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Design of Some Aspects of an Instructional Mobile Robots Based on Material Handling to Enhance the Skills of Mechanical Students

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***Abstract*—** Robots are becoming an indispensable part of our society and have a great potential for application in mechanical engineering and Science Technology Engineering Mathematics in general. Robots are also gradually being integrated into our society. Robotics remains an important sector also in a manufacturing sector, as most engineers engage in manufacturing robots that can perform specific task and give appropriate results for the task. In other words, the engineers attempt to fabricate robots with perfect accuracy or 0 percent margin of error which is quite practicable as the technology improves. The success of the World Robotics Competition focusing on manufacturing teaching modules, the planning of mechanical design, the control of system and mobility of the robots through microprocessor technology has attracted educationists and researchers.

Teaching and Learning Based Robots (TLBR) are learning concept where teachers or instructors bring the real-world cases into the workshop, laboratory or classroom and encourage students to connect between knowledge possessed by its application in everyday life. Motivated by the technological process, this study utilized 4-D models as research and development process to design some aspects of instructional mobile robots to enhance the skills of mechanical students. The Models include four phases: definition phase, design phase, develop phase and disseminate stage. The research was carried out using Applied Research Design Development (ARDD) with the aim of producing learning tool in the form of an instructional mobile robot modules and kit for the skill advancement of mechanical engineering and technology students. The material selection process is critical in selecting the right material for this frame. Wood, aluminum, or steel may be suitable materials for the robot frame, but Al 3003 aluminum alloy becomes the best choice for the required parameters. These materials have excellent mechanical properties such as high tensile strength, high strength-to-weight ratio, corrosion resistance, ductility, formability, recyclability, etc. For these reasons, Aluminum alloys have been used in most of the applications. The strength of aluminum frame is very high, the cost is very low, and it is relatively light in weight. The results reveal that the models contain detailed data showing the complete mechanics of the system. This is enough to provide good information about instructional robotics and devices as well as robotic system. The results further underscore the effectiveness of each component by isolating all the components and individually testing them rigorously before integration. When fully integrated, the isolation and testing of all individual signals proves beneficial. Finally, the results show that the developed instructional mobile robot was found valid and reliable.

***Keywords*—** Instructional Mobile Robot: Material Handling: Skills: Mechanical Students: 4D Model.

INTRODUCTION

Robotics remains an important sector also in a manufacturing sector, as most engineers engage in manufacturing robots that can perform specific task and give appropriate results for the task. In other words, the engineers attempt to fabricate robots with perfect accuracy or 0 percent margin of error which is quite practicable as the technology improves [1]. Among the specific tasks or applications is Instructional robot (IR). The IR is a broad term that refers to a collection of activities, instructional programs, physical platforms, educational resources and pedagogical philosophy [2]. However, instructional robotics is most applicable to the so-called STEM (Science, Technology, Engineering and Mathematics) education; a teaching model designed to teach science, mathematics and technology simultaneously, where practice takes precedence over theory [3].

The model focuses on the production of teaching modules, the planning of mechanical design, the control of system and mobility of the robots through microprocessor technology. Teaching and Learning Based Robots (TLBR) are learning concept where teachers or instructors bring the real-world scenarios into the workshop, laboratory or classroom and

encourage students to connect between knowledge possessed and its application in everyday life [4]. Therefore, the crux of this study is how the curriculum and the learning modules are implemented in accordance with the approach of Industrial 4.0 needs [5]. In order to support competency-based curriculum needs of the Industry 4.0, the model has also compiled modules (both manual and interactive) oriented to the achievement of competence as well as accommodate the working life skills. With regard to the problems that will arise is what kind of learning modules appropriate to the characteristics of the attainment of the goal of learning the world of work as well as the achievement of competence in the field of life skills by using the main teaching materials in the form of modules and learning device [6].

Further, most of the mechanical engineering and technology students lack attention and learning initiative, which directly affect the students' attitude and learning effect in class, laboratories, and workshops. Relevant studies show that the introduction of Artificial Intelligence (AI) technology into STEM teaching cannot only improve students' interest in STEM learning, but also deepen students' memory, enrich their sense of context, and improve their STEM application ability [7].

To address these problems, this study utilizes 4-D models to design some aspects of instructional mobile robots to enhance the skills of mechanical engineering students, which is in line with the needs of Industry 4.0 Revolution. Expected results of this study should be able to bridge the gap in needs of energy, particularly of graduates majoring in Mechanical Engineering and Technology Universities, Polytechnics, Colleges of Education in Nigeria who will serve as an engineering, technology and vocational teacher or plunge into the world of Industry 4.0.

REVIEW OF RELATED WORK

The popularity of the Internet and artificial intelligence (AI) technology has promoted the development trend of intelligence and resource utilization in various industries. In this era, new changes and developments have taken place in the education industry [8]. In the teaching of various subjects like STEM, intelligent technology and equipment are widely used in teaching practice, and good teaching results have been achieved [9]. In order to study correctly and effectively, learning tools such as instructional materials are required. Instructional materials play an important role in learning. Instructional materials are tools and media that provide opportunities for students to gain learning experience, and are an important part of modern education practices implemented by many educational institutions [10]. The existence of instructional materials makes it easier to implement learning and help students learn more easily. Teachers, instructors and students can use instructional materials to improve learning. With the instructional material available, learners gain experience in dealing with facts from life; models of life; symbols used in life. Therefore, instructional materials arranged in modules provide more opportunities for students to achieve the above goals [11]. Also, among the instructional materials is instructional robot brought about by the current technological advancement.

Preliminary studies have shown that with the rapid development of China's intelligent robot industry especially Industry 4.0, all walks of life are using robots to replace humans in some relatively dangerous and repetitive tasks, mainly engaged in rescue, guidance, service and other work such as education industry [12, 13]. In the field of education industry, robots also play a very important role. Educational robot also known as instructional robot is an intelligent tool for assisting learning developed for the field of education [14, 15]. The use of intelligent instructional robots can cultivate students' creativity, analytical ability, imagination [16]. Instructional robots can fully mobilize the initiative of students. It has the characteristics of openness, intelligence and good human-computer interaction, and it often plays a very prominent role in the teaching activities of college students [17]. In the process of teaching practice, instructional robots can be used as teaching assistants to assist teachers or instructors in related activities such as course demonstrations, which can greatly improve students' attention and concentration [18]. At the same time, educational robots can also be used as educational companions for students, allowing learners to learn to interact with robots after class that fully embodies the concept of entertaining [19, 20]

Likewise, in most developed countries, the used of robots are widely deplored as teaching aids to train students from kindergarten to high school (universities and polytechnics) [21]. Common examples are: NAO a robot that can both teach programming and help teachers harvest students' attention while teaching [22]; Robosem, a telepresence-focused robot that teaches English Language and other subjects to children in South Korea [23]; Nijiya Kurota, a robot that teaches calligraphy in Japan [24]. Similarly, teaching robotics in

secondary schools and higher schools, [24, 25] portray that the robot in general is capable of creating employment opportunities, increasing students' interest in engineering and computer science among future university candidates, empowering students. It improves students' academic achievement and provides solutions to digital divide issues. This is farfetched as education is the foundation of any nation's development and the best legacy any government can bestow on its people [26]. For any society to experience any meaningful socio-economic growth and national development, its people must be educated to acquire the necessary technological competencies [27]. Considering the important role that robots play in education as a learning tool, it can be said that they are indeed facilitators of national development and enhance the skill of engineering students especially, mechanical engineering and technology students [28].

Additionally, material handling plays an important role in machine shops and in general Industry 4.0. Today, most robots are used in manufacturing operations. These applications can be grouped into three categories: (i) material handling, (ii) machining operations, and (iii) assembly and inspection [43]. Material handling applications include material conveying and machine handling. Material transfer applications requires robots to move material or work parts from one location to another. Many of these tasks are relatively simple, requiring robots to pick parts from one conveyor belt and place them on another [44]. Other transfer operations are more complex, such as placing parts onto pallets in an arrangement that must be calculated by a robot. Machine handling operations utilize robots to load and unload parts from production machines. This requires the robot to be equipped with a gripper that can grip the part. Oftentimes, fixtures must be designed specifically for specific part geometries [45]. Thus, by teaching robots about material handling, mechanical students should be able to connect and integrate STEM [46, 47, and 48]. By extension, the question of hands-on ability is strengthened.

2.1 The 4D Development Model Phases

Therefore, this study used 4-D model (Define, Design, Development, and Disseminate) to design instructional mobile robots to enhance the skills of mechanical students. The models are a research and development method used to develop learning tools (see figure 1). The 4-D model was developed by S. Thiagarajan, Semmel and Semmel in 1974 [29]. Researchers, policy makers and educational administrators widely used the model as it is arranged systematically with sequences of activities that can be used for proper problem solving on learning instruments [30]. Therefore, 4-D development model can be adapted to the universities and polytechnics needs and its student characteristics, for it is flexible, affordable and conditional.

2.1.1 Define

The first phase of the 4-D model is to develop the requirements definition. This stage is the requirements analysis stage of product development. Requirements analysis is where the developer analyzes and gathers information that is required for the model development [31].

The stage of defining or analyzing requirements can be done by analyzing previous studies. Thiagarajan et al. (1974) mentioned four activities that can be performed in defined phases including:

Front-End Analysis

The primary analysis is to identify and define fundamental issues in the learning process, making them a context for developmental needs. By performing a preliminary analysis, the researcher/developer gets an overview of the facts and alternative solutions. This helps to identify and select the learning tools to be developed [32].

Learners Analysis

The activity of identifying student characteristics as the targets of learning tool development is called profiling students or learners. The development of cognitive, psychomotor, academic, motivation and personal skills related to the subject of study, device, media, form and language are the subjects of special issues [33].

Task Analysis

Task analysis aims to identify the skills that researchers study and then analyze applying a set of additional skills that may be required [34]. In this case, the educator analyzes the main tasks that the student must master in order for them to achieve the prescribed minimum competencies.

Concept Analysis

Concept analysis involves identifying the main concepts to be taught, placing them in a hierarchical fashion, and breaking down the individual concepts into key and irrelevant items. Concept analysis, in addition to analyzing the concept to be taught, it is also pertinent in arranging the logical steps to proceed. This conceptual analysis includes an analysis of competency standards, determination of the quantity and type of teaching

materials and an analysis of learning resources, invoking sources that support the development of teaching material definitions [35].

Formulation of Learning Objectives

The learning objective formula is used in the summary of the results of the concept and task analysis to determine the behavior of the research subjects [36].This summary serves as a basis for designing learning tools and writing tests for further integration into learning device materials.

2.1.2 Design

A second stage in the 4-D model is design. This stage must go through 4 steps, consisting of standard preparation test, media/device selection, format selection, and initial design [29].

Construction Criterion-Referenced Test

Standardization testing is a step that connects the definition and design phases. Standard preparatory tests are based on the specification of learning objectives and the results of student analysis. As a result, the learning outcome test form is compiled. The test is adjusted to the student's cognitive, psychomotor and affective ability, and the scores of the test results are used in an assessment guide that includes scoring guidelines and key answers to the questions.

Learning Device/Media Selection

Therefore, device/media selection is to identify learning device/media that are suitable/relevant to the properties of the material. Device/Media selection is based on the results of conceptual analysis, task analysis, characteristics of students as users, and a distribution plan using various device/media variants. The choice of device/media must be based on the process of developing the material to maximize the use of the material during the learning process.

Format Selection

The choice of format in learning tool development aims to formulate instructional device/media design, strategy selection, methodology, development methodology, and learning resources.

Initial Design

Thiagarajan et al (1974) mentioned that the initial design is the overall design of the learning device. The overall design must be finalized before conducting experiments [29]. The design includes a variety of structured learning activities and exercises for different learning abilities through microteaching.

2.1.3 Develop

The third stage of development is the development of 4-D model learning tools to produce product development, in this case, an instructional robot. This phase consists of two steps: expert assessment (Expert Evaluation) with revision and trial development (Pilot Development) [29].

Expert Evaluation:

Expert evaluation is a technique for obtaining recommendations for material improvement. By being assessed by an expert and getting recommendations for improving learning equipment, revisions are made based on expert advice. Expert assessment promises to make learning tools more precise, effective, time-tested, and more technical [37].

Pilot Development:

Development trials were carried out for direct input to response sheets, reactions sheets, comments on student sheets, observer input to prepare learning tools. Trial and error and modification with the aim of obtaining effective and consistent learning tools [37].

2.1.4 Disseminate

The final phase of the 4-D model learning tool development is the dissemination phase. The final stage of final packaging, dissemination and adoption are important but often overlooked. The dissemination phase is to promote the developed product and make it accepted by users (system, group or individual). Packaging materials must be chosen to produce true form. According to Thiagarajan (1974) [29], the dissemination phase is divided into three main phases: verification testing, packaging, and dissemination and adoption. Therefore, during the verification test phase, the product modified during the development phase is implemented on real targets. In this phase, the measurement of goal achievement is also carried out to determine the effectiveness of the product being developed. Then, after implementation, the researcher needs to observe the results of achieving the goals, and solutions that do not achieve must be explained so as not to repeat the same mistakes after the product is disseminated [38]. In the Packaging and Diffusion Adoption phase, the product packaging is disseminated by printing an application manual so that it can be absorbed (diffusion) or understood by others and used in their classes (adoption) [39]. Besides, what needs to be considered for dissemination are user analysis, strategy and theme, dissemination timing, and selection of dissemination instructional device/media.

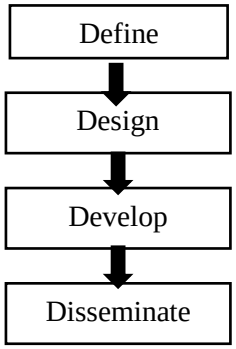


Fig 1. *4D Development Model Flowchart*

MATERIAL/METHODS

Material Used: Al 3003 Aluminum Alloy

Al 3003 alloys have high ductility and corrosion resistance; Aluminum 3003 alloy has moderate strength and good corrosion resistance; the strength of this alloy can be increased by cold working [49]. The Aluminum 3003 alloy is used in ductwork, chemical equipment, and it is also used in manufacturing the following items: Cooking utensils, heat exchanger, gas line, gasoline tanks, refrigerator panels, and pressure vessels [40, 41].

Table 1: *Chemical composition of Al 3003 Aluminum Alloy*

Chemical composition								
Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
0.20	0.25	0.04	0.003	0.03	-	0.04	0.03	Bal.

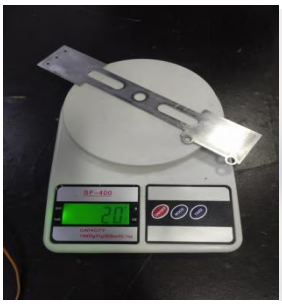
Table 2: *Mechanical properties*

Mechanical properties		
UTS	YS	Elongation%
130MPa	125MPa	10

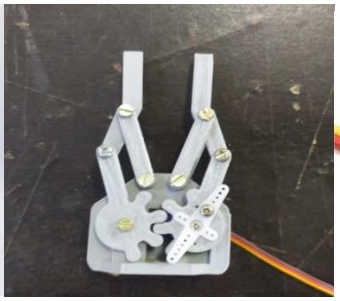
The design of some aspect of the instructional mobile robot prototype is used in research called Applied Research Design Development (ARDD). The development design makes hand-on instructional mobile robotics that contains a system controlled microcontroller. Table 3 shows sources needed in developing some design aspect of instructional mobile robotics. Fig. 2 a-j show some design images of the Instructional Robot.

Table 3: *Other components and their functions*

S/no.	**Component (s)**	**Functions**
1.	Al3003 alloy	Use for the hands-on instructional robot framework
2.	Servo motors	Serve as actuators
3	Arduino Nano(Atmega 328)	Microcontroller use to store various commands
4	Drive board	Use to control servo motors
5	Bluetooth module HC-05	Wireless communication module that communicates commands from the smartphone to the microcontroller
6	4 potentiometers	Used to control manually, for both the arms in different directions
7	Power battery	A regulated 5V DC powered the microcontroller, motor driver and liquid crystal display (LCD), while 12V DC battery powered each of the six DC motors used.
8	Jumper M-M, F-M	The cables used to supply power from the batteries to various components
9	End effector	Used for pick and place

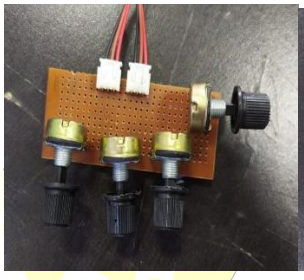

a) During Testing Process

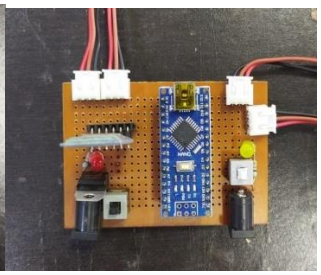

b) Robot Frame

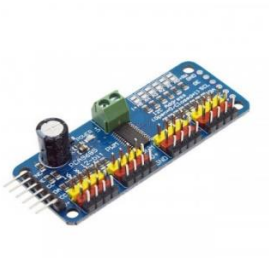

c) End Effector


d) Actuator


e) HC05 Bluetooth


f) Potentiometer


g) Arduino Nano


h) Servo Motor Driver


i) IR under development

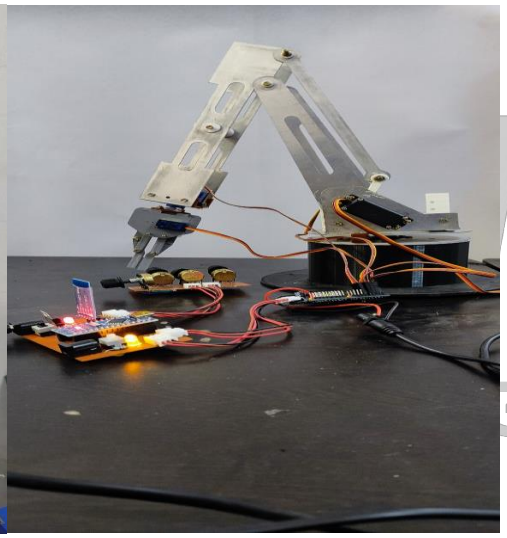

j) Completed Instructional Robot

Fig. 2: *Some design aspect images of the Instructional Robot.*

3.2 Research Methods

This study is to produce a learning tool in the form of an instructional robot using ARDD as a teaching tool for situation-based teaching and learning in the Departments of Mechanical Engineering and Technology in Nigerian universities to enhance the skills of mechanical engineering and technology students.

Program development under study proceeds through the following phases:

- Through literature research and data mining, the study identifies various problems of some design aspect of instructional robots used in robot competitions and education industry, and provide reference for the formulation of theory, simulation and application methods;
- Analyze and formulate the identification of various issues related and relevant to the development of some design aspect of instructional robots in the Department of Mechanical Engineering and Technology;
- Scenario analysis and design of the learning and infrastructure required for the development of equipment, teaching staff and laboratory/workshop personnel, and

establishment of a corresponding evaluation system for material demand of instructional robots;

- Develop success indicators for a teaching process oriented towards performance requirements for fulfilling professional needs;
- Implement the manufacture of instructional robots using situational teaching as a teaching tool, and use theory, simulation, and application as means to combine various issues such as learning needs and instructional robot competitions and other education activities;
- Guided by the need to master the ability, conduct a field test on the learning tools of the instructional robot course based on the material handling teaching of the Department of Mechanical Engineering and Technology;
- Analyze the results of field trials and make improvements to validate test procedures and test results;

Results of Final Revision, Field Testing and Validation of Instructional Robots as Teaching Tools Based on Teaching and Learning Material Handling [42]

3.3 Method of Data Analysis

The data is analyzed using quantitative and qualitative descriptive techniques approach. Where, information on the results of hands-on/fieldwork exercise and discussions on the implementation of the Nigerian Robotics Competition, other education activities as related to instructional robot and the standard requirements for learning equipment is examined. While, information from focus group discussions, in the form of theory, simulations and applications to identify and formulate fundamental topics for an integrated robotics course as teaching material is analyzed through the use of qualitative techniques.

RESULTS AND DISCUSSIONS

4-D models are an easy method in the product development process. A research model is broken down into a few steps, namely: 'Define', 'Design', 'Develop' and 'Disseminate'. The approach begins by identifying the student's material needs.

4.1.1 Define Phase

Preparation level: Activities carried out at this level are: a) Brainstorming and supporting literature; b) Research design, Method of data collection, Method of data analysis. After thoroughly conducting a review of literature, the research crew carry out research design with the following results as terms of reference:

1. Determination of the observer's crew
2. Preparation of the Research Activity Schedule, calls planning implementation: Preparation and implementation activities learning tools including the use of instructional devices, media, subject/course taken, class/workshop/lab used, class/workshop/lab schedule used, the model/method/approach used, and the learning outcomes test that will be used at end of the study. At the end, the study produced learning tools that include:
   - The contract of lecturer/teacher/instructor
   - The plan of semester lecture/lab/workshop
   - Worksheet
   - Learning media (Instructional robot)
   - Process and outcome assessment instruments learning
   - Observation sheet of learning
   - The validation sheet of learning tool
   - The implementation stage

Learning device (Instructional robot) development procedure using the 4D Thiagarajan Model which will be done including the Defining phase (Define), Designing phase (Design), Development phase (Develop), and Disseminating phase (Disseminate).

- Data Analysis level: Data analysis level also known as Preparation of Program Implementation Report (PPIR), this level constitutes, Monitoring, Evaluation, Supervision and Planning Follow-Up
- Analysis of Results and Discussion Level Based on the observation can be explained that:
  - Students activities during learning observation results of student's activities made effective
    - ✓ Ability of lecturers/teachers/instructors to manage learning: Based on the observation of ability of lecturers/teachers/instructors to manage learning as follows:
    - ✓ Implementation–
      1, the ability of lecturers/teachers/instructors in managing classroom/workshop/lab is generally valuable excellently moderate
    - ✓ Implementation – 2, the ability of lecturers/teachers/instructors in managing learning category is highly good

- ✓ Implementation – 3, the ability of lecturers/teachers/instructors in managing learning is very well.

Therefore, it can be said that the lecturers/teachers/instructor's ability to manage learning is effective. Results of the learning outcome tests conducted at the end of students' studies after implementation – 1, implementation – 2, implementation – 3. Table 4: shows the results.

Table 4: *Mastery of Learning Outcomes Using Instructional Robot*

ML/IM	Greater Than or Less Than	Sum of Students Response	Percentage (%)
Mastery learning	(>70)	76	76
Imastery learning	(<70)	24	24
Grand Total		100	100

4.1.2 Results of Students Responses Questionnaire

Using the instructional robot, when hands-on/fieldwork exercise is followed by 100 students, by an administration of questionnaire based on the learning gained.

According to the results of the response in Table 5, the student responses after using the instructional robot based on hands-on/fieldwork exercise are positive by using the instructional robot.

Table 5: *Results of Students Responses Questionnaire to learning using the instructional robot, when hands-on/fieldwork exercise*

Classification	Sum of Students Response	Percentage (%)
Excellent	8	8
Very Good	12	12
Good	51	51
Moderate	24	24
Low	5	5
Grand Total	100	100

CONCLUSION

The study observes that lecturers/teachers/instructors faced some difficulties in teaching and learning engineering and technology-related courses (STEM), specifically based on material handling. Therefore, this study emphasizes the importance of the development of university instructional materials. Instructional materials adapted to a specific class require basic teaching methods and techniques adapted to the needs of the students. The study, concluded that:

- The instructional robot is found valid and reliable
- The students' activities during learning have shown effective results.
- The lecturer/teacher/instructor's ability to manage learning is effective.
- The student's responses to learning using the instructional robot based on hands-on/fieldwork exercise is active(Positive)

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