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The Influence of a Robotics Program on Students' Attitudes Toward Effective Communication

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Abstract: This research aimed to explore the influence of a robotic program using the robot kit "RoboBuilder RQ+110" on students' attitudes toward effective communication. The study used a quantitative research design and involved 475 grade 4 (10 years old) students from Malaysia's Selangor and Malacca states. A quasi-experimental research (pre-test & post-test) approach with control and experimental groups was adopted, and the data were analyzed with inferential statistical test and repeated measures analysis of variance (ANOVA) using SPSS 25 software at 0.05 significance level. Questionnaires were administered to collect data from the experimental and control groups. The results showed statistically significant changes ($\alpha \leq .05$) in attitudes toward effective communication for the experimental group that received a robotics program compared with the control group. The study results suggest that innovative technological tools or programs such as robotics programs are recommended as innovative science, technology, engineering, and mathematics (STEM) program rooted in constructivism to improve students' attitudes toward effective communication.

Keywords: *Attitude, effective communication, robotics, students.*

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Introduction

Encouraging active participation and fostering positive attitudes toward 21st-century skills such as effective communication, problem-solving, and critical thinking remain challenging for teachers in today's closely scrutinized learning environment. Buasuwan et al. (2022) emphasize the importance of effective communication as a critical skill that 21st-century students acquire. However, Lowry-Brock (2016) observed that students perceived as more capable by their peers often dominate classroom discussions, while students with weaker academic backgrounds tend to withdraw from active participation. Previous studies suggest incorporating educational technology programs such as robotics can increase student engagement and improve behavior (Hirtz, 2020). Nonetheless, the shift toward online learning due to the COVID-19 pandemic has been a significant barrier to student engagement, as noted by Farooq et al. (2020), Nickerson and Shea (2020), and Perets et al. (2020).

Kukard (2020) highlights that maintaining collaboration and engagement during the global pandemic was particularly challenging, resulting in students' inability to acquire essential 21st-century skills. LEGO-based education introduces novel technological tools consistent with Bruner's theory, which draws on and adapts the work of John Dewey. Dewey emphasizes the importance of learning through hands-on experiences (Parker & Thomsen, 2019). This approach taken by LEGO Education involves the use of blocks in various colors and sizes. By constructing tangible shapes and patterns, students participate in a concrete and experiential learning process. The aim is to encourage active participation, increase motivation, and facilitate the development of problem-solving, collaboration, and communication skills. The strategy used by LEGO Education is consistent with Bruner and Dewey's theory, which emphasizes learning through practical application (Chu et al., 2017).

Due to the positive results, integrating educational technology programs has become essential for education in Malaysia. The country has taken numerous initiatives to foster students' inclination toward 21st-century skills, such as problem-solving and effective communication. In 2012, under the Science to Action (S2A) strategy, the Malaysian government introduced various programs and initiatives to foster students' interest in 21st-century skills and achieve a 60:40 science-to-arts ratio. However, despite these dedicated efforts, these goals have proven elusive. According to the

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Organization for Economic Co-operation and Development's (OECD) 2019 report, over 60% of Malaysian students do not achieve the minimum standard in mathematics required for active and effective participation in life. Additionally, Dato' Professor Dr. Noraini, the chairman of the national science, technology, engineering, and mathematics (STEM) movement, also pointed out that in 2020, only 19% of students participated in STEM-related courses in middle schools and higher educational institutions (Chonghui, 2020). She emphasized that children should be encouraged to take these courses while still in primary school. This shows that Malaysian students lack enthusiasm and attitude toward 21st-century skills. As Sima et al. (2020) and Marsili (2005) noted, in the coming years, many professions and industries will require workers with expertise in science, technology, engineering, and mathematics (STEM).

While many previous studies have focused on assessing the effectiveness of robotics programs on students' academic achievement and various skills, there has been a lack of attention given to evaluating changes in students' attitudes after participating in robotics programs. For example, Saad and Sharif (2018) conducted a study to examine the effectiveness of a robotics program in enhancing Matriculation students' achievement in biology on the topic of respiratory cells. They concluded that introducing robotics into the learning process can increase students' interest in science and promote the development of 21st-century skills such as problem-solving, motivation, and teamwork. Similarly, Ching et al. (2019) examined the development of STEM attitudes and perceived learning in an elementary school project-based, STEM-integrated robotics curriculum in elementary school. The study found significant improvements in students' attitudes toward science based on quantitative and qualitative data. Similarly, Diken (2022) investigated the impact of educational robots on secondary students' attitudes toward STEM. The study aimed to determine whether incorporating educational robots in the classroom affects students' perceptions of STEM fields and their motivation to learn mathematics. The results indicate a significant positive impact of educational robots on attitudes toward problem-solving and STEM careers. In addition, the use of educational robots in the classroom was found to increase student's motivation to learn mathematics.

While teachers primarily emphasize academic achievement in subjects through a combination of hands-on and technology-based learning modules, it is critical to also focus on developing students' attitudes, as there is a lack of research on the use of robotics to improve attitudes (Papadakis et al., 2021; Tsakeni, 2021). Although robotics is recognized as an interactive tool for improving skills, there is a scarcity of studies that explore its potential for developing effective communication skills in learners (Ioannou & Makridou, 2018). Moreover, even less attention has been paid to the intersection between academic achievement and effective communication skills (Sun et al., 2021). Therefore, it is important to investigate the role of robotics in improving students' attitudes toward effective communication. Therefore, the present study aims to examine the impact of a robotics program on students' attitudes toward effective communication. To gain a comprehensive understanding, this study is guided by the following research questions:

1. Is there a difference in the mean score of students' attitudes towards effective communication in pre-test, post-test 1, and post-test 2 for the experimental group?
2. Is there a difference in the mean score of students' attitudes towards effective communication in pre-test, post-test 1, and post-test 2 periods for the control group?

Theoretical Discussion

The robotics design program incorporates various theories of learning and behavior, such as Piaget's and Vygotsky's theories of constructivism, the theory of operant conditioning, and Ajzen's theory of planned behavior. Regarding the robotics program, it draws on Piaget's theory of constructionism, which is based on constructivism. This approach emphasizes the importance of personal interaction with objects and events in developing understanding and problem-solving skills. In addition, the program's challenges encourage students to engage in repeated tasks, allowing for absorbing information and knowledge. This repetitive behavior is thought to enhance learning, which is also supported by Kalyuga and Plass (2009). Table 1 below provides more detail on how these theories have been applied in research:

Table 1. Theories Involved in Developing Educational Technology Robotics Program

Instructions	Explanation	Theory
The participants have been divided into smaller groups, with each group consisting of four students. Subsequently, these teams collaborate to discuss the process of assembling the designated robot.	• Effective communication within groups is essential for students to accurately construct the robot. • Students need to reach a consensus on task allocation to successfully complete the task. • Integrating Science and Math concepts needed for students to resolve issues during the project.	Social Constructivism Vygotsky's Theory Constructivism Piaget's Theory
In each task, the SCRATCH code was utilized to issue motion commands to the robot. The students' problem solutions, incorporating mathematical and scientific principles, will determine the robot's movements.	• The participants are required to actively engage in the utilization of the SCRATCH coding software, demonstrating proficiency in technology and computer literacy. • Students are expected to retain and apply the principles taught in mathematics and science throughout the program.	Constructivism Piaget's Theory
The robot successfully reaches the finish line due to the accurate arrangement of programming blocks within the SCRATCH program.	• Robots are employed as educational tools to impart fundamental mathematical concepts by utilizing tangible objects.	Constructivism Piaget's Theory
In the event that the robot fails to reach the finishing point, the participants are required to repeat the process until the robot achieves success.	• In case the robot of a student group fails to progress to the next level, there is a requirement for repetition as a form of consequence.	Operant Conditioning Theory
The group whose robot arrives first is recognized as the winner.	• Competition exists among participants within groups, fostering higher levels of engagement and learning.	Ajzen’s Theory Ajzen’s Theory of Planned Behavior Theory of Constructionism
Every participant from each team will provide a response regarding the program.	• Evaluate the effectiveness of the program.	Vygotsky's Theory of Social Constructivism

Robotics Program

Using educational technology in the classroom can improve student access to instruction and reduce feelings of social and academic isolation. This approach encourages participation in various academic activities and environments (Lynch et al., 2022). One example of such a program is the robotics program, which teaches students how to design, develop, and build robots, as shown in the work of Lopez-Belmonte et al. (2021). This interactive and educational science toy allows children to foster their creativity and problem-solving abilities while immersing them in realistic scenarios, as Shih et al. (2013) pointed out.

Educators in numerous countries have recently explored the integration of educational technology programs that use robotic activities to enhance learning in mathematics, science, and engineering domains (Bratzel, 2005; Kaloti-Hallak et al., 2019). In addition, incorporating robotics in the form of games in classroom activities has become increasingly prevalent in educational technology programs (Arkin, 1998; Challinger, 2005; Mee et al., 2020). By leveraging the mechanical and dynamic aspects inherent in game processes, the educational system can motivate students and cultivate 21st-century skills while encouraging the exploration of information, as Iosup and Epema (2014) point out. C. Rogers and Portsmore (2004) and Yang and Baldwin (2020) suggest that educational technology programs such as robotics enhance students' scientific and mathematical capabilities, as well as their behavior and 21st-century skills. Programs such as robotics that incorporate problem-solving, experimentation, and inquiry skills can help students learn scientific and mathematical principles while improving their communication and interaction abilities.

In addition, integrating educational technologies into the classroom improves students' understanding of various topics. It mitigates their academic and social isolation while allowing them access to a comprehensive academic curriculum and diverse educational programs (Lynch et al., 2022). One specific program that aims to teach students effective communication, problem-solving concepts, and hands-on development, design, and construction skills is the robotics program (Lopez-Belmonte et al., 2021). Students can use this engaging and informative scientific toy to increase their creativity and develop 21st-century skills by recreating real-world scenarios (Shih et al., 2013). In addition, Hughes et al. (2022) highlighted in their study that robotics and artificial intelligence improved elementary students' social skills, especially communication skills. In that study, they gave students tasks with programming a robot named Dash™ to move in a square. Hughes et al. mentioned that effective communication is one of students' most important skills in solving the problem. Consequently, in the present study, the researchers used the RoboBuilder RQ+110 robot set developed by a South Korean research group to implement a robotics program. This program included hands-on or practical exercises such as robot assembly and disassembly, troubleshooting, and acquiring knowledge of robot development based on scientific principles. The program was conducted for one hour after school, with groups consisting of three to four children.

Attitude Towards Effective Communication

Effective communication during the learning process means conveying ideas or understanding among students without causing conflict within the group (Salamondra, 2021; Tubbs & Moss, 2003). This can be achieved through satisfaction, mutual respect, and willingness to collaborate among the parties involved (Brinia et al., 2022). Clarity, trust, effective delivery methods, continuity, and listening skills are key elements of effective communication (Brinia et al., 2022; Verderber & Verderber, 2002). Understanding, enjoyment, maintaining trust/faith in the target audience, and follow-up are the four characteristics of effective communication (Verderber & Verderber, 2002). According to Lemke (2002), effective communication in the learning process includes teamwork and collaboration, interpersonal skills, and individual responsibility (Duta et al., 2015; Friedrich et al., 2020).

The Malaysian Ministry of Education has proactively equipped students with 21st-century skills, particularly in enhancing their scientific understanding, problem-solving abilities, and effective communication attitudes. This is accomplished by implementing reformed curricula, namely the Kurikulum Standard Sekolah Rendah (KSSR) for primary schools and the Kurikulum Standard Sekolah Menengah (KSSM) for secondary schools. The Malaysia Education Blueprint 2013-2025 emphasizes the importance of teachers developing themselves to improve their teaching skills in line with the demands of the 21st century (Mahanani et al., 2022; Ministry of Education Malaysia, 2013). Integrating technology into the classroom has also become essential for educators (Amran & Rosli, 2017; Langworthy, 2013; Rusdin, 2018). Abdul Rahim and Abdullah (2017) suggest that using information and communication technology (ICT) in pedagogy and teaching methods can motivate and assist students to improve their communication skills and, thus, engage in 21st-century learning. Technology integration enables learners to actively engage in an interactive environment and acquire 21st-century skills (Amran & Rosli, 2017; Walser, 2008). In addition, the instructional techniques teachers use in the classroom play an important role in shaping 21st-century learning outcomes and student attitudes (Amran & Rosli, 2017; Langworthy, 2013).

This study uses effective communication to enhance mastery of content learned in the classroom through honest discussion, constructive disagreement, and collaborative sharing during the weekly robotics program. In addition, each group member is willing to take on different roles, actively participate, and solve problems to achieve the shared objective during the robotics program. As mentioned in the introduction, teachers need to address students' attitudes in addition to academic performance, starting from primary school to produce holistic students with 21st-century skills, especially effective communication skills, to achieve the Malaysian government's S2A policy of 60:40 science to art ratio. Dato' Professor Dr. Noraini, the Chairman of the National STEM Movement, highlighted communication skills as one of the skills that need to be developed in primary school students (Chonghui, 2020). Given this, the present study specifically focused on how the robotics program affects students' attitudes toward effective communication.

Methodology

Research Design

In this research, a quantitative approach was used to increase the ecological validity of the study through a quasi-experimental design (Gill & Johnson, 2010; Konting, 2005; J. Rogers & Révész, 2019). Data were collected using questionnaires, with a series of instruments administered to respondents. The final data obtained in this study were numerical and analyzed statistically. This method is consistent with Borgstede and Scholz (2021) and Noyes et al. (2019), who emphasize using quantitative research methods to address research problems using data from values and statistical methods. In addition, a questionnaire was used to assess the type of activity that has become a community practice. Adiyanta (2019) and Gürbüz (2017) stated that a questionnaire enables the measurement of multiple desirable variables by including different questions in a single instrument.

Participant and Sampling Method

This study used a purposive sampling method to select the participants, which is commonly used when studying the effectiveness of interventions or programs (Bernard, 2002). This sampling approach has the advantage of selecting participants who can provide valuable information, knowledge, or experience (Sharma, 2017). The sample consisted of 474 4th-grade students in a public school, all aged ten years. Within the sample, 294 students were assigned to the treatment group, which received a robotics program, while 180 students were assigned to the control group, which received conventional learning methods. Selection criteria required students to have moderate to good reading and understanding skills to complete the questionnaires and good attendance to ensure continued participation in the researcher's program without frequent absences. All students were given informed consent to participate in the study. During the initial meeting, they were informed about the research project and were allowed to transfer to other classes if they did not want to participate. This ensured that students were aware of the voluntary nature of their participation and that there were no consequences if they decided not to participate.

Research Instrument and Tool

Malaysian 21st Century Skills Instrument (M-21CSI): This study assessed effective communication using a questionnaire adapted from Osman et al. (2012). The questionnaire consists of 15 questions about effective communication that were rated on a 5-point scale ranging from "strongly agree," "agree," "not sure," "disagree," to "disagree at all." Before its use, the questionnaire was pilot tested with the study population, yielding a Cronbach's alpha reliability coefficient of .98, indicating high internal consistency. Additionally, the researcher conducted confirmatory factor analysis (CFA), specifically Bartlett's test, to confirm the validity of the M-21CSI instrument and to ensure that the Kaiser-Meyer-Okin (KMO) score was above .50, which is required for validity (Hair et al., 2018; Husain & Aziz, 2022). This pilot study obtained a KMO value of .90, indicating that the instrument was valid and appropriate for use in the present study.

RoboBuilder RQ+110: The RoboBuilder RQ+110 is a flexible robotics set manufactured in South Korea. With this set, students can construct up to 10 robots and program in coding activities using the open-source SCRATCH. Like LEGO robots used in schools, the RoboBuilder RQ+110 can perform various operations but offers a more affordable alternative. Students can learn programming skills in schools through SCRATCH coding, a widely used programming language.

Figure. 1. RoboBuilder RQ+110

Study Procedure and Intervention

The study spanned 12 weeks, during which the intervention was implemented for nine weeks. The intervention took place in two phases: from the 2nd to the 5th week and from the 7th to the 11th week. Prior to the start of the program, the researcher organized a meeting attended by the trainer, school headmaster, the curriculum head teacher, the co-curriculum head teacher, and the designated facilitators, who were *Reka Bentuk dan Teknologi* ([RBT], Design and Technology) and mathematics teachers for each class. The purpose of this meeting was to provide information and discuss the class groups participating in the program. The trainer and facilitators were provided with clear instructions and guidance on how to conduct the program one week prior to the start of the program. The researcher used the ROBOBUILDER RQ +110 robotics kit, along with the instruction manual and module provided by the manufacturer. In addition, the researcher provided a list of topics from fourth-grade subjects, including math and RBT, to be incorporated into the robotics program. These topics were selected by the respective subject teachers and approved by the head teachers.

The experimental and control groups attended regular classroom learning during the scheduled week. To ensure the homogeneity of the sample, all students received a pre-test with the M-21CSI questionnaire before starting the program. Following this, the experimental group received after-school treatment through the robotics program, while the control group participated in traditional revision classes after school on the selected topics. Both groups participated in after-school programs for 12 weeks; each lasted one hour. In the experimental group, students were involved in hands-on activities such as assembling robots, learning algorithms and pseudocode, and coding to solve assigned problems. Students in the experimental group also discussed and solved the problem given by the trainer to enable the robot to move. For example, the trainer instructed the students that their robot must move forward ten steps without encountering obstacles and rotate clockwise at the end of the line. So, the students discussed how to solve this problem and reach the goal without making mistakes. The full activity for the experimental group is shown in Table 2 below. Besides trainers, the teachers also played an important role by supporting the students throughout the program by monitoring the students' effective communication in the group. Teachers must also ensure that each group member can participate in the assigned activity during the program. This ensured that all students in the group had an equal opportunity to participate in all activities. At the end of each class task, the trainer and facilitators explained the underlying theory of mathematics problems. One of the problems with doing each activity in a robotics program was the limited time and participation of all group members. Teachers were tasked with assisting the trainer by monitoring the time for each student and ensuring that all students participated in the group. Conversely, the control group received traditional teaching revisions on science and mathematics problems each week for 12 weeks, conducted by the trainers, without involving robotics programs. The study procedure and intervention are shown in Table 2.

Table 2. Study Procedure and Intervention

Week	Activity
1	• Introduction to Robotics Program & Components of Robot. • Pre-Test (M-21CSI)
2	• Treatment 1: - Creating Robots Utilizing Reusable Materials - Revision on the scientific skills and elements of design topics
3	• Treatment 2: - Assemble Punching Bot Robot Base - Revision on Length topic
4	• Treatment 3: - Assemble Punching Bot Robot and it is sensors - Revision on Mass topic
5	• Treatment 4: - Connect the wires to the battery and use the controller to guide the robot to the finish line as per the instructions, which include making the robot turn clockwise, move forward towards the final line, turn 360 degrees counterclockwise, and finally stop. - Revision on Time topic
6	• Post – Test 1 (M-21CSI)
7	• Treatment 5: - Get introduced to algorithms, pseudocode, flowcharts, SCRATCH coding, and learn to move your robot based on written pseudocode, with instruction turning on the robot, moving it forward by 10 steps, and stopping it. - Revision on Coding topic
8	• Treatment 6: - Compose algorithms, pseudocode, flowcharts, and create a 4-line SCRATCH code to guide your robot's movement in a given coordinate set. The robot should turn on, move 5 steps along the x-axis, then 10 steps along the y-axis, and finally stop. - Revision on Coordinate topic
9	• Treatment 7: - Create algorithms, pseudocode, flowcharts, and use 5 lines of SCRATCH code to move the robot and turn on the LED light. The robot should be turned on, moved forward for 10 steps, wait for 3 seconds, turn on the LED for 5 seconds, and then stop. - Revision on Coding topic
10	• Treatment 8: - Create algorithms, pseudocode, flowchart, and implement a 6-line SCRATCH code to move your robot, activate the LED light, sound the buzzer. The robot should turn on, move forward for 10 steps, wait for 3 seconds, turn the LED on for 5 seconds, activate the buzzer for 3 seconds, and finally stop. - Revision on Coding topic
11	• Treatment 9: - Create algorithms, pseudocode, and flowchart to program your robot using SCRATCH to execute instructions for specific problems. These instructions include turning on the robot, turning on the LED and buzzer for 5 seconds, moving forward for 10 steps, rotating clockwise 360 degrees, waiting for 2 seconds, activating the buzzer for 3 seconds, moving forward for 5 steps, moving backward for 3 steps, rotating anticlockwise 360 degrees, and finally stopping the robot. - Revision on Time & Angle topic
12	• Post – Test 2 (M-21CSI)

Data Collection Procedure

After obtaining approval from the schools, the researcher scheduled a meeting with each school's headmasters and appointed teachers (facilitators) to discuss the classes assigned to the control and experimental groups. The program was conducted over 12 weeks, beginning with two briefing sessions during the first week. Trainers and facilitators attended these sessions and introduced the program to the students in the sample. Following the briefings, a 15-minute pre-test was administered using the M-21CSI questionnaire. The intervention activities with robotics for the experimental group and post-test 1 for the control and experimental groups were conducted during weeks 2 through 5. The robotics program continued for the experimental group in weeks 7 to 11. In week 12, the M-21CSI questionnaire was distributed to both groups for post-test 2, evaluating students' attitudes.

Data Analysis

Descriptive and inferential statistical tests were utilized for data analysis in this study. The data obtained from the questionnaires were analyzed using the Statistical Packages for the Social Sciences (SPSS) version 25.0 for Windows software. To compare the mean scores of the post-tests 1 and 2 between the control and experimental groups, the researcher performed a repeated measures analysis of variance (ANOVA) with a significance level of 0.05.

Findings/Results

This study examined the impact of implementing a robotics program, an educational technology intervention, on students' attitudes toward effective communication. To answer the research questions, descriptive analyses were conducted to evaluate the experimental and control groups separately. The control group had a pre-test mean score of 4.2801, while the experimental group had a pre-test mean score of 4.0221. In the experimental group, the mean score for post-test 2 increased significantly and reached 4.7688, a difference of 0.746 compared to the control group's mean score of 4.1900, which decreased by 0.090. The results of the descriptive analysis indicate a notable increase in the mean scores of students in the experimental group across the three assessment points, while the control group showed a decrease from pre-test to post-test 2. The full results of the descriptive analysis are presented in Table 3.

Table 3. Descriptive Statistics Score of Attitude Towards Effective Communication by Study Sample Group

Parameter	Control Group			Experimental Group		
	Pre	**Post 1**	**Post 2**	**Pre**	**Post 1**	**Post 2**
N	180	180	180	294	294	294
Mean	4.28	4.19	4.19	4.02	4.75	4.76
Standard Deviation	0.72	0.75	0.75	0.84	0.55	0.55

The following analysis focused on addressing the first and second research questions of the study, which are:

1. *Is there a difference in the mean score of students' attitudes towards effective communication in the pre-test, post-test 1, and post-test 2 for the experimental group?*
2. *Is there a difference in the mean score of students' attitudes toward effective communication in the pre-test, post-test 1, and post-test 2 for the control group?*

To examine the significance of these differences within the experimental and control group, a repeated measures ANOVA with a significant level of α = .05 was employed. Tables 4 and 5 present the experiment and control group analysis results.

Table 4. Test of Within-Subjects Effects for Experiment Group

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Attitude Towards Effective Communication	Sphericity Assumed	1.165	2	.582	276.022	.000	.766
	Greenhouse-Geisser	1.165	1.282	.909	276.022	.000	.766
	Huynh-Feldt	1.165	**1.286**	.906	**276.022**	**.000**	**.766**
	Lower-bound	1.165	1.000	1.165	276.022	.000	.766
Error (Attitude Towards Effective Communi cation)	Sphericity Assumed	.895	424	.002			
	Greenhouse-Geisser	.895	271.702	.003			
	Huynh-Feldt	.895	**272.632**	.003			
	Lower-bound	.895	212.000	.004			

Table 5. Test of Within-Subjects Effects for Control Group

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Attitude Towards Effective Communication	Sphericity Assumed	.002	2	.001	.153	.080	.001
	Greenhouse-Geisser	.002	1.906	.001	.153	.080	.001
	Huynh-Feldt	.002	**1.925**	.001	.153	**.080**	**.001**
	Lower-bound	.002	1.000	.002	.153	.080	.001
Error (Attitude Towards Effective Communication)	Sphericity Assumed	2.681	376	.007			
	Greenhouse-Geisser	2.681	358.347	.007			
	Huynh-Feldt	2.681	**361.923**	.007			
	Lower-bound	2.681	188.000	.014			

The repeated measures ANOVA analysis results revealed that the experimental group yielded a significant value since F (1.29, 272.63) = 276.02, p < .000, and partial η^2 = .766, as presented in Table 4. This p-value is below the predetermined significance level of .05, indicating that the robotics program has significantly influenced the students' attitudes toward effective communication. Conversely, the repeated measures ANOVA test conducted on the control group yielded a non-significant value since F (1.93, 361.92) = .153, p = .08, and partial η^2 = .001, as shown in Table 5. This value surpasses the set significance level of 0.05. Hence, it can be inferred that the control group, which underwent the conventional revision method without the robotics program as an after-school activity, did not improve their attitude toward effective communication. Moreover, the profile plots showed the effectiveness of the implemented robotics program in improving students' attitudes toward effective communication for the experimental group, while the students in the control group without the robotics program showed no signs of improvement in attitudes toward effective communication. The results of the profile plots are shown in Figure 2.

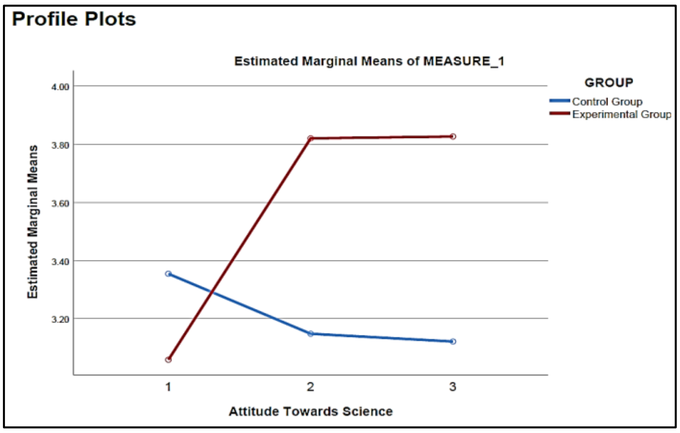

Figure 2. Profile Plot – Experiment and Control Group

Discussion

The results of this study are consistent with the research of Darmawansah et al. (2023), who emphasized the importance of effective communication in meaningful learning with robots. The experimental approach used in this study highlights the need for students to understand and communicate effectively with their group members to coordinate robot coding and problem-solving tasks successfully. Effective communication is critical to clearly understanding and interpreting peers' messages (Salamondra, 2021; Verderber & Verderber, 2002). When students do not understand, or misunderstand their peers' words or ideas, communication becomes ineffective, resulting in the robot's inability to perform its intended actions. Using educational robots in the classroom creates a more active and lively learning environment. Students communicate within their groups, observe other participants, and strive to minimize errors at each program stage. In contrast, control group schools using traditional teaching methods experience a less stimulating learning environment where students participate individually, resulting in a more boring classroom atmosphere.

In experimental schools, trust among group members is emphasized. Each individual is expected to possess the necessary skills to perform their group responsibilities, such as coding the robot, answering questions, and directing its movements. Completing these tasks is interconnected and crucial in guiding the robot to the intended destination. Effective communication is central to this process, requiring a high-quality interaction in which the listener trusts the speaker (Jahromi et al., 2016; Tubbs & Moss, 2003). Consequently, building trust and gaining the trust of other group members within the same team becomes essential for accomplishing each task level. The instructional approach used in the experimental schools promotes collaboration and encouragement among group members. Effective communication can motivate listeners to improve their performance (Jahromi et al., 2016). Therefore, each student in the group must encourage their peers since completing all assigned tasks is interconnected and critical to the group's overall success.

Educational technology programs such as robotics have positively impacted students' learning, motivating them and fostering the development of 21st-century skills (Tsai et al., 2020; Van Alten et al., 2020). It has also contributed to their overall learning experience (Andujar & Nadif, 2022; El Sadik & Al Abdulmonem, 2021; Zheng & Zhang, 2020). Furthermore, this learning approach involves students actively constructing their knowledge through scientific inquiry activities (Palazón-Herrera & Soria-Vílchez, 2021; Purba, 2021). This teaching method fosters an interactive learning environment that allows students to acquire knowledge, apply it, and enhance their critical thinking and effective communication abilities. Numerous research studies demonstrate that communication is critical for students to identify problems, investigate solutions, and draw conclusions (Can et al., 2017; Hairida & Junanto, 2018; MacLeod & Van der Veen, 2020). In addition, the robotics program is particularly engaging because of the competitive element it introduces (Danelid & Fältman, 2021; Höllig et al., 2020).

Robotics serves as a hands-on learning platform (Bravo et al., 2021; Selby et al., 2021), but integrating robotics with an active learning strategy is critical to fostering student communication, and its effectiveness is enhanced when the two are well-coordinated (Lopez-Caudana et al., 2020). Diverging from previous literature, this study highlights the role of a robotic program in stimulating active student engagement through two-way communication in the classroom. The research participants enthusiastically participated in all activities and actively conveyed their problem-solving processes using creative and imaginative methods. In addition, gaining experience is a continuous encompassing of an individual's past experiences and new experiences. People's different life experiences significantly impact how they perceive and comprehend the world (Manikutty, 2021). In this study, participants consistently compared their previous experiences with their newly developed understanding to guide their actions during robotics activities. By providing detailed insights into the connections between past life experiences and each activity, this research contributes to enriching knowledge and communication skills.

In addition, using a scaffolding strategy corresponds to the concept of decomposition in fostering effective communication (Angeli & Valanides, 2020; Zhang et al., 2021), especially when integrating educational robotics as a tool. Previous literature highlights that the learning process involving robotics in this study led to the cultivation of profound communication skills and meaningful knowledge, largely due to the scaffolding design employed. Consistent with Angeli's (2022) research, participants diligently constructed their robotics models and scripted programs to achieve the desired outcome. In our study, participants indicated that subsequent activities in the robotics program became easier after they learned and completed the robotics programming task. Participants demonstrated a determined mindset and persevered until they solved the problem or identified remaining errors. Robotics introduced a novel experience for the participants, and the challenges facilitated their adaptation to acquire relevant knowledge and cultivate 21st-century skills, especially effective communication skills.

Conclusion

The findings of this study have significant implications and benefits for various stakeholders, including the ministry, teachers, and students, and impact areas such as research, practical applications, and educational models. By highlighting the important role of robotics, this work contributes to the existing literature, particularly by expanding the scope of previous studies that focused on learning experiences. Integrating robotics programs has provided active learning experiences and positively changed students' attitudes toward effective communication. This study has also shown that it is possible to implement a robotics program in school as an extracurricular program to enhance students' attitudes and foster their interest in STEM. From a practical perspective, educators who conduct hands-on learning activities with students can benefit from the findings of this research. Moreover, this study is consistent with the 21st-century learning model and the concept of technology-assisted learning, which, if implemented effectively, can improve students' attitudes toward learning.

Noh and Karim (2021) found that traditional teacher-centered teaching methods are still prevalent among educators, suggesting that a mindset promoting educational competitiveness is needed. This study equips educators with the knowledge necessary to transition from teacher-centered to student-centered teaching assisted by technology. This will create valuable learning experiences that improve student attitudes and their ability to apply information in real-life situations. It is anticipated that this study will boost teacher and educator confidence in utilizing robot-assisted learning methods and enable the expansion of these programs to other behaviors and skills, particularly those related to 21st-century competencies.

Recommendations

This study presents a foundation for future practitioners to explore other skills within robotics programs. It is recommended that further research be conducted with a larger sample size and over a longer period to gain more comprehensive insights. Furthermore, since the current study was limited to primary school students, it would be beneficial to conduct similar studies in suburban and rural secondary schools to determine if the results are consistent with or different from those of the present study. Future research can incorporate qualitative methods such as interviews with students and their parents to gain additional perspectives. It is also suggested that future practitioners consider including participants from diverse racial backgrounds to observe how the program responds to students from diverse backgrounds. In addition, future researchers should explore how robotics programs can improve language skills such as listening, reading, writing, and grammar. Future research can also be extended to developing integrated modules that link robotics to science and math curricula to monitor academic performance. This present study can be used as evidence for educational institutes to encourage their teachers to shift paradigms from traditional teacher-centered teaching to technology-based, student-centered teaching.

Limitations

The generalizability of the results of this study is limited due to the small sample size. The study used a quantitative approach and a quasi-experimental design with control and experimental groups. The questionnaire used in this study specifically targeted students' attitudes toward effective communication. Therefore, the results of this study should be interpreted in the context of the questionnaire used, the specific location of the study, and the conditions under which it was conducted.

Ethics Statements

The Ministry of Education Malaysia and the University Malaysia Sabah reviewed and approved the studies involving human participants. The participants provided their written informed consent to participate in this study.

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Conflict of Interest

The authors report that no potential conflict of interest may be affected by the research reported in the enclosed paper.

Authorship Contribution Statement

Sharif: Conceptualization, reviewing, administration, supervising. Muniandy: Writing, design, data collection, analysis, editing. Mariappan: technical support, editing, reviewing.

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