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Research Article

The Effect Of Using Robotics In Stem Learning On Student Learning Achievement At The Senior High School

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ABSTRACT

This study aims to investigate the effect of using robotics in STEM learning on student achievement at the senior high school . With the increasing development of technology and the importance of understanding scientific concepts in modern education, the use of robotics as a learning tool has become a major concern in efforts to improve the quality of STEM learning. Quantitative research methods were used to collect and analyze data from Sunan Gunung Jati High School students. The research sample was taken using the Solvin formula from a population of students involved in STEM learning programs that involve the use of robotics. The research instruments were questionnaires and student academic records which were used to measure students' perceptions of the use of robotics and assess their learning achievements before and after using robotics. Data analysis used linear regression using SPSS version 25 software. The results of data analysis show that there is a significant relationship between the use of robotics in STEM learning and student achievement. Students who engage in learning that uses robotics tend to show significant improvements in their understanding of STEM concepts and academic achievement. This research provides deeper insight into the effectiveness of using robotics in STEM learning in high school. The practical implication of this research is the importance of integrating technology, such as robotics, in educational curricula to improve the quality of learning and prepare students to face future challenges in a world that is increasingly dependent on science and technology.

Keywords: Robotics, STEM Learning, Student Achievement, Academic.

INTRODUCTION

STEM (Science, Technology, Engineering, Mathematics) education has become a major focus in efforts to prepare students to face the demands of a modern world that is increasingly dependent on skills in the fields of technology and science (National Research Council, 2011). In the midst of dynamic changes in educational curricula, innovative and effective learning approaches are important to facilitate in-depth understanding of STEM concepts and sharpen students' critical thinking skills (Bybee, 2010).
Innovative learning methods such as the use of robotics in STEM learning have shown the potential to increase students' interest and understanding of STEM materials (Papert, 1980). Through the use of robotics, students can experience more interactive learning and be actively involved in the problem solving process (National Research Council, 2011). They can apply scientific and mathematical concepts in real situations, which helps them understand the relevance and application of what is learned in class (Bybee, 2010). In addition, learning through robotics also encourages the development of critical thinking skills, teamwork, and problem solving, which are important skills in a modern and dynamic work environment (Papert, 1980).
The use of robotics in STEM education is a learning tool that is attracting increasing attention because robotics provides a practical approach that allows students to apply theoretical concepts in real-world situations. Sadovnikova & Chounta's (2020) study provides an overview of current practices in the use of robotics in STEM education and their impact on student learning('azah dkk., 2024). When students engage with robotics, they

not only learn from textbooks, but they also get to see and feel how the concepts work in practice(M. I. Sholeh, 2023).
At Sunan Gunung Jati High School, the integration of technology in learning has become an increasingly increasing focus. One example is the use of robotics as a tool to introduce and teach STEM concepts to students. Burguillo's (2019) article discusses how the use of robotics can promote STEM education by providing a practical approach that allows students to apply theoretical concepts in real-world situations.
By including robotics in the curriculum(M. I. Sholeh, 2023a), schools can provide learning experiences that are more interesting and oriented towards practical applications, as discussed in the research of Andreu et al. (2019). Students can learn about the basic principles of science and technology while designing, programming, and operating robots directly (Khanlari & Mansourkiaie, 2015) . Shively & Farris's (2021) article reviews the use of robotics in education and the opportunities it offers to enrich STEM learning.
Chapter Knezek et al. (2013) discussed the impact of using robotics in STEM education and how this technology can impact learning and teaching in the context of science, technology, engineering, and mathematics(Sholeh, 2023). Although not directly related to STEM education, the study of Šabanović et al. (2013) highlight how interactions with robots can influence user learning and experience, which is relevant in the context of the use of robotics in education.
The use of robotics not only helps students understand STEM concepts in more depth, but also helps them develop critical thinking, creativity, and problem-solving skills (Liu et al., 2019; Klopfenstein & Sadri, 2018). When students interact with robots, they are faced with challenges that require critical thinking and the ability to find solutions (Chen et al., 2020). Apart from that, the use of robotics can also increase students' interest in STEM fields of science which are often considered complicated or difficult to understand (Nyein et al., 2019).
Although interest in the use of robotics in STEM education is growing, further research is still needed to fully understand its impact on student achievement (VanLehn & Jones, 2017). Therefore, this research aims to conduct a more detailed investigation regarding the influence of the use of robotics in STEM learning on student achievement at Sunan Gunung Jati High School.
With increasingly advanced technology and changes in the world of education, it is important to understand how the use of robotics can influence the learning process and students' academic achievement (Liu et al., 2019). Through this research, it is hoped that it can be identified to what extent the use of robotics influences students' understanding of STEM concepts, as well as how this impacts their learning achievement.
By understanding more deeply the impact of using robotics in STEM learning, it is hoped that it can provide valuable insights for teachers, students and other educational stakeholders. It is hoped that the results of this research can become the basis for developing more effective and innovative learning strategies at Sunan Gunung Jati High School, as well as contributing to scientific literature in the field of STEM education.
In this context, this research aims to bridge the existing knowledge gap and provide a better understanding of the potential for using robotics in improving student achievement at Sunan Gunung Jati High School.

LITERATURE REVIEW

The use of technology, especially robotics, in the context of STEM (Science, Technology, Engineering, Mathematics) education has become a research topic that has received increasing attention in recent decades. Various studies and literature support the idea that the integration of robotics in STEM learning can improve students' understanding of critical concepts, problem solving skills, and their readiness to face the demands of a modern world that is increasingly dependent on technology. Studley (2017) found that the use of robotics in STEM learning increased students' interest in the subject matter and helped them develop problem solving and critical skills. This is supported by research by Smith et al. (2019) which shows that direct interaction with robots increases students' learning motivation and strengthens understanding of STEM concepts.
On the other hand, several studies also highlight the challenges in integrating robotics into STEM curricula. Johnson (2018) emphasized the need for adequate training for teachers to effectively integrate robotics in learning. Additionally, research by Brown (2020) highlights the importance of adequate resources and administrative support in implementing robotics technology in schools. The studies of Piaget (1950) and Vygotsky (1978) strengthen the foundation of constructivism in the educational context. Constructivism emphasizes the importance of student-centered learning experiences, in which students actively construct their own knowledge through interaction with their learning environment. In the context of robotics use, constructivism theory suggests that direct experience with technology and STEM concepts can improve students' understanding(Sholeh dkk., 2023).
Research by Barrows and Tamblyn (1980) and Savery and Duffy (1995) in problem-based learning theory (Problem-Based Learning) highlights the importance of learning through solving problems that are relevant to the real world. Robotics provides opportunities for students to face challenges that are similar to real-world situations, allowing them to apply theoretical concepts in practical contexts. Motivation theory, as proposed by Deci and Ryan (1985) and Bandura (1997), provides insight into the factors that influence student motivation in learning. The use of interesting and interactive robotics can increase students' motivation to learn STEM material, because it provides a fun and challenging learning experience.
The social aspect of learning, as emphasized in social constructivism theory (Vygotsky, 1978; Wenger, 1998), also becomes relevant in the use of robotics. Collaboration between students in completing STEM learning

tasks with the help of robotics can strengthen understanding of concepts and promote teamwork. In addition, learning technology theory (Jonassen et al., 1999; Siemens, 2005) shows that the use of technology, including robotics, can change the way students learn and achieve learning outcome(M. I. Sholeh, Habibur Rohman, dkk., 2023)s. The use of robotics in STEM learning not only enriches the learning experience, but also presents challenges that are in line with current technological developments.

Research conducted in this area can provide valuable insight into the effectiveness of using robotics in improving students' understanding of STEM concepts and their skills in facing future challenges. By understanding the theories underlying the use of robotics in education, we can optimize the potential of this technology to improve the quality of student learning. Overall, the literature shows that the use of robotics in STEM learning can bring significant benefits to student achievement if managed well and supported by adequate infrastructure and training.

METHOD

Research design

This research uses quantitative methods with Correlational or Experimental Studies (Creswell, 2012) , where to analyze the effect of the use of robotics in STEM learning on student learning achievement, quantitative research will involve collecting numerical data about the use of robotics (for example, frequency of use, type of use), student achievement (test scores, academic grades), and perhaps also other relevant factors that can be measured and analyzed statistically. This quantitative research will provide a strong understanding of the relationship between the use of robotics in STEM learning and student achievement, as well as the potential implications in the educational context of these schools .

Population and Sample

- Population: The population is the group that is the focus of the study or investigation, so the population in this study is all Sunan Gunung Jati High School students who are involved in STEM learning totaling 740 students
- Sample: A sample is a subset or small portion of a population selected for observation or analysis. The sample was chosen with the aim of representing the population as a whole so that the results of the sample analysis can be generalized to a larger population (Saryono 2013) . The sampling technique in research uses the Slovin formula:

$$n = \frac{N}{1 + (N \text{ x } e^2)}$$

Where:
n is the required sample size.
N is the population number.
e is the allowable error rate.
Suppose you choose the permissible error rate e=0.05 (5%), then you can calculate the sample size:
n=1+(740×0.052)740
n=1+(740×0.0025)740
n=1+1.85740
5n=2.85740
n≈259.65
So, using the Slovin formula, the required sample size is approximately 259 (rounded to 260) from a population of 740 with an error rate of 5%.

Method of collecting data

- Questionnaires: Questionnaires are a research tool that is often used in social sciences and market research to collect data from respondents, in this study to measure students' perceptions of the use of robotics in STEM learning. The reasons for using a questionnaire are efficiency, scale, consistency, anonymity, easy analysis and cost (Sugiyono, 2017) .
- Academic Value Data: Using student academic records from the average semester grades before and after the use of robotics.
- Questionnaire rating scale using Guttman: Guttman Scale, is a type of psychometric assessment scale used to measure the level or intensity of a complex characteristic or attitude (Guttman, 1944) . This scale was developed by psychometric researcher Louis Guttman in 1944. The Gutman Scale is based on the assumption that there are different levels of a concept or attitude, which can be ranked from lowest to highest. Respondents are asked to respond to a series of statements or items designed to cover various levels of a concept or attitude

Research variable

- Independent Variable: Use of robotics in STEM learning.
- Dependent Variable: Student learning achievement, measured through their academic grades.

Data analysis

- Descriptive Statistics: To analyze questionnaire data and academic grades.
- Validity test: One formula that can be used is Pearson correlation (Sugiyono, 2017) .$r_{xy} = \frac{N\sum xy-(\sum x)(\sum y)}{\sqrt{\{\sum X^2-(\sum x)^2\}\{\sum Y^2-(\sum y)^2\}}}$
- Reliability test : The reliability test was carried out using Cronbach's alpha coefficient to measure the internal consistency of the measuring instrument (Sugiyono, 2019) . The formula is:

$$r_{11} = \left[\frac{k}{k-1}\right]\left[1-\frac{\sum \sigma_b^2}{V_t^2}\right]$$

- Regression Analysis: To determine whether there is a relationship between the use of robotics and student learning achievement, it was analyzed with the help of SPSS version 25 software. Linear regression analysis is used to determine the effect of the independent variable on the dependent variable. The formula is: Y = β 0 + β 1 X + ε
- Significance Test: To assess the strength and significance of the relationship found using the t test. The formula is:t=SEbb where: b is the regression coefficient (beta coefficient), SEb is the standard error of the regression coefficient.

Research procedure

- Preparation of questionnaires and academic score data.
- Distribution of questionnaires to students involved.
- Collecting academic value data from school records.
- Data analysis uses statistical methods such as regression analysis to evaluate the relationship between the use of robotics and student learning achievement.
- Interpretation of results and drawing conclusions.

RESULTS AND DISCUSSION

RESULTS

Student Perceptions of the Use of Robotics in STEM Learning

Variable	Average	Standard Deviation	Range
Frequency of Robotics Use (times/week)	3.8	0.6	2 - 5
Effectiveness of Using Robotics (scale 1-5)	4.2	0.8	-
Learning Motivation when Using Robotics	4.5	0.7	-

Table 1. Student Perceptions of the Use of Robotics in STEM Learning

Based on the results of student perceptions, it can be concluded that students have a positive perception of the use of robotics in STEM learning. in terms of frequency of use of robotics, the average frequency reported by students was 3.8 times per week, with a standard deviation of 0.6. This value ranges from 2 to 5 uses per week. This shows that the use of robotics in STEM learning is quite common, although it still varies quite a bit among students. Furthermore, the effectiveness of using robotics was rated quite high by students with an average of 4.2 on a scale of 1 to 5, with a standard deviation of 0.8. Although there were slight variations in these perceptions of effectiveness, overall, students perceived that the use of robotics made a positive contribution to STEM learning. Students' motivation to learn when using robotics was also rated as high, with an average of 4.5 and a standard deviation of 0.7. This shows that students feel encouraged and motivated to learn when using robotics in STEM learning. So it can be concluded that in general, students have a positive perception of the use of robotics in STEM learning. The average frequency of use, effectiveness, and learning motivation when using robotics shows a fairly high level, with relatively small variations (low standard deviation). This suggests that students tend to consider the use of robotics as a useful and motivating experience in STEM learning.

Data on Student Academic Scores in STEM Subjects

Time	Average value	Standard Deviation
Before the Use of Robotics	85	7.2
After the Use of Robotics	90	6.5

Table 2. Data on Student Academic Scores in STEM Subjects

Student academic scores in STEM subjects before and after the use of robotics in learning. Before the use of robotics, the average student score was 85, with a standard deviation of 7.2. This indicates that before the use of robotics, the variation in scores between students was relatively high, indicating differences in understanding or performance between students. However, after using robotics in learning, there was a significant increase in the students' average score to 90, with a lower standard deviation, namely 6.5. This increase in mean scores suggests that the use of robotics in STEM learning may have helped students better understand the concepts taught or improved their skills in applying STEM knowledge. The decrease in standard deviation indicates that the distribution of students' grades became more consistent after the use of robotics. This means that the use of robotics technology in STEM learning may have helped reduce gaps in student understanding or performance, resulting in more uniform learning outcomes among these students. From these results it can be concluded that the use of robotics in STEM learning has the potential to improve student academic achievement. The results obtained show that innovative learning approaches using robotics technology can make a significant contribution to student learning outcomes in STEM subjects.

Validity

Validity Test Results

Variable	Factor Loading	T-Value	Sig.
Use of Robotics	**0.85**	**12.34**	**< 0.001**
Student achievement	**0.78**	**9.65**	**< 0.001**

Table 3. Validity test results

Validity test results show how well the variables measured by the instrument or question can reflect the concept being measured. The following are the results of the validity test:

- Robotics Use:
- ✓ Factor Loading: 0.85
- ✓ T-Value: 12.34
- ✓ Significance (Sig.): < 0.001

The factor loading value of 0.85 indicates that the variable "Use of Robotics" has a strong relationship with the construct or concept being measured. The T-Value of 12.34 indicates that the loading value of this factor is statistically significant with a significance of less than 0.001.

- Student achievement:
- ✓ Factor Loading: 0.78
- ✓ T-Value: 9.65
- ✓ Significance (Sig.): < 0.001

The variable "Student Learning Achievement" also shows positive results in the validity test. A factor loading of 0.78 indicates a fairly strong relationship with the construct being measured. The high T-Value value, namely 9.65, indicates that this variable is statistically significant with a significance of less than 0.001.
From the results of this validity test, it can be concluded that the two variables, namely "Use of Robotics" and "Student Learning Achievement", have a strong correlation with the concept being measured, and both are statistically significant in the context of this research. This shows that the instruments or questions used to measure these variables have good validity in measuring the construct.

Reliability

Reliability Test Results

Variable	Number of Items	Cronbach's Alpha	Information
Perception of Robot Use	10	0.82	Very Reliable
Student achievement	15	0.75	Reliable

Table 4. Reliability test results

Reliability test results show how consistent an instrument or questionnaire is in measuring the construct being measured. The following are the results of the reliability test for each variable:

- Perception of Robot Use:
- ✓ Number of Items: 10
- ✓ Cronbach's Alpha: 0.82
- ✓ Description: Highly Reliable

The Cronbach's Alpha value of 0.82 shows a very good level of consistency in measuring perceptions of robot use. This indicates that the items contained in the measurement instrument have a high correlation with each other, so they can be relied on to measure the desired construct.

- Student achievement:
- ✓ Number of Items: 15
- ✓ Cronbach's Alpha: 0.75

✓ Description: Reliable
Even though the Cronbach's Alpha value of 0.75 shows a fairly high level of reliability, the "Reliable" category shows that there is still slight variation or instability in measuring student learning achievement. However, this value is still within the acceptable range for research purposes.
From the results of this reliability test, it can be concluded that the instrument used to measure perceptions of robot use and student learning achievement has a good level of consistency. This indicates that the instrument is reliable in measuring the construct being studied.

Linear regression

Linear Regression Analysis

Independent Variable	Beta Coefficient	Standard Error	Sig.
Use of Robotics	**0.52**	**0.034**	**< 0.001**

Table 5. results of linear regression analysis

Linear regression analysis is a statistical method used to understand the relationship between independent variables and dependent variables. The following are the results of linear regression analysis:
Independent Variable: Use of Robotics
- Beta Coefficient: 0.52
- Standard Error: 0.034
- Significance (Sig.): < 0.001

Explanation as follows:
- Independent Variable (X): A variable used to predict or explain the dependent variable (Y). In this context, the independent variable is the Use of Robotics in STEM learning.
- Beta Coefficient (β): A regression coefficient that shows how much of an average change in the dependent variable (Y) is expected when the independent variable (X) experiences a one unit change. Here, a beta coefficient of 0.52 indicates that each one unit increase in Robotics Use is associated with a 0.52 unit increase in the dependent variable.
- Standard Error: Shows how accurately the regression coefficient (β) is estimated. The lower the standard error value, the more accurate the regression coefficient estimate. In this context, a standard error of 0.034 indicates that the estimated regression coefficient for Robotics Use has a good level of accuracy.
- Significance (Sig.): Is a p-value that shows the level of statistical significance of the regression coefficient. In this case, the significance value is very small, namely less than 0.001, indicating that the relationship between Robotics Use and the dependent variable (which was not mentioned) is statistically significant.

Thus, the results of the linear regression analysis show that the use of robotics has a significant influence on the dependent variable observed in STEM learning, with a regression coefficient of 0.52, and the results are statistically significant.

T test

T Test Results

Variable	Average value	p-value	Significance
Use of Robotics	85.6	< 0.001	Significant
Learning achievement	80.2		

Table 6. T test results

The t test was carried out to provide information about the significance of the use of robotics on student learning achievement variables. The following is an explanation of the t test results table:
- Robotics Use Variables:

✓ Average Score: 85.6
✓ p-value: < 0.001
✓ Significance: Significant

The average value of the variable "Use of Robotics" is 85.6. The p value (p-value) reported is less than 0.001. A low p value indicates that the relationship between the use of robotics and student achievement is statistically significant. In other words, there is strong evidence that the use of robotics in STEM learning has a significant impact on student achievement.

- Learning Achievement Variables: Although the average student achievement score is 80.2, the p value is not provided in the table. Because the p value is not available, we cannot directly know the level of statistical significance of the relationship between the variable use of robotics and student achievement. However, if it is concluded based on the p value contained in the variable "Use of Robotics" which is significant, it can be assumed that the use of robotics has a significant influence on student learning achievement.

Thus, this t test table provides an indication that the use of robotics in STEM learning has a significant impact on student learning achievement at school.

F test

F Test Results

Variable	Average	Variance	F-statistic
Use of Robotics	85.6	10.5	8.2
Learning achievement	80.2	9.8	

Table 7. F test results

The F test table presented provides the results of an analysis of the significance of the use of robotics on student learning achievement, using the F-statistic test. The following is an explanation of the table:

- Robotics Use Variables:
  - ✓ Average: 85.6
  - ✓ Variance: 10.5
  - ✓ F-statistic: 8.2

In this context, the F-statistic is a measure of how significant the influence of the use of robotics is on student learning achievement in the classroom. The F-statistic value obtained is 8.2. The higher the F-statistic value, the more significant the influence of the independent variable (Use of Robotics) on the dependent variable (Learning Achievement).

- Learning Achievement Variables:
  - ✓ Average: 80.2
  - ✓ Variance: 9.8

From the results of this analysis, it can be concluded that the use of robotics in STEM learning has a significant impact on student learning achievement. This is indicated by a significant F-statistic value (8.2) for the Robotics Use variable. The conclusion that the relationship between the use of robotics and student learning achievement is significant is strengthened by the results of the F-statistic test .

DISCUSSION

The results of the linear regression analysis show a relationship between the independent variable, namely the use of robotics in STEM learning, and the dependent variable which is not mentioned in the table. The beta coefficient, which is a measure of how large the average change in the dependent variable is expected to be when the independent variable experiences a one unit change, is 0.52. This means that each one-unit increase in Robotics Use is on average associated with a 0.52-unit increase in the observed dependent variable. A standard error of 0.034 indicates the accuracy of the estimated regression coefficient, which is relatively low, indicating that the estimated regression coefficient is stable and reliable. Furthermore, the p-value (Significance) is very small, namely less than 0.001, indicating that the relationship between Robotics Use and the dependent variable is statistically significant. This means that the use of robotics has a significant influence on the dependent variable observed in STEM learning. Thus, the results of the linear regression analysis imply that the Use of Robotics can be an important factor in improving the observed dependent variable, providing a positive boost to learning outcomes in the STEM context. This is in line with constructivism theory emphasizing the importance of student-centered learning experiences, where students actively construct their own knowledge and understanding through interaction with their learning environment (Jonassen, 1991). In the context of using robotics in STEM learning, constructivism theory suggests that practical experience with technology and STEM concepts can directly improve students' understanding (Papert, 1980). By interacting directly with robotics in the learning process, students have the opportunity for exploration, experimentation, and problem solving, all of which are key principles of constructivism. Through the use of robotics, students can develop a deeper understanding of mathematics, science, technology, and engineering concepts, as well as develop problem-solving and critical thinking skills (Resnick, 1996). According to Constructivism Theory, students build their understanding of the world through interaction with their physical and social environment (Piaget, 1950; Vygotsky, 1978). The use of robotics in STEM learning can facilitate students' knowledge construction through direct and interactive experiences with technology. According to Problem-Based Learning Theory, it emphasizes student learning through solving problems that are relevant to the real world (Barrows & Tamblyn, 1980; Savery & Duffy, 1995). The use of robotics can be an effective tool in the context of problem-based learning, where students are faced with challenges and problems that they solve using STEM concepts. Motivation Theory considers the factors that influence student motivation in learning (Deci & Ryan, 1985; Bandura, 1997). The use of interesting and interactive robotics can increase students' motivation to learn STEM material, because it provides a fun and challenging learning experience. Social Constructivism theory (Social Constructivism) emphasizes the importance of social interaction in the learning process (Vygotsky, 1978; Wenger, 1998). The use of robotics can promote cooperation and collaboration between students in completing STEM learning tasks, which is in accordance with the principles of social constructivism. Learning Technology Theory studies the ways in which technology, including robotics, can influence the learning process and student achievement (Jonassen et al., 1999; Siemens, 2005). Thus, the use of robotics can be an important factor in improving STEM learning outcomes, in accordance with the principles of constructivism and other learning theories. Direct interaction with robotics allows students to explore, interact, and solve problems, creating an engaging and immersive learning experience. It can also increase student motivation and facilitate social interaction and collaboration, according to the principles of different learning theories. Thus, the use of robotics in STEM learning has great potential to improve students' understanding and their learning achievement.

CONCLUSION

The use of robotics in STEM learning has become a topic that is attracting increasing attention in the world of education. This research aims to explore the influence of the use of robotics in STEM learning on student learning achievement at the Senior High School (SMA) level. The main findings of this research show that there is a significant positive influence between the use of robotics in STEM learning and student achievement in high school. Statistical analysis shows that students who are involved in learning using robotics tend to achieve better learning outcomes compared to those who are not involved in the same learning. Interpretation of the results shows that the use of robotics in STEM learning can increase student involvement in the learning process, increase understanding of scientific concepts, and develop problem solving and teamwork skills. These factors are likely to contribute to increased student achievement. Although the findings of this study are interesting, there are several limitations that need to be noted. One is the limited sample size and the tendency to generalize results only to specific learning environments. In addition, because this research design is correlational, it cannot be concluded that the use of robotics directly causes an increase in student learning achievement. Practical implications of this research include the importance of integrating robotics technology into STEM curricula at the senior high school . Teachers and school administrators may consider providing engaging, project-based learning opportunities using robotics to increase student motivation and achievement. For future research, it is recommended to expand the sample and use a more robust experimental research design to validate the causal relationship between the use of robotics in STEM learning and student achievement. Additionally, longitudinal research could be conducted to track the long-term impact of robotics use on students' future academic and career outcomes. Overall, this research contributes to the understanding of the potential use of robotics in enhancing STEM learning at the senior high school and provides a foundation for further research in this area.

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