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Application of Robotics Project-Based Learning to Improve Elementary School Student's Technological Literacy

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Abstract

This research aims to analyze the effectiveness of project-based learning in increasing technological literacy in elementary school students. Activities were carried out for three months for 25 class V students at SDN Margorejo 1 Surabaya. The material includes an introduction to basic electronic components, sensors, and simple robot assembly such as line follower and obstacle avoidance. The research used a mixed-method approach with a one-group pretest-posttest design. The main instruments are a technology literacy test and a participatory observation sheet. The results showed an increase in the average score from 48.2 (pretest) to 78.4 (posttest), with the t-test results showing significance ($p < 0.05$). Qualitatively, students show high enthusiasm, increased curiosity, as well as collaborative and problem-solving abilities. These results indicate that robotics project-based learning is effective in increasing the technological literacy of elementary school-aged children and is worthy of being integrated into basic STEM learning.

I. INTRODUCTION

In the rapidly developing digital era, the ability to understand and utilize technology from an early age has become an essential requirement in basic education[1]. Technological literacy is no longer limited to the use of electronic devices alone, but rather includes an understanding of the working principles of technology, logical thinking, and the ability to solve problems systematically[2]. In the context of 21st century learning and the implementation of independent learning in Indonesia, children need to be introduced to activities that are able to stimulate critical and creative thinking through a fun approach[3]. One potential approach is the integration of simple robotics into the learning process, where students not only play, but also learn to understand how tools work, develop command logic, and evaluate experimental

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results independently[4]. By combining cognitive and affective aspects in one activity, simple robotics acts as an effective learning medium in increasing technological literacy from elementary school age[5].

Literacy culture is the lowest in Indonesia, so the development of literacy in technology requires mastery of technological literacy from an early age[6]. Technological literacy is not just the use of digital tools, but includes understanding the working principles of technology, technical problem solving and computational thinking skills[7]. At the elementary school level, technological literacy can be fostered through experience-based learning, one of which is learning simple robotics[8] .

Increasing technological literacy at the elementary school level is an important focus in the current digital era[9]. Technological literacy not only includes the ability to use digital devices, but also an understanding of the working principles of technology, computational thinking skills, and the ability to solve technology-based problems[3][10]. In the context of basic education, strengthening technological literacy needs to be carried out through a contextual, fun and applicable approach[11].

II. RELATED WORKS

One approach that is considered effective is project-based learning (PjBL). This model allows students to build knowledge through exploratory activities oriented to real products[12]. In other words, PjBL encourages students to learn by doing, strategize, collaborate, and develop solutions to given problems. In a technological context, projects oriented towards the creation of digital products or mechanical devices can provide a more meaningful learning experience[8].

Robotics as a learning medium has been proven to be able to increase student involvement, especially in aspects of logic, creativity and problem solving skills[5]. Through robotics, students can learn the basics of electronics, sensors, programming logic, and systematic thinking. The use of robotics in children's learning has shown significant improvements in students' learning motivation and cognitive abilities[13]. Apart from that, robotics is also an effective means of implementing an integrated STEM (Science, Technology, Engineering, and Mathematics) approach[14].

Several previous studies have shown that the integration of robotics in project-based learning can help elementary school students understand technological concepts more concretely[8]. However, there is still limited research that explicitly examines the impact of simple, project-based robotics learning on technological literacy at the elementary school level within a systematic training period[11][15].

Based on this background, this research aims to analyze the impact of simple robotics project-based learning on increasing elementary school students' technological literacy. It is hoped that this research can provide an empirical contribution to the development of technology learning models that are applicable and appropriate for children's ages.

Robotics has the potential as a learning medium that is able to integrate aspects of science, technology, engineering and mathematics (STEM). However, there are still limited studies that specifically examine how simple project-based robotics learning can increase elementary school students' technological literacy[16].

The application of robotics project-based learning can increase the technological literacy of elementary school students because with students' interest in responding to seeing an electronic device working as the device operates[17], students will dig into the product datasheet that makes up the electronics so that indirectly students will read and reason about how the electronic device works and then respond to it[18].

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III. METHODS

3.1 Research Approach and Design

This research uses a mixed method approach that combines quantitative and qualitative data to gain a more comprehensive understanding of the impact of robotics project-based learning on elementary school students' technological literacy. The quantitative design used is a pre-experiment with one-group pretest-posttest type, which aims to measure changes in students' technological literacy abilities before and after participating in the learning intervention. Meanwhile, a qualitative approach is used

to capture the dynamics of the learning process, student perceptions, as well as non-cognitive aspects that cannot be explained numerically.

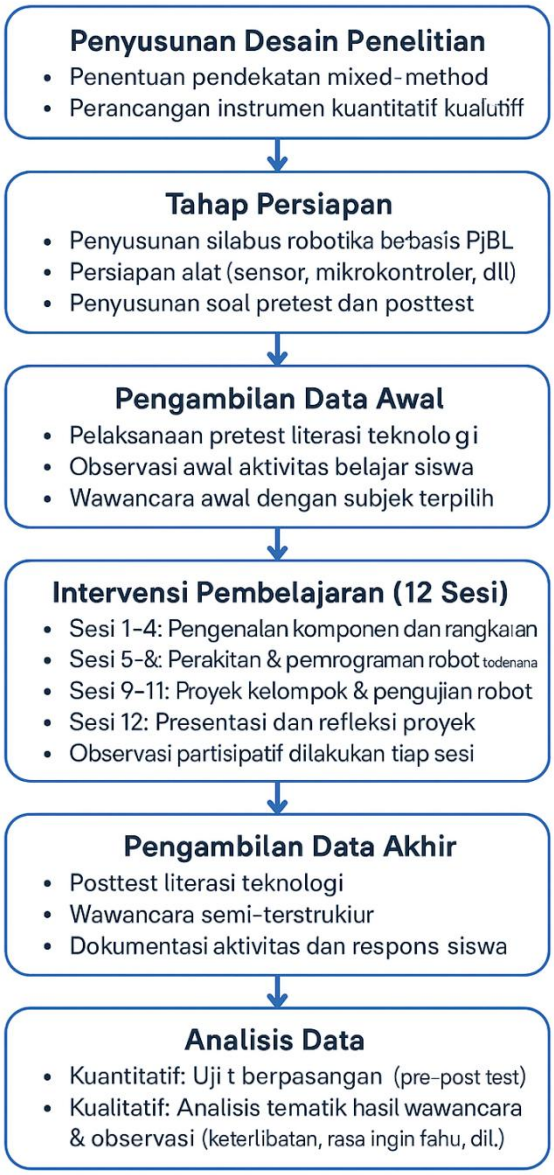

Figure 1. research method flow diagram

Figure 1 show the flow of research, how the practical electronic robotic can be increase literation and can make student more interested to explore theory with literation.

3.2 Research Subjects and Locations

The research was carried out at SDN Margorejo 1 Surabaya with subjects as many as 25 class V students who actively participated in the entire series of simple robotics learning activities. This activity lasted for three months with a total of 12 meeting sessions, each lasting 90 minutes. Subject selection is carried out purposively based on availability and active involvement of students in the program.

3.3 Research stages

The research activity flow model is designed in five main stages as follows:

a. Preparation
- Preparation of a simple robotics learning syllabus using a project-based approach (PjBL).
- Development of a technology literacy pretest-posttest instrument based on basic digital literacy indicators for children.
- Preparation of tools and materials such as microcontrollers, sensors, motors, breadboards and robot line tracer modules.

b. Pretest
- Implementation of a pre-test to measure students' level of technological literacy before intervention.
- Initial data collection through classroom observations and initial interviews with several students as a baseline for learning behavior.

c. Learning Intervention
- Learning activities were carried out over 12 meetings, which included:
  1. Introduction to the basics of electronics and robotics components.
  2. Practice assembling simple robot circuits and modules[19].
  3. Implementation of simple programming logic (drag-and-drop or visual blocks).
  4. Making group line follower and obstacle avoidance robot projects.
  5. Presentation and testing of project work results.

  Each meeting is accompanied by observations of the learning process and field notes.

d. Posttest and Interview
- Implementation of the final test (posttest) uses the same instrument to measure increased technological literacy.
- Semi-structured interviews were conducted with student representatives to explore their experiences while participating in activities.

e. Data analysis
- Quantitative data from the pretest and posttest were analyzed using a paired sample t-test to see the significance of differences in scores.
- Qualitative data from observations and interviews are analyzed thematically, identifying emerging patterns in students' learning behavior, emotional responses, and development of understanding.

3.4 Research Instrument

The research instrument consists of:
- Technology literacy test, in the form of multiple choice questions and short essays based on indicators of the ability to recognize, understand and use technology responsibly.
- Participatory observation sheet, which records student involvement in learning activities, teamwork, persistence and creativity.
- Semi-structured interview guide, which explores student perceptions of the process and benefits of learning robotics.

IV. RESULTS AND DISCUSSIONS

The results of measurements of students' technological literacy levels before and after the learning intervention showed a significant increase. The average pretest score achieved by students was 48.2 with a standard deviation of 7.6. After participating in a series of project-based robotics learning activities, the average posttest score increased to 78.4 with a standard deviation of 6.8. Thus, there is a difference in increasing the average score of 30.2 points.

Table 1. Descriptive statistics and t-test of students' technological literacy pretest and posttest scores

Statistik	Pretest	Posttest	Δ Skor
Mean	48,2	78,4	+30,2
Std Dev	7,6	6,8	-

To ascertain whether the difference is statistically significant, a paired sample t-test was carried out. The test results produced a significance value of $p = 0.000$ ($p < 0.05$), which indicates that the increase in scores between the pretest and posttest is statistically significant. This means that learning interventions through a project-based approach actually have a positive impact on elementary school students' technological literacy abilities.

Figure 2. Discussion for problem solving functionality robot component

In figure 2 shows that when the experiment project fail they take the act of restudy and discuss with their friend through manual book or datasheet of the component

Quantitative Results: Increased Technological Literacy

The results of the pretest and posttest analysis show that the project-based robotics learning intervention has a significant positive impact on the technological literacy of elementary school students. The average pretest score obtained by students was 48.2 with a standard deviation of 7.6, while the posttest score increased substantially to 78.4 with a standard deviation of 6.8. An average increase of 30.2 points indicates a positive change in students' ability to understand and apply basic technology concepts.

o test the significance of this increase, a paired sample t-test was carried out. The results of statistical analysis show a p-value of 0.000 ($p < 0.05$), which indicates that the difference between pretest and posttest scores is statistically significant. These findings support the hypothesis that project-based learning that integrates robotics practicum activities can increase technological literacy effectively.

This change is in line with previous research by Nugroho et al. (2021), which states that active involvement in technology projects can accelerate the development of computational thinking skills and technological understanding among elementary age students. Apart from that, this increase also indicates that the hands-on approach has a key role in building digital competencies that are more contextual and applicable.

Qualitative Outcomes: Non-Cognitive Dynamics of Learning and Development

Qualitative findings obtained through participant observation and semi-structured interviews reveal interesting learning dynamics. During the intervention process, most students showed active involvement, high enthusiasm, and strong curiosity, especially when they succeeded in assembling a circuit or testing their robot work. Debugging activities when a project does not go according to plan are actually an important moment in cultivating perseverance and problem solving skills.

Interviews with some students show that they feel more confident in understanding how technology works. One student stated: "At first I didn't know what a sensor was, but now I can explain to other friends how a robot can follow a line." This expression reflects a shift from passive understanding to active and applied understanding.

Furthermore, the collaborative aspect has also developed significantly. Students learn to share tasks, respect friends' opinions, and resolve conflicts through negotiation when dividing roles in a team. This skill is an important indicator of broader technological literacy, as stated by Ananiadou and Claro (2009) that 21st century literacy does not only include technical aspects, but also social-cognitive aspects such as cooperation, communication and creativity.

Integration of Findings: Convergence of Quantitative and Qualitative Data

The convergence between quantitative and qualitative data strengthens the internal validity of this research. The increase in quantitative scores does not only stand alone, but is reinforced by in-depth qualitative narratives regarding the transformation of student learning behavior. In other words, the increase in scores is not the result of superficial intervention, but rather a manifestation of students' active involvement in the comprehensive learning process.

The thematic patterns that emerged from interviews and observations—such as increased persistence, curiosity, and collaborative abilities—make it clear that learning robotics with a project approach not only has an impact on the cognitive domain, but also on affective and social aspects. These findings are in line with the principles of constructivist pedagogy, where meaning is constructed through direct experience and social interaction.

V. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of quantitative and qualitative analysis, it can be concluded that simple robotics learning with a project-based approach (Project-Based Learning) has a significant impact on increasing the technological literacy of elementary school students. This is proven by an increase in the average technology literacy score from 48.2 (pretest) to 78.4 (posttest), with an average difference of 30.2 points. The paired t-test shows a significance value of $p = 0.000$ ($p < 0.05$), which indicates that the increase is statistically significant.

Qualitative findings also strengthen the quantitative results, where students show active involvement, high enthusiasm, and increased conceptual understanding of technology, especially in understanding the function of robotic components and simple programming logic. The process of debugging and group work also helps develop students' collaborative attitudes, perseverance and problem-solving skills.

Thus, project-based robotics learning is not only effective in improving cognitive abilities related to technological literacy, but is also able to foster non-cognitive aspects that are important in 21st century

learning. This program is worthy of being recommended as part of an innovative STEM learning curriculum at the elementary school level.

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