katniyon, et al. 2023). Also, local production of play based off-screen robots has not been prioritised as part of the early childhood STEM curriculum (Fabiyi *et al.,* 2016). Research reports about deployment of Play- based educational robotics curriculum and testing in early childhood STEM in Nigeria is not available. There is a need to design and test robotics curriculum appropriate to Nigerian pre service learners based on recent NCCE minimum standards. This study therefore sets out to design an educational robotics curriculum and test an off- Screen play- based educational robotics and curriculum for early childhood STEM pre- service teachers.

Problem Statement

Despite this progress and growing relevance of digital revolution in education especially at the early childhood level, Research in Nigeria Cirfat et al (2022); Katniyon et al. (2023) shows a gap exist in the robot design skills for teacher preparation programmes and pre - school curriculum. This situation has Led to absence of indigenous tangible hands on robots materials for incorporation for use in play – based STEM learning and its curriculum in early childhood level. Off-screen educational robotics has been used effectively for early childhood STEM in USA and UK. It has been found to engage children in development of 21st century skills, it is also age appropriate and does not require electricity and thus compatible to Nigeria rural school environment (Bers 2015; Elkin 2016). Nigeria seems to be lagging behind in this technology and curriculum. This situation is worrisome and needs urgent attention. It is at the backdrop of this that this research intends to design and test an off- screen play based educational Robotics and curriculum for early childhood STEM Learning.

Theoretical Framework

Two theories guiding this research are constructivism and constructionism. Constructionism as an educational theory is student-centered and emphasizes discovery learning, where students are encouraged to work with tangible objects in the real world and use what they already know to gain more knowledge. Constructivism Theory states that knowledge constructed by connecting new experience to existing ideas. This aptly applies to the design of educational robots and curriculum using tangible technology to create new knowledge. The implication of this theory to the current study is that children will be provided with robotics education using the STEM curriculum as a spring board for acquiring skills required for effective 21st century world of work.

Objectives

The purpose of this research is to Explore the design and testing of an off - screen Educational Robotics curriculum among early Childhood STEM teachers in Plateau State. Specifically it intends to:

1. Find out if pre - service teachers' are able to identify robots components?
2. Assess if participants are able to demonstrate competence in robots design skills
3. Assess if teachers designed robots are effective when exposed to functionality test?

Research Questions

The following research questions will guide the study:

1. To what extent are participants able to demonstrate competence in robots design skills?
2. To what extent are pre - service teachers' able to identify robots components?
3. To what extent are the designed robots functional when exposed to functionality test?

Methodology

The research design is experimental design which intended to design and test Educational Robotics (ER) curriculum for pre-service teachers. The population will consist of NCE one students in the department of early childhood offering the course Science Technology Engineering and Mathematics STEM (ECE 124) in the 2023/2024 session. A Sample of 60 Pre service NCE teachers were selected. The school was selected as a research site in order to see how the robotics curriculum would unfold in a typical Nigerian public school, outside of a research lab setting. The course and level was selected to empirically observe how the new component STEM in the NCCE minimum standards for early childhood will be implemented by would be teachers. Also, it will provide an opportunity for pre- service teachers to be proficient in teaching 21st century engineering and technology aspects of STEM compared to peers in UK, Crete and USA.

The study lasted for 4-week with each week having an activity. Data was collected from the participants using two assessments instruments: the Robot Parts test (which will assess robotics knowledge) and secondly the Solve-Its tasks (which will assess design process). Robotics knowledge Test will assess pre-service teachers' knowledge of the use of educational robotics. The activities lasted for 4 weeks. Data was analysed using percentages, mean and Standard Deviation.

Curriculum Design Procedure

The educational robotics curriculum was implemented over the course of 4 weeks, four sets of pre-service teachers completed an introductory robotics curriculum taught by trained research assistants from the Departments of Early childhood, Technology and Computer of Federal

College of Education, Pankshin. Participants were evaluated using two instruments: Robots parts task and Solve -it Task

Off- screen Educational Robotics Curriculum

The robotics lessons were integrated with as part of the NCCE (2020) minimum standard for the course in early childhood education called Science Technology Engineering and Mathematics (STEM) course (ECE 124 and 212) were pre-service teachers explore the robotics component of each lesson involving a hands-on building or programming task that were completed in groups lasting 4 weeks. Each lesson was built on the concepts taught from the previous week, leading up to a culminating project with an interactive robot map representing the community. In the following sections, more details will be provided regarding the curriculum.

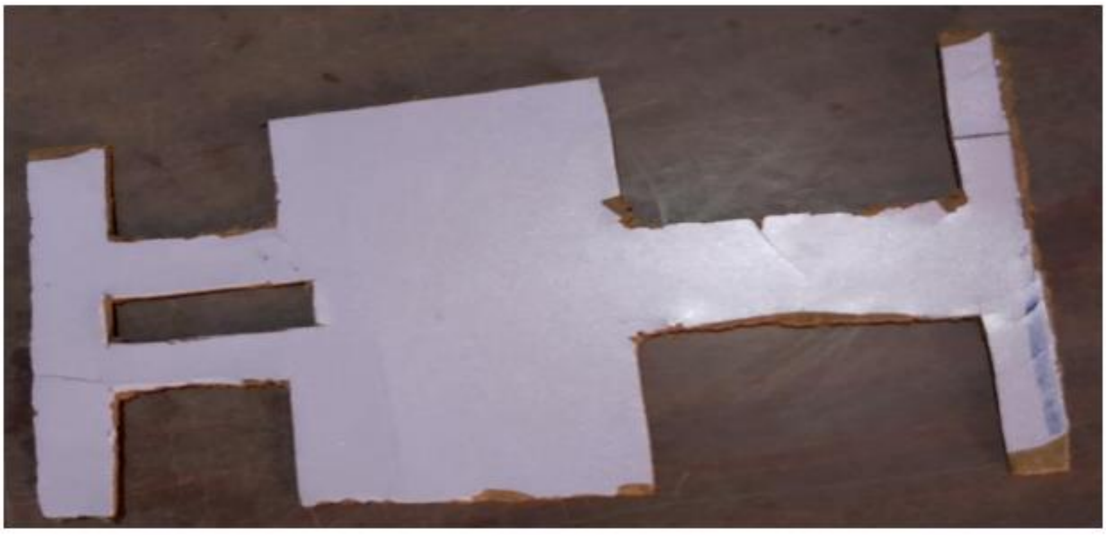
Week One: Introduction to Robots Parts

Participants were introduced to the following robots parts and their uses:

DC motors, Lithium ion battery, jumpers wire, plastic bottle, covers, 4mm electric conductors, carton paper , super LGC Gum glue, Popsicles sticks, half inch ply wood, razor blade, colour tape, aluminum sheet, shoe sawing trade, a mathematic set, a lighter, saw blade, rubber rings, empty biro straw, binding wire.

Activity 1:

Half-inch ply wood is cut in specific dimensions as show in Figure 1 using a hack saw blade which form our robotic chassis or base.



Figureure 1: Robot Chassis

Activity two:

Participants undertook the following activity: 4mm electric conductor is cut at 2cm in pairs to be used on the base rollers or tyres on left and right turn directions.

Figureure 2: Poles for front control motor

i. The empty biro straw (i.e the outer pipe) is also measured at 2cm and cut also in pairs, then the pipe is cut vertical at about 1.5cm to create an opening as shown in Figure 1;

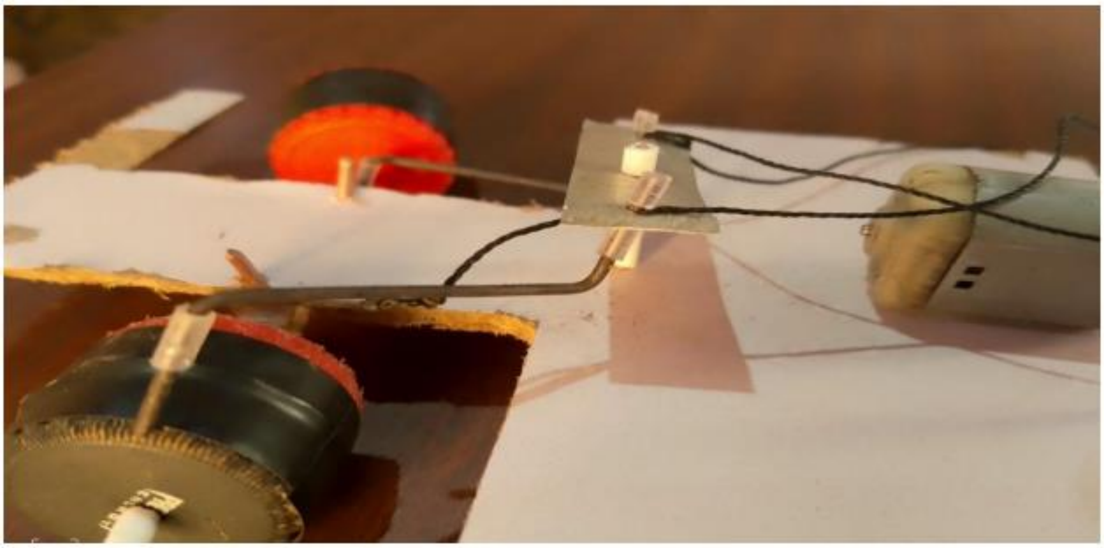
Figureure 3: Biro and Popsicle sticks straws

ii. Popsicle straw is also measure 2cm and cut in pairs to serve as opening connecting the controlling unit (steering system of the left and right direction motor of our robot chassis.

Figureure 4: Houses for front balancing control

Week Two: Robots part Design

The following curriculum activity was done: A hole was also bored on the Popsicle straw as was done in iii above to accept a pivot in which the front steering system is balanced with the help of an aluminum sheet of 6cm attached to 4mm conductor cut at 4cm balancing the aluminum sheet at the middle with Popsicle straws shielding the conductor as shown in Figure 3:

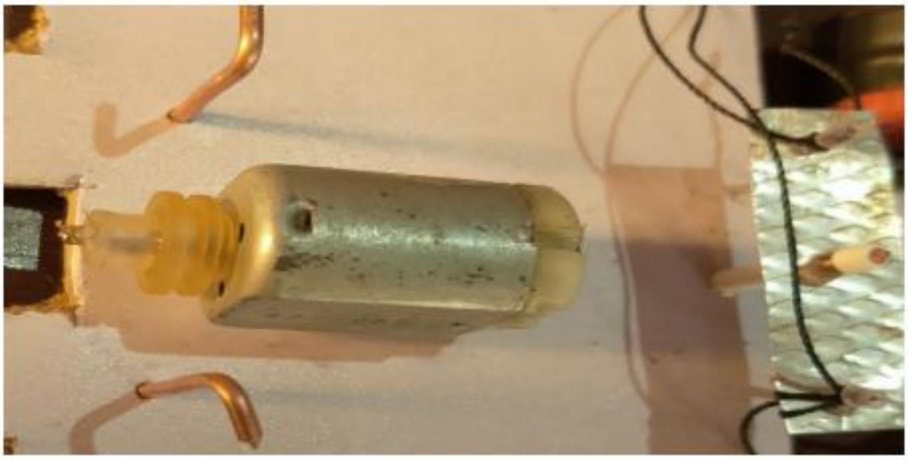


Figureure 5: Front wheel left and right balance

6cmm should be measured from pivoting pole backward and 2cm horizontally (i.e from left to right to mount two 3.5cm of 4mm pole ben at .5cm as shown in Figure 5;

Figureure 6: Aluminum Sheet for front balance

i. A DC motor should be mounted 6cm from the pivot pole and 1cm from above mounted poles in the middle with rotating shaft of the motor aligning to the two poles

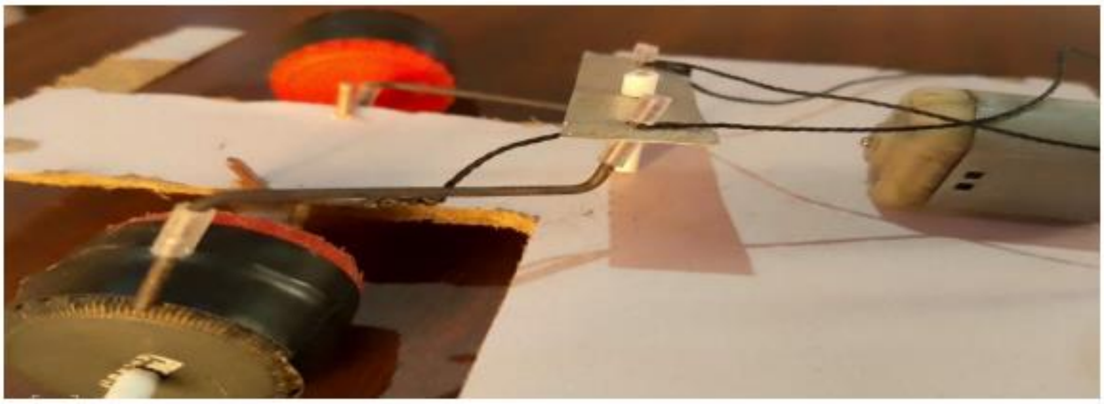


Figureure 7: Front wheel motor with poles

ii. A binding wire of 7.5cm should be cut and ben 1.5cm from one side and 2cm from the opposite side.

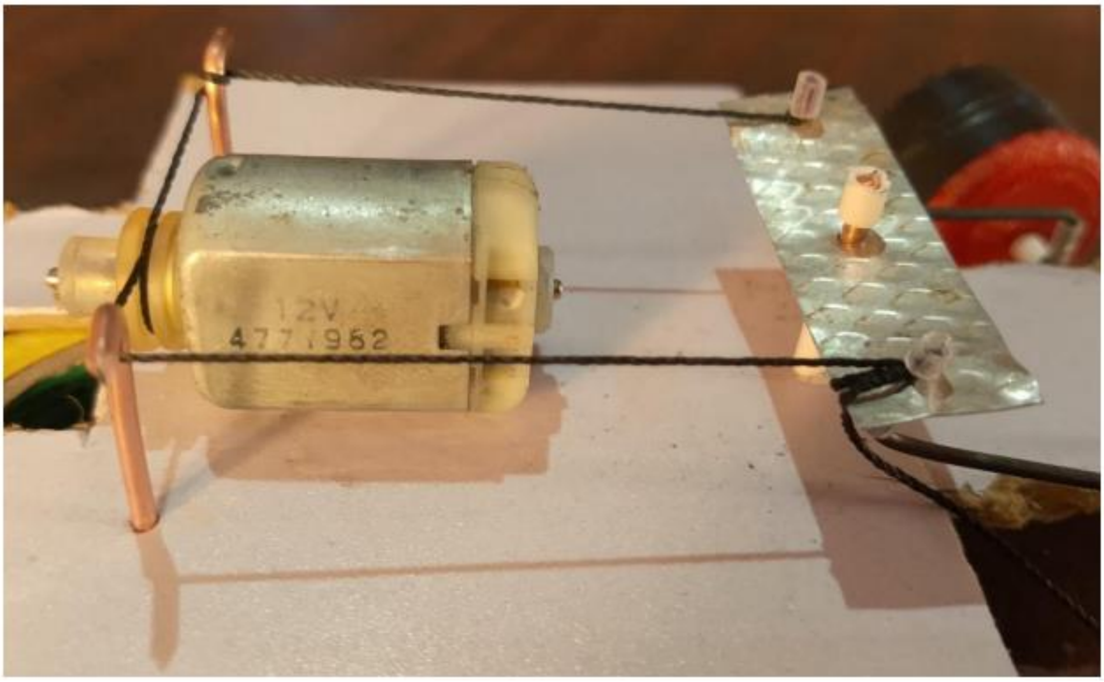
Figureure 8: Front wheel control rods

iii. The bended 1.5cm side should be connected through an empty biro (inner straw) through the loli pop straw connecting the rollers (tyres) at the front steering system



Figureure 8: Front wheel control sections connected to rollers

iv. A shoe sawing trade of about 17cm should be measured and cut out, this should pass through the aluminium sides .5cm from the edge where the binding wire is connected to the steering system from one side turning on the standing pivot pole through the DC motor shaft twisted to the other pole and back to the other edge of the aluminium sheets on the poles to serve as network facilitated the left and right turn of the robotic chassis.



Figureure 9: Front wheel complete control unit

Week Three: Robots Tyres Design

Two bottle covers of equal diameter should be tape using the coloured tape to form the rollers (tyres) and should be replicated to have four, such that two will be used at the front and two at the back to facilitate rolling or movement of out robot as shown in Figure 10;

Figureure 10: Rollers and tyres

i. Front wheels (tyres) are to be made from the two sealed bottle covers with 4mm conductor passing in the middle and terminated with a popsicle sticks at the outside such that the 4mm conductor wire is gum through the popsicle sticks that is connected at the front rollers (tyres)

ii. A carton of 1cm, .5cm diameter should be cut and duplicated each, then using a small hot gum wax to make gears to aid the movement of the rear rollers (tyres) connecting the big and small gears, such that the big is connected to the other DC motor then back to the small one passing through the rear rod made of broom stick and shielded with popsicle stick through an opening made 4.5cm from the pivot poles with a rubber ring as shown in Figure 11;

Figureure 11: Gear system parts

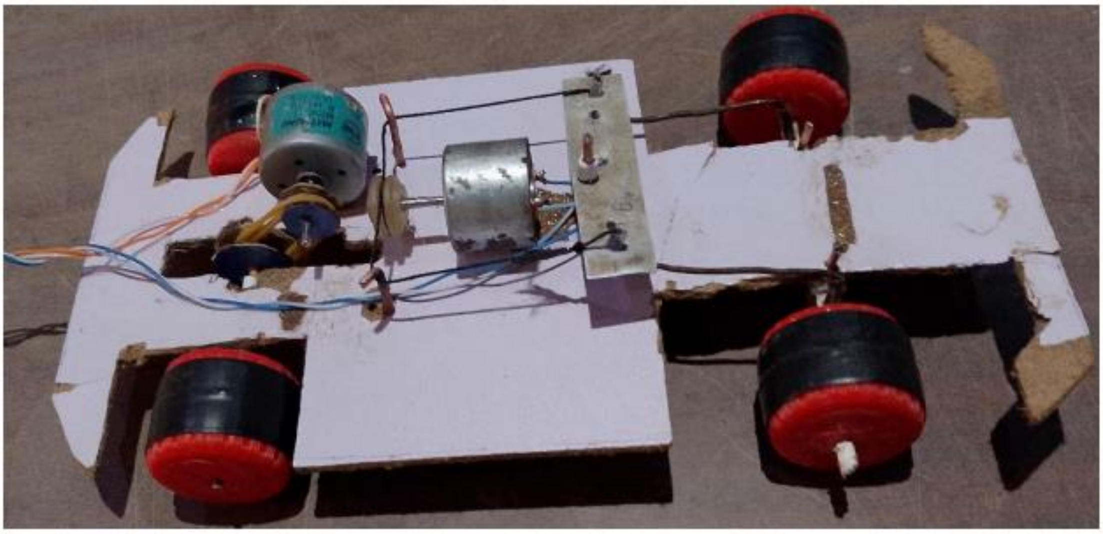
Week Four: Robots coupling Activities

The final aspects of the robots curriculum saw participants use of:

vii. Jumpers wire from rj45 cable from the DC motor terminals one negative and the other positive extended to a panel for controlling of the whole system mounted on a half-inch ply wood 13x8cm as shown in Figure 6; in order control left and right turned, forward and reverse movement of the front and rear rollers (tyres) of the entire robot platform

Figureure: 12: Jumper wires

The final coupling and testing of robot function test was done at the fourth week. Picture is seen in Figureure 13.



Figureure 13: Completed off screen robot

Figureure 13 presents the completed design of the robot car after the 4 weeks

Results

Findings from the study is presented based on the research questions as follows:

Research Question one:

To what extent are pre - service teachers' able to identify robots components?

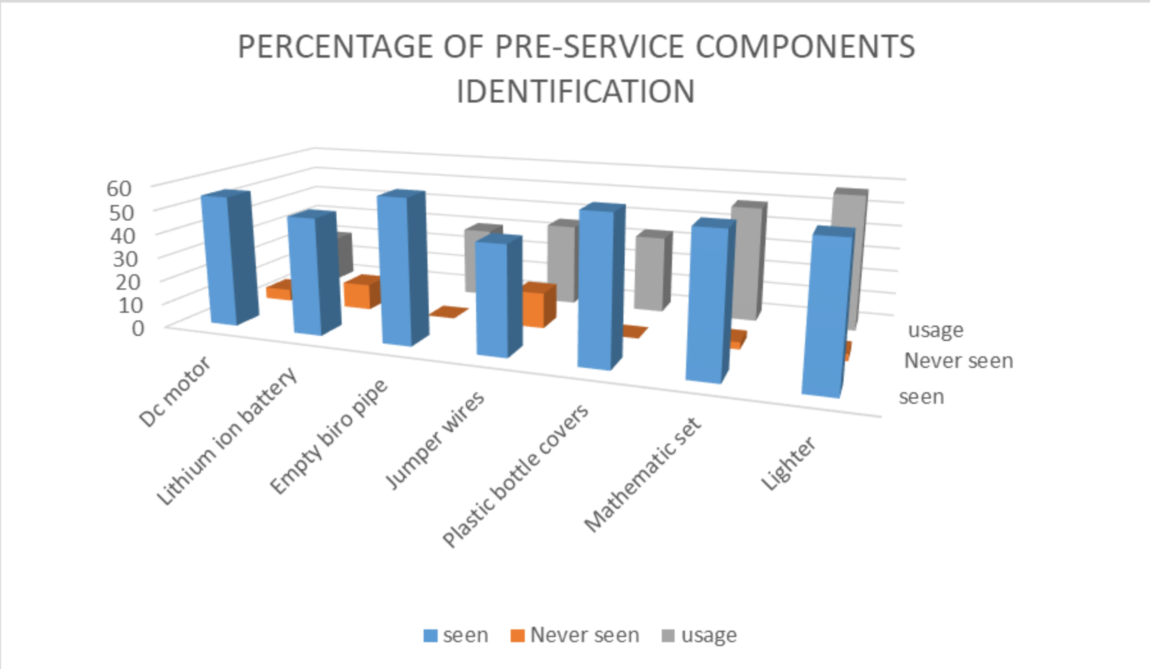
Table 1: Percentage of Component Identification by Participants

S/N	Components	Robot parts Identification			
		Low	percentage	High	Percentage
1	DC motor	55	91.66	5	8.34
2	Lithium ion battery	49	81.66	11	18.34
3	Empty biro pipe	40	66.66	0	33.34
4	Jumper wires	45	75	15	25
5	Plastic bottle covers	4	6.67	56	93.33
6	Mathematic set	50	83.33	10	16.67
7	Lighter	56	93.33	4	6.67

Source: Pre-testing exercise 2024

Data on Table 1 shows item being presented for identification include DC motors, Lithium ion battery, jumpers wire, plastic bottle, covers, 4mm electric conductors, carton paper , super LGC Gum glue, popsicle sticks, half inch ply wood, razor blade, colour tape, aluminum sheet, shoe sawing trade, a mathematic set, a lighter, saw blade, rubber rings, empty biro straw, and binding wire.

Table 1: Component Identification Survey



Figureure 14: Source: Pre-test exercise 2024

From data on table 1 and Figureure 50% of our participants did greatly in identification, 10% had never seen some of the components and a 55% has ever use the components in this project exercise. The fact that they have now seen, used it in this project exercise is an evidence that whatever they have seen, handle could be excellently use to achieve other projects of like manners less stressfully, also as they conceived an idea they can execute such without much issue. This implies that pre-service teachers are novice to robot part and use. This is agreement with findings of Cirfat et al (2022) and Katniyon et al (2023) who found teachers to possess poor digital skills including robot parts. This position is worrisome, if the educational and societal benefits of robots design and use is to be effective in Nigeria and globally, then teachers must be availed opportunities to interact with and design robots parts which will positively influence their classroom practices in STEM teaching and learning.

Research Question Two:

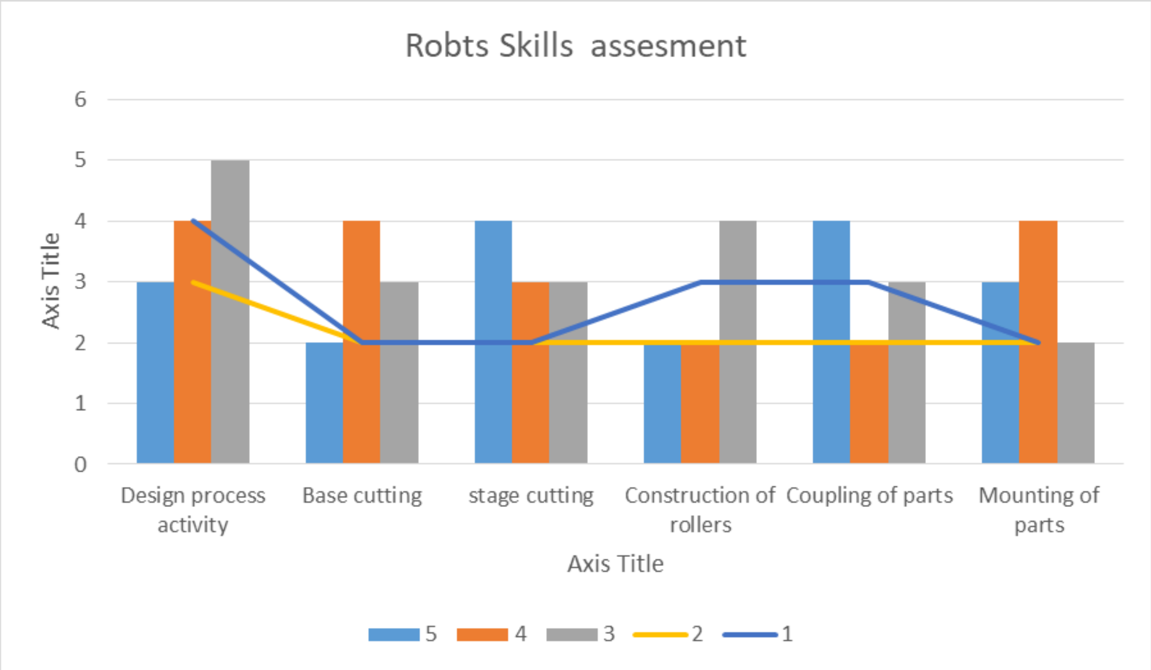
To what extent are participants able to demonstrate competence in robots design skills?

Table 2: Mean Robot Design Skills competence exhibited by participants

	Robots design skills being assessed	**N**	**X**	**SD**	**Decision**
1	Robots design process activities	60	3.6	0.80	VC
2	Robot base cutting	60	3.1	0.92	VC
3	Robots stage cutting	60	3.0	0.84	C
4	Construction of robots rollers	60	2.8	0.64	C
5	Coupling of robots parts	60	2.7	0.82	FC
6	Fixing of robots parts	60	3.2	0.66	C

Source: Pre-test exercise 2024

KEY: VC Very Competent, C =Competent, FC= fairly competent, NC Not competent



Figureure 15: Bar Chart of Robot skills test

Data on Table 2 shows the performance of participants had a very high competence in design process activities mean of 3.6, SD 0.80. While coupling of robots parts had the lowest competence mean of 2.7 SD 0.82. This implies that participants were effective in 90% of the task assigned to them. Data on Table 2 shows that participants were very competent in robot design process activities and robot base cutting. The also showed competence in Robot stage cutting, construction of rollers and fixing of robot parts. They however showed only fair competence in coupling of robots parts. This in consonant with findings of Katniyon et al (2023) who discovered that teachers exposed to robots design training pick up interest and improved with practice. If Nigeria must be part of the 4 and 5th industrial revolution globally, then its teacher's must be deliberately exposed to 21st century pedagogical methodologies such as robot designs to impart these skills on the children they teach especially at the foundational school levels. Early design skills are capable of laying adequate foundation for future careers in STEM areas.

Research Question Three

To what extent are the designed robots functional when exposed to functionality test?

Table 3: Mean functionality test exhibited by designed robots

	Robots design skills being Assessed	**Functionality**				
		N	**Low**	**Average**	**High**	**Decision**
1	Completeness of form	60		X		Functional
2	Age appropriate	60			X	Functional
3	Ease of use	60		X		Functional
4	Motion and functioning	60		X		Functional
5	Compliance with safety	60	X			Needs improvement
6	Durability	60		X		Functional
7	Educational value	60			X	Functional

Source: Pre-test exercise 2024

Data on table 3 indicate that the designed robots have high educational value and are age appropriate. The robots are averagely complete in form, ease of use motion and durability. The designs however have low compliance to safety. This implies an average functionality test for the design off screen robots. Functionality test of any engineering equipment is very important if it must not be an excise in futility. Interest and attitude towards a design process increases if there is a functional display of the usability of the product from participants (Eguchi, 2016; Katniyon et al 2023). In a classroom setting the teacher's confidence to improve the technology and engineering component of STEM engagements is enhanced in areas of age appropriateness ease of use safety compliance and educational values amongst others. Ultimately enhancing learner's creativity, critical thing and problem solving skills.

Conclusion

In our growing technological world today, exposing teachers to education robotic curriculum is highly encouraged as it boost teacher's confidence to improve their 21st technology and engineering skills component of STEM. This improves teacher competence, preparation in areas of technology and engineering, age appropriateness of instructional materials ease of use safety compliance and educational values amongst others. Ultimately developing learner's creativity, critical thing and problem solving skills for viable products design and patent acquisition.

Recommendation

The problem of neglect of the T and E aspects of Science Technology and Engineering (STEM) at the early childhood levels of education in Nigeria due to teachers 'low capacity to engage lower level learners with the engineering and technology aspects of the STEM curriculum can be addressed by engaging the following:

i. Teacher training institutions should organise workshops and training on design of an off-screen, play based educational robotic curriculum should be implemented in order to allow early exposure to STEM.

ii. Universities and Colleges of education should be a design educational robotics curriculum and tools for early childhood robotics.

iii. Teacher training colleges should organised in-service training to improve teacher competent in handling engineering and technology parts and programming of STEM robots.

Acknowledgement

Researchers acknowledge the funding support from Tertiary Education Trust fund for this Research

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