



Effectiveness of Robotics Programs in Promoting Technological Skills Among Students

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Abstract:

These studies, titled “Effectiveness of Robotics training in promoting Technological competencies amongst college students,” became performed with college students elderly 12 to 17 at NUST. A total of 35 students from this age organization participated inside the software prepared by using the analyze Bots middle at NUST university. The look at aimed to spotlight the demanding situations encountered during robotics-based activities, degree the development in students’ technological know-how earlier than and after their participation inside the program, and analyze their engagement and learning behaviors for the duration of the robotics periods. Through integrating palms-on robotics activities with interactive mastering reviews, the program provided college students with opportunities to layout, construct, and program robots collaboratively.

Keywords: *Technological abilities, Experiential studying, STEM education, palms-on learning problem-fixing, abilities Programming and gaining knowledge of consequences*

INTRODUCTION

1 Background of the Study

Educational robotics applications have come to be popular in most developed international locations and have become an increasing number of general within the developing world as well. Robotics is used to educate trouble solving, programming, design, physics, math or even music and art to college students in any respect tiers of their education. This bankruptcy provides an overview of some of the important robotics packages at the side of the robotic systems and the programming environments typically used. Like robotic systems used in studies, there is a consistent development and improve of hardware and software program – so this chapter offers a picture of the technologies getting used at this time. The chapter concludes with an evaluation of the evaluation strategies that may be used to decide if a particular robotics application is benefitting college students in the supposed ways.

Inside the context of higher education, mainly in developing countries like Pakistan, robotics education is gaining popularity as an effective technique for selling technological literacy and getting ready students for STEM-related careers. However, regardless of its capacity, the effectiveness of robotics training in developing technological talents among college students has not been drastically tested in close by contexts. This examines, consequently, targets to evaluate the effectiveness of robotics schooling in promoting technological capabilities amongst college students at the national college of sciences and generation (NUST).

Grounded in Kolb’s Experiential getting to know idea, the studies explore how robotics schooling allows college students to research through direct experience, mirrored image, and energetic experimentation—reworking theoretical expertise into realistic competence. As Hauser (2025) notes, experiential getting to know environments like robotics labs allow college students to construct confidence, follow era creatively, and increase higher-order wondering talents vital for the twenty first century.

1.2 Statement of the Problem

Despite the fact that robotics has been identified globally as a promising educational device, its implementation in Pakistani better education remains inside the early ranges. Many conventional

teaching strategies retain to prioritize theoretical education over experiential gaining knowledge of, which limits students' possibilities to increase essential technological abilities. As a result, college graduates frequently battle to apply technical expertise to actual-global issues, hindering their innovation capability and self-belief in the usage of cutting-edge technologies.

This study seeks to evaluate the effectiveness of robotics education in promoting technological abilities amongst college students. Especially, it investigates whether participation in based robotics software at NUST leads to measurable upgrades in college students' technological knowledge, trouble-fixing capacity, creativity, and teamwork.

1.3 Objectives

The specific objectives are:

1. To measure the improvement in students' technological understanding before and after participation in a robotics program.
2. To analyze students' engagement and learning behaviors during robotics-based activities.
3. To highlight the challenges of robotics activities in robotics programs.

1.4 Research Questions

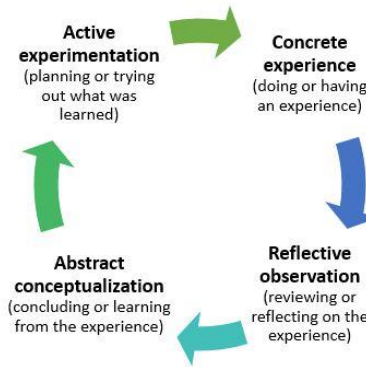
1. What degree does robotics education enhances students' technological understanding between pre-test and post-test stages?
2. What patterns of engagement and learning behaviors are observed among students during robotics-based activities?
3. What challenges students face in robotics activities?

1.5 Significance of the Study

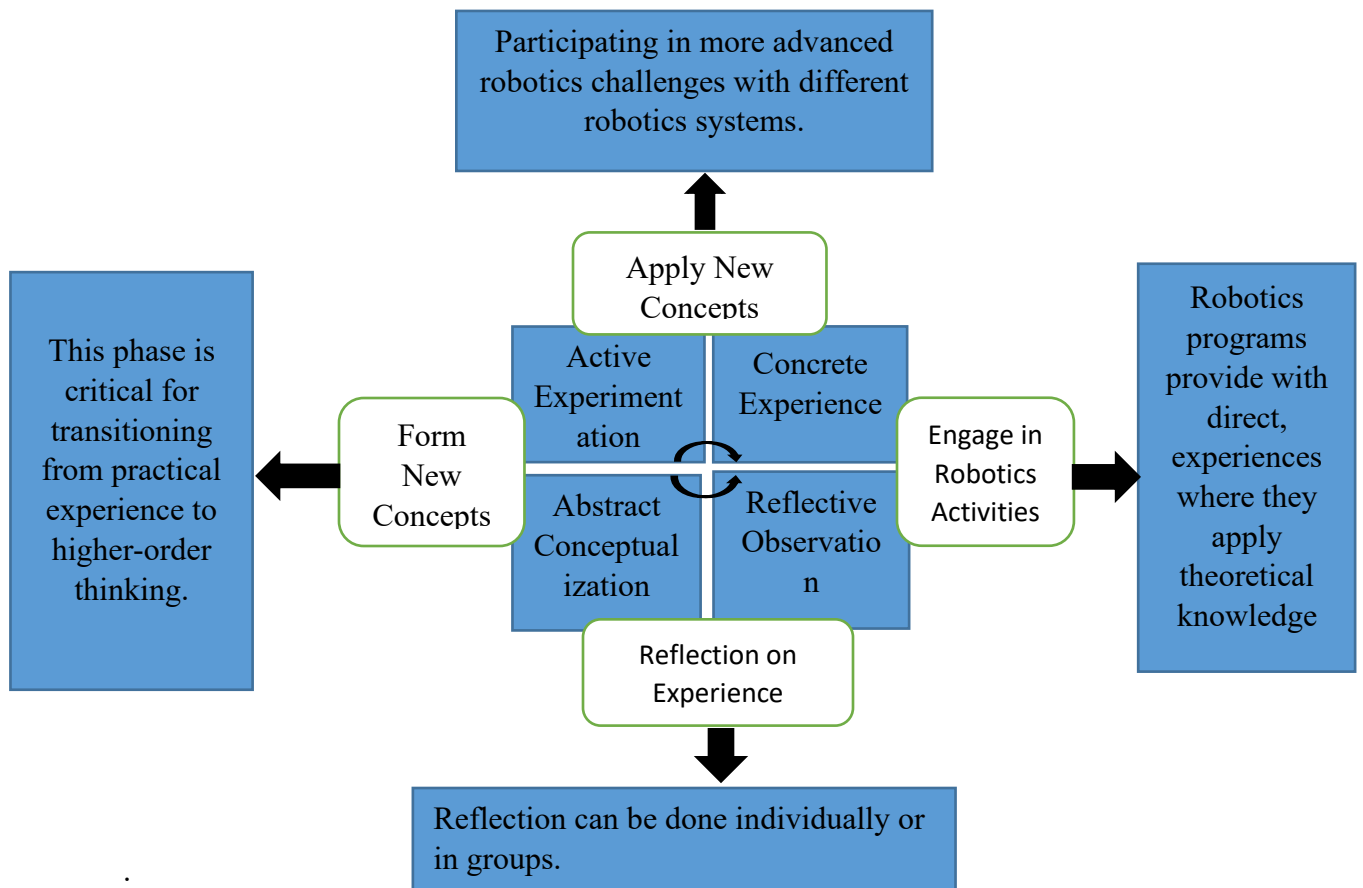
This have a look at is significant as it examines how robotics packages assist students to develop technological talents. It highlights the challenges students face, how they apply school room knowledge to actual-global robotics activities, and how they flip new thoughts into realistic answers. The findings will help to improve robotics education, making it more powerful in making ready college students for destiny careers in technology.

1.6 Theoretical Framework

Kolb's Theory of Experiential Learning emphasizes learning through experience, particularly through a cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation.



1.7 Conceptual Framework:



1.8 Delimitations of the Study

This take a look at changed into conducted on the national college of Sciences and era (NUST) that specialize in a three weeks robotics training application aimed at improving college students' technological capabilities. Individuals protected students from STEM-associated disciplines.

The observe changed into confined to:

- Quantitative information accrued thru pre- and post-tests, analyzed using SPSS.
- Qualitative facts received from day by day lecture room observations using a established checklist.
- Age institution (12 to17)

1.9 Operational definitions

Technological Skills

Technological skills on these studies denote students' potential to effectively apprehend, use, and apply technological standards including programming, automation, synthetic intelligence, and virtual design. Development in technological abilities reflects students' more desirable capacity for trouble-fixing, innovation, and digital fluency.

Experiential Learning

Experiential getting to know is described steady with Kolb's experiential studying idea as a way of acquiring information via lively participation, reflected picture, and alertness. In this look at, robotics training served as an experiential mastering platform wherein students discovered with the aid of doing constructing and programming robots, reflecting on outcomes, and experimenting with new mind to improve overall performance.

Literature review

2.1. History of Robotics Education

Robotics education emerged as a specialized field alongside the development of educational technology and STEM gaining knowledge of initiatives. During the 1960s and 1970s, early robotics education became in the main restrained to universities and technical institutes, where students studied industrial robots as part of engineering and automation courses. Education targeted on programming, mechanical design, and manipulates systems linked to production desires (Engel Berger, 1980).

The 2000s marked a primary growth of robotics schooling global. The boom of global robotics competitions along with FIRST Robotics, VEX Robotics challenges, and Robocup Junior advocated schools to integrate robotics into STEM curricula. These competitions provided possibilities for assignment-based mastering, teamwork, and real-world problem fixing (Eguchi, 2014). Robotics sports increasingly more supported gaining knowledge of in mathematics, physics, engineering design, and computer programming.

2.2. Robotics as an Education Tool

Robotics education hence promotes technological literacy by using combining bodily construction, coding, and experimentation. It encourages learners to design, take a look at, and refine robot answers to actual troubles, assisting both cognitive and sensible technological competencies essential for the twenty first century (Benitti, 2012).

Robotics training (or instructional robotics) is an educational method that uses programmable robot systems and interactive, palms-on sports to interact novices in designing, building, programming and deploying robots, with the goal of growing technical capabilities, computational questioning, problem-solving capabilities, and STEM knowledge. (Tailored from Voutyrakou & Panos, 2022; “recent Advances”, 2023).

2.3. Scholastic Robotics as a Learning Tool

Robotics amalgamation inside the coaching and gaining knowledge of drill is demarcated as the usage of robotics by means of college students as a device that complements their mastering

experience and helps the fulfillment of explicit studying desires (Eteokleous, et al.). This method is associated with the studying with processors or PCs as mindtools (Jonassen, 1999a), where computer systems and average generation is delivered as apprentices' partners within the instruction and book learning manner studying with generation calls for fit in computer systems and typical era as mindtools in the school rooms to guide positive studying.

2.4. Robotics as a Catalyst for STEM

Robotics is extensively recounted as a powerful element of STEM education, because it introduces freshmen to the intersection of clinical reasoning, mathematical modeling, and technological innovation. Bers (2010) emphasized that robotics can function a gateway to studying applied mathematical concepts, hassle-solving strategies, and the medical approach of inquiry. Similarly, Han (2013) and Kennedy et al. (2014) discovered that robots help college students create mental representations of summary concepts via bodily modeling them via robot structures.

Via hands-on engagement, college students manage coding instructions, sensors, and mechanical additives, remodeling abstract theories into tangible movements. Such stories construct both conceptual information and sensible technological talents. Robotics schooling as a consequence bridges theoretical expertise with actual international applications, improving college students' ability to layout, application, and troubleshoot systems key signs of technological literacy.

2.5. The “Skill Break”

The ostensible “potential gap” turns into a essential trouble: the dearth of labor force with obligatory skill gadgets is almost Omni gift, while the sort or degree of operative's skills is different from that required to appropriately carry out the interest (worldwide hard work organization, 2014). Regardless of the eye salaried to these marvels and all the proposed elucidations, this hole repels all energies for termination (Ogun & Ogun, 2019). Not merely methodical capabilities however moreover operatives' transferable gentle capabilities are scarce (gentle talent gap) (Kraisuth & Panjakajornsak, 2018; McNamara, 2009).

2.6. The Role of Robotics in Fostering Computational Thinking

Computational wondering is a core aspect of technological skill development and key final results of robotics education. Research shows that enticing with robotics supports computational

reasoning, algorithmic design, and abstraction, all of which are essential to modern technological proficiency (Grover & Pea, 2013; Wilensky et al., 2014).

2.7. Challenges in Integrating Robotics into Mainstream Education

In spite of developing evidence of its instructional fee, integrating robotics into mainstream school rooms provides several demanding situations. Teachers frequently lack gets right of entry to established curricular materials that align robotics sports with age-suitable studying consequences (Barr et al., 2011; Khanlari, 2016). Many to be had assets emphasize programming mechanics instead of applying robotics to interdisciplinary STEM learning or real-global trouble fixing.

For robotics education to correctly promote technological abilities, it has to be embedded within an integrative STEM framework one which connects arithmetic, technological know-how, and era thru genuine, problem-based gaining knowledge of experiences. Chang et al. (2010) and Karim et al. (2015) argue that robotics curricula designed to satisfy precise content material requirements are more likely to be followed by educators and to provide meaningful gaining knowledge of results. Integrative curricula allow students to use technological expertise to clinical inquiry, enhancing each cognitive and technical talent.

2.8. Factors Enhancing the Effectiveness of Robotics Education

A couple of studies have diagnosed unique situations that make robotics training greater effective in promoting technological talent development. Mury et al. (2022) found that sustained teacher assist and get entry to look groups like Roteco extensively elevated the adoption and high-quality of robotics classes. Teachers with ongoing training and shared sources designed richer, greater integrated sports that aligned with curricular requirements. similarly, Chevalier et al. (2022) and Shahmoradi et al. (2021) highlighted that structured school room orchestration consisting of function rotation, time making plans, and clean studying desires enhances scholar engagement and guarantees balanced participation in robotics projects.

2.9. Pair Learning in Robotics Education

Pair getting to know has emerged as a powerful academic method in robotics schooling to beautify students' technological talents and learning efficiency. Not like large group collaborations which could face challenges together with unequal participation or restricted task engagement for some

members, pair gaining knowledge of guarantees that both college students actively make contributions to the development, programming, and checking out of robots (Liu et al., 2010; Hwang & Wu, 2014).

2.10. Theoretical Framework Kolb's Experiential Learning Theory

The effectiveness of robotics education in selling technological competencies can be meaningfully understood via Kolb's Experiential gaining knowledge of principle (ELT). According to Kolb, getting to know is a continuous process whereby understanding is created through the transformation of enjoy. The model includes 4 cyclical levels Concrete revel in, Reflective statement, summary Conceptualization, and active Experimentation which together describe how newbies integrate movement and mirrored image to build expertise.

The next phase, Reflective statement, happens while students examine what worked or failed in their robot's performance. This mirrored image in my opinion or collaboratively—helps freshmen compare the reasons of mistakes, apprehend patterns, and expand metacognitive attention about their hassle-solving methods. Ching and Hsu (2023) emphasize that based reflection and peer discussion significantly fortify computational-thinking capabilities and deepen conceptual know-how.

Ultimately, in lively Experimentation, students apply new insights with the aid of remodeling or reprogramming their robots, trying out revised answers, and watching results. This iterative experimentation not only consolidates getting to know but additionally builds persistence and self-belief trends critical for technological competence (Ouyang & Xu, 2024). The cycle then restarts, promoting continuous, self-directed learning.

With the aid of following Kolb's experiential version, robotics training transforms summary technological principles into lived reviews. It encourages students to research through doing, replicate on their studies, and refine their expertise via repeated cycles of testing and development. This experiential process makes robotics a mainly effective medium for developing technological capabilities inclusive of programming, algorithmic wondering, debugging, and layout innovation. As Kolb and Kolb (2018) later reaffirmed, experiential getting to know environments that emphasize lively engagement and reflective exercise foster deeper, extra enduring skill improvement exactly the sort of results sought in twenty first-century STEM schooling.

RESEARCH METHODOLOGY

3.1. Research Design

This take a look at accompanied a blended techniques layout to observe the effectiveness of robotics education in selling technological abilities among students on the national college of Sciences and era (NUST). The investigation turned into carried out in phases quantitative and qualitative. Within the first phase, an established pre-take a look at questionnaire containing 25 items become administered to assess students' initial stages of technological understanding, creativity, and problem-fixing skills. Students then participated in a 10-day robotics application involving fingers-on sports consisting of building, programming, and trying out robots, in conjunction with designing 3-D models and engaging in collaborative STEM demanding situations.

3.1.1. Mixed Research

This method permits the researcher to research upgrades in students' technological understanding via quantitative records, while concurrently capturing their engagement, creativity, and collaborative mastering via qualitative observations. The quantitative segment employed pre- and publish-check questionnaires to measure adjustments in students' technological talents, whereas the qualitative segment concerned day by day lecture room observations to explain how students interacted, hassle-solved, and reflected during robotics-primarily based activities.

3.2. Target Population

The goal populace for this study changed into the learnbots middle in NUST University Islamabad. The 35 students selected from third age organization (12-17) years. This small group of sample represents the populace. The studies were experimental studies.

3.3 Sampling method and sampling technique

The researcher selected a random cluster sampling technique to gather the facts. The sample of this observes become college students who join in robotics software.

3.4 Instrument

The instrument was evaluation of MCQS for quantitative research whereas statement checklists were made for qualitative part. Device contained 25 questions which have been disbursed into 35 students with the aid of trainer the use of experimental have a look at.

3.4.1. Validity of Instrument

Validity stands for an instrument's capacity to measure what it changed into meant to, measure. As an end result, a tool is called "valid" if it measures what it turned into designed to measure. The validation of research device on this studies become done via

1. The expert in the field of Education, Air University, Islamabad Dr Sohaib Sultan
2. Robotics Education expert Dr Noman Naseer

3.4.2. Reliability of an instrument

An instrument which is dependable makes sure to get correct, repeatable and steady results. This can be executed thru Cranach's alpha in SPSS. Cranach's alpha (α) fee 0.80.

3.5. Data Collection

Quantitative and qualitative information were analyzed the use of wonderful but complementary strategies to make certain a complete know-how of the effectiveness of robotics training in promoting technological abilities amongst students.

For the quantitative analysis, information from pre- and post-exams have been processed the usage of SPSS software program thru a Paired sample t-check. This statistical check compared imply ratings earlier than and after the 10-day robotics application to determine whether or not there has been a great development in college students' technological information, hassle-fixing, and innovative wondering. Effects with a p-price much less than zero.05 were considered statistically great, indicating a significant change due to the robotics intervention.

DATA ANALYSIS

4.1 Quantitative analysis

Table for T- test of attention

T -Test for Attention

S.no	Statement	Mean	t	df	Significant Value
1.	What is the main purpose of this learning program?	-0.11	-2.09	34	0.044
2.	Which of the following areas is NOT a focus of this program?	-0.45	-5.35	34	0
3.	What kind of thinking does this program encourage.	-0.31	-3.51	34	0.001
4.	What age group is this program designed for.	-0.22	-2.47	34	.019
5.	What kind of technologies are students exposed to	-0.37	-4.01	34	0
6.	What is one of the key learning methods used?	-0.40	-4.27	34	0
7.	Which field deals with studying and engineering living organisms?	-0.31	-3.19	34	0.003
8.	What is 3D printing mainly used for in this context.	-0.28	-2.95	34	0.006
9.	Which of these best describes Artificial Intelligence	-0.57	-6.73	34	0
10.	How are students encouraged to share their ideas?	-0.54	-6.35	34	0

11.	Which technology helps machines make decisions like humans.	-0.54	-6.35	34	0
12.	What is one main purpose of Robotics in this program?	-0.54	-5.72	34	0
13.	What can Quantum Computing are used for.	-0.54	-5.72	34	0
14.	Which of these technologies uses living organisms to solve problems	-0.54	-5.72	34	0
15.	What does Space Tech include?	-0.34	-3.43	34	0.002
16.	What does “market research” help with	-0.31	-3.51	34	.001
17.	What is the purpose of a Minimum Viable Product (MVP)?	-0.25	-3.43	34	.002
18.	What does the Business Model Canvas (BMC) help entrepreneurs do?	-0.42	-4.54	34	0
19.	In this program, pitching is about.	-0.51	-6	34	0
20.	. What does “testing and troubleshooting” focus on?	-0.4	-3.63	34	.001
21.	. Which quality is important in a good leader	-0.42	-5.05	34	0
22.	What is one way to be a good problem solver?	-0.4	-3.63	34	.001
23.	Who is considered a change maker?	-0.54	-6.35	34	0
24.	How does the program help build character.	-0.45	-4.82	34	0
25.	What is the main focus of leadership training in this program?	-0.37	-4.01	34	0

4.2. Qualitative Analysis

Theme 1: Hands-on Engagement

This subject matter emerged strongly at some stage in Days 1 and 4, wherein college students constructed and examined the CubeSat model and designed 3-D-revealed innovations. The ones sports required energetic participation, bodily manipulation of substances, and technical experimentation. Students showed enthusiasm at the same time as assembling fashions and trying out designs, indicating that direct engagement fostered interest and patience. via arms-on robotics responsibilities, students associated theoretical STEM ideas with real-worldwide packages, constant with Kolb's experiential studying cycle.

Theme 2: Development of Technological Thinking

Technological thinking turned into maximum obtrusive all through Days 2, three, and 6, when college students designed their personal crypto currency, created a climate data dashboard, and evolved an AI fake news detector. Those sports required algorithmic reasoning, logical sequencing, and vital evaluation of technological gear. Observations confirmed that students moved from simple information to making use of computational not unusual sense, at the side of using records assessment and AI models to clear up proper issues. They mounted developing independence and precision in coding and troubleshooting.

Theme 3: Collaboration and Communication Skills

This subject matter changed into extremely well at some stage in Days 5, 7, and nine, wherein teamwork and conversation have been imperative to the space Base mission, MVP + BMC improvement, and pitching intervals. College students collaborated in companies to layout prototypes, talk strategies, and supply enterprise displays. Teachers located active feature distribution, peer remarks, and powerful teamwork throughout the ones sessions. Introvertex college students observed out to barter mind, integrate various perspectives, and speak technical facts honestly.

Theme 4: Creativity and Innovation in Technological Design

Creativity and innovation were visible inside the course of Days 4, 7, and eight, in which college students designed prototypes, constructed MVPs, and developed branding and advertising

strategies. They experimented with a couple of idea, revised their designs after remarks, and showed originality in growing sensible solutions. Observations indicated that robotics activities recommended open-ended exploration, wherein students accomplished creativity to technical challenges as opposed to following fixed commands.

Theme 5: Reflection, Confidence, and Self-Efficacy

Mirrored image and self-efficacy have been evident throughout Day 10 (From concept to impact) and at some point of debrief classes at the stop of every interest. Students mentioned what that they had observed out, recognized challenges, and related their projects to global technological issues. Many expressed pleasure in their progress, extra confidence in coding and layout, and motivation to pursue in addition technological mastering. The final presentations and peer remarks revealed a trade from initial hesitation to ownership of learning effects.

RESULTS AND DISCUSSIONS

5.1 Introduction

This bankruptcy gives the précis of the vital findings from every quantitative and qualitative analyses carried out in this examine on the Effectiveness of Robotics schooling in promoting Technological capabilities among college students at NUST. The discussion integrates these findings with preceding research and theoretical perspectives to interpret the importance of the outcomes. Ultimately, the chapter concludes with hints for educational exercise and future research guidelines.

5.2. Interpretation of Quantitative Findings

The paired t-test outcomes suggest that the post-check ratings had been notably better than pre-take a look at rankings across all 25 items ($p < 0.05$). This confirms that the robotics education program appreciably progressed students' knowledge of technological principles, innovation methods, and leadership competencies.

5.3 Interpretation of Qualitative Findings

Qualitative data were collected through daily observation using a structured checklist across the 10-day robotics program. Thematic analysis revealed five dominant themes reflecting students' experiential growth. Hands-on Engagement: Students actively participated in practical robotics activities such as CubeSat construction and 3D printing. Direct manipulation of tools increased motivation and curiosity.

5.4 Discussion of Findings

The qualitative data enrich these results by revealing *how* these skills were developed. Students learned through hands-on exploration, teamwork, and iterative reflection stages that align closely with Kolb's Experiential Learning Theory. The progression from concrete experience (building robots) to reflective observation (discussing errors) and active experimentation (revising designs) mirrors Kolb's four learning phases. This experiential process explains the observed increase in confidence, problem-solving skills, and innovation across the program.

Collectively, these results confirm that robotics education provides a multidimensional learning environment where students not only acquire technical knowledge but also develop collaboration, creativity, and self-efficacy key indicators of technological competence in the 21st century.

5.5 Conclusion

This study concludes that robotics education is a powerful and effective approach for promoting technological skills among students. Through both quantitative and qualitative evidence, the NUST robotics program demonstrated measurable improvement in students' understanding of STEM concepts. The findings affirm that experiential, hands-on robotics learning encourages active participation, reflective thinking, and creativity of effective technological education.

The ability of integrating robotics as a getting to know tool to obtain particular mastering goals in addition to expand pupil-centered surroundings is discovered. Consequently, it provides to the enormously new frame of literature associated with robotics integration as mindtools.

The study contributes to the growing body of literature supporting robotics as a catalyst for STEM engagement and as a pedagogical tool that equips students with the skills necessary for innovation and adaptability in the modern digital era.

5.6 Summary

This study set out to examine the effectiveness of robotics education in promoting technological skills among students at the National University of Sciences and Technology (NUST). The research employed a mixed-methods design, combining quantitative analysis using SPSS and qualitative observation through thematic analysis of a 10-day robotics program. Together, these methods provided a comprehensive understanding of how robotics-based program contributes to students' technological development.

5.7 Recommendations

Based on the findings and discussions, the following recommendations are proposed to enhance the integration and effectiveness of robotics education in developing technological skills among students:

1. Educational institutions need to include robotics modules across science, engineering, and technology courses to reinforce computational and design thinking as a core learning outcome rather than a co-curricular activity.
2. Robotics programs need to adopt experiential learning models such as Kolb's Learning Cycle, enabling students to learn through doing, reflecting, conceptualizing, and applying knowledge to new challenges.
3. Robotics initiatives need to design to include teamwork across STEM disciplines and even non-STEM areas such as business, design, or ethics to encourage holistic innovation and communication skills.
4. Future studies need to explore the long-term effects of robotics education on career pathways, innovation competencies, and employability in technology-driven sectors.
5. Institutions must ensure equitable access to robotics kits, software, and laboratories. Students from all socioeconomic backgrounds should have the opportunity to engage in robotics-based learning.

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