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The Application of PjBL with STEM Integration: Its Effect on Science Problem-Solving Abilities

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Abstract: This study aims to investigate the effectiveness of the PjBL Model with the STEM Approach in improving junior high school students' science problem-solving abilities. It is a quasi-experiment with a nonequivalent control group design. The population is grade VIII students of State Junior High School 3 Magelang, and the sample is grade VIIIB and VIIIF students, established by using the purposive sampling technique, with VIII B students as the experimental class and VIIIF students as the control class. The data were collected using a test. The results showed the post-test scores of the experimental class were higher than those of the control class with the sig. (2-tailed) < 0.05, namely 0.000 from the independent sample t-test. The N-gain test shows that the N-gain of the experimental class is higher than that of the control class (0.678> 0.412), both in moderate criteria, so it can be concluded that the PjBL Model with the STEM Approach can improve the science problem-solving abilities of junior high school students.
Keywords: problem-solving ability, project-based learning, STEM approach.

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INTRODUCTION

The increasingly advanced era of globalization as it is today cannot be separated from the learning process to improve 21st-century skills (Erlinawati et al., 2019). Astutik and Hariyanti (2021) state that 21st-century skills are a series of knowledge that students must have so that they can survive due to developments and changes in the era. Partnership for 21st-century skills (2019) explains that 21st-century skills in learning include critical thinking and problem-solving skills, innovation, creativity, communication, and collaboration.

One of the 21st-century skills that students need to master is problem-solving abilities. Problem-solving abilities are interpreted as an individual's ability to find solutions (Irwanto et al., 2018). The more complicated and complex a problem is in students' daily lives where scientific knowledge is needed to deal with it, the more necessary it is to teach the ability to solve problems (Fiteriani et al., 2021; Lieung et al., 2019). Learning activities that familiarize students with problem-solving make students more sensitive and creative in solving a problem and in training and improving their critical thinking skills, creativity, and communication skills (Supiyati et al., 2019). So, this problem-solving ability needs to be instilled early on and given more attention by teachers when teaching so that it is required by students for solving real-life problems based on correct and appropriate procedures.

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Indonesian students still have very low problem-solving abilities that require analytical skills, logic, reasoning, creativity, and evaluation skills (Kurniati et al., 2016). The problems that are often encountered in science teaching are students' weak problem-solving abilities, especially essential skills in the form of developing contextual questions. The obstacles experienced by students are the difficulty in finding problems that teachers want to solve, where students find it difficult to describe, especially in abstract questions or materials (Sukmasari & Rosana, 2017)

The Programme for International Student Assessment (PISA) in 2018 showed that Indonesia was ranked 62 out of 71 countries, with an average score of 396 for science (OECD, 2019). These findings show that Indonesian students have a low level of competence in achieving scientific literacy in terms of knowledge, competence, and scientific background (Asikin & Yulita, 2019; Dewi et al., 2021; Hadiprayitno et al., 2021; Santoso et al., 2022). This happens because Indonesian students are not trained adequately to answer questions that have characteristics like PISA questions, which can be seen from examples of learning outcome assessment instruments that have been developed. In general, however, the content is less relevant to students' life situations and does not facilitate them to express their thinking processes and arguments (Mutialawati et al., 2024). The results of the 2022 Indonesian PISA show that Indonesia's ranking has increased by 5 to 6 positions compared to the 2018 PISA results, where reading and mathematics rose by 5 ranks, while science rose by 6 ranks. These results show that if Indonesia's ranking increases, the PISA score obtained will decrease. The 2022 PISA survey showed that the average score of PISA participating countries decreased by 80% for reading literacy scores, 82% for mathematics scores, and 52% for science scores (Kemdikbud, 2023).

The results of an interview conducted with one of the science teachers at SMP N 3 Magelang regarding students' problem-solving abilities show a teacher-centered teaching, where teachers dominate learning activities and lack habituation of implementing problem-solving-based learning activities by teachers, causes students to be less active in solving a problem. This is supported by the opinion of Asfar & Nur (2018) who explain that teachers' lack of habituation of students to carry out problem-based activities in the learning process will result in low students' problem-solving abilities. In contrast, if learning is more student-centered and supported by a problem-solving-based learning model such as the Problem-Based Learning (PBL) Model, students' problem-solving abilities will be better and increase compared to before. The students’ low interest in solving problems also causes students to have difficulty finding appropriate solutions or answers and ultimately makes their problem-solving abilities low. The results of problem-solving ability tests administered in class VIII on vibration and wave material show in answering the descriptive questions on the material, most students are less able to answer questions correctly and appropriately because they are too focused on memorizing formulas from books and only understand the example questions explained by the teacher, without looking for other example questions to train their problem-solving abilities. The four indicators of problem-solving ability used show that to answer descriptive questions on vibration and wave material students still find it difficult to answer questions on the second and third indicators, namely making plans to solve problems and implementing problem-solving plans.

Based on the existing problems, one of the ways to improve students' problem-solving abilities is to implement the PjBL Model. The PjBL Model is a project-based learning model in which facilities and challenges are provided and it can motivate students to create their knowledge while increasing their creativity (Anindayati & Wahyudi, 2020). The PjBL Model is defined as a learning model that is carried out by giving students a project, and in the project, there is a combination of various subjects that emphasize real-life problems (Wardah et al., 2022). On the other hand, the PjBL Model is also a constructivist and collaborative learning model, where students play a central role in their learning activities, allowing them to work together to solve a problem and learn together to increase knowledge and understanding (Sumarni et al., 2016).

In addition to the PjBL Model, the STEM Approach is also applied to support the learning model. This is because when the PjBL Model is used, it cannot optimize high-level thinking skills to face the increasingly advanced era of globalization, because students are not involved in formulating problems and the product designing process, so they are not allowed to further explore problem-solving in the real world (Windasari, 2019). Basically, in the PjBL Model, there are stages of providing basic questions with relevant topics based on facts in the field as a problem regarding a topic and allowing examination and investigation to solve it (Satriana, 2021). At that stage, however, it is difficult for students to solve problems (Kemdikbud, 2014). This is because, in the PjBL Model, the difficulties faced by students are concrete. They are also

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required to find a way to solve problems and work on projects in a team to overcome problems (Muyassaroh et al., 2022), so a teaching approach is needed to support the PjBL Model, namely the STEM Approach. The STEM Approach can train students to develop learning and innovation skills, solve problems, design or discover new things, understand themselves, think logically, and be technology experts (Devi et al., 2018). In addition, the STEM Approach was chosen because this approach combines four disciplines (science, technology, engineering, and mathematics) which can be used to solve real-world problems and foster students' creativity so that they have 21st-century skills (Devi et al., 2018). The PjBL Model and the STEM Approach also complement each other, because students can understand a concept by making a product through the PjBL Model, while the design and redesign process (engineering design process) is through the STEM Approach so that a desired product is produced (Lutfi et al., 2018). The phases/stages of the PjBL Model with the STEM Approach can be seen in Table 1 (Satriana, 2021).

Table 1. Syntax of PjBL with the STEM Approach

Phases of PjBL Model	Teaching activities
Phase 1: Determining Essential Questions	Presenting videos/phenomena of earthquakes and the damage or impacts caused (science). In addition, there is a video containing a comparison of two different buildings during an earthquake, where the two buildings have different basic materials and building designs (technology, engineering, and mathematics), and providing videos as essential questions to provoke knowledge, responses, criticisms, and ideas that can offer an overview to solve the problems from the questions.
Phase 2: Project Planning	Planning a project in the form of a miniature earthquake-resistant building collaboratively by searching for references or literature to first find out the concept of earthquake-resistant building design in more detail (science), selecting tools and materials to make the project and the procedures/work methods that will be carried out later and making an initial product design (technology, engineering), measuring the design of the miniature earthquake-resistant building that is made, for example, height, width, length, and others (mathematics) to answer essential questions.
Phase 3: Scheduling	Making a timeline for completing the project to find out how much time is needed to complete the project
Phase 4: Monitoring students and project completion and development	A systematic monitoring framework is implemented to oversee student project creation, ensuring the provision of necessary facilities throughout the product development lifecycle. Students collaboratively execute predetermined projects, employing tools and materials, adhering to production procedures, and realizing initial design concepts, thus applying integrated technology, engineering, and mathematics disciplines.
Phase 5: Testing the result	The teacher tests the completed project to prove the questions asked by students. At this stage, students must be able to explain the characteristics of the earthquake-resistant building miniature that has been completed (science); and the reasons for choosing the tools, materials, steps/procedures, and project designs that have been made (technology, engineering); measurements taken when doing the project, such as height, length, and width (mathematics). At this stage, students are also given responses or feedback regarding their understanding and project results in the form of input or suggestions by the teacher.
Phase 6: Evaluating experience	Presenting the results of the project and their group discussion. At this stage, students must be able to explain the characteristics of the miniature earthquake-resistant building that was made (science), explain the reasons for choosing the tools, materials, steps/procedures, the design of the project that was made, and why it can be said to be an earthquake-resistant building (technology, engineering), and measurements taken when doing the project, such as height, length, and width (mathematics). This stage is almost the same as the results testing stage, but at this stage, the project that was made has been completed according to the joint decision of the group members, and the delivery of the project results is explained in front of the other group members. In addition to the presentation, students reflect on the activities carried out during the

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	project creation by expressing experiences and obstacles faced when carrying out project tasks.

The implementation of the PjBL Model with the STEM Approach explained in the syntax shows that the project assignment that students must do in groups is a miniature earthquake-resistant building. Making this miniature earthquake-resistant building can improve students' problem-solving abilities because before making the miniature, students first watch two videos illustrating buildings when an earthquake occurs. The two videos have differences in the design and building materials used by the two buildings. The video show aims to encourage students to respond to questions, criticisms, or ideas based on their analysis. It also provides an overview of how to solve problems from questions, criticisms, and ideas submitted previously. In addition to the video presentation, the students prepare and plan the project starting from the design, tools and materials, and the procedure for making the project. From this activity, students will encounter problems that must be solved. For example, when planning the project students choose wood, but because wood is hard to find students need to replace the wood with other materials. When the project material is replaced, the design and procedure for the project are also replaced to suit the needs and desires of the students.

This can stimulate students to train and improve their problem-solving abilities. As to the potential contained in the PjBL Model and the STEM Approach, both are suitable to be combined and can be used as an alternative to improve students' problem-solving abilities. This can be proven based on research by Afriana et al. (2016) which explains that learning by applying the model and approach is more interesting. It increases students' learning motivation, provides an understanding of the learning material, and fosters a creative attitude. In addition, the research by Ismayani (2016) also reports that the PjBL Model and the STEM Approach lead students to carry out more meaningful learning to master a concept. Students will also be able to explore something with project activities so that they become more active learners. Based on the problems explained, the researcher is interested in investigating and conducting this research entitled "The Effectiveness of the PjBL Model with the STEM Approach in Improving the Science Problem-solving Abilities of Junior High School Students".

METHOD

Type of Research

This study uses a quasi-experimental design which has an experimental group (Sugiyono, 2017). There are two groups, namely, the experimental group and the control group which are given different treatments, and the results of the reactions of the experimental and control groups are compared with each other. The form of the quasi-experimental design used is a nonequivalent control group design.

Time and Place of Research

The research was conducted at SMP Negeri 3 Magelang from February 2024 to May 2024, in the even semester of 2023/2024.

Research Subjects

The research subjects are all grade VII students of SMP Negeri 3 Magelang with 250 students divided into eight classes. The sample was established using the purposive sampling technique, based on some provisions and considerations. Class VIII B was the experimental class and Class VIII F was the control class. The considerations used were the number of students in one class and the average results of the Mid-Semester Summative Assessment (ASTS) were relatively the same.

Procedure

Before learning, students took a pretest of problem-solving abilities to determine their problem-solving skills before implementing the PjBL Model with the STEM Approach. Teaching and learning activities were carried out in four meetings with material in the form of earthquakes, and sub-chapters of earth structure and its development. Learning activities were filled with project preparation and planning, creation and completion, and students making presentations of project results. The post-test was administered after the learning process, with a test aiming to compare the results of students' problem-

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solving ability scores before and after implementing the PjBL Model with the STEM Approach. The pretest and post-test data were then analyzed using a hypothesis test to show whether the PjBL Model with the STEM Approach effectively improved students' problem-solving abilities.

Data Collection Technique and Instrument

The data collection instrument used in this study is a written test, both for the pretest and post-test. The test contains descriptive questions to make it easier for the researchers to measure students' problem-solving abilities. Before being used, the test was tested for validity and reliability. The validity test consisted of content validity and item and construct validity. The content validation aimed to determine the quality of the content of the test, and the content validation was done by five experts/validators. Meanwhile, the item/construct validity test was administered to 32 grade IX students to show the accuracy and precision of the test in measuring certain aspects. Generally, item or construct validity is related to the quality of the content of each question or item in an instrument. The results of the content validity test using Aiken's V calculation showed that all questions were declared valid. Meanwhile, the results of the item/construct validity test using calculations through the Pearson correlation item with the help of SPSS showed that the eight pretest and post-test questions were also declared valid. The reliability test calculated through Cronbach-alpha assisted by SPSS 25 produced a value of 0.721> 0.06, so the pretest and post-test questions were declared reliable.

Data Analysis Technique

The data analysis techniques used in this study are prerequisite and hypothesis tests with the help of SPSS 25. The data were used to conduct prerequisite tests and hypothesis tests, namely pretest and post-test results. The prerequisite tests used are normality tests and homogeneity tests. The normality test was carried out to reveal if the data were normally distributed, while the homogeneity test aimed to discover whether the data had the same variances. The results of both tests showed that the pretest and post-test values were normally distributed and homogeneous. The hypothesis test was conducted through the independent sample t-test and the N-gain test to determine the effectiveness of the PjBL Model with the STEM Approach in improving students' problem-solving abilities.

FINDINGS AND DISCUSSION

The study was conducted with a face-to-face learning system, adjusting to the predetermined learning schedule. The experimental class implemented the PjBL Model with the STEM Approach, and the control class implemented the model commonly used in that class, namely the Student Teams Achievement Division (STAD) learning model. This study aims to analyze the effectiveness of the PjBL Model with the STEM Approach in improving students' problem-solving abilities. The PjBL Model with the STEM Approach was declared effective in developing problem-solving skills, which can be seen from the results of the t-test and the N-gain test where if the results obtained showed that there was a difference in the post-test results in the t-test and was an increase in N-gain in the experimental class.

The results of this study were obtained from students' answers to a written test consisting of eight descriptive questions in both the pretest and posttest to make it easier for the researchers to analyze and measure students' problem-solving abilities based on their indicators. Siburian & Suryana (2021) explain several indicators of problem-solving skills which include:

1. understanding problems: focusing on success in achieving resolution or solutions to problems and linking deeper exploration of problem situations, choosing based on facts, identifying relationships between facts, and formulating questions;
2. making plans for solving problems: students identify appropriate methods/methods/formulas to solve problems;
3. implementing the problem-solving plans: students apply predetermined strategies or arrangements so that problems can be solved;
4. re-checking: checking whether the results obtained meet the provisions and whether there are any discrepancies with the questions asked, with four main recommendations that can be described in this indicator, such as:
   a. matching the results obtained with the question asked,

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b. interpreting the answers obtained,
c. finding other ways to solve the problem,
d. finding other results or answers that match.

The average pre-test and post-test scores for students' problem-solving abilities are presented in Table 2.

Table 2. Average Pretest and Post-test Scores

Group	N	Average	
		Pretest	Post-test
Experimental	32	65.49	88.93
Control	32	65.89	79.82

Table 2 shows that the average score before the treatment (pretest) in the experimental class was 65.49 and in the control class was 65.89. Meanwhile, the average score after the treatment (post-test) in the experimental class, which implemented the PjBL Model with the STEM Approach, was 88.93. The average score of the control class, which implemented the STAD cooperative learning model, was 79.82. These results show that the average post-test value of the experimental class has a higher score than the control class.

The hypothesis test was carried out through an independent sample t-test from the pretest and post-test data from all students to determine whether there was a difference in the post-test results on students' problem-solving abilities after treatment was given to the experimental and control classes. The results of the independent sample t-test are presented in Table 3.

Table 3. Result of Independent Sample T-Test on the Problem-solving Abilities of Experimental and Control Groups

		Lavene's Test		t-test for equality of means		
		F	Sig.	t	df	Sig.(2-tailed)
Pretest	Equal variances assumed	1.847	0.176	-0.224	62	0.823
	Equal variances not assumed			-0.224	57.654	0.823
Post-test	Equal variances assumed	3.226	0.77	5.262	62	0.000
	Equal variances not assumed			5.262	56.592	0.000

Table 3 shows that the independent sample t-test hypothesis test produces a sig. (2-tailed) value for the pretest, which is 0.823 > 0.05 so that it is stated that there is no difference in the pretest results in the experimental and control classes. However, for the post-test, which produces sig. (2-tailed) which is 0.000 < 0.05 so it is stated that there is a difference in the post-test results in the experimental and control classes.

After the independent sample t-test, the N-gain test was then carried out to see how much the PjBL Model with the STEM Approach could increase the problem-solving ability of junior high school students. The increase that occurred in the N-gain test was used to determine whether the PjBL Model with the STEM Approach was effective or not in improving the problem-solving ability of junior high school students. The results of the N-gain test of students' problem-solving ability are presented in Figure 1.

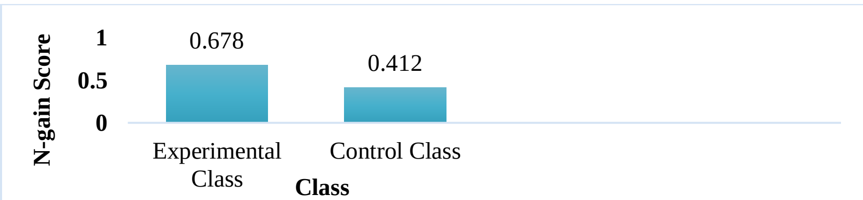

Figure 1. Result of N-Gain Test of Problem-solving Abilities

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Figure 1 shows that the N-gain in the experimental and control classes were 0.678 and 0.412 respectively, where the N-gain scores of both were included in the moderate criteria. Both classes had the same N-gain criteria, but the N-gain of the experimental class was higher than the control class (0.678 > 0.412), so it can be concluded that the problem-solving ability of students in the experimental class is higher than the control class or it can be said that a more significant increase in N-gain results occurred in the experimental class on students' problem-solving abilities. This follows the statement stating that if the PjBL Model is integrated with STEM, it produces a PjBL Model with the STEM Approach that shows positive results on students' problem-solving abilities as one of the 21st-century skills (Baran et al., 2021). The results of the study by Sarwi et al. (2021) show that the PjBL with the STEM Approach can significantly increase students' problem-solving abilities. The N-gain results for each indicator of problem-solving ability are presented in Figure 2.

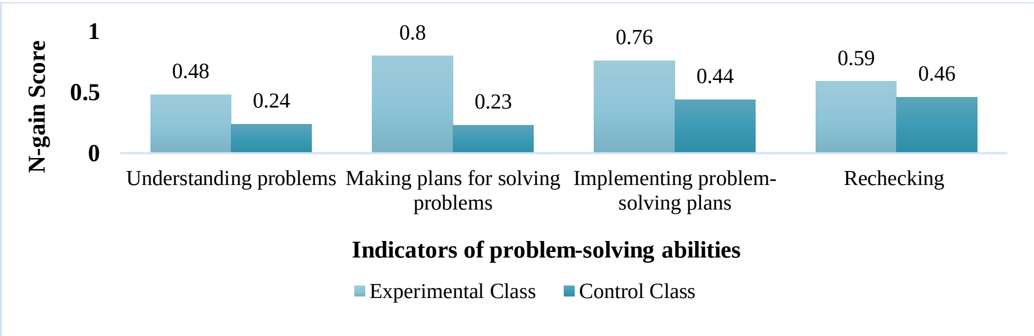

Figure 2. Result of N-gain Test of Each Problem-solving Abilities Indicator

Figure 2 shows that in the experimental and control classes, the N-gain increased in each indicator of problem-solving ability. A higher increase in N-gain occurred in the experimental class than in the control class, where the experimental class had a medium N-gain criterion of 0.48 and 0.59 and a high N-gain criterion of 0.8 and 0.76. Meanwhile, the control class had a low N-gain criterion of 0.24 and 0.23 and a medium N-gain criterion of 0.44 and 0.4.

In addition, Figure 2 shows that the N-gain score of the problem understanding indicator in the experimental class produces a score of 0.48 and is included in the medium criteria. The control class gets an N-gain score of 0.24 with a low criterion, indicating that students in the experimental class can understand the problem better than the control class. The higher increase in the problem understanding indicator in the experimental class occurred because, in the PjBL Model with the STEM Approach, there was a stage of determining essential questions by providing problems from videos of earthquake phenomena and impacts (science) followed by a comparison video of two buildings with different basic materials and designs during an earthquake (technology, engineering, mathematics). Students at this stage must conclude what facts or problems are in the video and what the solution to the problem should be. Providing learning videos can make a learning object more concrete and realistic so that it makes students more enthusiastic and motivates them to solve problems (Apsari et al., 2018; Purwati, 2015)

This problem-understanding indicator shows the lowest increase compared to other problem-solving ability indicators in the experimental class. This happens because when implementing the PjBL Model with the STEM Approach, students cannot understand the problems the teacher gave well. They often ask the teacher to ensure that the difficulties they understand follow the given problems, resulting in the lack of ability to understand the questions and difficulty answering questions based on problems. This is in line with Rahayu's research (2018) which states that students find it hard to understand problems because they cannot write down what is known and asked in the questions.

On the other hand, the students still need to understand the problem because it does not follow their experiences or daily lives, resulting in a lack of ability to understand students' problems. The problems that need to link experiences or lives are supported by the opinion of Mahrus et al. (2022) who explain that problem-solving abilities are an essential part of science learning which plays a paramount role because it is related to everyday life. Noviana & Julianto (2017) also explain that PISA provides criteria for science content, one of which is relevant to real-life situations.

Furthermore, the indicator of making plans to solve problems produces an N-gain score of 0.8 in the

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experimental class, which is included in the high criteria. The control class produces an N-gain score of 0.23, which is included in the low criteria. The indicator of implementing problem-solving planning produces an N-gain score of 0.76, which is also included in the high criteria in the experimental class. The control class produces an N-gain score of 0.44 with moderate criteria. Based on these two indicators, students in the experimental class can make plans to solve problems and implement problem-solving planning better than in the control class.

Figure 3. Making a miniature earthquake-resistant building project as an implementation of problem-solving planning by students

Figure 4. Result of a miniature earthquake-resistant building project

The increase in N-gain in the experimental class showed higher results because when the PjBL Model was applied with the STEM Approach, there were stages in the form of compiling a project plan and completing the project (monitoring), where at this stage students were enthusiastic in designing and making miniature earthquake-resistant building projects, starting from developing tools and materials, the manufacturing methods used, making initial project designs, to compiling projects (science, engineering, technology, mathematics), so that engaging and creative miniature earthquake-resistant building projects were produced. This follows the research results which explain that students are very enthusiastic about making products. This can be seen from the preparation of designs for what materials must be made first (Elisabet et al., 2019). Students are also happy because they can make their products through projects (Barus et al., 2023).

Then, the re-examination indicator produced an N-gain score of 0.59 in the experimental class and 0.46 in the control class, which were included in the moderate criteria. Although both classes had moderate criteria, the N-gain results of the experimental class were higher than those of the control class, indicating that students in the experimental class could re-examine their work better than those in the control class. This can happen because, in the STEM Approach PjBL Model, there is a stage of testing the results where students examine the results of the completed earthquake-resistant miniature building project, whether it has the characteristics of a building design that is suitable for withstanding earthquakes and whether or not the problems contained in the stage of determining essential questions (science, technology, engineering, mathematics). The increase in N-gain in the re-examination indicator that occurred in the experimental class was the second lowest after the indicator of understanding the problem because some students were still not careful when examining the results of the earthquake-resistant miniature building project that was made so that earthquake-resistant miniature buildings were found whose results did not follow the characteristics of the earthquake-resistant building design. The results of the study by Rahayu et al. (2023) also showed that the re-checking indicator got poor results because students did not know how to re-check correctly, so they tended not to re-check the results of their work and felt that their work was appropriate and correct, but it turned out to be wrong.

Basically, both in the experimental and control classes, there was an increase in each indicator of problem-solving ability. However, a more significant increase was found in the experimental class due to the PjBL Model with the STEM Approach. The PjBL Model with the STEM Approach makes students actively participate in learning because they are required to make a product from project activities. The PjBL Model with the STEM Approach can train students to determine problems and analyze appropriate solutions to solve these problems using knowledge related to science, technology, engineering, and mathematics (Kartini et al., 2021).

Thus, the PjBL Model with the STEM Approach is more effective in improving problem-solving

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abilities than the conventional learning model (STAD model). This is because the STAD model cannot improve students' problem-solving skills much. After all, students are less trained in how to solve problems. Teaching that applies the PjBL Model with the STEM Approach makes students produce products from project activities where in making projects they are also trained to plan projects that will later be used as solutions to a problem, stimulate them to ask questions, and train their analytical or reasoning skills in making solutions to a problem. In addition, the teaching process that applies the PjBL Model with the STEM Approach becomes more interesting and enjoyable.

CONCLUSION

Based on the explanation of the results and discussions described previously, it can be concluded that the PjBL Model with the STEM Approach can improve the problem-solving abilities of junior high school students, as seen from the difference in post-test results with sig (2-tailed) <0.05, namely 0.000 in the independent sample t-test, and N-gain in classes that apply the PjBL Model with the STEM Approach gets higher results, namely 0.678 with moderate criteria.

The researcher suggests that teachers present problems better according to students' experiences and daily lives and provide questions that can train students' problem-solving abilities, considering that there are indicators of problem-solving skills that have not improved optimally, namely understanding problems and conducting re-examinations. In addition, for researchers, it is expected that the results of this study can be a reference and motivation with the use of different research variables or the selection of other materials that are appropriate for the PjBL-STEM model.

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