IJIE (Indonesian Journal of Informatics Education)

Research Paper ISSN: 2549-0389

The Application of Arduino-Based Line Follower Robotics Technology as a Tool to Enhance Students' Self-Efficacy

[*1]Slamet Kurniawan Fahrurozi, [1]Muhammad Hassan Massaty, [2]Cucuk Wawan Budiyanto, [3,4]Bayu Sutanto

[1]Information Technology, Nest Polytechnic, Indonesia

[2]Informatics and Computer Engineering Education, Sebelas Maret University, Indonesia

[3]Department of Mechanical Engineering, Politeknik Negeri Semarang, Indonesia

[4]Department of Mechanical and Aerospace Engineering, University of Manchester, United Kingdom

Corresponding Email: skfahrurozi@politekniknest.ac.id

Abstract:

This study evaluates the effectiveness of the Robotics Self-Efficacy Test (RSE-Test) in measuring students' confidence in key robotics tasks, including assembly, programming, and control. By using robotics as a learning medium, the research enhances student engagement and practical skills while addressing the need for precise self-efficacy measurement tools in robotics education. Data collection involved a 10-item RSE-Test questionnaire completed by 30 students engaged in robotics activities. The responses were analyzed using descriptive statistics, including mean scores and standard deviations, along with reliability tests such as item-total correlations and Cronbach's Alpha. Pearson correlation analysis was also conducted to examine relationships between test items.. The overall mean score was 3.9835, indicating high confidence, with a pooled standard deviation of 0.687, showing minimal variation. The pooled Standard Error of the Mean was 0.128, reflecting high precision in estimating the overall mean. Cronbach's Alpha of 0.810 confirms the test's strong internal consistency, and item-total correlations ranged from 0.423 to 0.703, supporting the reliability of the RSE-Test. Pearson correlation analysis revealed significant relationships between items, further validating the tool. Results indicate high self-efficacy in basic robotics tasks, although students showed slightly lower confidence in more advanced tasks, suggesting areas for further support. This study validates the RSE-Test as an effective tool for measuring self-efficacy in technical education, emphasizing the role of foundational skills in building student confidence. The findings provide valuable insights for curriculum developers, suggesting the need for targeted support in advanced robotics tasks.

Keywords: *robotics education, robotics self-efficacy, self-efficacy, student confidence*

IJIE (Indonesian Journal of Informatics Education)
Vol 8 Issue 2 2024
DOI: http://dx.doi.org/10.20961/ijie.v8i2.97994
Received: 10/01/25 Revised: 06/03/25 Accepted: 06/03/25 Online: 23/03/25

Introduction

In the era of the Fourth Industrial Revolution, robotics technology has become an essential element in various sectors, including education (Fonna, 2019). As automation and intelligent systems become more prevalent, integrating robotics into educational curricula equips students with essential skills to navigate and contribute to this evolving landscape (Adel, 2024). The integration of robotics into the educational curriculum aims to prepare the younger generation with relevant skills and the ability to adapt to the rapidly advancing technology (Ilori & Ajagunna, 2020; Peea et al., 2024). As robotics education expands, its implementation in vocational training becomes increasingly relevant, particularly in equipping students with hands-on technical skills. One such application is the microcontroller automation program based on Arduino, as implemented at SMK Negeri 1 Kaliwungu. In this program, students learn to build a line-following robot, which is a robot that can autonomously follow a specific path. Through this learning, students are expected to develop analytical skills, programming abilities, and creativity in designing technical solutions (Budiyanto et al., 2023; Christi & Rajiman, 2023; Fricticarani et al., 2023).

Arduino-based robotics education not only enhances technical skills but also plays a crucial role in developing students' self-efficacy—the belief in their ability to complete tasks and achieve goals (Bandura, 2006; Massaty et al., 2020; Tsai et al., 2021). Strong self-efficacy helps students stay motivated, confident, and persistent in overcoming challenges (Massaty et al., 2024). In vocational education, where students are expected to be independent and take initiative (Deprez et al., 2021; Schunk & DiBenedetto, 2022), self-efficacy becomes even more critical. Specifically, in Arduino-based robotics learning, students need confidence in assembling circuits, understanding microcontrollers, and programming robots (Petrovič, 2022). Many students, particularly those new to robotics, struggle with these tasks, making self-efficacy a key factor in their learning success. A structured learning approach that provides step-by-step guidance can help reduce fear and hesitation, enabling students to engage more actively and persistently in problem-solving. Research has shown that high self-efficacy positively impacts academic achievement (Latikka et al., 2019), motivation (Robinson et al., 2020), and perseverance in technical learning (Ananda & Wandini, 2022). In the context of robotics, students with strong self-efficacy are more likely to tackle complex projects with enthusiasm and resilience, as they believe in their ability to solve programming and circuit-related challenges.

The implementation of robotics learning at SMK Negeri 1 Kaliwungu serves as a teaching model that not only enhances technical skills but also fosters students' self-efficacy and character development. Increased self-efficacy prepares students to face challenges in both the industrial sector and higher education while also strengthening critical and creative thinking skills essential for career advancement (Ratu et al., 2021). Mastery of Arduino-based robotics further opens pathways to emerging technologies such as artificial intelligence and the Internet of Things (Rahmat & Muljono, 2024).

This study aims to develop an effective Arduino-based robotics learning application that can be widely implemented in vocational schools. By making robotics education more engaging and accessible, this application is expected to enhance students' technical competencies while also strengthening their confidence in problem-solving and independent learning. Beyond technical mastery, the research contributes to the development of students as independent, motivated learners prepared for future challenges in both academia and industry.

Research Method

This study employs a post-test-only experimental design (Cook & Campbell, 2007) to assess the impact of implementing an Arduino-based line-following robot learning program on students' self-efficacy. The research method follows a structured experimental approach, as illustrated in Figure 1, which outlines the steps of the post-test-only design used in this study.

The study involved 30 eleventh-grade students from SMK Negeri 1 Kaliwungu, selected purposively based on their interest in technology and robotics. These students, who already had a basic understanding of technology, participated in the Arduino-based line-following robot learning program. Through hands-on activities such as constructing and programming a robot, they engaged in a practical learning experience designed to enhance their self-efficacy. After completing the program, the students take a post-test to measure their self-efficacy related to robotics and technology. The results of the post-test are then analyzed to determine the impact of the program on students' self-efficacy, providing insights into the effectiveness of the learning experience.

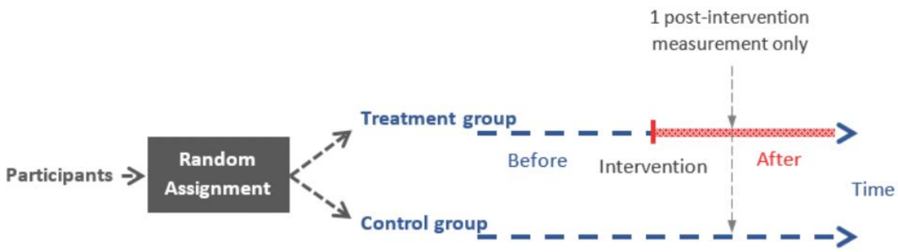

Figure 1. Posttest-Only Control Group Design (Kadir et al., 2023)

This method is designed to assess the program's outcome without relying on pre-test data, allowing a focused evaluation of the intervention's effects. In this study, all participants were included in the Arduino-based line-following robot learning program to maximize learning opportunities and ensure equitable access to educational resources. This decision aligns with ethical considerations, as withholding the intervention from a control group could have denied students valuable learning experiences. Consequently, a post-test-only design was employed to evaluate the program's impact on students' self-efficacy, acknowledging that the absence of a control group may limit the ability to attribute observed changes solely to the intervention. Furthermore, a control group would not provide a valid baseline for measuring the specific impact of the Arduino-based learning program. Instead, this study focuses on evaluating the changes in self-efficacy within the experimental group after completing the hands-on program. By using a post-test-only design, the study aims to examine the effects of the intervention without the confounding variable of prior robotics experience. This approach has been employed in various studies where pre-existing differences between groups are not relevant or feasible to control (Cook & Campbell, 2007)

The line-following robot project, which integrates Arduino technology, was chosen as it offers students a real-world application of programming and electronics, two critical skills in the field of robotics. By designing and programming the robot to autonomously follow a line, students are exposed to key concepts such as sensors, actuators, and algorithmic thinking. This interactive learning experience is expected to foster confidence in their technical abilities and problem-solving skills

The first session introduced the basics of robotics through interactive lectures and hands-on demonstrations. Students engaged with foundational robotics concepts, explored Arduino components, and examined the operational principles of line-following robots. This blended instructional approach aimed to establish a solid theoretical and practical understanding, preparing students for subsequent hands-on activities. The goal of this session was to establish a foundational understanding of the theory and components that would be used in the practical sessions. The image from the first session can be seen in Figure 2.

Figure 2. First Session: Introduction to the Basics of Robotics

In the second session, students began hands-on practice by assembling the robot and connecting the Arduino components according to the provided instructions. Additionally, they were introduced to the basic programming required to operate the line-following robot. Figure 3 shows an image from the second session, highlighting the students' active engagement with the assembly process.

Figure 3. Second Session: Assembling and Connecting the Robot

In the third session, students refined the programming of the line-following robot, tested the robot on a track, and discussed the challenges they encountered during the learning process. This final session also included a reflection on the skills and understanding they had gained throughout the program. Figure 4 provides an image from the third session, capturing the testing phase and group discussions.

Figure 4. Third Session: Testing and Addressing Challenges

The instrument used to measure students' self-efficacy in robotics is the Robotics Self-Efficacy (RSE) Test, which consists of 10 statement items (Jäggle et al., 2020). Each item uses a 5-point Likert scale, with response options ranging from "strongly disagree" to "strongly agree." The RSE focuses on the students' confidence in their ability to complete tasks related to assembling, programming, and operating the line-following robot. The instrument and item correlations can be seen in Table 1, providing a detailed overview of how each item contributes to measuring the students' self-efficacy in robotics.

Table 1. Instrument and Item Correlations

Number	Item-total Correlation	Self-Efficacy Context	Questionnaire
RSE1	0.562	Positive Feeling (Lead robots)	I'm confident that a robot will move the way I want it.
RSE2	0.430	Competence (Built robots)	I'm sure I can build a robot.
RSE3	0.382	Achievement (Content about robots)	It's easy for me to understand the parts of a robot.
RSE4	0.451	Achievement (Difficulties with robots)	It would not give me any difficulties to let a robot drive along a line.
RSE5	0.360	Positive Feeling (Control robots)	If I don't know what to do, I'll find a way to control the robot.
RSE6	0.611	Effort (Create robots)	I can create a robot that solves other people's problems if I effort.
RSE7	0.483	Achievement (Working with robots)	I will work well with robots when I have a chance.
RSE8	0.649	Positive Feeling (Solving robotics tasks)	I am someone who immediately solve robotic tasks.
RSE9	0.529	Positive Feeling (Robotic Researcher)	I think that I will be able to everything that a robotic researcher has to do.
RSE10	0.433	Achievement (Function of robots)	I'm the one who will explain how robots work.

Item-total correlation analysis assesses how well each questionnaire item aligns with the overall self-efficacy scale, ensuring that each item contributes meaningfully to the construct being measured. In this study, such analysis was employed to validate the RSE-Test by identifying items that effectively reflect students' self-efficacy in robotics tasks. A value above 0.3 is generally acceptable, indicating that the item contributes positively to the scale's reliability (Streiner, 2003). Strong correlations were observed for RSE6 (0.611) and RSE8 (0.649), suggesting these items are central to the self-efficacy construct, particularly in areas like effort and solving robotics tasks. Moderate correlations, such as RSE1 (0.562) and RSE7 (0.483), reinforce the scale's reliability, though they are slightly less impactful. On the lower end, RSE3 (0.382) and RSE5 (0.360) still meet the threshold but might be less representative of self-efficacy, reflecting areas where participants feel less confident, such as understanding robot components or addressing control challenges.

Contextual insights highlight distinct dimensions of self-efficacy. Items focusing on "positive feelings" (e.g., RSE1, RSE5, and RSE9) reveal varying confidence levels, with RSE5 indicating potential challenges in controlling robots. Achievement-related items like RSE3 and RSE4 show moderate connections, with understanding robot parts being less influential than addressing functional challenges. Effort and competence, as reflected in RSE6 and RSE2, show stronger associations, emphasizing participants' confidence in creating solutions through effort.

To assess the internal consistency of the positive affect subscale, which consists of 10 items, a Cronbach's Alpha calculation was conducted. The subscale demonstrated acceptable internal consistency (α = 0.810), as shown in Table 2. This indicates that the items within the subscale are measuring a cohesive construct, and the results can be considered reliable for further analysis.

Table 2. Cronbach's Alpha of RSE-Test

N	Mean	Cronbach's Alpha	Item Quantity
30	3.984	0.810	10

A Cronbach's Alpha value of 0.810 suggests that the subscale has good reliability, as values above 0.7 are typically considered acceptable for social science research (Streiner, 2003). This strengthens the validity of the data collected through the subscale, ensuring that it consistently measures the intended positive affect dimension across the sample.

This analysis confirms that the RSE-Test is a reliable instrument for assessing self-efficacy in robotics education, as indicated by the acceptable Cronbach's Alpha value (0.810). However, items with lower correlations, such as RSE3 (0.382) and RSE5 (0.360), may benefit from refinement to enhance their contribution to the scale's overall reliability. The findings highlight areas for targeted interventions, such as enhancing understanding of robot components, while leveraging strengths in problem-solving and effort to boost student confidence in robotics. Overall, the questionnaire provides a meaningful tool for assessing self-efficacy in this educational context.

Result and Discussion

Data collection took place immediately after students completed all the sessions. At the end of the final session, participants were given the questionnaire to complete on-site. Some items in the questionnaire were accompanied by explanations provided directly by the researchers to ensure that the respondents fully understood the intent and purpose of each question. This clarification aimed to minimize potential misunderstandings and ensure that each participant's responses accurately reflected their experiences and perceptions regarding the robot-related tasks assessed in this study. To further reduce response bias, students were assured of their anonymity and encouraged to answer honestly without fear of judgment. The data collection process is illustrated in Figure 5.

Figure 5. Data Collection Process

Result

This study collected data from 30 respondents to assess their self-efficacy in performing ten robotics-related tasks, providing insights into their confidence levels and identifying potential areas for instructional improvement. These tasks, central to the assessment, were designed to measure the respondents' confidence and perceived capability to successfully perform specific robot-related activities. Each task was represented as an item within the RSE scale. The descriptive statistics for these RSE items are presented comprehensively in Table 3, summarizing key metrics such as the mean, standard error of the mean (SEM), standard deviation, and variance scores for each item. These statistics provide valuable insights into the distribution of responses, highlighting patterns in self-perceived competencies among participants. By examining these descriptive data, we gain a deeper understanding of variations in respondents' self-efficacy across different robotic tasks, thereby setting the stage for further analysis of factors influencing individual confidence in robotics.

Table 3. Analysis of Individual RSE Items at SMK N 1 Kaliwungu

Item	N	Mean	Standard Error of the Mean	Standard Deviation	Variance Statistic
RSE1	30	3.967	0,131	0,718	0,516
RSE2	30	3.967	0,112	0,615	0,378
RSE3	30	4.067	0,106	0,583	0,340
RSE4	30	3.967	0,131	0,718	0,516
RSE5	30	4.000	0,136	0,743	0,552
RSE6	30	3.933	0,126	0,691	0,478
RSE7	30	3.967	0,122	0,669	0,447
RSE8	30	4.000	0,144	0,788	0,621
RSE9	30	3.900	0,111	0,607	0,369
RSE10	30	4.067	0,135	0,740	0,547

Table 3 presents the descriptive statistics for ten self-efficacy items (RSE1 to RSE10), which assess participants' confidence in performing various robot-related tasks. The data, collected from a sample of 30 respondents, reveals several notable trends and patterns in self-efficacy perceptions.

The mean scores for the items range from 3.900 to 4.067 on a five-point Likert scale, indicating a generally high level of self-efficacy across all tasks. Tasks such as RSE3 and RSE10, with the highest mean scores of 4.067, reflect the greatest levels of confidence among respondents, whereas RSE9, with a mean score of 3.900, represents the lowest. Despite this slight variation, the overall proximity of mean values underscores a consistent perception of capability among the participants.

The SEM, ranging from 0.106 to 0.144, suggests a high degree of precision in estimating the population means. Lower SEM values, observed in items such as RSE3 (0.106) and RSE9 (0.111), indicate greater confidence in these mean estimates compared to items like RSE8 (0.144), which show slightly less precision.

As illustrated in Figure 6, the bar chart with error bars provides a clear visualization of the mean scores along with their respective SEM. This graph underscores the consistency in self-efficacy ratings while highlighting minor variations in confidence levels across the items. The error bars effectively capture the precision of the estimates, facilitating an easy comparison of the respondents' perceptions of their capabilities for each task.

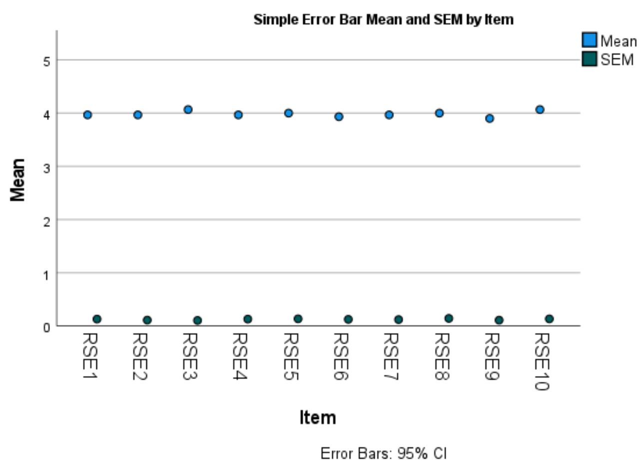

Figure 6. Bar Chart of Mean Self-Efficacy Scores with 95% Confidence Intervals for Robot-Related Tasks

The standard deviation (SD) values, ranging from 0.583 (RSE3) to 0.788 (RSE8), provide insights into the variability of responses. A smaller SD, as observed for RSE3, implies that participants' self-efficacy ratings were relatively consistent and closely aligned with the mean. Conversely, a larger SD, such as in RSE8, indicates a wider dispersion of responses, suggesting variability in perceived confidence levels among respondents.

The variance, which is the square of the standard deviation, further quantifies this variability. Higher variance values in tasks such as RSE8 suggest a wider range of self-efficacy levels, indicating that some students may feel significantly less confident in those activities compared to others. Variance values range from 0.340 (RSE3) to 0.621 (RSE8), reflecting the extent of differences in participants' responses. A lower variance, such as in RSE3 (0.340), indicates greater agreement among respondents regarding their confidence levels. In contrast, higher variance, as observed in RSE8 (0.621), signifies greater diversity in perceptions, likely due to differences in familiarity or experience with the associated task.

Overall, the data indicates a high level of self-efficacy among respondents, with some tasks demonstrating greater variability in confidence levels. Items such as RSE8, which exhibit higher standard deviation and variance values, highlight tasks that may be perceived as more challenging or unfamiliar. These findings provide valuable insights for identifying areas where targeted interventions or additional training may be necessary to enhance participants' confidence and performance.

Based on the analysis of the data, the overall mean across all items is calculated to be 3.984, indicating a generally positive response from participants. The individual means, ranging from 3.900 to 4.067, show consistent responses, suggesting that participants' perceptions or agreements were uniform across the different items. The pooled standard deviation is calculated as 0.701, which indicates relatively low variation in the responses. This suggests that the participants' ratings are concentrated around the overall mean, implying a strong consensus among the respondents. The pooled Standard Error of the Mean (SEM) is calculated to be 0.128, which reflects a high level of precision in estimating the overall mean. The SEM is a measure of how much the sample mean is expected to differ from the true population mean. A smaller SEM indicates that the sample mean is a more reliable estimate of the population mean. In this case, the value of 0.128 suggests that the mean calculated from the sample data is a precise reflection of the true population mean, with minimal expected variation. This low SEM value enhances the confidence in the overall mean, providing assurance that the results obtained from the sample are likely to be accurate and representative of the larger population (Rhemtulla, 2016). The relatively moderate sample size (N=30 for each item) ensures the accuracy and stability of the mean estimate. In conclusion, the data demonstrates a high degree of consistency in participant responses with minimal variability. The small pooled standard deviation and SEM indicate the reliability of the results, making the findings robust for further interpretation and application. This statistical stability adds credibility to the conclusions derived from the dataset, as shown in Table 4.

Table 4. Overall Analysis

N	Mean	Standard Deviation	Standard Error of the Mean
30	3.984	0.701	0.128

Table 5. Pearson Correlation Analysis

		RSE1	RSE2	RSE3	RSE4	RSE5	RSE6	RSE7	RSE8	RSE9	RSE10
	Pearson Correlation	1	.154	.335	.265	.194	.342	.572**	.548**	.308	.329
RSE1	Sig. (2-tailed)		.418	.071	.157	.305	.064	.001	.002	.098	.076
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.154	1	.199	.466**	.075	.400*	.081	.285	.452*	.308
RSE2	Sig. (2-tailed)	.418		.293	.009	.692	.028	.670	.127	.012	.097
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.335	.199	1	.252	.080	.097	.360	.375*	.117	.309
RSE3	Sig. (2-tailed)	.071	.293		.178	.676	.611	.051	.041	.539	.097
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.265	.466**	.252	1	.065	.620**	.285	.244	.308	.069
RSE4	Sig. (2-tailed)	.157	.009	.178		.734	.000	.127	.194	.098	.716
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.194	.075	.080	.065	1	.269	.208	.354	.382*	.377*
RSE5	Sig. (2-tailed)	.305	.692	.676	.734		.151	.269	.055	.037	.040
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.342	.400*	.097	.620**	.269	1	.219	.443*	.558**	.346
RSE6	Sig. (2-tailed)	.064	.028	.611	.000	.151		.245	.014	.001	.061
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.572**	.081	.360	.285	.208	.219	1	.589**	.161	.144
RSE7	Sig. (2-tailed)	.001	.670	.051	.127	.269	.245		.001	.394	.447
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.548**	.285	.375*	.244	.354	.443*	.589**	1	.360	.296
RSE8	Sig. (2-tailed)	.002	.127	.041	.194	.055	.014	.001		.050	.112
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.308	.452*	.117	.308	.382*	.558**	.161	.360	1	.246
RSE9	Sig. (2-tailed)	.098	.012	.539	.098	.037	.001	.394	.050		.191
	N	30	30	30	30	30	30	30	30	30	30
	Pearson Correlation	.329	.308	.309	.069	.377*	.346	.144	.296	.246	1
RSE10	Sig. (2-tailed)	.076	.097	.097	.716	.040	.061	.447	.112	.191	
	N	30	30	30	30	30	30	30	30	30	30

In this study, we also conducted a Pearson correlation analysis (Field, 2024) to examine the relationships between the various variables, as shown in Table 5. The table displays the correlation strength between each pair of variables, with the Pearson correlation values ranging from positive to negative, indicating both direct and inverse relationships. Specifically, an asterisk (*) denotes that the correlation is significant at the 0.05 level (2-tailed), meaning there is less than a 5% probability that the observed correlation occurred by chance. A double asterisk (**) indicates that the correlation is significant at the 0.01 level (2-tailed), meaning there is less than a 1% probability that the observed correlation is due to random chance. These significance levels help to determine whether the relationships between the variables are statistically meaningful and not due to random fluctuation.

Upon reviewing the correlation coefficients, it is apparent that several pairs of variables demonstrate strong and significant relationships. For example, RSE1 and RSE7 show a very strong positive correlation of 0.572 with a p-value of 0.001, indicating a highly significant relationship between these two variables. Similarly, RSE7 and RSE8 also display a strong positive correlation of 0.589, which is significant at the 0.01 level ($p = 0.001$).

In contrast, several correlations between other variables are weaker, with some being statistically insignificant. For instance, RSE1 and RSE2 have a low correlation of 0.154 ($p = 0.418$), suggesting a weak, non-significant relationship between these variables. Similarly, RSE4 and RSE5, with a correlation of 0.065 ($p = 0.734$), show no significant relationship.

The correlation analysis reveals strong positive associations between certain variables, such as RSE1 and RSE7 ($r = 0.572$, $p = 0.001$), suggesting that confidence in one robotics task may positively reinforce confidence in related tasks. Conversely, weak or insignificant correlations, such as between RSE1 and RSE2 ($r = 0.154$, $p = 0.418$), indicate that self-efficacy in these tasks may be influenced by different factors. This analysis helps to identify the key relationships between the variables under study, providing valuable insights into the data and guiding further research or decision-making processes.

Discussion

The study's findings highlight key aspects of respondents' self-efficacy in performing robot-related tasks, particularly in areas such as effort, problem-solving, and task completion. These insights are crucial for understanding how students develop confidence in robotics education and identifying factors that influence their learning process. Beyond the numerical results, these findings offer broader implications for robotics education and technological advancements, highlighting potential areas for future research and curriculum development.

In the context of robotics learning, self-efficacy directly influences students' ability to engage with complex problem-solving, apply theoretical knowledge to practical tasks, and persist through technical challenges. Higher self-efficacy is associated with greater adaptability in troubleshooting and innovation, making it a key factor in developing effective robotics education strategies (Warshawski, 2022). Understanding these dynamics can help educators and policymakers refine instructional methods to better support students in acquiring both technical skills and confidence in applying them

The familiarity of tasks and the associated confidence levels reported by the respondents suggest that the integration of fundamental robotics skills, such as assembly and basic programming, is a key element in building self-efficacy. Educational programs that focus on foundational skills, providing both theoretical background and hands-on experiences, are likely to foster higher self-efficacy among students (Bush et al., 2022). The results also suggest that self-efficacy in more complex tasks, such as advanced robotics programming or troubleshooting, is shaped by prior experience, exposure to technology, and the learning environment. Students with hands-on experience in similar tasks may develop greater confidence due to repeated practice and familiarity with problem-solving strategies. Exposure to robotics through workshops, competitions, or real-world applications can reinforce their belief in their ability to tackle challenging problems. Additionally, a supportive learning environment that includes access to resources, mentorship, and collaborative opportunities can further enhance self-efficacy by providing encouragement and constructive feedback.

Educational implications from these results emphasize the importance of task complexity in shaping self-efficacy perceptions, particularly in the context of robotics education. While respondents feel more confident with simpler, foundational tasks, it is crucial to support students in mastering more complex tasks. Teaching strategies like scaffolding, which involve gradually introducing more challenging topics as students solidify foundational skills, can play a crucial role in developing self-efficacy. By providing structured support at each stage, scaffolding allows students to gain confidence as they successfully complete simpler tasks before progressing to more complex robotics concepts. This gradual increase in difficulty helps reinforce their belief in their ability to tackle advanced challenges, ultimately strengthening their self-efficacy in robotics education (Spigner, 2023), as seen in Figure 7. Additionally, promoting hands-on practice, peer collaboration, and real-world problem-solving opportunities can further boost students' confidence, especially in advanced or unfamiliar tasks. These strategies can enhance self-efficacy by providing a more structured and supportive learning environment.

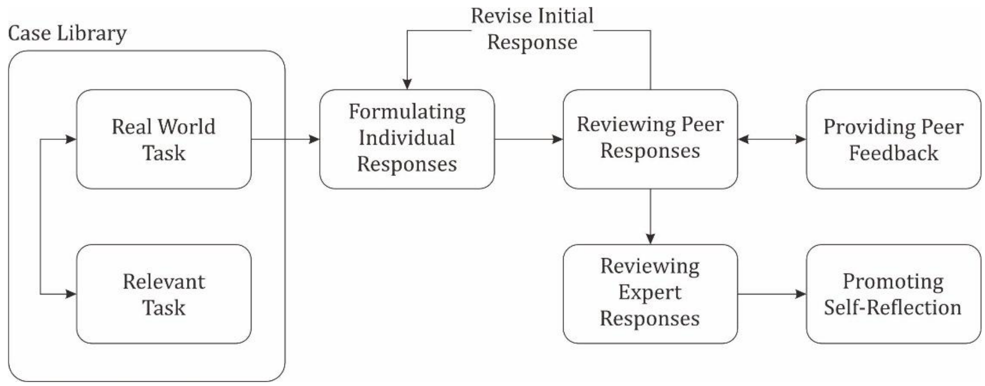

Figure 7. Scaffolding process

The study underscored the effectiveness of hands-on robotics programs in enhancing problem-solving skills and fostering interest in STEM fields. As all participants were included in the Arduino-based robotics program to ensure equitable access to learning, the absence of a control group limited direct comparisons between different instructional approaches. While this decision was ethically justified, it makes it challenging to determine whether the observed improvements in self-efficacy resulted solely from the program or other external influences. Future studies could explore alternative research designs, such as pre-test/post-test comparisons or matched control groups, to strengthen causal inferences. The moderate sample size (N=30 per item) further constrained the generalizability of the findings. Future research should explore external factors, such as prior exposure to robotics, resource availability, and teaching methods, to better understand their influence on self-efficacy. Longitudinal studies could examine the evolution of self-efficacy over time, while incorporating psychological aspects like growth mindset for deeper insights into belief development. Additionally, demographic variables such as gender, age, and cultural background may significantly shape self-efficacy in STEM and warrant inclusion in future studies. Finally, examining the relationship between self-efficacy and actual performance could provide valuable insights for refining robotics education, ensuring that confidence translates into measurable skills and competencies. By aligning self-efficacy with practical learning outcomes, future research can contribute to more effective instructional strategies and curriculum designs in STEM education.

Conclusion

This study demonstrated that the Arduino-based robotics learning program significantly enhanced students' self-efficacy in performing robot-related tasks, reinforcing the effectiveness of hands-on learning in vocational education. These findings highlight specific areas where targeted instructional interventions can further enhance students' confidence and proficiency in robotics.

This study highlights the effectiveness of an Arduino-based line-following robot program in enhancing students' self-efficacy in robotics. By engaging in hands-on learning activities, students developed greater confidence in designing, programming, and operating robotic systems. The Robotics Self-Efficacy (RSE) assessment revealed that most students felt capable of completing robotics-related tasks, though confidence levels varied across specific skills. While students exhibited strong self-efficacy in assembling and basic programming, their confidence was lower in more complex tasks such as debugging and advanced algorithm implementation. These findings affirm the critical role of experiential learning in fostering both technical expertise and self-belief among students in vocational education.

The implementation of this program at SMK Negeri 1 Kaliwungu provides valuable insights into integrating robotics education into the curriculum. The structured approach, which combines theoretical instruction with practical application, proved effective in stimulating students' confidence. Key elements such as scaffolding, iterative testing, and access to adequate resources played a significant role in enhancing both their problem-solving abilities and practical skills in real-world contexts. Moreover, the study underscores the importance of creating a supportive learning environment. The availability of resources, step-by-step guidance, and opportunities for iterative testing allowed students to overcome initial apprehension and achieve significant learning outcomes. Such an approach not only strengthens technical competencies but also promotes a mindset of persistence and adaptability, essential traits in the rapidly evolving technological landscape.

Building on these findings, future research could explore the application of similar programs in other technological domains, such as artificial intelligence, IoT, or advanced robotics. This would help determine whether the hands-on learning approach observed in this study can similarly enhance student skills and confidence in different fields. Additionally, longitudinal studies could assess the long-term impact of these programs on students' career trajectories, particularly their employability and ability to adapt to emerging technologies in professional settings. Tracking graduates' career progress and industry integration would provide valuable insights into the relevance of robotics education in preparing a skilled workforce.

Acknowledgement

We would like to extend our heartfelt appreciation to SMK N 1 Kaliwungu, particularly the 11th-grade students from the Computer and Network Engineering and Automotive Engineering departments, for their active participation and enthusiasm. Our sincere gratitude also goes to Vice Principal, Mr. Dody Indrajati, S.T., and Mr. Stephanus Fajar Pamungkas, S.Pd., Gr., M.Pd. for his valuable support and guidance throughout this study, and Mrs. Hery Ridawati, S.Pd., M.Pd., the Principal of SMK N 1 Kaliwungu, for their encouragement and leadership. We are also thankful to all parties at SMK N 1 Kaliwungu who contributed to facilitating and supporting this community service and research project, making its successful implementation possible.

References

Adel, A. (2024). The convergence of intelligent tutoring, robotics, and IoT in smart education for the transition from industry 4.0 to 5.0. *Smart Cities*, *7*(1), 325-369. https://doi.org/10.3390/smartcities7010014

Ananda, E. R., & Wandini, R. R. (2022). Analisis kemampuan literasi matematika siswa ditinjau dari self efficacy siswa. *Jurnal Obsesi: Jurnal Pendidikan Anak Usia Dini*, *6*(5). https://doi.org/10.31004/obsesi.v6i5.2659

Bandura, A. (2006). Guide for Constructing Self-Efficacy Scales (Revised). *Self-efficacy beliefs of adolescents*, *5*, 307–337.

Budiyanto, C. W., Amri, S., Yuana, R. A., Widiastuti, I., & Harjunowibowo, D. (2023). Integrasi Computational Thinking Menggunakan Lego Robotika Pada Pembelajaran Pemrograman. *DEDIKASI: Community Service Reports*, *5*(1). https://doi.org/10.20961/dedikasi.v5i1.66483

Bush, S., Calloway, A., Bush, E., & Himelblau, E. (2022). A course-based teaching experience for STEM undergraduates improves student perceptions of teaching self-efficacy and attitudes toward teaching careers. *CBE—Life Sciences Education*, *21*(1), ar7. https://doi.org/10.1187/cbe.21-04-0105

Christi, S. R. N., & Rajiman, W. (2023). Pentingnya Berpikir Komputasional dalam Pembelajaran Matematika. *Journal on Education*, *5*(4), 12590-12598. https://doi.org/10.31004/joe.v5i4.2246

Cook, T. D., & Campbell, D. T. (2007). *Experimental and quasi-experimental designs for generalized causal inference*. Figures.

Deprez, J., Peeters, E. R., & Gorgievski, M. J. (2021). Developing intrapreneurial self-efficacy through internships? Investigating agency and structure factors. *International Journal of Entrepreneurial Behavior & Research*, *27*(5), 1166-1188. https://doi.org/10.1108/IJEBR-09-2020-0642

Field, A. (2024). *Discovering statistics using IBM SPSS statistics*. Sage publications limited.

Fonna, N. (2019). *Pengembangan revolusi industri 4.0 dalam berbagai bidang*. Guepedia.

Fricticarani, A., Hayati, A., Ramdani, R., Hoirunisa, I., & Rosdalina, G. M. (2023). Strategi pendidikan untuk sukses di era teknologi 5.0. *Jurnal Inovasi Pendidikan Dan Teknologi Informasi (JIPTI)*, *4*(1), 56-68. https://doi.org/10.52060/pti.v4i1.1173

Ilori, M. O., & Ajagunna, I. (2020). Re-imagining the future of education in the era of the fourth industrial revolution. *Worldwide Hospitality and Tourism Themes*, *12*(1), 3-12. https://doi.org/10.1108/WHATT-10-2019-0066

Jäggle, G., Lammer, L., Wiesner, J.-O., & Vincze, M. (2020). *Towards a Robotics Self-Efficacy Test in Educational Robotics*.

Kadir, F., Permana, I., Saputra, I., & Azmar. (2023). Effect of Guided Discovery Methods on Students' Motivation and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*, 9893-9898. https://doi.org/10.29303/jppipa.v9i11.4326

Latikka, R., Turja, T., & Oksanen, A. (2019). Self-efficacy and acceptance of robots. *Computers in Human Behavior*, *93*, 157-163. https://doi.org/10.1016/j.chb.2018.12.017

Massaty, M. H., Budiyanto, C. W., Tamrin, A., & Fahrurozi, S. K. (2024). The Future of Learning: Integrating Robotic Efficiency for Enhanced Educational Efficacy. *Journal of Global Hospitality and Tourism Technology*, *1*(1), 1-9. https://doi.org/10.5281/zenodo.11294759

Massaty, M. H., Budiyanto, C. W., & Tamrin, A. G. (2020). Revisiting the roles of educational robotics in improving learners' computational thinking skills and their positive behaviour. *Journal of Physics: Conference Series*, *1511*(1), 012088. https://doi.org/10.1088/1742-6596/1511/1/012088

Peea, F., Anneke, D. R., & Naibaho, L. (2024). Revolusi Pemikiran: Memahami Peran Pendidikan dalam Menghadapi Era Teknologi 5.0. *Jurnal Kridatama Sains dan Teknologi*, *6*(01), 25-33. https://doi.org/10.53863/kst.v6i01.1067

Petrovič, P. (2022). Using microcontrollers for educational robotics in undergraduate university study program. *EDULEARN22 Proceedings*, 7631-7641. https://doi.org/10.21125/edulearn.2022.1780

Rahmat, B., & Muljono, M. (2024). Pemrograman Internet of Things (IoT) dengan Arduino dan Python Jilid 1.

Ratu, T., Sari, N., Mukti, W. A. H., & Erfan, M. (2021). Efektivitas Project Based Learning Terhadap Efikasi Diri dan Kemampuan Berpikir Kritis Peserta Didik. *Konstan-Jurnal Fisika Dan Pendidikan Fisika*, *6*(1), 1-10. https://doi.org/10.20414/konstan.v6i1.74

Rhemtulla, M. (2016). Population performance of SEM parceling strategies under measurement and structural model misspecification. *Psychological Methods*, *21*(3), 348. https://doi.org/10.1037/met0000072

Robinson, N. L., Hicks, T.-N., Suddrey, G., & Kavanagh, D. J. (2020). The robot self-efficacy scale: Robot self-efficacy, likability and willingness to interact increases after a robot-delivered tutorial. *2020 29th IEEE international conference on robot and human interactive communication (RO-MAN)*, 272-277. https://doi.org/10.1109/RO-MAN47096.2020.9223535

Schunk, D. H., & DiBenedetto, M. K. (2022). Academic self-efficacy. In *Handbook of positive psychology in schools* (pp. 268-282). Routledge. https://doi.org/10.4324/9781003013778-21

Spigner, M. S. (2023). The Use of Project-Based Learning to Scaffold Student Social and Emotional Learning Skill Development, Science Identity, and Science Self-Efficacy. https://scholarcommons.sc.edu/etd/7566/

Streiner, D. L. (2003). Starting at the beginning: an introduction to coefficient alpha and internal consistency. *Journal of Personality Assessment*, *80*(1), 99-103. https://doi.org/10.1207/S15327752JPA8001_18

Tsai, M.-J., Wang, C.-Y., Wu, A.-H., & Hsiao, C.-Y. (2021). The development and validation of the robotics learning self-efficacy scale (RLSES). *Journal of educational computing research*, *59*(6), 1056-1074. https://doi.org/10.1177/0735633121992594

Warshawski, S. (2022). Academic self-efficacy, resilience and social support among first-year Israeli nursing students learning in online environments during COVID-19 pandemic. *Nurse Education Today*, *110*, 105267. https://doi.org/10.1016/j.nedt.2022.105267