



EDUCATIONAL ROBOTICS IN THE TEACHING OF MICROPROCESSOR SYSTEMS TO ENGINEERING STUDENTS

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DOI: <https://doi.org/10.54476/ioer-imrj/939805>

ABSTRACT

This investigation developed and systematically integrated educational robotics into the pedagogical framework for teaching microprocessor systems to engineering students within Higher Educational Institutions across Pangasinan, Philippines. The research addressed a significant pedagogical gap, wherein the majority of institutions continued to employ traditional instructional methodologies centered on microprocessor trainer boards and conventional lecture-based delivery. Employing a descriptive research design, the study engaged 124 respondents, comprising 10 faculty members and 114 engineering students from four higher educational institutions in Pangasinan, Philippines. Data collection occurred through structured survey questionnaires, with subsequent analysis utilizing descriptive statistics and independent samples t-test procedures. The findings revealed that three of the four participating institutions had successfully adopted educational robotics within their microprocessor system courses. The developed educational robotics instructional material encompassed comprehensive activities for constructing mobile robots, obstacle avoidance systems, line follower robots, and diverse robotic applications utilizing Arduino microcontroller platforms. The acceptability level received classification as 'Most Highly Acceptable' from both faculty members (weighted mean = 4.56) and engineering students (weighted mean = 4.22), yielding an overall average of 4.39. Statistical analysis via t-test demonstrated no significant difference between faculty and student acceptability levels ($t = 1.742$, $p = .084$), indicating comparable perceptions across stakeholder groups. Educational robotics demonstrated substantial merit as an essential pedagogical tool for maintaining pace with technological advances in contemporary engineering education. The study advocates for broader adoption of educational robotics in microprocessor courses, regular revision and updating of instructional materials, and strategic integration into related engineering disciplines to enhance student competencies and optimize preparation for future careers in technology and engineering fields.

Keywords: Educational robotics, Microprocessor systems, Engineering education, Arduino microcontrollers, STEM education

INTRODUCTION

Robotics constitutes a multidisciplinary domain positioned at the convergence of engineering, computer science, and cognitive

sciences, encompassing the systematic design, construction, operation, and application of automated mechanical systems. Within contemporary society, robotics has transcended its traditional industrial automation origins to

P – ISSN 2651 - 7701 | E – ISSN 2651 – 771X | www.ioer-imrj.com

LOPEZ, R. M., ORTEGA, M. C. B., FELSTEAD, P. M. P., *Educational Robotics in the Teaching of Microprocessor Systems to Engineering Students*, pp. 50 - 59



become an integral component of educational systems across the globe. The integration of robotics into educational frameworks, particularly within engineering disciplines, has emerged as a transformative pedagogical approach for teaching complex technical concepts and fostering higher-order thinking skills (Zamora et al., 2025; Kaur & Singh, 2025).

Educational robotics has evolved into an accessible and engaging instructional tool for teaching science, technology, engineering, and mathematics (STEM) disciplines, alongside design principles and sophisticated problem-solving methodologies. This pedagogical approach enables students to apply theoretical knowledge within practical environments, thereby strengthening their comprehension of algorithms, mechanical design, automation systems, and control mechanisms (Shastri, 2025). The inherently hands-on nature of robotics facilitates the instantaneous application of scientific and mathematical principles, effectively bridging the gap between abstract conceptual frameworks and tangible real-world applications.

Within the Philippine educational context, higher educational institutions confront the persistent challenge of modernizing their engineering curricula to align with evolving global standards and industry requirements. While technologically advanced nations such as Japan, Singapore, and the United States have successfully integrated educational robotics into their core engineering curricula, numerous Philippine institutions continue to rely predominantly on traditional teaching methodologies utilizing microprocessor trainer boards accompanied by conventional lecture-based instruction. This disparity underscores the critical need for comprehensive curriculum enhancement and the adoption of contemporary educational technologies that better prepare students for the demands of modern engineering practice.

Microprocessor systems education represents a fundamental component of engineering programs, particularly within electronics, computer, and electrical engineering

disciplines. The Commission on Higher Education (CHED) Memorandum Orders No. 13, 24, and 34 series of 2008 establish comprehensive policies and standards for Bachelor of Science programs in Computer Engineering, Electronics Engineering, and Electrical Engineering respectively. These regulatory guidelines ensure both breadth of foundational knowledge and depth of specialized competencies in engineering education. However, the implementation of innovative teaching methodologies, such as educational robotics, remains largely at the discretion of individual institutions, resulting in considerable variability in pedagogical approaches across the higher education landscape.

Recent empirical research demonstrates that educational robotics significantly impacts student learning outcomes across multiple dimensions. Studies have consistently shown that robotics integration promotes critical thinking, advanced problem-solving abilities, creative ideation, collaborative teamwork, and comprehensive technical skills development (Martínez et al., 2023; Chatzopoulos et al., 2022). The constructivist and constructionist learning experiences facilitated by educational robotics enable students to construct knowledge actively through hands-on engagement rather than passively receiving information through traditional transmission models. This pedagogical orientation aligns with contemporary educational theories emphasizing active learning, student-centered instruction, and experiential knowledge construction.

The Arduino platform has emerged as a particularly suitable tool for educational robotics implementation due to its accessibility, affordability, and extensive community support infrastructure. Research evidence indicates that Arduino serves as an effective pedagogical bridge to more advanced embedded systems, allowing students to develop programming competencies while simultaneously working with physical hardware components (García-Tudela & Marín-Marín, 2023; Miao, 2024). The platform's open-source architecture and extensive repository of educational resources



render it ideal for diverse educational applications across various engineering disciplines and educational levels.

This study investigated the development and integration of educational robotics into microprocessor systems instruction within engineering programs in Pangasinan, Philippines. The findings offer compelling insights into the current state of adoption, the design of comprehensive instructional materials, and the degree to which educational robotics is accepted by both faculty members and engineering students. The extent to which educational robotics can bridge the gap between traditional and contemporary pedagogical approaches—and the implications for broader institutional adoption—are examined in the subsequent sections of this paper.

OBJECTIVES OF THE STUDY

This study aimed to develop and systematically integrate educational robotics into the pedagogical framework for teaching microprocessor systems to engineering students within Higher Educational Institutions across Pangasinan, Philippines. Specifically, this research sought to: (1) determine the current status of educational robotics usage in teaching microprocessor systems across selected higher educational institutions, (2) develop comprehensive educational robotics instructional material specifically designed for teaching microprocessor systems to engineering students, (3) assess the acceptability of the developed educational robotics approach among both faculty members and engineering students, (4) compare the acceptability levels between faculty members and engineering students through statistical analysis, and (5) evaluate the potential of educational robotics as an effective teaching tool for microprocessor systems within contemporary engineering education contexts.

METHODOLOGY

Research Design. This investigation employed a descriptive research design to systematically determine the acceptability of integrating educational robotics into the teaching of microprocessor systems. Descriptive research methodology provides comprehensive answers to fundamental research questions of who, what, when, where, and how, focusing on describing existing phenomena without manipulating independent variables. This design proved appropriate as the study involved systematic description, recording, analysis, and interpretation of current conditions and practices within engineering education contexts.

Respondents and Sampling. The study engaged 124 total respondents comprising 10 faculty members and 114 fourth-year engineering students from four Higher Educational Institutions across Pangasinan: Philippine College of Science and Technology (PhilCST), Pangasinan State University-Urdaneta Campus (PSU-Urdaneta), Urdaneta City University (UCU), and University of Pangasinan (UPang). Complete enumeration methodology was utilized for faculty members teaching microprocessor systems courses, while purposive sampling techniques were employed for selecting fourth-year engineering students currently enrolled in microprocessor systems courses.

Research Instruments. Two structured questionnaires were developed for data collection: one for faculty members and another for engineering students. The instruments assessed the acceptability of educational robotics across multiple dimensions including its value as a learning aid, skill development potential, practical applicability, learning activity effectiveness, software usability, future application utility, overall satisfaction, ease of use perception, and recommendation worthiness. The questionnaires utilized a five-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (5).



Data Collection Procedure. Permission was secured from institutional authorities before conducting the study. The researcher personally administered the questionnaires to ensure proper understanding and completion. Respondents were briefed on the study's objectives and assured of data confidentiality. The educational robotics instructional material was presented to participants prior to questionnaire administration to ensure informed evaluation.

Data Analysis. Descriptive statistics, specifically weighted means, were computed to determine acceptability levels. The following scale was used for interpretation: 4.21-5.00 (Strongly Agree/Most Highly Acceptable), 3.41-4.20 (Agree/Highly Acceptable), 2.61-3.40 (Uncertain/Acceptable), 1.81-2.60 (Disagree/Less Acceptable), and 1.00-1.80 (Strongly Disagree/Not Acceptable). Independent samples t-test was employed to determine significant differences between faculty and student acceptability levels at 0.05 significance level. Statistical Package for the Social Sciences (SPSS) software facilitated the data analysis process.

RESULTS AND DISCUSSION

1. Current Status of Educational Robotics Implementation

The investigation revealed that three out of four participating higher educational institutions (75%) had integrated educational robotics into their microprocessor systems curriculum. PSU-Urdaneta, UCU, and UPang had adopted robotics-based teaching methodologies, while PhilCST continued using traditional microprocessor trainer boards. This finding aligns with global trends indicating increasing adoption of educational robotics in engineering programs (Roldán-Álvarez et al., 2024). The institutions implementing educational robotics primarily utilized Arduino-based platforms due to

their accessibility, affordability, and extensive community support, consistent with research highlighting Arduino's effectiveness in STEM education (García-Tudela & Marín-Marín, 2023).

1.1 Development of Educational Robotics Instructional Material

The developed instructional material incorporated a series of progressive activities designed to teach microprocessor concepts through practical robotics applications. The curriculum framework included fundamental Arduino programming, sensor integration, actuator control, and culminated in comprehensive robot development projects. Specific applications included mobile robot construction, obstacle avoidance systems, line follower robots, object tracking robots, remote-controlled vehicles, and light-sensing robots.

The instructional design followed Rapid Application Development (RAD) principles, emphasizing iterative prototyping and hands-on learning over extensive theoretical planning. This approach proved particularly suitable for robotics education, where students benefit from immediate feedback and iterative refinement of their designs. The material incorporated constructivist and constructionist learning principles, enabling students to construct knowledge through active engagement with physical computing systems (Harel & Papert, 1991; Papert, 1980).

1.2 Acceptability of Educational Robotics

The assessments demonstrate very high acceptance levels, testifying that the use of educational robotics in microprocessor systems education is highly acceptable among instructors. The data reveals exceptionally high acceptability ratings from faculty members, with an average weighted mean of 4.56 categorized as 'Strongly Agree' or 'Most Highly Acceptable.' The highest-rated aspect was the belief that integrating robotics develops valuable skills such



as creativity, teamwork, designing, and problem-solving (WM = 4.90). This finding aligns with research indicating that educational robotics enhances transversal competencies beyond technical skills (Rebelo, 2025). Faculty members also strongly agreed that physical manipulation of three-dimensional objects facilitates conceptual understanding more effectively than traditional instruction methods (WM = 4.80). All ten items received 'Strongly Agree' ratings, indicating unanimous faculty endorsement of educational robotics as a pedagogical approach for microprocessor systems instruction.

1.3 Acceptability of Educational Robotics Assessed by Engineering Students

The results demonstrate favorable student perceptions, indicating that contemporary technological trends in education generate substantial student interest and engagement. Engineering students rated educational robotics with an average weighted mean of 4.22, categorized as 'Most Highly Acceptable.' Students particularly appreciated how robotics develops essential skills such as creativity, teamwork, and problem-solving (WM = 4.55), and recognized robots as powerful learning aids that capture imagination and interest (WM = 4.47). The data reveals strong student endorsement across most dimensions. However, slightly lower ratings for Arduino IDE software usability (WM = 4.05) and initial course difficulty perception (WM = 4.12) suggest areas requiring additional instructional support and scaffolding. These findings corroborate research showing that while students generally respond positively to educational robotics, proper pedagogical support remains essential for optimal learning outcomes (Almulla & Al-Rahmi, 2023).

1.4 Overall Acceptability of Educational Robotics

Table 1 presents the overall acceptability assessment combining both faculty and student ratings. The data demonstrates that educational robotics in microprocessor systems instruction is 'Most Highly Acceptable' across all stakeholder groups.

Table 1
Overall Acceptability of Educational Robotics

Respondents	AWM	Descriptive Equivalent
Faculty Members	4.560	Most Highly Acceptable
Engineering Students	4.225	Most Highly Acceptable
Overall	4.393	Most Highly Acceptable

The overall acceptability rating of 4.39 indicates strong endorsement from both stakeholder groups. This high acceptance rate suggests readiness for broader implementation across engineering programs. Faculty members demonstrated slightly higher acceptance (AWM = 4.56) compared to students (AWM = 4.22), though both groups rated the approach as 'Most Highly Acceptable.' The positive reception aligns with international research demonstrating educational robotics' effectiveness in enhancing student engagement, motivation, and learning outcomes in STEM education (Zamora et al., 2025; Kaur & Singh, 2025).

2. Comparative Analysis of Stakeholder Acceptability

Table 2 presents the statistical comparison of acceptability levels between faculty members and engineering students using independent samples t-test analysis.

Statistical analysis revealed no significant difference between faculty members



and engineering students regarding educational robotics acceptability ($t = 1.742$, $p = .084 > .05$).

Table 2

Difference in the Level of Acceptability between Faculty Members and Engineering Students
t-test for Equality of Means

Level of Acceptability	AWM	Mean Difference	t calc	t tabular	Sig.
Faculty	4.560	0.335	1.742	1.980	.084
Students	4.225				

Note: AWM=Average Weighted Mean

The calculated t-value of 1.742 fell below the critical value of 1.980 at the 0.05 significance level, leading to acceptance of the null hypothesis. Although faculty members demonstrated a higher average weighted mean (4.56) compared to students (4.22), the mean difference of 0.335 was not statistically significant. This finding indicates comparable perceptions between instructors and learners regarding educational robotics' value and effectiveness.

The convergence of faculty and student perspectives suggests genuine pedagogical value rather than stakeholder-specific bias. When both teaching and learning constituencies independently recognize educational innovation's worth, implementation likelihood increases substantially. This alignment creates favorable conditions for institutional adoption and sustained integration of educational robotics in engineering curricula.

Pedagogical Implications

The integration of educational robotics in microprocessor systems education represents a paradigm shift from traditional instructor-centered teaching to student-centered, experiential learning. This transition aligns with constructivist pedagogical theory, which posits that learners construct knowledge through active engagement rather than passive reception (Piaget, 1954). Educational robotics embodies this principle by enabling students to design, build, program, and test physical computing

systems, thereby transforming abstract microprocessor concepts into tangible, manipulable artifacts.

Furthermore, the hands-on nature of robotics education facilitates deeper understanding through multiple learning modalities. Visual learners benefit from observing robot behavior, kinesthetic learners engage through physical construction and manipulation, and analytical learners develop understanding through programming and troubleshooting. This multimodal approach accommodates diverse learning preferences, potentially improving educational equity and accessibility.

Recent research supports these pedagogical advantages. Studies demonstrate that robotics-based education significantly enhances computational thinking, problem-solving abilities, and creativity compared to traditional instruction methods (Wang et al., 2021; Noh & Lee, 2020). The collaborative nature of robotics projects additionally promotes teamwork and communication skills essential for professional engineering practice (Cassone et al., 2021). These competencies align with industry expectations and prepare graduates for contemporary engineering challenges.

CONCLUSIONS

Based on the research findings, the following conclusions were drawn:

The findings reveal several significant implications for microprocessor systems education in higher education institutions. Educational robotics has achieved substantial adoption among institutions in Pangasinan, with approximately 75% of surveyed institutions incorporating this pedagogical approach into their curricula. This trend aligns with broader international movements toward experiential, technology-enhanced engineering education. Institutions that continue to employ traditional instructional methods may benefit from pedagogical modernization to maintain institutional competitiveness and deliver



contemporary learning experiences that meet evolving educational standards.

The developed educational robotics instructional material presents a comprehensive pedagogical framework for teaching microprocessor concepts through progressive, hands-on learning activities. The curriculum effectively integrates theoretical knowledge with practical application, facilitating students' ability to construct functional robotic systems while simultaneously mastering fundamental microprocessor principles. This dual emphasis on conceptual understanding and technical skill development addresses critical gaps in traditional engineering education.

Furthermore, educational robotics demonstrates substantial acceptability among both faculty members and engineering students, with overall ratings characterizing the approach as "Most Highly Acceptable." This robust endorsement from primary stakeholders validates educational robotics as an efficacious pedagogical instrument for microprocessor systems instruction and suggests strong potential for sustainable implementation.

Statistical analysis reveals comparable acceptability levels between faculty and student populations, indicating genuine pedagogical value that transcends stakeholder-specific perspectives. This convergence of perspectives establishes favorable conditions for sustained implementation and institutional support, as both instructors and learners recognize the approach's educational merit.

Collectively, these findings position educational robotics as an essential instrument for modernizing engineering education, cultivating student competencies, and maintaining institutional competitiveness within an increasingly technology-driven educational landscape. Strategic integration of this pedagogical approach enables institutions to align with national and international educational standards while more effectively preparing graduates for professional engineering practice in contemporary technological environments.

RECOMMENDATIONS

Based on the study's conclusions, the following recommendations are proposed:

Higher educational institutions currently employing traditional microprocessor teaching methodologies should prioritize the systematic integration of educational robotics to enhance pedagogical effectiveness and maintain competitiveness with peer institutions. This integration requires comprehensive institutional commitment including administrative support, appropriate resource allocation, dedicated laboratory facilities, and sustained faculty development programs. Institutions should develop multi-year implementation plans that address resource requirements, faculty preparation, curriculum alignment, and assessment strategies to ensure successful, sustainable integration rather than superficial adoption.

Faculty members teaching microprocessor systems should actively incorporate the developed instructional material as supplementary support for existing curricula. The material provides structured guidance for implementing robotics-based activities while maintaining alignment with established course objectives and intended learning outcomes. Instructors should adapt the material to their specific instructional contexts, student populations, and available resources, recognizing that effective implementation may require modifications to suit local conditions. Faculty members should also participate in professional development activities to build confidence and competence in educational robotics pedagogy and technology.

Regular updating and modification of instructional materials should occur to reflect technological advances in robotics, microcontrollers, and educational best practices. Continuous improvement ensures sustained relevance and pedagogical effectiveness.

Educational robotics integration should extend beyond microprocessor systems courses to related engineering disciplines. Courses in embedded systems, automation, control



systems, and mechatronics could benefit from similar pedagogical approaches.

Institutions should explore alternative microcontroller platforms beyond Arduino, including Raspberry Pi, ESP32, and STM32 microcontrollers, to broaden students' technical knowledge and provide exposure to industry-standard tools and technologies.

Faculty development programs should provide adequate preparation time and training for effective educational robotics implementation. Instructor familiarity and confidence significantly influence pedagogical success.

Future research should investigate long-term impacts of educational robotics on student learning outcomes, retention rates, and career preparation. Longitudinal studies could provide valuable insights into sustained benefits and inform continuous improvement efforts.

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