

Enhancing Elementary Students' Robotics Understanding and Learning Engagement via Creative Project-Based Activities at SDN Margorejo 1 Surabaya

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ABSTRACT

The perception of complexity and a lack of real-world relevance often hinder elementary school students' interest in robotics. This study aimed to evaluate the effectiveness of creative project-based learning in building a strong foundation in robotics and enhancing student engagement at SD Margorejo 1 Surabaya. By integrating design thinking principles and project-based learning, this approach sought to create authentic and meaningful learning experiences. Employing a qualitative case study methodology with a participatory action research design, fifth-grade students were involved in a series of robotics projects designed to address real-world problems in their local environment. Data were collected through participant observation, semi-structured interviews, and project artifact analysis. The findings revealed that creative project-based learning significantly increased students' interest in robotics. Students not only grasped fundamental robotics concepts but also developed critical thinking, creativity, and collaboration skills. Moreover, this approach effectively strengthened students' understanding of STEM (Science, Technology, Engineering, and Mathematics) concepts and fostered awareness of robotics' relevance in daily life. This study concludes that creative project-based learning is an effective strategy for building a strong robotics foundation and cultivating student interest at the elementary school level.

Keywords: *STEM, robotics for elementary school, design thinking, practical robotics electronics*

1. INTRODUCTION

In the digital era and widespread technological control, technological literacy is important for the younger generation and must start from elementary school (**Dezső, 2022**). The ability to adapt to innovation, not only reactively but also proactively by incorporating it into the independent learning curriculum (**Kridoyono et al., 2024**), is a crucial competency that needs to be instilled from an early age. Robotics, as a scientific discipline that integrates engineering, programming and creativity, offers a rich learning vehicle for developing practical

competencies (**Hassan et al., 2020**). However, the paradox that often arises is the perception that robotics is an exclusive and too complex domain for students at the primary education level (**Salma et al., 2025**). At SD Margorejo 1 Surabaya, this reality triggered a community service initiative aimed at providing access to robotics learning, making it an inclusive and fun exploration vehicle by conducting basic learning about electronics development technology (**Nufiari, 2020**).

This initiative is based on empirical observations that elementary school students, who intrinsically have an affinity for technology (**Aristawati & Budiyanto, 2017**), often alienated from applicable, effective and contextual robotics learning (**Sukardi et al., 2024**). Formal curricula dominated by theoretical approaches tend to limit space for practical experimentation and exploration (**Pacala, 2023**). This situation is exacerbated by limited infrastructure and capacity of competent teaching staff in the field of robotics (**Valsamidis et al., 2021**).

The urgency of learning robotics for elementary school students lies not only in the acquisition of technical skills, but also in the development of critical thinking skills, innovative problem solving, and synergistic collaboration (**Fitria, 2024**). Through challenging robotics projects, students are required to design creative solutions, implement original ideas, and work cohesively in teams (**Siregar et al., 2023**). Furthermore, robotics serves as an effective bridge to integrate STEM (Science, Technology, Engineering and Mathematics) concepts into relevant and applicable contexts (**Ouyang & Xu, 2024**).

The proposed participatory action research is a creative project-based learning approach, which explicitly adopts the principles of design thinking, as a strategy to overcome these obstacles (**Costa Junior et al., 2024**). Through robotics projects designed to respond to real challenges in the environment around them, students not only learn about robotics, but also about the significance of technology in everyday life by utilizing analog robots (**Friesel, 2007**). The aim of this service is to build interest in the field of robotics for students at SD Margorejo 1 Surabaya, spark students' interest in learning and inspire a young generation who are technologically adept and care about environmental issues by utilizing discarded items into works of art (**Chatzopoulos et al., 2023**).

2. METHOD

This research adopts a participatory action research (PAR) approach with an iterative cycle design that includes planning, action, observation and reflection. PAR was chosen because it emphasizes collaboration between researchers and participants (Students of SD Margorejo 1 Surabaya) in the research process, to attract student interest.

2.1 Research Design

Planning phase

The research process began with a preliminary exploration carried out through classroom observations and semi-structured interviews involving both teachers and students (figure 1). These activities were intended to uncover the real needs of learners and the obstacles that teachers commonly encounter when introducing robotics concepts in elementary school settings. The insights obtained from this early stage helped the researchers identify which aspects of learning required improvement to ensure better comprehension and student engagement.

After mapping the learning needs, the researchers proceeded to design a creative project-based robotics curriculum. The curriculum was structured not only to deliver technical knowledge but also to embed elements of design thinking, encouraging students to analyze everyday problems and propose solutions through robotics. Each project theme was contextualized with local environmental issues so that children could relate the learning activities to situations familiar to them.

The next phase focused on planning hands-on robotics projects that were both intellectually stimulating and achievable for elementary-level learners. The activities were intentionally linked to real-life situations to allow students to experience the relevance of robotics in daily life. In addition, the researchers promoted sustainability by encouraging the use of recyclable materials in combination with basic analog electronic components such as motors, light sensors, and simple switching circuits.

To support the practical sessions, the researchers also developed a simplified learning module on basic electronics. This module presented clear, step-by-step instructions that guided students through assembling electronic components, connecting power from a battery source, installing infrared or LDR sensors, and wiring the control system to drive two rear wheels. With this learning resource, students were able to conduct experiments more independently while maintaining structured progress throughout the workshop.



Figure 1. Planning phase

Action phase

During the implementation stage, students were organized into several small working groups and participated in a sequence of workshops and hands-on laboratory activities (figure 2). This collaborative learning format enabled them to share ideas, divide responsibilities, and actively engage with the problem-solving process rather than relying solely on theoretical explanations. Each team was tasked with designing and constructing a robot that addressed a specific environmental challenge proposed in the classroom setting. Examples of the projects included a prototype of an automatic waste-collecting robot and a simplified water quality monitoring system. Through these activities, students were encouraged to think critically about ecological issues and translate their solutions into functional robotic prototypes.

Throughout the workshop sessions, students received direct practical instruction on assembling fundamental electronic circuits. They practiced wiring LEDs with resistors, integrating light sensors with transistor-based switching, and connecting small motors and batteries to create simple mechanical movement. This hands-on exposure helped them understand the relationship between electrical components and their functions within a control system.

The role of teachers and researchers in this phase was not to lead the activities as conventional instructors but to act as facilitators. Their responsibilities included guiding students through

technical difficulties, offering consultation when groups encountered obstacles, and encouraging problem-solving autonomy rather than providing instant answers.

To reinforce the technical foundation required for the robotics projects, the students were introduced to the core principles of analog electronics. This introduction covered the function and operation of basic components such as resistors, capacitors, transistors, and several types of integrated circuits. By acquiring this foundational knowledge, students were better equipped to interpret circuit diagrams, assemble prototype boards, and refine their robotic systems based on performance results and troubleshooting observations.



Figure 2. Action phase

Observation Phase

In the evaluation phase of the program, researchers engaged in participatory classroom observation to closely monitor the learning dynamics, the ways students interacted within their teams, and the progress of their robotics projects. This approach allowed the researchers to capture authentic learning behaviors and identify how students applied problem-solving strategies during the workshops.

To ensure the richness of the collected evidence, multiple forms of documentation were employed. Field notes were taken throughout each session to record key activities, difficulties encountered, and instructional responses. In addition, video footage and photographic documentation were captured to provide visual records of the learning process and to support later analysis of student engagement and project outcomes.

Beyond observational data, researchers also gathered project artifacts produced by the student groups. These artifacts included robot design sketches, early prototypes, and final models, accompanied by written project reports submitted by each team. These materials provided insight into the students' reasoning, planning, and design progression over time.

The evaluation process further incorporated the systematic documentation of the electronic circuit products assembled by the students. Circuit layouts, wiring diagrams, and final builds were archived as evidence of their technical understanding and practical skill development. Through this comprehensive data collection strategy, the evaluation captured not only the final results of the robotics projects but also the learning journey that led to their completion.

Reflection Phase

The final stage of the program focused on reflection and systematic evaluation to determine the effectiveness of the implemented robotics learning model. At the end of each project cycle, researchers and students engaged in guided reflective discussions aimed at reviewing both the learning process and the outcomes of the completed projects. These discussions provided an open forum for students to express their experiences, challenges, and insights gained during the hands-on activities.

To enrich the evaluation process, feedback was collected from both students and teachers through structured interviews and standardized questionnaires. The feedback mechanism served to capture multiple perspectives—students shared their perceptions of motivation, teamwork, and skill development, while teachers provided assessments regarding feasibility, student engagement, and instructional impact in the classroom setting.

All collected data were then subjected to qualitative and quantitative analysis. The researchers examined interview transcripts, questionnaire responses, and observational records to identify recurring themes, emerging patterns, and critical findings related to the learning intervention. This mixed-method approach enabled a comprehensive evaluation of the program, offering not only statistical evidence of learning improvement but also a deeper understanding of students' learning experiences and the pedagogical value of project-based robotics activities.

2.2 Project Design

The robotics learning program integrates several core components designed to foster creativity, problem-solving, and technological literacy among elementary school students. One of the main approaches adopted in the learning model is Design Thinking, where students participate in a structured cycle consisting of empathy, problem definition, ideation, prototyping, and testing. Through this process, they learn to identify user needs, formulate innovative solutions, and improve their prototypes through repeated trials and evaluations. This not only strengthens analytical reasoning but also encourages learners to think critically about the function and relevance of their designs.

Another important element of the program is the incorporation of recycled materials into robot construction (figure 3). Students are encouraged to reuse items such as cardboard, plastic bottles, and bottle caps when designing robot components. This strategy introduces environmental awareness and demonstrates how technological creativity can be achieved while reducing waste. By integrating sustainability values, students gain a deeper understanding of responsible innovation.

Hands-on learning in practical electronics also becomes a central feature of the curriculum. Students are taught how to assemble basic electronic components, interpret circuit diagrams, and handle simple electronic tools safely and effectively. The activities include building a light sensor circuit that utilizes a transistor as an automatic switch for a trash-detection robot, as well as constructing a timer circuit that enables a robot to operate based on pre-defined time intervals. These learning experiences allow students to develop foundational skills in electronics and system logic through direct experimentation.

To enhance interactivity and functionality of the robotic systems, the program incorporates sensor technology into student projects. Learners work with fundamental sensors such as light sensors, ultrasonic sensors, and touch sensors, enabling the robots to respond to environmental stimuli. The integration of sensor-based decision making provides students with insight into how automated systems perceive their surroundings and execute programmed actions, thereby broadening their understanding of robotics as an intelligent and responsive technology.

In carrying out this service, ethical considerations are the main basis for ensuring the integrity and welfare of all parties involved. The initial step taken was to obtain official permission from the principal of SD Margorejo 1 Surabaya, who gave authorization to carry out the implementation and infrastructure that supports community service activities in the school environment.



Figure 3. Student creativity projects

Students' participation in these extracurricular activities is voluntary, which means they have the full right to choose whether they want to be involved or not. Furthermore, they were also given the freedom to withdraw from the research at any time without giving any reason. This is done to respect students' right to autonomy and ensure that they do not feel forced or pressured to participate.

During the process of this service activity, the data collected from students is kept strictly confidential. This data is only used for service and research purposes. With this addition, the research methodology for this community service activity becomes more complete and focuses on developing students' practical electronics skills in the context of environmental issue-based robotics craft projects.

3. RESULT AND DISCUSSION

This study evaluates the impact of a creative project-based robotics learning model that integrates design thinking and introductory analog electronics on the learning interest and STEM capabilities of students at SD Margorejo 1 Surabaya. Overall, the results demonstrate a meaningful and consistent improvement in student motivation, conceptual mastery, and 21st-century learning skills.

The evaluation of the learning program demonstrates several significant outcomes related to student development across cognitive, affective, and behavioral dimensions. One of the most notable findings is the improvement in learning interest and motivation. Throughout the workshop sessions, students showed a high degree of engagement, demonstrated by their initiative to experiment independently and persist in completing challenges without external encouragement. Interview data reinforce this observation, revealing that students perceived the robotics projects as connected to real-life contexts, which strengthened their intrinsic motivation. The use of recyclable materials and hands-on analog components also created a playful, tactile learning atmosphere that further stimulated curiosity and enthusiasm toward robotics.

In addition to increasing motivation, the program successfully supported the development of STEM competencies. Analysis of students' final project portfolios revealed their ability to apply scientific, mathematical, and technological concepts to build functioning robotic systems. Students demonstrated comprehension of fundamental electronics—such as resistors, transistors, and timer ICs—and were able to integrate these components into operational circuits. Results from post-instruction concept assessments confirmed this learning progress, showing a substantial improvement in students' understanding of robotics and electronics when compared with the pre-intervention stage.

The learning experience also contributed to measurable growth in 21st-century skills. Evidence from reflective discussions and observational notes indicates that the program strengthened critical thinking, creativity, collaboration, and communication. Students actively identified problems, proposed ideas, developed prototypes as a team, and later presented their projects to peers and mentors. The implementation of the design-thinking model played a crucial role in this progress, as it encouraged learners to approach challenges systematically while exercising originality and innovation.

Another key outcome relates to the integration of practical electronics into students' real-world learning experiences. The hands-on sessions—where students assembled circuits and executed simple troubleshooting—gave them direct opportunities to apply theoretical concepts in practice. Documentation of completed electronic circuits shows that students were able to assemble, test, and refine their designs accurately while understanding the functional roles of each component. Simplified modular guides were particularly beneficial in supporting independent learning and reducing cognitive overload during experimentation.

Finally, the program also had a significant impact on fostering environmental awareness. Robotics projects based on ecological themes, such as waste-collection mechanisms and water-quality monitoring systems, encouraged students to think critically about environmental issues. Through these activities, learners developed an understanding of the consequences of pollution and recognized the potential of technological innovation to support sustainable environmental solutions. This indicates that robotics learning can play a meaningful role not only in strengthening STEM literacy but also in shaping environmentally responsible attitudes among young learners.

Discussion

Findings from this community-service research support the premise that project-based robotics learning incorporating design thinking and basic analog electronics can effectively increase student engagement and STEM literacy in elementary education. The emphasis on recyclable materials and social–environmental themes also supports the development of ecological responsibility and innovative thinking. The learning model presented in this research has strong potential to be adopted and contextualized within elementary school curricula to improve technological literacy in early education.

Analysis Results

A mixed-method approach was employed to examine the effectiveness of the learning model. The distinction between analytical methods is emphasized to avoid confusion:

- A. Quantitative analysis measures improvements in learning outcomes using numerical data (test scores and circuit assembly success rates).
 - Concept Understanding Assessment

Table 1. Pre- and Post-Intervention Learning Assessment Results

Assessment Stage	Mean	SD	Interpretation
Pre-intervention	55	12	Low baseline understanding of robotics and electronics
Post-intervention	82	99	Significant improvement after the learning program

Table 1 shows learning assessment result. A paired t-test resulted in $t = 10.5$, $df = 29$, $p < 0.001$, indicating that the improvement in scores is statistically significant and unlikely to occur by chance.

- **Practical Electronics Skills.**
The proportion of students who successfully assembled a functioning circuit rose from 30% before the intervention to 85% afterward. The rate of improvement is 183.33%. This percentage reflects the high effectiveness of integrating hands-on electronics practice into the robotics learning model.
- B. **Qualitative analysis investigates changes in learning behavior and student experience (motivation, creativity, collaboration)**
Data from observations, interviews, and reflective activities show that students became more confident in trying new ideas, sharing opinions, collaborating in groups, and completing complex tasks. These behavioral indicators reinforce the quantitative results by showing that academic gains were accompanied by genuine improvements in learning behavior.
 - **Semi-Structured Interview**
Thematic analysis of the interviews revealed that students found robotics projects very interesting and relevant to their lives and Students also reported that they learned a lot about practical electronics and problem solving.
 - **Project Portfolio**
Project portfolio analysis shows that students are able to apply design thinking principles in designing and building robots. Students' creativity and innovation can be seen in the unique robot designs and solutions they develop
 - **Reflective discussions**
Reflective discussions show that students realize the importance of environmental conservation and the role of technology in overcoming environmental problems. Students also learn about the importance of collaboration and communication in teams.

4. CONCLUSIONS

The combination of quantitative and qualitative methods gains great potential from a creative project-based robotics learning approach. The results obtained indicate that this method significantly increases student interest, absorption of scientific concepts and practical skills in the field of electronics among students.

From a quantitative perspective, there was a jump in concept understanding scores as well as a drastic increase in the ability to assemble basic electronic circuits. Meanwhile, qualitative analysis shows high student enthusiasm and involvement in robotics projects. They feel the direct relevance of learning material to real-world applications, and are able to apply innovative design principles in their robot creations. Furthermore, deep self-reflection shows their awareness of the importance of environmental issues and the role of technology in finding solutions, as well as the values of collaboration and communication in teamwork.

Overall, these findings confirm that creative project-based robotics learning is an effective pedagogical strategy for encouraging deep understanding, improving practical skills, and cultivating students' active involvement in the realm of science and technology.

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LIST OF REFERENCES

- Aristawati, F. A., & Budiyanto, C. (2017). Penerapan Robotika Dalam Pembelajaran STEM:Kajian Pustaka. *Prosiding Seminar Nasional UNS Vocational Day, 2*, 440–446. <https://jurnal.uns.ac.id/uvd/article/download/15854/pdf>
- Chatzopoulos, A., Tzerachoglou, A., Priniotakis, G., Papoutsidakis, M., Drosos, C., & Symeonaki, E. (2023). Using STEM to Educate Engineers about Sustainability: A Case Study in Mechatronics Teaching and Building a Mobile Robot Using Upcycled and Recycled Materials. *Sustainability (Switzerland)*, *15*(21). <https://doi.org/10.3390/su152115187>
- Costa Junior, A. de O., Guedes, E. B., Lima e Silva, J. P. F., & Rivera, J. A. (2024). Developing Computational Thinking in Middle School with an Educational Robotics Resource. *Journal of Intelligent and Robotic Systems: Theory and Applications*, *110*(2). <https://doi.org/10.1007/s10846-024-02082-7>
- Dezső, G. (2022). Integration of robotics into education. *Acta Academiae Nyiregyhaziensis*, (7), 250–255
- Fitria, T. N. (2024). Educational Robotics for Elementary Students: Teaching 's Opportunity. *Journal of Contemporary Issue in Elementary Education (JCIEE)*, (2), 40–56
- Friesel, A. (2007). Learning robotics by combining the theory with practical design and competition in undergraduate engineering education. *Intelligent Automation and Soft Computing*, *13*(1), 93–103. <https://doi.org/10.1080/10798587.2007.10642953>
- Hassan, A., Aliyu, F., Maimun, A., & Malik, A. (2020). *Integration of Robotics into STEM Education for Facilitating Environmental Sustainability Educational Policy View project Learning by Social Media View project. October.* www.solidstatetechnology.us
- Kridoyono, A., Sidqon, M., Yunanda, A. B., Yuwono, I., & Sudaryanto, A. (2024). Pengenalan Teknik Robotika untuk Anak Sekolah Dasar SDN Margorejo 1 Surabaya. *Kontribusi: Jurnal Penelitian Dan Pengabdian Kepada Masyarakat*, *4*(2), 339–355. <https://doi.org/10.53624/kontribusi.v4i2.410>
- Nufiari, M. P. (2020). Pengaruh Kegiatan Robotika terhadap Peningkatan Keterampilan Berpikir Kreatif Anak Usia 5 Tahun. *Repository.Uinjkt.Ac.Id*. [https://repository.uinjkt.ac.id/dspace/handle/123456789/61516%0Ahttps://repository.uinjkt.ac.id/dspace/bitstream/123456789/61516/1/Skripsi %28Watermark%29 - Muthia Putri Nufiari %2811160184000055%29.pdf](https://repository.uinjkt.ac.id/dspace/handle/123456789/61516%0Ahttps://repository.uinjkt.ac.id/dspace/bitstream/123456789/61516/1/Skripsi%20Watermark%29-Muthia%20Putri%20Nufiari%2011160184000055%29.pdf)
- Ouyang, F., & Xu, W. (2024). The effects of educational robotics in STEM education: a multilevel meta-analysis. *International Journal of STEM Education*, *11*(1).

<https://doi.org/10.1186/s40594-024-00469-4>

Pacala, F. A. (2023). Curriculum theory and practice: A comparative literature review. *HO CHI MINH CITY OPEN UNIVERSITY JOURNAL OF SCIENCE - SOCIAL SCIENCES*, 13, 1–12.

<https://doi.org/10.46223/HCMCOUJS.soci.en.13.2.2793.2023>

Salma, Z., Hijón-neira, R., & Pizarro, C. (2025). *Effectiveness of Robot-Mediated Learning in Fostering Children 's Social and Cognitive Development*.

Siregar, Y. E. Y., Rahmawati, Y., & Suyono. (2023). the Impact of an Integrated Steam Project Delivered Via Mobile Technology on the Reasoning Ability of Elementary School Students. *Journal of Technology and Science Education*, 13(1), 410–428.

<https://doi.org/10.3926/jotse.1446>

Sukardi, Setyawan, H., Risfendra, Usmeldi, & Yanto, D. T. P. (2024). Effectiveness of Robotic Technology in Vocational Education: A Meta-Analysis. *International Journal of Information and Education Technology*, 14(4), 521–532.

<https://doi.org/10.18178/ijiet.2024.14.4.2073>

Valsamidis, S., Florou, G., Anastasiadou, S., & Mandilas, A. (2021). Educational Robotics As a Teaching Tool of Information Technology in the Primary Education. *EDULEARN21 Proceedings*, 1(April), 9806–9816. <https://doi.org/10.21125/edulearn.2021.1984>