Integration of educational robotic in STEM learning to promote students' collaborative skill

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Abstract. The study aims to determine the effect of integration of educational robotics in STEM learning to promote students' collaborative skills. Collaborative skills can be developed by implementing learning strategies that lead to learning activities as hands-on activities, technology engagement, and teamwork between students. These learning activities can be covered by integrated educational robotics in STEM learning. The descriptive method with a quantitative approach was applied in this research with 36 ten-grade students as subject research. The teacher team observed students' collaborative skills before and after the implementation of STEM-Robotic learning. The observation using the instrument that developed based on indicators of collaborative skills activities. Collaborative skills activities consist of participation, perspective-taking, and social regulation. The results showed that STEM-Robotic learning can promote students' collaborative skills in participation aspects by 55.93%, perspective-taking aspects by 56.03%, and social regulation aspects by 67.34%. The results indicate that STEM-Robotic learning is an alternative learning strategy that can be implemented to develop 21st-century skills, especially collaborative skills.

1. Introduction
The rapid development of science and technology requires learning in the classroom more creative and innovative according to the necessity of the era. Learning in the classroom must develop students' 21st-century skills, including problem-solving skills, metacognitive, creative, critical, collaborative, and communicative skills. These skills are demands that must be mastered by students in the 21st-century [1]. The development of 21st-century skills aims to prepare students to contend the real and tight global competition in this era. The 21st-century has the challenges of life without borders, globalization, and internationalization [2]. Referring to the global competition era, learning in the classroom must accommodate a variety of student activities through learning activities that are not just a transfer of knowledge from teacher to student. More than a transfer of knowledge, learning must involve technology and digitalization as an adaptation with this era and collaboration between individuals, groups, and machines [3].

Collaborative skill is significant for students in the 21st-century. Students who collaborate in completing group assignments have better performance than students who complete their work independently [4]. Collaborative activities in learning can increase collective knowledge, confidence, motivation, social interaction, and concern for other students [5]. In the context of the learning process, collaboration in student activities can increase learning productivity [6]. More specifically on improving 21st-century skills, collaboration students in learning can enhance students' collaborative skills [7][8].
Collaborative activities and good learning productivity can be realized by developing collaborative learning between students during the learning process.

Collaborative learning can be developed through cooperative learning models with jigsaw type [9] cooperative learning with team accelerated instruction type [10] and the provision of group projects [11]. Collaborative learning can be developed also through the use of technology that leads to student center and hands-on activity projects in the learning process. The educational robot is a technology that has been developed to support the learning process. Educational robots in learning can improve collaborative and cooperative skills, learning motivation, and students' learning outcomes [12][13]. Furthermore, robotic activities in learning can improve systems thinking, problem-solving, and student teamwork skills [14].

The educational robot is used as a tool to support the learning process that is related to technology and engineering, namely learning with the STEM approach (science, technology, engineering, and mathematic). In many schools, STEM learning implementation is more focused on the science and mathematics field, and the portion of technology and engineering in STEM learning still low [15]. These conditions make STEM learning not optimal in preparing students to face an increasingly digital world. Educational robots offer alternative learning strategies when combining STEM and applications [14]. Robotic is one of the technologies that can be used by teachers to develop STEM curricula, specifically in technology and engineering [15].

In line with this, integration robotic in STEM learning can create a learning environment, hands-on activities, creativity, and problem-solving [14], create more meaningful learning, and give the student experience in applying technology [16], and enhance basic STEM skills, such as mathematical skills, scientific methods, and engineering design skills [13][17]. More specifically, the integration of educational robots in STEM learning can enhance hands-on and minds-on activities that create collaborative learning environments [18][19][20]. Based on the description, this study has investigated the effect of the integration of educational robotic in STEM learning to promote students' collaborative skills. Collaborative skills in this research consist of three main parts: participation, perspective-taking, and social regulation [21]. Every part of the collaborative skills has indicators as the basis for developing the instrument of collaborative skills.

2. Methods
The study used a descriptive method with a quantitative approach. These methods determine the value of the independent variable, either one or more (independent) variables without making comparisons or linking with other variables [22]. This study determines the effect of the integration of educational robotic in STEM learning to promote students' collaborative skills. The effect of learning treatment observed in the before and after STEM Robotic learning. In this study, the instrument of students' collaboration skills developed by collaborative skills aspects, namely participation, perspective-taking, and social regulation [23]. Each aspect has indicators of student behaviors, it becomes the focus of observation by the teacher.

This study used 36 ten-grade science students as research subjects. In the curriculum of the school, STEM becomes a regular curriculum with 2 hours of learning in one week (2 x 45 minutes per week). This study was conducted during 8 learning meetings. The teams of teachers observed students' collaborative skills at the first and 8th meetings. Every teacher observed one group of students during STEM Robotics learning. The integration of educational robots in STEM learning was carried out in six learning meetings to provide group projects as a learning strategy. The results of observations of students' collaborative skills were analyzed and processed in the average percentage of students' collaborative skills. The improvement of students' collaborative skills was analyzed by converting the average scores of students' collaborative skills into N-gain scores.

3. Results and discussion
The results and discussion are based on research findings and analysis of the integration of educational robots in STEM learning (STEM-Robotic learning). The results and discussion focused on the effect of
the implementation of STEM-Robotic learning to promote students' collaborative skills. Students' collaborative skills in this study consist of 3 main aspects, namely, participation, perspective-taking, and social regulation [23]. Each aspect has indicators of students' collaborative skills. The teacher team observed students' collaborative skills before and after the implementation of STEM-Robotic learning.

3.1. Participation aspect
Participation is an aspect of collaboration skills such as all student activities in groups, student interactions with other students, and student contributions in groups [23]. All activities of students related to the participation aspects observed by the teacher team using the instrument of observation, it developed based on indicators of participation aspects in collaborative skills. Table 1 describes the participation aspects and explanation of activity indicators [23].

| Participation Aspect | Behavioral Indicator                                      |
|----------------------|----------------------------------------------------------|
| Action               | Activity within the environment                          |
| Interaction          | Interacting with, promoting, and responding to contributions' of other |
| Task completion/     | Undertaking and completing a task or part of a task individually |
| Perseverance         |                                                           |

The observation of actions and interactions aspects related to students' activities and interactions when working and discussing projects. The task completion aspects were observed related to student perseverance in completing group assignments on STEM-Robotic projects. The observation of participation aspects was conducted before and after the implementation of STEM-Robotic learning. The purpose of the observation is to get a description of participation aspects before and after STEM-Robotic learning. The results of the participation aspect showed in the average score of students' collaborative skills for participation aspects.

| Observation | Average Score of participation aspect (%) | N-Gain (%) | Category |
|-------------|------------------------------------------|------------|----------|
| Initial     | 53.60                                    | 55.93      | Medium   |
| Final       | 79.55                                    |            |          |

Table 2 showed the average score of students' collaborative skills for participation aspect in initial observation of 53.6%, and the average score of students' collaborative skills for participation aspect in final observation of 79.55%. The promote in students' collaborative skills for participation aspect of 55.93%. The results indicate that STEM-Robotic learning can promote students' collaborative skills for participation aspects. The results in line with the finding of research [16] stated that students who studied STEM using robots show a higher level of interaction and participation than students who studied STEM without robots. Furthermore, the integration of robots in STEM learning was effective in promoting student enthusiasm and involvement during learning [14][21][23].

Student participation in STEM-Robotic learning consists of design activities, such as designing the basic NXT robot, programming the NXT to move the wheels, moving the robot using sound, ultrasonic, touch and light sensors, designing the NXT in the form of the steering wheel, and running it along the lines until the finish. The activities and interactions of students can also be seen in the design of Arduino devices, such as practice how to light the LED through a button and practice how to turn on seven segments to form 0-9. In the design activities, indicators of participation aspects such as action, interaction, and task completion of each student developed through working in a project. The results of observations showed that interactions between students indicate excellent students help other students
in completing their Lego projects. The result in line with the opinion that students are more experienced
in a particular programming situation help to teach other students to complete in Lego program [16].

3.2. Perspective-taking aspect
Perspective-taking is an aspect of collaboration skills, the perspective-taking that consists of adaptive
responses and audience awareness. All students' activities related to the perspective-taking aspect
observed by the teacher team using instruments. The instrument developed based on indicators of
perspective-taking aspects in collaborative skills. Table 3 describes of perspective-taking aspect and
activity indicators [23].

| Table 3. Perspective-taking aspect and behavioral indicators. |
|-------------------------------------------------------------|
| Perspective-Taking Aspect | Behavioral Indicator                                      |
|---------------------------|----------------------------------------------------------|
| Adaptive responsiveness   | Ignoring, accepting or adapting contributions of others   |
| Audience awareness (mutual modeling) |Awareness of how to adapt behavior to increase suitability for others. |

The observed adaptive response consists of various student activities in the completion of the STEM
Robotic project, such as the student's response when other students gave an idea about project
completion. The observed audience awareness related to the awareness of a student in adjusting his
behavior when other students have more ability in completing the STEM Robotic project. All
perspective-taking activities were observed to get a description of perspective-taking aspects during
STEM Robotic learning. The results of the observations presented in the average score of perspective-
taking aspects and its improvement as follows.

| Table 4. Percentage of collaborative skill scores for participation aspects. |
|-------------------------------|---------------------------|-----------------|---------------|
| Observation       | Average Score of perspective-taking aspect (%) | N-Gain (%) | Category |
|-------------------|-----------------------------------------------|------------|----------|
| Initial           | 43.10                                         |            |          |
| Final             | 74.98                                         | 56.03      | Medium   |

Table 4 shows the average score of perspective-taking aspects at the initial observation is 43.10%
and at the final observation is 74.98%. Table 4 also shows that STEM Robotic learning can promote
students' collaborative skills in perspective-taking aspects by 56.03%. STEM Robotic learning provides
learning strategies that lead to teamwork activities between students on completion of a project. This
learning strategy of STEM Robotics learning can promote students' collaborative skills in participation
aspects. The research findings, in line with the results of the study [24][25] state that the involvement
of technology in learning can improve perspective-taking skills.

The development of collaborative skills in the perspective-taking aspect is developed during STEM
Robotic learning through the provision of projects using Lego NXT and Arduino. Every student has a
different role in the group during project completion. The different roles in groups aim to give an active
role to each student in taking action during project completion. The role of students in groups includes
the design of project completion, the preparation of the Lego NXT or Arduino according to the project,
and the making of coding to run the robot. In the implementation, all students have a role in work
together with other students in completing projects with hand-on activities. The finding in line with the
opinions and research findings [20][22][26][27] state that STEM learning integrated with robotics can
increase students' hands-on activity.
3.3. Social regulation

Social regulation is an aspect of collaborative skills that consists of negotiation, self-evaluation, transactive memory, and responsibility initiative [23]. Every student activity related to the social regulation aspect is observable before and after STEM-Robotic learning. Table 5 showed the indicators of social regulation aspects.

Table 5. Social regulation aspect and behavioral indicators.

| Participation Aspect | Behavioral Indicator                                      |
|----------------------|----------------------------------------------------------|
| Negotiation          | Achieving a resolution or reaching a compromise          |
| Self-evaluation      | Recognizing own strengths and weaknesses                 |
| Transactive memory   | Recognizing the strengths and weaknesses of others       |
| Responsibility initiative | Assuming responsibility for ensuring parts of the task is completed by the group |

In this study, the collaborative skill of social regulation aspects related to various student activities when presenting and discussing STEM Robotic projects. The observation of social regulation activities includes student activities in communicating the result of the project, assessing the results of their groups' project and other groups, receiving and responding to suggestions and input from other groups. The activities will be obtained by students when presentations and discussions. These activities lead to the development of collaborative skills in social regulation aspects. The results of observations on the collaborative skills of social regulation aspects in STEM Robotic learning can be seen in table 6.

Table 6. Percentage of Collaborative Skill Scores for Social Regulation Aspects

| Observation | Average Score of Social Regulation aspect (%) | N-Gain (%) | Category |
|-------------|----------------------------------------------|------------|----------|
| Initial     | 45.50                                        | 67.34      | Medium   |
| Final       | 82.20                                        |            |          |

Table 6 shows the average score of students' collaborative skills on social regulation aspects before STEM-Robotic learning by 45.5% and after STEM Robotic learning by 82.2%. Table 6 also shows that STEM Robotic learning can promote students' collaborative skills in the social regulation aspect by 67.34%. The results indicate that STEM Robotic learning positively impacts students' collaborative skills in social regulation aspects. Teamwork and collaboration activities during the completion of the project make every student understand his role and role of his friend, a condition called trans-active memory [23]. These conditions have an impact on promoting students' collaborative skills in social regulation aspects.

STEM Robotic learning is set up by providing group projects that lead to the development of social regulation, especially in inter-group discussion activities. During the discussion activities, students learn how to respect the opinions and answers of others, evaluate each group project and other group projects, and help other students in their group when answering questions from another group. These activities can improve social regulation aspects. The increase in social regulation aspects will have an impact on promoting students' collaborative skills. The results are in line with the findings of [28][29] whose state that socially shared regulation has a positive effect on the process of collaboration among students.

4. Conclusion

In many schools, STEM learning implementation is more focused on the science and mathematics field, and the portion of the technology and engineering field still low. Educational robots offer alternative learning strategies to develop STEM curricula in the technology and engineering field. The integration of educational robots in STEM learning (STEM Robotic learning) is learning strategies that lead to hands-on activities, technology engagement, and the development of 21st-century skills. This research
investigated the effect of STEM Robotic learning to promote one of the 21st-century skills, namely collaborative skills. In this research, collaborative skills consist of participation aspects, perspective-taking aspects, and social regulation aspects. The results showed STEM Robotic learning could promote students' collaborative skills in the participation aspect by 55.93%, perspective-taking aspects by 56.03%, and social regulation aspects by 67.34%. The results indicate that STEM-Robotic learning is an alternative learning strategy to develop 21st-century skills, especially collaborative skills.

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