



DESIGN AND DEVELOPMENT OF AN INSTRUCTIONAL MOBILE ROBOT FOR EFFECTIVE LEARNING OF MATERIAL HANDLING IN MECHANICAL WORKSHOPS IN NORTH-EASTERN NIGERIAN UNIVERSITIES: A REVIEW

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Abstract: Instructional robotics can play a vital role in solving some of the challenges faced by tertiary institutions in Nigeria, especially North-Eastern universities. The main challenges hindering the effective teaching and learning process include the lack of qualified teachers, teaching and learning facilities, and the absence of information on how to design and develop a valid, reliable, and affordable educational or instructional robotics that will facilitate the learning process and also supplement conventional teaching and learning methods. People are increasingly interested in the field of robotics as an educational tool. However, few people pay attention to undergraduates. In this study, the researchers investigated and analysed the currently available over 140 related articles to instructional robots and their applicability in teaching and learning in different fields. It also introduces the role of instructional robots as an indispensable tool for Science, Technology, Engineering, and Mathematics (STEM) education, its benefits and challenges, and finally highlights the process or procedure for designing and developing a valid, reliable instructional mobile robot for effective material handling in mechanical workshops in North-Eastern Nigerian universities.

Keywords: *instructional mobile robot; effective learning; material handling; mechanical workshop.*

1.0 Introduction

Robots are becoming an indispensable part of our society and have a great potential for being used for technology education and STEM in general. Robots also are slowly being integrated into our society. Robotics is a hot topic these days, wherein in 2021, many cutting edge technologies are connected with the field of robotics, like machine learning, and AI, IIRDT, man-machine-collaboration, or autonomous mobile systems (IFR et al., 2021). In the same vein, Robots are gradually integrating into our daily lives at home and school, enhancing their efficiency and effectiveness. Instructional mobile robots play a crucial role in undergraduate STEM education, enhancing knowledge development and intellectual growth (Mubin et al., 2013). Mobile robots are increasingly being utilized in educational systems worldwide to address various educational issues.

Furthermore, Crnokic et al. (2017) pointed out that mobile robots are gaining attention from scientists and educators due to their applications in various fields, including space exploration, underwater research, and medical applications and by extension Industry 4.0. Educational robotics, a motivating learning environment, focuses on creating robots that help students develop practical, teaching, cognitive, and motor skills, stimulating interest in research and science. Robotics is increasing in pre-school, primary, secondary, and higher education.

However, robotics systems are an excellent demonstration technology for STEM education due to their inherent multidisciplinary nature (Merdan et al., 2017). Therefore, according to Rubio et al. (2019) robots are divided into the following categories, including: i. Land-based (a. wheel mobile robot; b. walking or legged mobile robot; c. tracked ship/skid locomotion; d. hybrid); ii. Air-based; and iii. Water-based. The study further described that each system has its advantages and disadvantages. In addition, when choosing a robot platform for teaching, many important factors need to be considered, including cost, size, functionality, and interface. Educational robot platforms can also be roughly divided into three categories: manipulators (used for industrial robotics) Surendran et al. (2016), legged mobile robots (Michielletto et al., 2016), and wheeled mobile robots (Browne et al. (2017). In terms of practical or actual demonstrations or experiments, legged mobile robots are more expensive, larger, and more complex. Platforms like the Nao robot (Kofinas et al. (2015) cost about 65,000 euros per robot, which makes them infeasible for class sizes of more than 10 or 20. Humanoids, quadrupeds, and hexapods are all available. However, low-cost alternatives cannot provide the required functionality [6] (Michielletto et al., 2016). He further stressed that the wheeled robots are effective and reliable alternatives to teaching due to their unique locomotion method, allowing for independent subsystems to function independently. Therefore, wheeled robots are effective and reliable alternatives to teaching.

Therefore, this study will focus on wheeled robots. Wheeled mobile robots are playing a significant role in higher education because they provide a flexible platform to explore and teach a wide range of topics such as mechanics, electronics, software, and materials (Arvin et al., 2019). With the support of (Jajoa et al., 2010 ; Chaudahary et al., 2016), the learning activities that can be carried out cover a full range of activities, starting with entry-level elementary school students, undergraduates (UG), and postgraduates (PG) (Scott et al., 2015; Wang et al., 016). This is to confirm that the instructional platform involves almost all aspects of the learning journey, but due to a lack of sufficient instructional devices, it will affect students' academic performance, creativity, teamwork, and collaborative skills.

Similarly, our students' academic performance, creativity, teamwork and collaborative skills, social ability, self-confidence, independence, and level of knowledge adaptability are affected by many factors (Browne et al., 2017; Alimisis et al., 2009). Many researchers have revealed some of these factors. The level of previously acquired cognitive information and psychomotor skills will undoubtedly have a substantial impact on the knowledge to be learned. In addition, individual differences in prior knowledge are not sufficient to explain the differences in further learning performance (Alimiisis et al., 2010). Therefore, the lack of instructional devices is one of the main factors.

The term "instructional robot" (IR) refers to a broad category of activities, instructional programmes, physical platforms, educational materials, and pedagogical philosophy. The fundamental goal of an educational robot is to provide a collection of experiences to help students develop knowledge, skills, and attitudes for the design, analysis, application, and operation of robots (Kai Wang, 2023). In the same vein, instructional robots, also known as robot teacher, are programmed to teach technical skills, provide educational solutions, and are free of charge for poor children who do not have access to technology (James et al. 2013). Figure 1 shows a robot teacher. (Merdan et al., 2017) clarifies that among them, mobile robots are the most common multidisciplinary method that can integrate different fields into one place to solve different changes and problems faced in the teaching process. Therefore, introducing effective mobile robots that will integrate different fields alone cannot solve the problems.



Fig.1. Robot Teacher

However, the successful implementation of educational innovation in schools requires not just acquiring new technologies, but also appropriate educational concepts, courses, and environments, and incorporating teaching methods that promote educational innovation (Alimisis et al., 2009). A study on mobile robotics in education by Cernokic et al. (2017) demonstrates its potential for interactive lectures, exercises, and strengthening specific knowledge and skills through design creation, assembly, and operation. And therefore, Mobile robots can enhance learning through playful learning, teamwork, social skills, and motivation, bridging different fields and enhancing technical skills.

1.1 Instructional Mobile Robots as a Multidisciplinary and Interdisciplinary Field

Instructional mobile robotics is a multidisciplinary field. It is naturally attractive to children and adolescents, as well as undergraduates, because it has a clear and unique relationship with science fiction and because it is usually embodied so that they can directly see, touch, and interact (Khailanri et al., 2013). Electronics, computer science, material science, physics, and mathematics are examples of knowledge areas that are covered by mobile robotics (Cronin et al., 2021). In the same vein, a mobile robot also has the multidisciplinary nature of integrating STEM fields (Michael et al., 2013; Johnson et al., 2003). To support this assertion, Khanlari et al. (2015) explored teachers' views on the use of mobile robots in STEM fields. Furthermore, various authors revealed that robotics promotes students' thinking in STEM courses (Michael et al., 2013) and (Khanlari et al., 2015). According to Merdan et al. (2017), it is recommended that mobile robots bring innovation and participation to STEM classrooms, where problem-solving and team skills are cultivated. Similar study by Kim et al. (2015) has shown that the use of mobile robotics can increase STEM participation and improve students' interest in STEM education. Fig.2 General Purpose Robotics Manufacturing Cell with Conveyor System for Material Handling

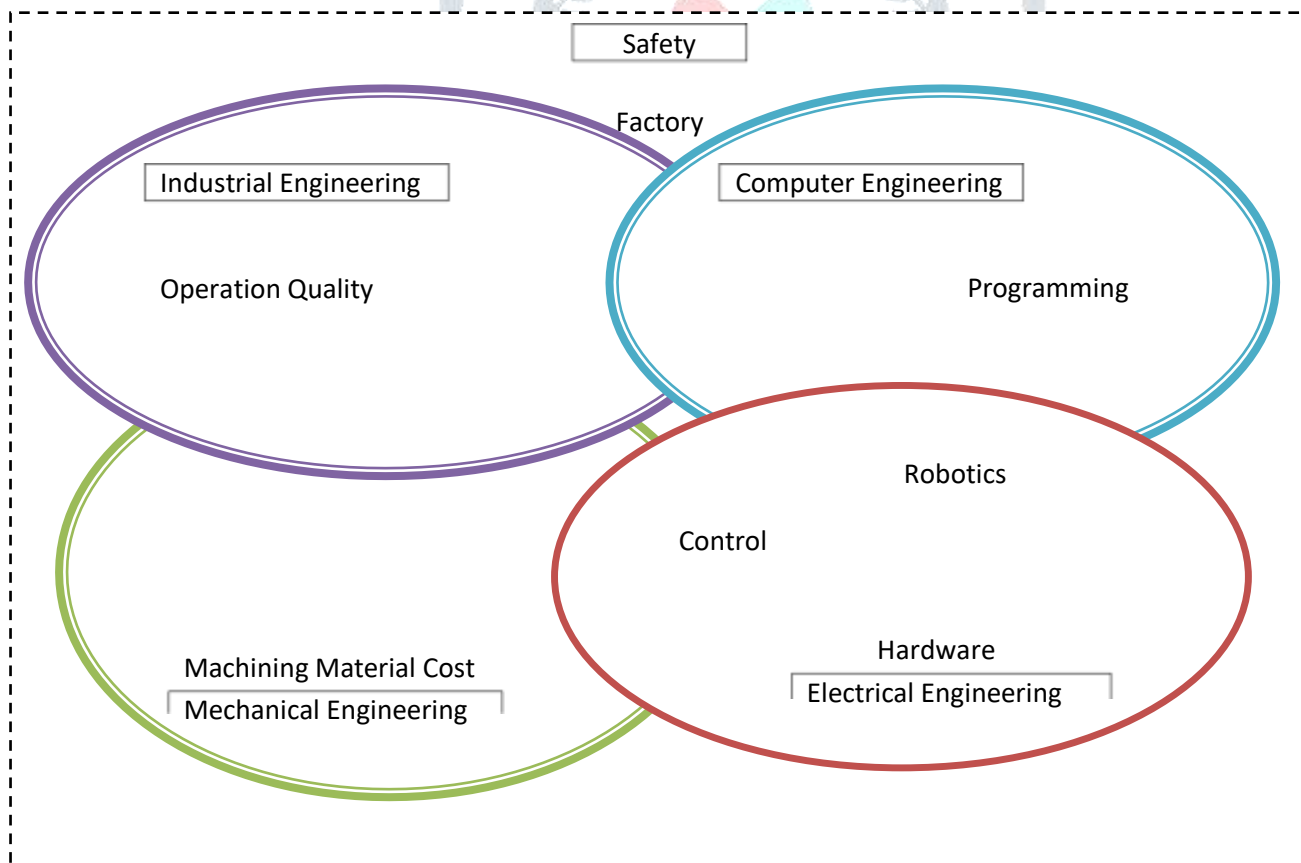


Fig.2 General Purpose Robotics Manufacturing Cell with Conveyor System for Material Handling

In a related development, some studies of (Alimisis et al., 2009; Atmatzidou et al., 2008); Carbonaro et al. (2004) suggest that educational robots can enhance students' skills in writing, reading, collaboration, and communication. Previous studies have also shown that children between the ages of three and eight can build and

programme simple robotics automation (Alimisis et al., 2009; Bers et al., 2002), and they can also learn powerful ideas in science, technology, engineering, art, and mathematics. In addition, they can also learn and understand the working principles of mobile robot material handling in the industry, markets, hospitals, workshops, and malls (Bers et al., 2018). Therefore, the use of manipulators can help achieve the goal.

In the same way, robotic learning tools enhance students' sensory-motor and hand-eye coordination skills, fostering collaboration and teamwork through their operation. Robotics offers fun and educational opportunities for students and teachers by integrating academic content, allowing technical and sports-related experimentation, and fostering narrative storytelling (Bers et al., 2018; Umam et al., 2019). By participating in this mobile robot learning project, undergraduate students can play and understand various concepts or creative backgrounds.

1.2 The Benefits of Using Instructional Mobile Robots in the Learning Process

The rapid global transformation, driven by the interconnectedness of the internet and social forces, has resulted in a flatter world according to Friedman et al. (2008). Digital devices like smartphones and tablets are being used by students in studies, with research mainly on secondary schools, but early robotics use may be beneficial (Pasztor et al., 2013). Therefore, learning activities will not lag behind technological progress. Mobile robotics learning activities enhance computational thinking theory, allowing teachers to develop students' skills while ensuring maximum test scores by Catlin et al. (2014). In the same vein, the effectiveness of instructional robots in improving students' learning outcomes and professional skills, such as communication and problem-solving, is supported by some evidence from various studies like Anwar et al. (2019).

The field of robotic systems brings together electrical engineering, mechanical engineering (or combined mechanical, electrical, and computer science) [31]. Felder et al. (2005), which happened to be born in mechatronics education today, where, since 1970, the term mechatronics has appeared in Japan for the first time and many definitions have been published. Professor Kevin Craig of Rensselaer Polytechnic Institute define mechatronics as a synergistic combination of mechanical engineering, electronics, control systems, and computer science (Grimheden et al., 2006) (Fig. 3). The key element in mechatronics is to integrate through the design of these areas from the beginning of the design process without passing through to allow additional components, as cited in Akonte et al. (2014).

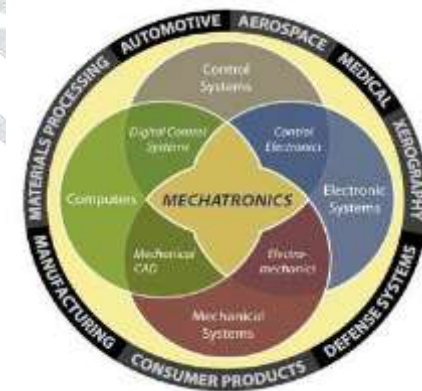


Fig.3 Mechatronics: Integrated Multidisciplinary (Source: Rensselaer Polytechnic Institute) (Akonte et al., 2014)

Lin et al.'s 2014 study on electronic pet robots in mechatronics engineering education highlights the need for developing diverse learning methods to address challenges in teaching interdisciplinary subjects. Their results further show that Project-based learning methods enhance student motivation, enhance performance, and provide practical experience for developing skills in mechatronics system design. Habeeb et al. (2018) highlight AI, deep learning, machine learning, and neural networks as powerful machine learning techniques for real-world problem-solving, with instructional robots increasing globally. Robots are rapidly being used in education due to their benefits in direct hands-on, interactive experiments, which stimulate critical thinking and understanding of physical and technological principles, leading to a growing application in education (Eguchi et al., 2014; Christofi et al., 2015).

The number of studies investigating educational robots and their impact on the academic and social skills of young learners has steadily increased. Educational robots are used both inside and outside schools to increase the participation of K–12 students and, by extension, undergraduates in various fields of STEM education (Scott et al., 2015), and (Wang et al., 2016). In addition, instructional robots are powerful tools that have the potential to help teachers deliver the curriculum in most subjects and fields. (Teague et al., 2014; Papadakis et al., 2021; Elkin et al. (2018) observed that students also believe that collaborative learning will have a beneficial impact on their learning outcomes. Elkin et al. (2018) believes that robotics provides a unique way for children (and adults) to explore sensors, motors, circuit boards, and other electronic components together from the inside. OECD et al. (2016) show that education is sometimes seen as a sector that resists change, and at the same time, it faces a productivity and efficiency crisis. Innovation can help improve the quality of education and provide more value for money” in times of budget pressure and rising demand.

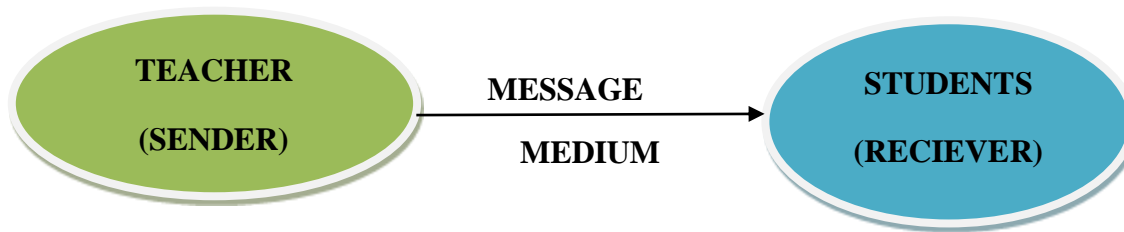
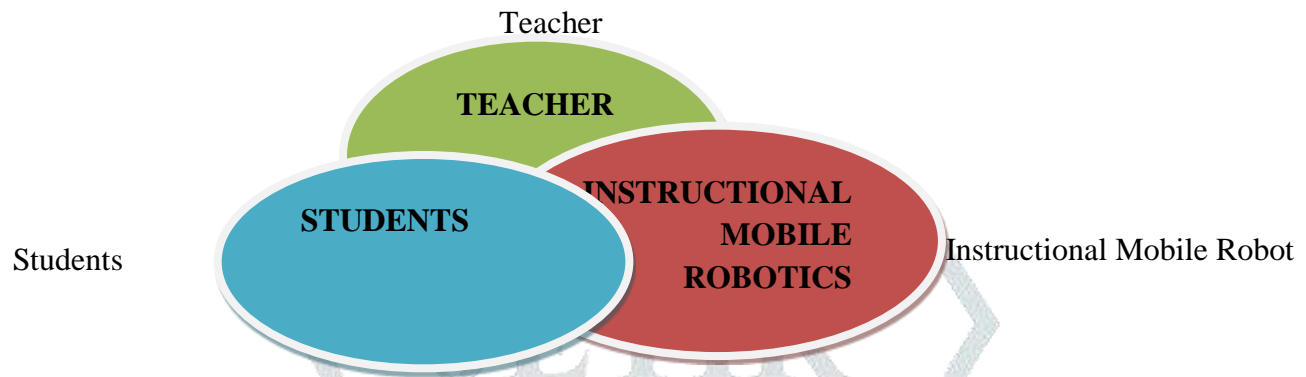
Also, Alimisis et al. (2009) believe that over the past few years, people’s interest in the educational use of robotics has increased, and many attempts have been made around the world to introduce robotics in STEM disciplines. Today, robotics is considered a flexible learning medium that can provide design and construction opportunities in a short period of time and with limited funding. It has been pointed out before that the goal of educational robotics is not entirely to teach learners to become robotic experts but to develop the basic components of successful experts in today’s world (Chevalier et al., 2020; H. Sanchez et al., 2019; Sullivan et al., 2021; Sophokleous et al., 2021; Cox et al., 2021)

1.3 Challenges

At present, European STEM and technology education methods often rely on passive learning, which lacks practicality for students to actively participate in the learning process. Current methods lack group work environments for students to develop soft skills and qualities needed for interdisciplinary research or industrial environments. The study explores the reasons behind the decline in interest in STEM-related research and careers among young people in Western countries today (Alimisis et al., 2009; Christofi et al., 2015). Nigeria, a country in Africa, faces challenges in learning appropriate skills due to the lack of effective, reliable, and appropriate instructional devices. Literature has reported the causes for this dismal performance in education is attributed to traditional methods, poor learning environments, lack of laboratories, and resistance to innovative strategies. Nigeria must adopt better instructional strategies and resources, including a learner-centered technology learning package, to effectively engage with the 21st-century economy's digital natives (Gambari et al., 2013). Beer et al. (2013) also stated that previous research indicated that early childhood educators lacked knowledge and understanding of technology and engineering; their findings revealed that levels of technology, self-efficacy, and attitudes towards technology improved statistically significantly.

According to Jegede et al. (2012) stated that insufficient instructional material in technical education and STEM leads to students' imaginations being stretched too far due to excessive word use, which is boring and demoralizing. Traditional teaching strategies heavily rely on teachers, with poor performance due to low quality and lack of necessary technology equipment, facilities, materials, and tools. Fig. 4 Traditional and Multimedia Learning Process. Therefore, educational robots (ER) are an emerging field of technology-enhanced learning (TEL) in which learners are introduced to robotics and programming through a variety of activities, often as part of what is known as STEM education (science, technology, engineering, and mathematics), an educational model in which the aforementioned disciplines are taught naturally for the practice of theory.

As a result, from an inventive standpoint, this effort is seen as a special sort of intervention in the sphere of education. Although the pedagogical intervention and better instructional composition in this research have already been confirmed to be valid, robot integration is not always successful. It is also possible to test whether the robot effect has benefited learning rather than the games themselves. Particularly in initiatives that involve technological innovation like Industry 4.0.

TRADITIONAL METHOD – A ONE WAY FLOW**MULTIMEDIA LEARNING – AN INTERACTIVE LEARNING PROCESS****Fig. 4:** Traditional and Multimedia Learning Process (Haruna, et al., 2020)

The Federal Government of Nigeria purchased a series of equipment and tools through the Tertiary Education Trust Fund (Tetfund) and distributed them to various colleges of education, polytechnics, universities, and other related institutions (Oyo et al., 2010). Some of the equipment and tools are not installed correctly for the correct use of students, teachers, instructors, and lecturers. (Uzoagulu, 1993) observed that, unfortunately, a large number of equipment and tools imported by the country to accelerate technical education and STEM education have not been uninstalled and cannot meet the demand. Uzoagulu further explained that some STEM lecturers use Tetfund scholarships to conduct domestic and foreign training programmes to improve their skills; unfortunately, due to the above problems, most students do not show the acquired skills and knowledge.

Consequently, Traditional teaching strategies may lead to student disinterest, poor performance, negative attitudes, poor retention of learning materials, and potential loss of employment opportunities or self-employment for graduates. Hitherto, the increasing youth unemployment in Nigeria may be linked to the widespread use of conventional methods in teaching technical courses. The government has implemented numerous educational policy reforms to enhance the quality of technical education and STEM education in general over the years. However, the government's effort remains unfruitful as the quality continues to dwindle (Nafees et al., 2012). Educational robots can play an important role in addressing some of the challenges faced by higher education in Africa (Ernest et al., 2019). Nigeria will not be spared from the challenges.

Empirically, there are at best scanty studies on the design and development of an instructional mobile robot. This study aims to design and develop an instructional mobile robot for effective learning of material handling in mechanical workshops in north-eastern Nigerian universities.

2.1 Development of an Instructional Mobile Robot

Instructional models, materials, and software enhance conventional methods in education, especially TVET schools, and integrate STEM through ICT, revolutionizing classroom activities. Instructional materials are crucial tools in school curriculums, allowing students to interact with words, symbols, and ideas, developing their abilities in reading, listening, solving, thinking, speaking, writing, using media, and technology. They include printed and non-printed items (Faize and Dahan, 2011; Bukoye et al. (2018).

The use of a reliable mobile robot model in mechanical technology workshops in North-Eastern Nigerian universities aims to teach students effective material handling tasks, as cited in Haruna et al. (2020). Didactic tools are crucial for effective and real-time learning, enhancing students' understanding and clarifying concepts, as noted by Anwar et al. (2019). The development of a reliable instructional robot model involves various steps, encompassing areas like perception, cognition, and navigation, as per research by Toke et al., 2020 and Cronin et al., 2021. The foundation of robotics encompasses areas like locomotive, perception, cognition, and navigation : Mechanics, kinematics, dynamics, and control theory are used to address locomotive problems; Perception encompasses signal analysis, computer vision, and sensor technologies; Cognition analyses sensor data and performs actions to fulfil the objectives of the educational mobile robot; Navigation necessitates expertise in planning algorithms, information theory, and AI, as per Nourbarkhsh et al. (2004). The locomotion system is crucial in mobile robot design, influenced by factors like maneuvering, control ability, terrain conditions, efficiency, and stability, and is determined by various factors (Rubio et al., 2019; Cronin et al., 2021; Nandivale et al., 2018).

Arvin et al. (2019) studied the development of an autonomous micro-mobile robot (AMIR) for swarm robotics research and education. The study identifies the feasibility of a mobile robot for educational purposes, focusing on its design for effective material handling in mechanical workshops. Zeb et al. (2007) studied the design and development of mobile robots for radiation protection assistance. The RPAR, a three-wheeled platform and four-degree articulated mechanical arm, aids in radiation mapping, handling, and transportation of radioactive material, requiring optimal kinematics and manipulator Jacobean analysis.

Previous research, such as Tareen et al.'s (2016) research on the robust arm autonomous mobile robot highlights the importance of successful multi-disciplinary design in achieving a comprehensive view and effective methods in mechatronics design, and teaching young engineers. Sadlauer et al.'s 2013 research on Trikebot explores mechatronics design and product development, revealing that the affordable price point of physical and electronic robots is achieved for daily use. Hsiu et al. (2019) conducted a study on the design of low-cost, expressive educational robots, finding similar results but slightly different outcomes. Fig.5 Product Development Process.

The Educational Robot Attitude Scale (ERAS) is an effective tool for measuring students' attitudes towards humanoids in educational environments (Sisman et al., 2018). Other studies have used scaffolding tools to link programming content and problem-solving skills in robot programming (Purnakanishtha et al., 2014; Khamis et al., 2006) found that mobile robots can be used to create new courses or update traditional ones. Liu et al. (2008) developed multimedia teaching materials for robotic education, which were effective and achieved high student satisfaction. Previous studies on instructional material design and development agree with this review, including (Froiz-Miguez et al., 2018; Juan et al., 2013; Miller et al., 2015; Bingham et al., 2015)

At present, with the rapid development of advanced intelligent robot industry, all walks of life are using robots to replace humans in some relatively dangerous and repetitive tasks, mainly in rescue, guidance, service, and other work Yang, C., Shuliang, H., & Yong, Y. (2020). In the field of education, robots also play a very important role. An educational robot is an intelligent tool for assisting learning developed in the field of education. The use of intelligent educational robots can cultivate students' creativity, analytical ability, and imagination (Henkemans, et al. (2017). Educational robots, with their openness, intelligence, and good human-computer interaction, can significantly improve students' attention and concentration in low-grade teaching activities. They can also serve as educational companions, allowing learners to learn about robot interaction after class, embodying the concept of education (Nam, 2013). It is very unfortunate and frustrating that robotics is not given the attention it deserves in Nigeria and that the government has failed to include it in the secondary school curriculum, which has certainly limited our technological capabilities. There have been numerous attempts in the past by individuals, private companies, and cooperative agencies to help in this regard. However, these are not enough. One wonders why robotics has not been fully and formally incorporated into the Nigerian secondary school and university curricula. As far as economic and technological progress is concerned, some senior officials in the government may not believe that the introduction of such technology will have any meaningful impact.

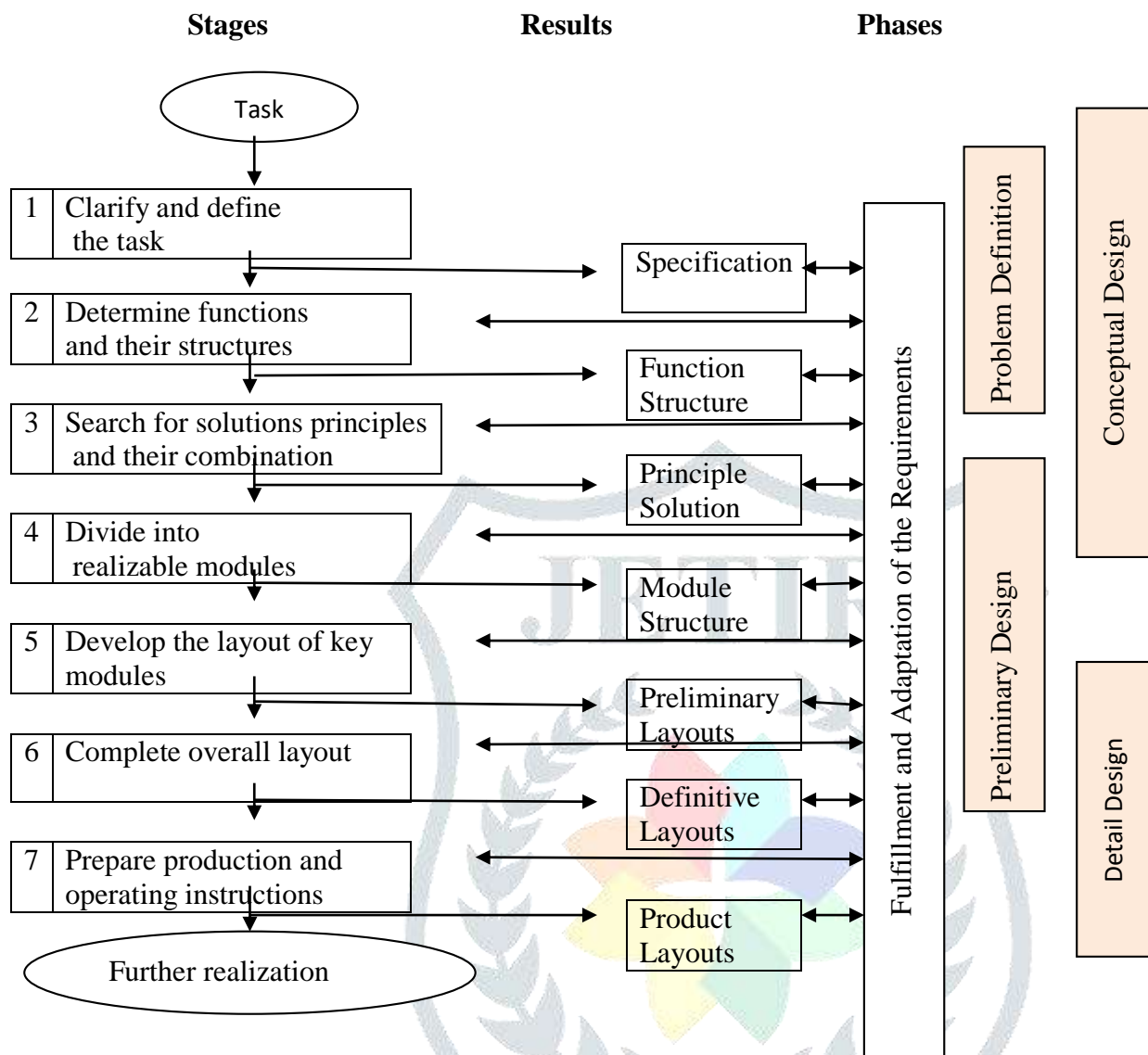


Fig.5 Product Development Process (Sadlauer, et al., 2013)

2.2 Validity of the Instructional Mobile Robot and Test Instrument

Validity refers to the extent to which exam items meet students' practical competencies, and is crucial in designing and developing effective test instruments and instructional devices (Haruna, et al., 2021). According to Nwabueze (2009), validity is the degree to which a test measures what it is designed or made to measure. An instrument with high validity will accurately measure the particular qualities it is supposed to measure (Felder et al., 2005; Shyr et al., 2011). In this review, the validation was divided into two categories, which include developing instructional mobile robots and test instruments for testing the effects of the developed instructional mobile robots. Researchers can choose between questionnaires that may have some evidence of validity and reliability (Krageloh et al., 2019). This review examines psychometric scales for understanding social acceptability in robots, considering psychometric attributes, questionnaire theoretical rationality, item development, and project project. This review examines psychometric scales for understanding social acceptability in robots, considering psychometric attributes, questionnaire theoretical rationality, item development, and project (Siddiqui et al., 2014; Platsidou et al., 2009; Kothari et al., 2004). This study will also conduct a descriptive analysis to check response distribution, including mean, frequency, correlation matrix, factor analysis, factor loading, and total Pearson product moment, using these as selection standards by Purnakamishtha et al. (2014)

2.2.1 Practical Parts of the Validation

After the design and development of the instructional mobile robot are completed, it needs to be verified and tested for reliability before it can be used in university teaching and learning material handling (Germanotta et al., 2018). This review discusses the design, development, verification, and testing of robotic systems for undergraduate students, addressing challenges in interactive architecture and verification and validation, focusing on hardware, software, and environmental interaction.

IEEE-STD-610 defines verification as a test to prove a system meets requirements at a specific stage, while validation ensures stakeholder needs are met. These activities are carried out at various stages of the development process, starting with verification activities. In the final stage, Validation actions are frequently required at the conclusion of the process to ensure that the system is providing the expected services (Yazici et al., 2021; Luckcuck et al., 2019). In this study, this study will also utilize methodologies like Model Checking, simulation-based testing, and user end validation to simulate human-robot interaction, overcoming the limitations of each technique to achieve varying levels of modeling detail (Webster et al., 2020).

Scholars argue that educational mobile robots should be autonomous, make decisions, and cooperate with people. To ensure their reliability and trustworthiness, formal verification and validation procedures will be used, as supported by various studies. This will ensure their performance meets expected standards (Matthiesen et al., 2015; Dixon et al., 2016); Agirre et al., 2020); Froiz-Miguez et al., 2018; Fisher et al., 2021). Fig.6 Framework For Collaborative of “V” and “V” of Instructional Mobile Robot.

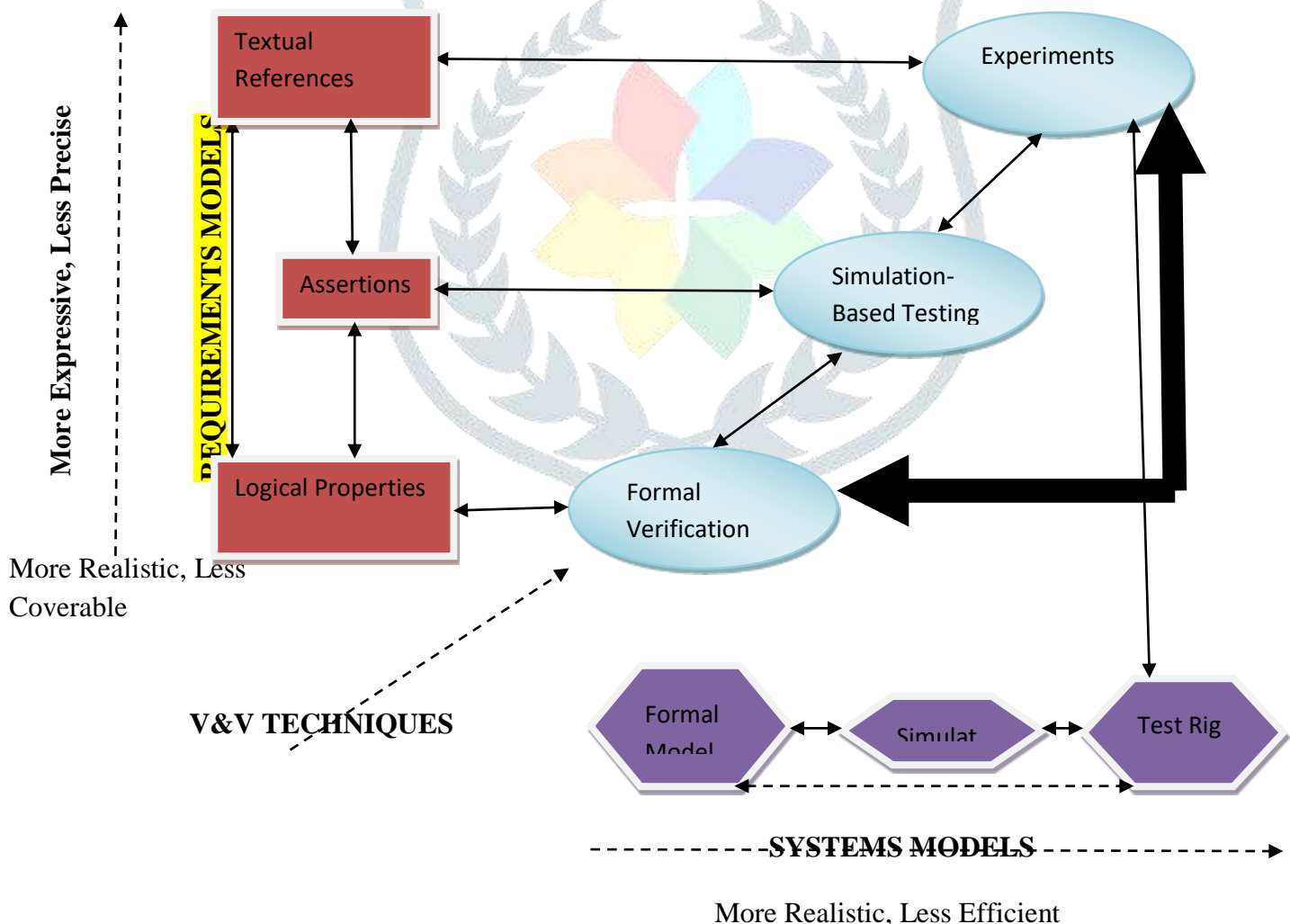


Fig.6. Framework For Collaborative of Verification and Validation of Instructional Mobile Robot

On the other hand Failure Modes and Effects Analysis, FMEA is a step-by-step method used to validate design, manufacturing, assembly processes, products, or services, pioneered by the US military in the 1940s,

identifying potential flaws and their repercussions (Ford., 2011). Researchers like (Siemens., 2016; Shrotri, et al., 2016; Sharma, et al., 2018; Mascia, et al., 2020) have emphasized the method. The process of identifying failure modes in FMEA involves the following steps as stated in the previous researches above:

Step 1: Identify potential failures and effects. The first FMEA step is to analyse functional requirements and their effects to identify all failure modes.

Example 1: Warping, electric short circuits, and fracture modes in one component can induce them in others. List all failure modes per function in technical terms, considering the ultimate effect(s) of each failure mode and noting the failure effect(s). Examples of failure effects include overheating, noise, abnormal shutdowns, and user injury.

Step 2: Determine severity. Severity is the seriousness of the consequences of failure.

Example 2: Usual practice rates failure effect severity(s) on a scale of one (1) to 10, where 1 is the lowest and 10 is the highest. The following table shows typical FMEA severity ratings and their meaning.

Table 1: Determine severity

s/no.	Rating	Meaning
1	1	No effect, no danger
2	2	Very minor—usually noticed only by discriminating or very observant users
3	3	Minor-only minor part of the system affected, noticed by average users
4	4-6	Moderate: most users are inconvenienced and/or annoyed.
5	7-8	High loss of primary functions, users are dissatisfied
6	9-10	Very high-hazardous, product becomes inoperative, customers angered. Failure constitutes a safety hazard and can cause injury or death.

Step 3: Gauge the likelihood of occurrence

Examine each failure mode and how often failure occurs. Look at similar processes or products and their documented failure modes. Examples of causes include incorrect algorithms, insufficient or excess voltage, an operating environment too hot, too humid, etc., and failure modes assigned an occurrence ranking of (0), again one to 10, as shown in Table 2.

Table 2: Gauge the likelihood of occurrence

s/no.	Rating	Meaning
1	1	No documented failures on similar products or processes
2	2-3	Low-relatively few failures
3	4-6	Moderate-some occasional failures
4	7-8	High-repeated failures
5	9-10	Very high-hazardous, product becomes incorporative, customers angered

Step 4: Failure detection

After remedial actions are determined, they should be tested for efficacy. Also, the design should be verified, and inspection procedures should be specified.

1. Engineers inspect current system controls to prevent failure mode occurrences or defect failures before they impact users or customers.
2. Identify techniques used with similar products or systems to detect failures.

The steps enable engineers to determine the likelihood of identifying or detecting failures. Then, each combination from steps one and two is assigned a detection value (D), which indicates how likely it is that failures will be detected and ranks the ability of identified actions to remedy or remove defects or detect failure. The higher the value of D, the more likely the failure will not be detected.

Table 3: Failure detection

s/no.	Rating	Meaning
1	1	A fault is certain to be caught by testing.
2	2	Faults are almost certain to be caught by testing.
3	3	High probability that tests will catch fault
4	4-6	Moderate probability that tests will catch fault
5	7-8	Low probability that tests will catch fault
6	9-10	The fault will be passed on to the user or customer unidentified.

2.3 Reliability of the Instructional Mobile Robot

Automation and robotization are replacing human jobs, particularly in repetitive, high-precision work and tasks requiring physical strain. Industrial robots perform complex tasks without tiring or becoming bored. According to a study, human operators are found to be significantly more reliable than their automated counterparts (Piotr, B., Grzegorz, G., & Adrian, K., 2020). Industrial robot reliability is a complex issue linked to safety regulations and specific robot-related difficulties, including near failure situations, hardware and software failures, singularity, and human errors (Adrian, 2018). The study further stated that safety is crucial in the workplace, as robot accidents, often fatal, are more often caused by human error than robot failure.

Similarly, Engleberger began researching robot reliability in 1974 with the publication of a summary of three million hours of labour by the first industrial robot, Unimate (Engleberger, 1974). Dhillon presents a fairly extensive study of the topic in his book, which addresses the difficulties of robot dependability and safety, including mathematical modelling of robot reliability and some examples (Dhillon, 2012). Ref. (Dhillon, 2012) provides a study of articles on robot dependability up to 2002, and the book (Dhillon, 2007). List some of the major newer works on robot reliability and related fields.

The reliability of items such as machines or robots is defined as the likelihood that they will function well for a particular period of time under specified working conditions. The general formula for calculating robot dependability is (Sharma, & Srivatava, 2018):

$$R_r(t) = \exp\left(-\int_0^t \lambda_r(t) dt\right) \dots\dots\dots (1)$$

Where:

$R_r(t)$ is the robot reliability at time t ,

$\lambda_r(t)$ is the robot failure rate.

In practice, for description of reliability, in most cases the MTTF (Mean Time to Failure) parameter is used, which is the expected value of exponentially distributed random variable with the failure rate λ_r (Sharma, & Srivatava, 2018).

$$MTTF = \int_0^\infty R_r(t) dt = \int_0^\infty e^{-\lambda_r t} dt = \frac{1}{\lambda_r} \dots\dots\dots (2)$$

In real industrial environments, the following formula can be used to estimate the average amount of productive robot time, before robot failure (Sharma, & Srivatava, 2018):

$$MTTF = \frac{PHR - DTDTRF}{NRF} \dots\dots\dots (3)$$

Where:

PHR – is the production hours of a robot,

NRF – is the number of robot failures,

DTDTRF – is the downtime due to robot failure in hours,

MTTF – is the robot mean time to failure.

In the case of repairable objects, the MTBF (Mean Time between Failures), and the MTTR (Mean Time to Repair) parameters, can be used.

$$MTBF = MTTF + MTTR \dots\dots\dots (4)$$

The reliability of the robotic system depends on the reliability of its components. The complete robotic workstation includes:

- A. Manipulation unit (robot arm),
- B. controller (computer with software),
- C. equipment (gripper, tools),
- D. workstation with workpieces and some obstacles in the robot working area,
- E. Safety system (barriers, curtains, sensors).

On the other hand, Reliability refers to an entity's ability to perform its functions under specific conditions over a specified timeframe, involving both prediction and experimental evaluations (Felder, & Spurlin, 2005). Uzoagulu (1998) argues that Kuder-Richardson formula-20 (KR20) is a more reliable measure of homogeneity due to its reliance on the availability of different paper response types by (Kothari, 2004). The project's reliability and internal consistency of the test instrument will be assessed using Kuder-Richardson formula-20 (KR20) which is a special case of coefficient α , where p_j represents the proportion of correct answers for each dichotomous item ($Y_j = 1$ and $Y_j = 0$) for item j .

However, in Fuebues et al. (2011) emphasize the dependability of measuring instruments, referring to their consistency in measuring phenomena and the design and development of the items they measure. Similarly, utilizing mobile robots for undergraduate material handling learning ensures students learn the correct method in mechanical workshops as observed by (Haruna, et al., 2021; Mang, 2018; Platsidou, et al., 2009) As a result, the instrument will undergo a pilot test with a small sample of university students to ensure reliability and internal consistency. The response will be assessed to determine its internal consistency (low-high). Therefore, the validity and reliability of the proposed method are confirmed, and its impact on students is then tested.

2.4 Effectiveness of the Developed Instructional Robot

The study will conduct an experimental study to evaluate the effectiveness of an instructional mobile robot, ensuring its validity and reliability in accordance with scientific research design. According to Haruna, et al. (2021) the experimental procedure involves a hypothesis, manipulable variables, and measurements, with data collected to support or reject the hypothesis, as illustrated in Fig. 7 Experimental Procedure

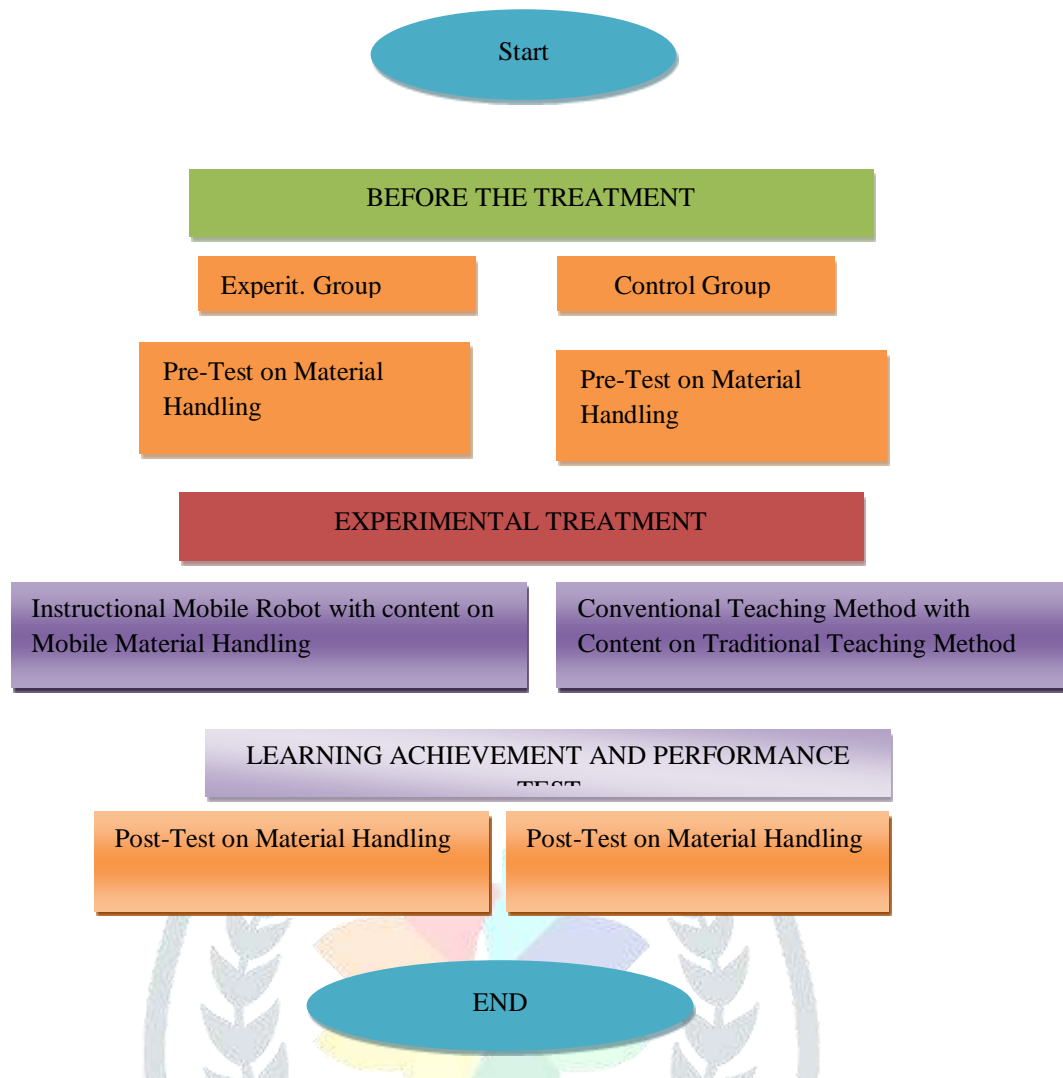


Fig. 7 Experimental Procedure

The empirical evidence of the influence of modern technological instructional devices, especially robots, also shows that students who teach with them perform better than those who teach with traditional methods. For example, Chen, et al. (2019) conducted a study on the topic of English, comparing the effects of instructional device strategies and traditional teaching methods. Their research results show that students who use an instructional device to teach perform better than students who teach using traditional methods. Similarly, other researchers found similar results, like those of (Kazakoff et al., 2012; Hsiu et al., 2019; Catlin et al., 2012; Rahman et al., 2021). In contrast, Fagin et al. (2014) and Cook et al. (2021) found that the group taught with methods performed almost similarly to that of the treatment group, where Fagin et al. (2014) observed that the factor responsible for the similar result was the lack of a simulator for robotics programming.

In the same vein, Sullivan et al. (2019) conducted a study on the Vex robot competition: gender differences in students' attitudes and experiences. A study of 675 Vex mentors and students found male students have more confidence in their technical abilities, suggesting that instructors should focus on enhancing female students' confidence in robotics construction and building. Therefore, this study is consistent with the studies of (Barker et al., 2018; Andic et al., 2015; Chin et al., 2014; Karaahmetoglu et al., 2019) but in a different instructional device, subjects, themes/topics, levels, and countries, they have the same focus. Therefore, this review differs from the above-mentioned studies in some respects but maintains a similar focus.

In addition, previous studies also proved that instructional devices, especially robots, have a significant impact on students' achievement and performance, such as (Smith et al., 2019; Finta et al., 2018; Chang et al., 2010; Anjararwati et al., 2016). Some studies have revealed the impact of integrating robots into science, technology, engineering, and mathematics (STEM) by Cheng et al. (2018).

2.5 Overview of Material Handling

A material handling system is described as the loading and unloading of automated equipment. Material handling technology is designed to minimise operator involvement and product movement (Cronin et al., 2021). Similarly, in the American Material Society Journal, as cited in Nandivale et al. (2018), "material handling functions include all types of movements: vertical handling, horizontal handling, or a combination of both of all types of fluid, semi-fluid, and discrete items, and movement of materials required for parking and storing. (Angerer et al., 2012; Shneier et al., 2015) provide criteria for using mobile robots in industrial applications, including changing environments, handling heavy weights, transporting components, offering a wide range of parts, and allowing interactive work.

Furthermore, according to the U.S. Department of Labour defines material handling as using hands for various tasks, with fingers only used for extending the hand, such as turning switches or shifting gears (Dir. et al. (2007). Dir. et al. (2007) further stated that improving the workshop can prevent injuries, energy and time waste due to physical conditions from material handling. Organizations can improve productivity, reduce workload, and reduce risk factors for musculoskeletal diseases by adjusting job requirements and employee capabilities, thereby reducing costs, absenteeism, and restraint (Ning et al., 2014; Portell et al., 2019).

Shirley et al. (2009) and Barosz et al. (2020) highlight the use of mechatronics concepts in material handling and logistics, enhancing classroom exercises, laboratory experiments, and design tasks. Katkar et al. (2015) explored obstacle-functioning material handling robots in manufacturing, highlighting their importance in non-automated industries. They highlighted the need to address issues like transportation and fatigue caused by manual material handling for efficient operations. Melo et al. (2020) and Bresher et al. (n.d.) emphasize the necessity of adaptable, user-friendly robot systems in small and medium-sized businesses for various applications and material handling tasks.

2.6 Finite Element Analysis (FEA)

Computer-aided design (CAD) is a tool that provides a computer-based engineering approach to mechanical engineering system design and stress analysis (R. Shih., 2016). The study further stated that the use of CAD programmes is becoming increasingly common in the engineering profession. A designer can use an AutoCAD programme to create a system or part and then test it using finite element analysis, stress analysis, or computer geometric modelling. Based on the AutoCAD drawings, engineering systems can subsequently be constructed utilising machining centres, lathes, mills, or prototyping machines. Autodisc's finite element analysis feature will be used to test the materials and loads on the instructional robot frame. Therefore, design-to-manufacturing cycle CAD/CAM systems aid in the automation of design and manufacturing tasks. In most manufacturing companies, the overall design of the production process is broadly similar (John, 1994) as represented in Figure 8 the design to manufacturing process.

Finite element analysis (FEA) is a method for calculating the basic stress on a designed system (R. Shih., 2016). FEA uses AutoCAD to analyze forces and moments on design, calculating displacements, strains, and stresses, revealing design flaws and safety aspects. The finite element approach (FEA) is a computational method used to generate mathematical equations for complex 3D drawings, representing complex systems or parts. As a result, the system must be split down into small pieces (the "finite elements") that can be easily calculated and solved. Finite elements can be one-dimensional, two-dimensional, or three-dimensional (Spatial, et al.2019).

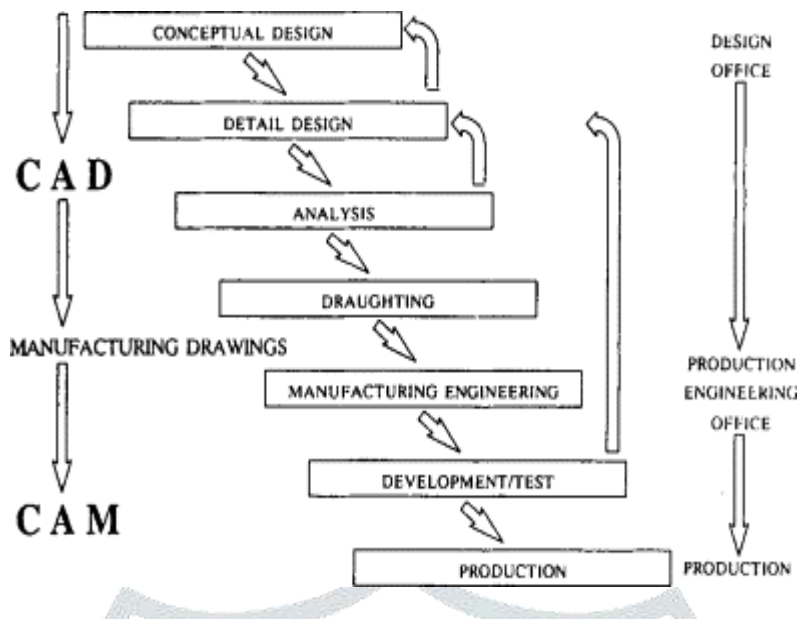


Fig.8. the Design to Manufacturing Process

3.0 Flow Chart of Present Research

Figure 9 depicts the flow chart of the current study.

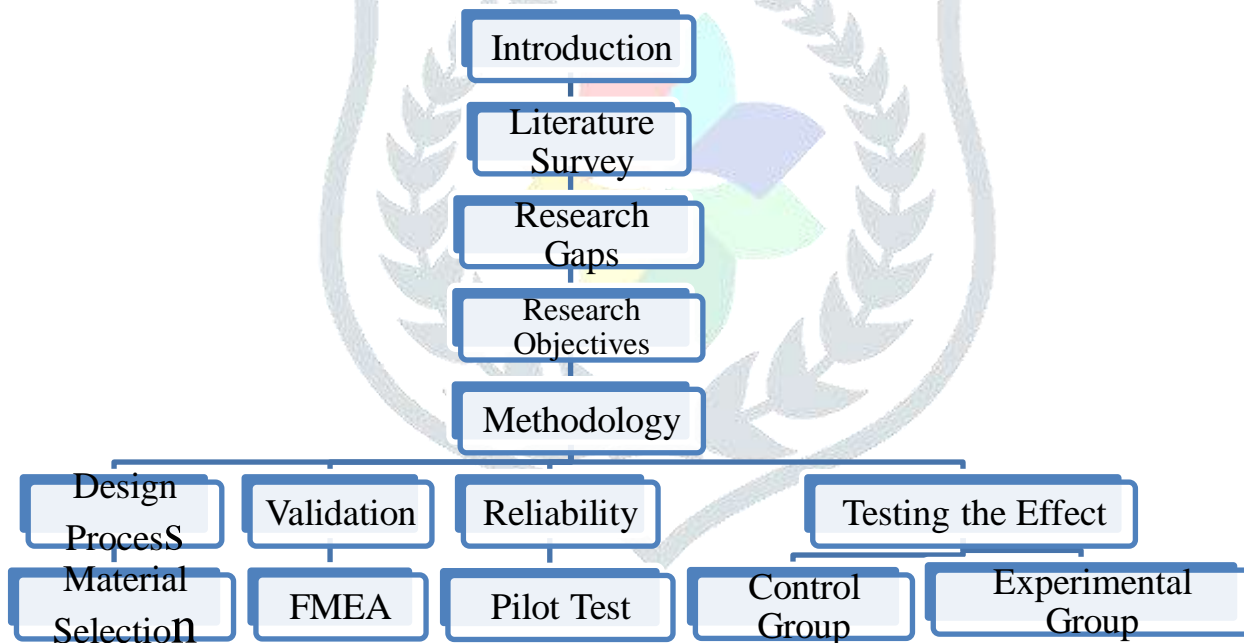


Fig.9 Flow Chart of Research

The flowchart above describes how the study will be carryout from the introductory, literature review, research gaps objectives up to methodology.

Table 4: Mapping Summary of the Review

S/No.	About the Author(s)		VARIABLES		METHODOLOGY		RESULT(S)	
	Author, Title, and Reference No.	Country	Independent Variables	Dependent Variables	Design	Statistical Tools	Findings	Gaps
1	Toke <i>et al.</i> (2020): Design and Development of a Material Handling Robot	India	Robot	Material handling	Instrumentation design	Qualitative approach	It improves efficiency, maximises space, reduces accidents, and saves money.	The researchers primarily focused on the design and development of robots, emphasizing their importance as learning tools..
2	Pásztor <i>et al.</i> (2013), Mobile Robots in Teaching Programming for IT Engineers and Their Effects	Hungary	Mobile robots in teaching programming	IT engineers and their effects	Experimental(qualitative) Constructive approach, project-based method	Mean, Standard Deviation, t-test, Cronbach alpha, Spearman-correlation	The results indicate that using mobile robots could improve the performance and attitudes of IT students.	There is a need to apply it to different fields and countries.
3	Ernest <i>et al.</i> (n.d.): Affordable Mobile Robotic Platforms for Teaching Computer Science at African Universities	African Universities	Affordable mobile robotics	Students in African universities	Experimental (qualitative)	Relative Scoring: ***=(Very Good, **=Good, *=Basic, -=Missing)	The researchers presented available and affordable mobile robotic platforms for teaching computer science in African universities.	The article emphasizes the need to focus on specific African universities and different subjects or topics in teaching computer science..
4	Khanlari (2013): Effect of Robotics on 21 st -century Skills	Canada	Robotics	Skills	Qualitative	Code-based builder software	There is improvement in students' creativity, teamwork, collaboration, self-confidence, and independence.	The study's inability to specifically examine the impact of robotics on specific grade levels underscores the need for further research..
	Haruna et al. (2020). Development and Evaluation of an Instructional Video for Teaching Sand Casting at the Technical College	Nigeria	Instructional video, sand casting	Technical college students	Instrumentation	Frequency counts, mean, and multi-stage approach	The result revealed that the sand casting instructional video was effective for teaching and learning sand casting.	The present study will look at different perspectives, such as an instructional robot, material handling, and undergraduate

	Level in Nigeria							students.
5	Lin et al. (2021): Development and Validation of Robot Patient Equipment with an Inertial Measurement Unit and Angular Position Sensors to Evaluate Transfer Skills Nurses	Tokyo	Robot patient equipment	Transfer skills, nurses	Quantitative and Qualitative (Experiment)	Mean, standard deviation, and t-test	The result reveals that most transfer steps affected the simulated patient and the robot patient, which demonstrated that the robot patient is a suitable substitute for an actual patient.	To measure the effectiveness of the learning and skill improvement of the nurses. Therefore, this present study will look into it, but with the students and material handling as a topic.
6	Sullivan et al. (2019), VEX Robotics Competition: Gender Differences in Student Attitudes and Experiences	USA	VEX Robotics Competition	Gender Differences in Student Attitudes and Experiences	(both quantitative and qualitative)	Mean, Standard Deviation, t-test,	Male students are significantly more confident in their general technical ability and their ability to put things together.	To track the mentors and students in order to gain information on retention and change over time.
7	Sisman et al. (2018). The study focuses on creating and confirming an Educational Robot Attitude Scale (ERAS) for Secondary School Students in an Interactive Learning Environment	Turkey	Educational robot attitude scale	Secondary school students, interactive learning environment	(both quantitative and qualitative)	Exploratory factor analysis (EFA), Cronbach alpha, t-test, mean, and standard deviation	The findings of the study reveal that the scale is valid, reliable, and efficient for measuring the dimensions of students attitudes towards humanoid robots in educational settings.	This study explores human-robot interaction in an educational context, considering robots as increasingly subject agents.
8	Purnakamishtha et al. (2014). Development and Validation of a Problem-Solving Skill Test in Robot Programming Using Scaffolding Tools	Thailand	Problem-solving skill test	Robot programming using scaffolding	(both quantitative and qualitative)	Kuder-Richardson Formula KR20	Their result reveals that the test can bridge the content of robot programming and problem-solving skills, and it is also useful for evaluating the skill progress of secondary school students.	The present study will look into evaluating undergraduate students using an instructional mobile robot and material handling as a topic.
Proposed study							Anticipated Outcome(s)	Gaps
Abdullahi I. Haruna(2021)		Nigeria	Instructional	Effective	Instrumentation &	Mean,	- it will improve	-lack of valid and

Design and Development of an Instructional Robot for Effective Learning Material Handling in Mechanical Workshops in North-Eastern Nigerian Universities		Robot	Learning Material Handling, Students,	Experimentation design(Both quantitative & qualitative)	Standard Deviation, t-test, Cronbach alpha, Spearman-correlation	students' academic performance, creativity, team-working and collaboration, self-confidence & independence, and social ability of undergraduates in STEM education.	reliable facilities - Overcrowded classroom - lack of qualified teachers
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4.0 Conclusion

There are discrepancies in the performance, creativity, teamwork and collaboration, self-confidence and independence, and social ability of undergraduates in STEM education all over the world, particularly in Nigeria's North-Eastern universities (Ifeyinwa, 2020). The instructive mobile robot bundle will help to bridge the gap. This study demonstrated that instructional mobile robots have the potential to boost students' performance, creativity, teamwork and collaboration, self-confidence and independence, and social ability in STEM and other related subjects. Previous studies advised, and this study anticipates, that lecturers, teachers, and instructors be trained, motivated, and encouraged to employ technological resources, particularly instructional mobile robots, in their workshops and classrooms for learning and how to integrate STEM education through instructional robot Hassan, et al., 2020).

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References

- [1] IFR. (2021). *Foreword World Robotics Industrial Robots*. Statistical Department.
- [2] Mubin, O., C. J., S., Shaheid, S., Mahmud, A., & Dong, J. J. (2013). A review of the applicability of robots in education. *Journal of Technology in Education and Learning* , Vol. 1.
- [3] Crnokic, B., Grubisic, M., & Volaric, T. (2017). Different Application of Mobile Robots in Education. *International Journal on Integrating Technology in Education*, Vol.6(3) 15-28.
- [4] Merdan, M. L. (2017). *Robotics in Education: Research and Practices for Robotics in STEM Education* . Bern: Springer.
- [5] Rubio, F., Francis, V., & Calos, L.-A. (2019). A Review of Mobile Robots: Concepts, Methods, Theoretical Framework and Application. *International Journal of Advanced Robotics Systems* , 1-2.
- [6] Surendran, A., & Mija, S. J. (2016). Sliding mode controller for robust trajectory tracking using haptic robot. *IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems*, (pp. 1-6).
- [7] Michieletto, S., Elisa, T., Enrico, P., & Emanuele, M. (2016). Teaching humanoid robotics by means of human teleoperation through RGB-D sensors. *Robotics and Autonomous Systems*, 75(671-678).
- [8] Browne, A., & Conrad, J. (n.d.). A Versatile Approach for Teaching Autonomous Robot Control to Multi-Disciplinary Undergraduate and Graduate Students. in *IEEE Access*. March 2017.
- [9] Kofinas, N., Orfanoudakis, E., & Lagoukis, M. (2015). Complete Analytical Forward and Inverse Kinematics for Nao Humanoid Robot. *Journal of Intelligent Robot System*, 77(2), 251-264.
- [10] Arvin, F., Espinosa, J., Bird, B., West, A., Watson, S., & Lennox, B. (2019). Mona: An Affordable Open-Source Mobile Robot in Education. *Journal of Intelligent & Robotic Systems*, 94:761-775.
- [11] Jajoa, E. M., Bravo, E. C., & Cortes, E. B. (2010). Tool for Experimenting with Concepts of Mobile Robotics as Applied to Children's Education. *IEEE TRANSACTIONS ON EDUCATION* , 53(1).
- [12] Chaudhary, V., Agrawal, V., Sureka, P., & Sureka, A. (2016). An experience report on teaching programming and computational thinking to elementary level children using lego robotics education kit. *IEEE Eight Internal Conference on Technology*, (pp. 38-41).
- [13] Scott, M. J., Counsell, S., Lauria, S., Swift, S., Tucker, A., Shepperd, M., et al. (2015). Enhancing Practice and Achievement in Introductory Programming with a Robot Olympics. *IEEE TRANSACTION ON EDUCATION*, 58(4), 249-254.

- [14] Wang, D., Chen, J., & Cili. (2016). Discussion of robot application laboratory construction. *International Journal of Education and Learning*, 1-12.
- [15] Alimis, D. (2010). Introducing Robots in Schools: Post-TERECOP experiences from a pilot educational program. *Proceedings of SIMPAR 2010 workshop Intl. Conference on Simulation, Modelling and Programming for Autonomous Robots*, (pp. 575-585). Darmstadt (Germany).
- [16] Kai Wang,(2023). The Effectiveness of Educational Robots in Improving Learning Outcomes: A Meta Analysis. *Sustainability*, 15(5), 4637; <https://doi.org/10.3390/su15054637>.
- [17] James McLurkin, M. I. (2013). Using Multi-Robot Systems for Engineering Education: Teaching and Outreach With Large Numbers of an Advanced, Low-Cost Robot. *24 IEEE Transactions on Education*, 22-33, Vol. 56, No.1.
- [18] Alimisis, D. (2009). *Teacher Education on Robotics-Enhanced Constructivist Pedagogical Methods*. Patras, Greece: School of Pedagogical Technological Education (ASPETE).
- [19] Khailanri, A. (2013). Effects of Robots on 21st Century Skills. *European Scientific Journal*, 9(27), 26-35.
- [20] Cronin, C., Awasthi, A., Conway, A., Riodan, D. O., & Walsh, J. (2021). Design and Development of a Material Handling System for an Automation Intelligent Vehicle for Flexible Manufacturing. *30th International Conference on Flexible Automation and Intelligent Manufacturing(FAIMA2021)* (pp. Procedia Manufacturing 51(2020) 493-500). Athens, Greece: Elsevier Ltd.
- [21] Michael, G. (2013). Robotics Intrigue Middle School Students and Build STEM Skills. *Technology and Engineering Teacher*, 72(6),12-16.
- [22] Johnson, J. (2003). Children, robotics, and education. *Artificial Life Robotics*, 7(1) 16-21.
- [23] Khanlari, A., & Kiaje, F. M. (2015). Using robotics for STEM education in primary/elementary schools: Teachers' perception. *The 10th International Conference on Computer Science & Education*. UK: Fitzwilliam College Cambridge University.
- [24] Merdan, M. L. (2017). *Robotics in Education: Research and Practices for Robotics in STEM Education*.Advances in Intelligent Systems and computing. Cham: Springer International Publishing. Switzerland. <https://doi.org/10.1007/978-3-319-42975-5>
- [25] Kim, C. Y. (2015). Robotics to promote elementary education pre-service teachers' STEM engagement, learning, and teaching. *Computer and Education*, 91(C), 14-31.
- [26] Alimisis, D., & Kynigos, C. (2009). Constructionism and robotics in education. In *Teacher Education on robotic-enhanced constructivist pedagogical methods* (pp. 11-26). School of Pedagogical and Technology Education[ASPETE] .
- [27] Atmatzidou, S., Markelis, I., & Demetriadis, S. (2008). The use of LEGO Mindstorms in elementary and secondary education: Game as a way of triggering learning. *Internal Conference on Simulation, Modelling, and Programming for Autonomous Robots*, (pp. 22-30). Venice (Italy).
- [28] Carbonaro, M., Rex, M., & Chamber, J. (2004). Using LEGO robotics in a project-based learning environment . *The Interactive Multimedia Electronic Journal of Computer-Enhanced Learning*, 6(1).
- [29] Bers, M. P. (2002). Teachers as Designers: Integrating Robotics in Early Childhood Education. *Association for Advancement of Computer in Education(AACE)*, pp. 123-145.
- [30] Bers, M. U. (2018). *Coding as a playground: Programming and Computational thinking in the early childhood classroom* . New York: NY: Routledge Press.

- [31] Umam, M. U., Budiyo, C., & Rahmawati, A. (2019). Literature review of robotics learning devices to facilitate the development of computational thinking in early childhood. *AIP Conference proceedings* 2194, 020133. AIP.
- [32] Friedman, T. L. (2008). *The World is Flat: A history of the Twenty-first Century*. NY: New York: Farrar, Straus, and Giroux.
- [33] Pasztor, A., Pap-Szegeti, R., & Torok, E. (2013). Mobile Robots in Teaching Programming for IT Engineers and its Effect. (*IJACSA*) *International Journal of Advanced Computer Science and Applications*, 4(11), 162-168.
- [34] Catlin, D., & Woolland, J. (2014). "Educational robots and computational thinking". *4th International workshop teaching robotics, teaching with robotics & 5th International Conference robotics in education*, (pp. 144-151). Padova(Italy).
- [35] Anwar, S. B. (2019). A Systematic Review of Studies on Educational Robotics. *Journal of Pre-College Engineering Education Research(J-PEER)* , 9(2), Article 2.
- [36] Felder, R. M., & Spurlin, J. (2005). Applications, Reliability and Validity of the Index of Learning Styles. *Int. J. Engng. Ed.*, Vol.21(1), 103-112.
- [37] Grimheden, M. (2006). *Mechatronics Engineering Education. Doctoral Thesis in Machine Design*. Stockholm, Sweden: School of Industrial Engineering and Management, Royal Institute of Technology .
- [38] Craig, K. (2003). The Role of Computers in Mechatronics . *Computing in Science and Engineering*, 5(2) pp. 8085.
- [39] Akonte, L. D. (2014). Mechatronics Engineering Education in the Republic of Benin: Opportunities and Challenges. *International Journal of Research in Engineering and Technology*. eISSN:2319-1163 pISSN:2321-7308, 03(03), 585-593.
- [40] Lin, W., Yueh, H.-P., & Chou, J.-j. (2014). Electronic Pet Robots for Mechatronics Engineering Education: A Project-Based Learning Approach . *International Journal of Engineering Education*, Vol.30(1) pp 221-239.
- [41] Habeeb, A. (2018). Introduction to Artificial Intelligence. *ResearchGate* , 1-8. Doi:10.13140/RG.2.2.25350.88645/1
- [42] Eguchi, A. (2014). " Robotics as a learning tool for educational transformation". *Proceedings of 4th International Workshop Teaching Robotics, Teaching with Robotics & 5th International Conferences Robotics in Education*, (pp. 27-34). Padova(Italy).
- [43] Christofi, N., Taleni, M., Holt, J., Paraskevas, L. S., & Papadopoulos, E. G. (2015). Orbital Robotics: A new Frontier in Education . *RiE2015 - Proceedings of 6th International Conference on Robotics in Education*, (pp. 20-26). Yverdon-Les-Bains, Switzerland.
- [44] Teague, D., & Paul, R. (2014). Collaborative Learning-towards a solution for novice programmers . <https://www.researchgate.net/publication/27476585> , 1-8.
- [45] Papadakis, S., Vaiopoulou, J., Eirini, S., Stamavlas, D., & Kalogiannakis, M. (2021). Attitudes towards the use of Educational Robotics: Exploring Pre-Service and In-Service Early Childhood Teacher Profiles. *Edu. Sci.* 11, 204 <https://doi.org/10.3390/educsci.11050204>.
- [46] Elkin, M., Sullivan, A., & Bers, U. M. (2018). Books, Butterflies Integrating Engineering and Robotics. In M. E. al., *Books, Butterflies and 'Bots: Integrating Engineering and Robotics into Early Childhood Curricula* (pp. 225-248). Singapore: L. English and T. Moore (eds.) , Early Learning , Early Mathematics Learning and Development .
- [47] OECD, (2016). *Innovating Education and Educating for Innovation: The Power of Digital Technologies and Skills* OECD Publishing. Paris. <http://dx.doi.org/10.1788/9789264265097-en>

- [48] Chevalier, M., Giang, C., Piatti, A., & Mondata, F. (2020). Fostering Computational Thinking THROUGH Educational Robotics: A Model for Creative Computational Problem Solving. *International Journal of STEM Education*, 7:39 1-18.
- [49] Sullivan, A., & Bers, M. U. (2019). Investigating the use of robotics to increase girls' interest in engineering during elementary school. *International Journal of Technology and Design Education*, 29:1033-1051.
- [50] H. Sanchez et al. (2019). Educational Robotics as a Teaching Tool in Higher Institutions : A bibliography analysis. *J. Phys.:Conf. Ser. 1391*, 012128, 1-5.
- [51] Sullivan, A., & Strawhacker, A. (2021). *Embedding STEAM in Early Childhood Education and Care*. Gewerbestrasse, 11,6330 Cham, Switzerland: Palgrave Macmillan Imprint.
- [52] Sophokleous, A., Christodoulou, P., Doitsidis, L., & Chatzichristofis, S. A. (2021). Computer Vision Meets Educational Robotics. *Electronics*, 10, 730. 1-24 doi.org/10.3390/electronics10060730.
- [53] Cox, A. M. (2021). Exploring the impact of artificial intelligence and robots on higher education through literature-based design fictions. *International Journal of Educational Technology in Higher Education*, 18:3 https://doi.org/10.1007/978-94-007-8654-1_23.
- [54] Gambari, A. I., Yaki, A. A., Gana, E. S., & Ughowa, Q. E. (2013). Improving Secondary School Students' Achievement and Retention in Biology Through Video-Based Multimedia Instruction . *A Journal of Scholarly Teaching*, 78-91.
- [55] Bers, M. U., Seddighin, S., & Sullivan, A. (2013). Ready for Robotics: Bringing Together the T and E of STEM in Early Childhood Teacher Education. *Jl. of Technology and Teacher Education*, 21(3) PP335-337.
- [56] Jegede, O. (2012). "Effects of Instructional Building Model on Students Performance and Interest in Technical Drawing ". *International Journal of Arts and TeCHNOLOGY Education*, 77-88.
- [57] Haruna, A. I., Yalams, Y. M., & Ali, I. (2020). Development and Evaluation of an Instructional Video for Teaching Sand Casting at Technical College level in Nigeria . *Journal of Science, Technology & Education (JOSTE)* , 250-259.
- [58] Oyo, A. A. (2010). *Evaluation of Human and Material Resources for Teaching Metalwork in Secondary Schools in Ekiti State*. Nsukka: A Master's Thesis, University of Nigeria, Nsukka .
- [59] Nafees, M., Farouq, G., & Tahirkheli, S. A. (2012). Effects on Instructional strategies on academic achievements in high school general science class. *International Journal of Business and Social Science*, 161-166.
- [60] Ernest, B. B., Hanheide, M., & Cielniak, G.(n.d) *Affordable Mobile Robotics Platforms for Teaching Computer Science at African Universities*. UK: School of Computer Science, University of Lincoln.
- [61] Bukoye, R. O. (2018). Utilization of Instruction Materials as Tools for Effective Academic Performance of Students: Implication for Counselling . *Proceedings in the 2nd Innovative and Creative Education and Teaching International Conference(ICETIC2018)* (pp. 1-7). Badajoz, Spain: Proceedings.
- [62] Toke, L. K., Avinash, S., Pawar, N., Panchal, K., & Pawar, V. (2020). Design and Development of Material Handling Robot. *International Journal of Disaster Recovery and Business Continuity* , 2110-2119.
- [63] Nandivale, A. L., Khumbhar, O. D., Kherade, A. R., Kolekar, A. V., & Hankare, S. D. (March 2018). A review on Automatic Conveyor System. *International Journal of Advance Research in Science and Engineering*, 7(1) ,949-955.
- [64] Arvin, F., Samsudin, K., & Ramli, R. A. (2009). Development of a Miniature Robot for Swarm Robotic Application . *International Journal of Computer and Electrical Engineering*, 434-442.

- [65] Zeb, J., Farooq, R., Iqbal, N., & Ahmed, N. (2007). Design and Development of Mobile Robot for Radiation Protection Assistance . *IJCSNS International Journal of Computer Science and Network Security*, vol.7(4)99-106.
- [66] Tareen, S. A. Design and Development of THE ROBUST-Autonomous Mobile . *Journal of Space Technology*, 14-23. VI(3), 2016.
- [67] Sadlauer, A., Hehenberger, P., Anzengruber, K., Kaintz, A., & Zeman, K. (2013). An Educational Concept for Mechatronics Design and Product Development. *REM-14th International Workshops on Research and Education in Mechatronics* (pp. 62-69). Vienna, Austria: Association for Supporting Automation and Robotics .
- [68] Hsiu, T., Richards, S., Bhawe, A., Perez-Berquist, A., & Nourbakish, I. (2019). *Designing a Low-cost, Expressive Educational Robot* . Pittsburgh: The Robotics Institute, Carnegie Mellon University .
- [69] Sisman, B., Gunay, D., & Kucuk, S. (2018). Development and Validation of an Educational Robot Attitude Scale (ERAS) for Secondary School Students, Interactive Learning Environment. DOI:10.1080/10494820.2018.1474234. ISSN:1049-4820 (Print) 1744-5191(Online).
- [70] Purnakamishtha, S., Suwannatthachote, P., & Nilsook, P. (2014). Development and Validation of a Problem Solving Skill Test in Robot Programming Using Scaffolding Tools. *Open Journal of Sciences*, 47-53 .
- [71] A. Khamis, F. Rodriguez, R. Barber & M.A., Salichs (2006). An Approach for Building an Innovative Educational Environment for Robotics. *International Journal of Engineering Education*, Vol.22(4) pp.732-742.
- [72] Liu, E. Z., Kou, C. H., Lin, C., Sheng, S. S., & Cheng, W. T. (2008). Developing Multimedia Instructional Material for Robotics Education. *WSEAS TRANSACTION on Communications*, Vol.7(11).
- [73] Froiz-Miguez, I., Fernandez-Carames, T. M., Fraga-Lamas, F., & Castedo, L. (2018). Design, Implementation and Practical Evaluation of IoT Home Automations System for Fog Computer Applications Based on MQTT and ZigBee-WiFi Sensor Nodes. *Sensors* 2018, 2660, 1-42, doi:10.3390/s18082 www.mdpi.com/sensors.
- [74] Juan, I. I. (2013). *Design and Implementation of an Educational Mobile Robot Platform Integrated within the WebLab-Deusto Framework*. Deusto Facultad de Ingenieria, Universidad de Deusto.
- [75] Miller, S., Berg, J. V., Frtz, M., Darrell, T., Goldberg, K., & Abbeel, P. (2015). A Geometric Approach to Robotic Laundry Folding. *International Journal of Robotics Research*, Vol.31(2) pp.249-267.
- [76] Bingham, G., Bohemia, E., Kovacevic, A., Parkinson, B., & Southee, D. (2015). Great Expectations: Design Teaching, Research, & Enterprise. *The 17th International Conference on Engineering & Product Education* (pp. 1-709). United Kingdom: The Design Society.
- [77] Haruna, A., Tafida, T., & Abdulkarim, Y. K. (2021). Validating and Testing the Reliability of the Developed Sand Casting Instructional Video Package for Effective Teaching at Technical College Level in Nigeria. *International Journal of Education and Social Research*, Vol.4(3) pp 226-280.
- [78] Felder, R. M., & Spurlin, J. (2005). Applications, Reliability and Validity of the Index of Learning Styles. *Int. J. Engng. Ed.*, Vol.21(1), 103-112.
- [79] Shyr, W.-J. (2011). Development and evaluation of mechatronics learning systems in a web-based environment . *TOJET: The Turkish Online Journal of Educational Technology*, 10(1),9-96.
- [80] Krageloh, C. U., Bharatharaji, J., Kutty, S. K., Nirmala, P. R., & Huang, L. (2019). Questionnaires to Measure Acceptability of Social Robots: A critical review . *Robotics* , 8, 88: doi:10.3390/robotics8040088 1-14.
- [81] Siddiqui, N. Y., Galloway, M. L., Geller, E. J., Green, I. C., Hur, H.-C., Langstone, K., et al. (2014). Validity and Reliability of the Robotic Objective Structured Assessment of Technical Skills. *Obstet Gynecol* 2014;123:1193-9, Level of Evidence II DOI: 10.1097/AOG.0000000000000288.

- [82] Platsidou, M., & Metallidou, P. (2009). Validation and Reliability Issues of Two Learning Style Inventories in a Greek Sample: Kolb's Learning Style Inventory and Felder & Solomon's Index Learning Styles. *International Journal of Teaching and Learning in Higher Education*, Vol.20(3), 324-335 <https://www.iset1.org/ijtlhe> ISSN 1812-9129.
- [83] Kothari, C. R. (2004). *Research Methodology: Method and Techniques (Second Revised Edition)*. New Delhi: New Age International Publishers.
- [84] Purnakamishtha, S., Suwannathachote, P., & Nilsook, P. (2014). Development and Validation of a Problem Solving Skill Test in Robot Programming Using Scaffolding Tools. *Open Journal of Sciences*, 47-53 .
- [85] Germanotta, M., Cruciani, A., Peccioli, C., Loreti, S., Spedicato, A., Meotti, M., et al. (2018). Reliability, Validity, and Discriminant Ability of the Instrumental Indices Provided by a Novel Planar Robotic Device for Upper Limb Rehabilitation. *Journal of Neuroengineering and Rehabilitation* , <https://doi.org/10.1186/s12984-018-0385-8>.
- [86] Yazici, A., Ozcan, M., & Demirci, Z. (2021). Verification and Validation Methods for Industrial Robots.
- [87] Luckcuck et al. (2019). *Formal Specification and Verification of Autonomous Robotics System*. UK: UK Research and Innovations. EP-SRC Hubs for Robotics and AI in Hazardous Environment EP/R0206092(FAIR-SPACE), EP/R026173(ORCA), and EP/R026084 RAIN.
- [89] Webster, M., Western, D., Araiza-Illan, D., Diron, C., Eder, K., Fisher, M., et al. (2020). A collaborative approach to verification and validation of human-robot teams. *The International Journal of Robotics Research*, Vol. 39(1) pp.73-99.
- [90] Matthiesen, S., Schmid, S., Klingler, S., Pinner, T., Eisenmann, M., Ludwig, J., et al. (2015). Supporting Validation Activities and Self Reflection Process in Interdisciplinary Design Teams. *International Conference on Engineering and Product Design Education 3 & 4*. Loughborough University, UK: Design School Loughborough, UK.
- [91] Dixon, C. (2016). Verification and Validation of Robotic Assistant. *High Industry Software Conference Conference (HISCONF 2016)* (pp. 1-23). UK: High Industry Software .
- [92] Agirre, et al.(2020) *Verification and Validation of Automated Systems Safety and Security*. The VALUE3S ECSEL Project.
- [93] Froiz-Miguez, I., Fernandez=Carames, T. M., Fraga-Lamas, F., & Castedo, L. (2018). Design, Implementation and Practical Evaluation of IoT Home Automations System for Fog Computer Applications Based on MQTT and ZigBee-WiFi Sensor Nodes. *Sensors* 2018, 2660, 1-42, doi:10.3390/s18082 www.mdpi.com/sensors.
- [94] Fisher, et al. (2021). An Overview of Verification and Validation Challenges for Inspection Robots. *Robotics* 2021,10, <https://doi.org/10.3390/robotics10020067>.
- [95] Ford. (2011). *Failure Mode Effects and Analysis. FMEA Handbook (with Robustness Linkages)*. Dearborn, MI: Ford Motor Company.
- [96] Siemens.(2016) *Siemens Ingenuity for Life: How to Conduct a Failure Modes and Effects Analysis(FMEA)*. USA: Siemens PLM Software www.siemens.com/plm.
- [97] Shrotri, A. P., Chitale, S., Hargude, N. V., Joshi, G. S., & Dandekar, A. R. (2016). Design Failure Mode Effect Analysis of the DFMEA. *International Journal of Current Engineering and Scientific Research (IJCESR)* , Vol. 3(1) pp 82-88 ISSN (PRINT) 2393-8374 ISSN (ON LINE) 2394-0697.

- [98] Sharma, K. D., & Srivatava, S. (2018). Failure Mode and Effect Analysis (FMEA) Implementation: A Literature review. *Journal of Advance Research in Aeronautic and Space Science* , vol.5(1&2) p1-17 Paper Reviewed Journal
- [99] Mascia, A., Cirafo, A. M., Bongiovanni, A., Colatti, G., Lacerra, G., Dicarlo, M., et al.(2020). A Failure Mode and Effect Analysis (FMEA)-Based Approach for Risk Assessment of Scientific Processes in Non-Regulated Research Laboratories. *Accreditation and Quality Assurance*, 25:311-321 <https://doi.org/10.1007/s00769-020-01441-9>. Springer.
- [100] Piotr, B., Grzegorz , G., & Adrian, K. (2020). Efficiency Analysis of Manufacturing Line with Industrial Robots and Human Operators. *Appl. Sci.*, 2862; doi:10.3390/app10082862 www.mdpi.com/journal/applsci.
- [101] Adrian, K. (2018). The Review of Reliability Factors Related to Industrial Robots. *Robot Autom Eng* , 3(5): 555624. DOI: 10.19080/RAEJ.2018.03.555624.
- [102] Engleberger, J. (1974). Three Million Hours of Robot Field Experience. . *The Industrial Robot*, 4(1): 164-168.
- [103] Dhillon, B. (2012). Introduction Kawasaki Robot Manual Pdf Copy. *University of the Philippines Diliman*, <https://isip.ovcrd.upd.edu.ph/23685/h/upload/url?PDF=kawasaki-robot-manual.pdf>.
- [104] Dhillon, B. (2007). *Applied Reliability and Quality. Fundamentals, Methods and Procedures*. New York, USA: Springer Verlag.
- [105] Felder, R. M., & Spurlin, J. (2005). Applications, Reliability and Validity of the Index of Learning Styles. *Int. J. Engng. Ed.*, Vol.21(1), 103-112.
- [106] Haruna, A., Tafida, T., & Abdulkarim, Y. K. (2021). Validating and Testing the Reliability of the Developed Sand Casting Instructional Video Package for Effective Teaching at Technical College Level in Nigeria. *International Journal of Education and Social Research*, Vol.4(3) pp 226-280.
- [107] Mang, C. S., Whitten, T. A., Cosh, M. S., Scott, S. H., Wiley, J. P., Debert, C. T., et al. (2018). Test-Retest reliability of the KINARM end-point robot for assessment of sensors, motor, and neurocognitive functions in young adult athletes. *PLOS ONE* , Plos ONE 13(4): e0196205 <https://doi.org/10.1371/journal.pone.0196205>.
- [108] Haruna, A. I., Mele, E. F., & Umar, A. T. (2021). Effectiveness of the Developed Instructional Sand Casting Instructional Video Package on Students' Achievement in Technical Colleges in Bauchi and Gombe States, Nigeria. *Journal of Science, Technology and Education*, vol.9(1)pp1-11.
- [109] Chen, C., Jones, K. T., & Xu, S. (2019). The Association Between Students' Style of Learning Preferences, Social Presence, Collaborative Learning and Learning Outcomes . *Journal of Education (Online)*, 1-16.
- [110] Kazakoff, E. R., Sullivan, A., & Bers, M. U. (2012). The Effect of a Classroom-Based Intensive Robotics and Programming Workshop on Sequencing Ability in Early Childhood. *Early Childhood Educ. J.* , pp1-11.
- [111] Catlin, D. (2012). Maximizing the Effectiveness of Educational Robotics through the Use of Assessment for Learning Methodologies. *Proceedings of 3rd International Workshop Teaching Robotics*, (pp. 2-11). (Trento) Italy.
- [112] Rahman, S. M. (2021). Assessing and Benchmarking Learning Outcomes of Robotics-Enabled STEM Education . *Edu. Sci.* , 11, 84. 1-25.
- [113] Cook, A. P. (2021). *"Effects of Robotics Instructional Methods on Computational Thinking Skills of Middle School Students"*. Boise: A PhD Dissertation, Boise State University.
- [114] Fagin, B., & Merkle, L. (2014). Measuring the Effectiveness of Robots in Teaching Computer Science. *ACM SIGSCE Bulletin* (pp. 307-311). Researchgate.

- [115] Sullivan, A., & Bers, U. M. (2019). VEX Robotics Competition: Gender Differences in Student Attitudes and Experiences. *Journal of Information Technology Education, Research*. Vol.18 , pp 97-112.
- [116] Barker, B. S., & John, A. (2018). Robotics as Means to Increase Achievement Scores in an Informal Learning Environment . *Journal of Research on Technology in Education*, 39(3), 229-243.
- [117] Andic, B., Grujicic, R., & Markus, M. M. (2015). Robotics and Its Effects on the Educational System of Montenegro. *World Journal of Education* , 39(3), 229-243.
- [118] Chin, K.-Y., Hong, Z.-W., & Chen, Y.-L. (2014). Impact of Using an Educational Robot-Based Learning System on Students' Motivation in Elementary Education . *IEEE TRANSACTIONS on Learning Technology*, Vol.7(4).
- [119] Ko, P. (2010). *"The Effect of a Middle School Robotics Class on Standardized Math Test Scores"* . Texas: A Master Thesis, Texas State University-San Marcos.
- [120] Karaahmetoglu, K. (2019). The effect of project-based arduino educational robot applications on students' computational thinking skills and their perception of basic stem skill levels. *Participatory Educational Research (PER)*, Vol. 6(2), pp.1-14 .
- [121] Finta, R., Nagy, E., & Bender, T. (2018). The Effect of diaphragm training on lumbar stabilizer muscles: a new concept for improving segmental stability in the case of low back pain . *Journal of Pain Research*, 11, 3031-3045.
- [122] Chang, C.-W., Lee, J.-H., Chao, P.-Y., Wang, C.-Y., & Chen, G.-D. (2010). Exploring the Possibility of Using Humanoid Robots as Instructional Tools for Teaching as Second Language in Primary School. *Educational Technology and Society*, 13(2), 13-24.
- [123] Smith, S. M. (2019). *" A Comparison of Computer-Based and Robotic Programming Instruction: Impact of Scratch Versus Cosmo on Middle School Students' Computational Thinking, Spatial Skills, Competency Beliefs, and Engagement"*. A Ph.D Dissertation, Kent State University College .
- [124] Anjararwati, D., Winargo, A., & Churiyah, M. (2016). Improving Learning Outcomes by Developing Instructional Media-Based Adobe Flash Professional CS 5.5 on Principles of Business Subject . *IOSR Journal of Research & Method in Education (IOSR-JRME)*, Vol. 6(5).
- [125] Cheng, Y., & Chang, C.-C. (2018). The Impact of an Integrated Robotics STEM Course with a Sailboat Topic on High School School Students Perceptions of Integrative STEM, Interest, Science and Career Orientation. *EURASIA Journal of Mathematics, Science and Technology Education*, 14(12) em1614 ISSN: 1305-8223 (online) pp1-19.
- [126] Cronin, C., Awasthi, A., Conway, A., Riodan, D. O., & Walsh, J. (2021). Design and Development of a Material Handling System for an Automation Intelligent Vehicle for Flexible Manufacturing. *30th International Conference on Flexible Automation and Intelligent Manufacturing (FAIMA2021)* (pp. Procedia Manufacturing 51(2020) 493-500). Athens, Greece: Elsevier Ltd.
- [127] Angerer, S., Strassmair, C., Staehr, M., Roetenbacher, M., & Robertson, N. M. (2012). Give me a hand-the potential of mobile assistive robots in automotive logistic and assembly applications. *In Proceedings of the IEEE International Conference on Technologies for Practical Robot Application (TEPRA2012)*, (pp. 111-116).
- [128] Shneier, M., & Bostelman, R. (2015). Literature Review of Mobile Robots for Manufacturing. *NISTIR 8022*, pp. 1-17.
- [129] DIR. (2007). *Ergonomic Guidelines for Manual Material Handling*. Cafonia: Department of Industrial Relations.

- [130] Shirley, T., Wagner, J., Colins, R., & Gramopadhye, A. (2009). *A Mechatronics (and Material Handling Systems) Course-Classroom Topics, Laboratory Experiments and Project*. American Society for Engineering Education.
- [131] Barosz, P., Golda, G., & Kampa, A. (2020). Efficiency Analysis of Manufacturing Line with Industrial Robots and Human Operators. *Appl. Sci.*, 1-15.
- [132] Katkar, S. A., Karikatti, G., & Ladawa, S. (2015). Material Handling Robot with Obstacle Detection . *International Journal of Engineering Research and Technology(IJERT)*, 4(5) pp 550-566.
- [133] Portell, M., Sene-Mir, A. M., Anguera, T. M., Johnson, G. K., & Losada, J. L. (2019). *Support System for the Assessment and Intervention During Manual Material Training at the Workplace: Contributions from the Systematic Observation*. Spain: Frontier School.
- [134] Melo, A. F., & Corneal, L. M. (2020). Case study: evaluation of the automation of material handling with mobile robots . *International Journal of Quality Innovation*, 6:3 1-14 <https://doi.org/10.1186/s40887>.
- [135] DIR. (2007). *Ergonomic Guidelines for Manual Material Handling*. Cafonia: Department of Industrial Relations.
- [136] Shirley, T., Wagner, J., Colins, R., & Gramopadhye, A. (2009). *A Mechatronics (and Material Handling Systems) Course-Classroom Topics, Laboratory Experiments and Project*. American Society for Engineering Education.
- [137] Barosz, P., Golda, G., & Kampa, A. (2020). Efficiency Analysis of Manufacturing Line with Industrial Robots and Human Operators. *Appl. Sci.*, 1-15. Research.Vol.18 , pp 97-112.
- [138] Yang, C., Shuliang, H., & Yong, Y. (2020). A Practical Teaching Mode for Colleges Supported by Artificial Intelligence. *International Journal of Emerging Technologies in Learning* , 15(17): 195-206. <https://doi.org/10.3991/ijet.v15i17.16737>.
- [139] Henkemans O. A. B., Bierman B. P. B., Janssen J., et al. (2017). Design and evaluation of a personal robot playing a self-management education game with children with diabetes type 1. *International Journal of Human-Computer Studies* , 106:63-76. <https://doi.org/10.10>.
- [140] Nam, H. W. (2013). Development of Attention Improvement Robot Education Program. *International Journal of Advancements in Computing Technology*, 5(11):491-496 <https://doi.org/10.4156/ijact>.
- [141] R. Shih, Parametric Modeling with Autodesk Inventor 2016, Mission, KS: SDC Publications, 2015.
- [142] John R. Painter, Gordon M. Mair, Trevor G. Clarkson, 5 - Computer-integrated engineering systems, Editor(s): Edward H. Smith, Mechanical Engineer's Reference Book (Twelfth Edition), Butterworth-Heinemann, 1994, Pages 5-1-5-44, ISBN 9780750611954, <https://doi.org/10.1016/B978-0-7506-1195-4.50009-9>. (<https://www.sciencedirect.com/science/article/pii/B9780750611954500099>)
- [143] Spatial Team. (2019, Nov 22,). *What is FEA (Finite Element Analysis) in CAD?* Retrieved oct. 15, 2023, from Spatial.com: <https://blog.spatial.com/what-is-fea>
- [144] Hassan, A., Faruku , A., Adi, M., & Abdul , M. (2020). Integration of Robotics into STEM Education for Facilitating Environmental Sustainability. *Solid State Technology*, 63(1s):767-783.
- [145] Ifeyinwa, N. (2020). Communicating needs for robots in a developing economy and national development : a case of Nigeria. *Open Education Journal*, URhttp://journals.openedition.org/ctd/2578 ; DOI : <https://doi.org/10.4000/ctd.2578>.