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Effect of a Problem-Based Learning Model Integrated with the STAD Cooperative Strategy on the Students' Critical Thinking Skills and Scientific Attitudes

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Abstract: Developing students' critical thinking skills and scientific attitudes remains a key challenge in science education for innovative and meaningful learning. This study aimed to analyze the effect of the Problem-Based Learning (PBL) model integrated with the Student Teams Achievement Division (STAD) cooperative strategy on students' critical thinking skills and scientific attitudes in the Earth Structure topic at SMP Negeri 2 Mataram. This study employed a quasi-experimental method with a Nonequivalent Control Group Design. The research sample was selected using purposive sampling, resulting in class VIII B as Experimental Class 1, which implemented the PBL model integrated with STAD, and class VIII E as Experimental Class 2, which implemented the STAD model. The research instruments consisted of a critical-thinking skills test and a scientific attitude questionnaire that met the criteria for validity and reliability. Data were collected through pretests and posttests and analyzed using the Shapiro–Wilk test, Levene's test, and the Mann–Whitney test at a 5% significance level. The results showed that students' critical thinking skills in both classes increased after the treatment. The N-Gain score for critical thinking skills was 82% in the PBL integrated with STAD class and 79% in the STAD class. The Mann–Whitney test showed no significant difference in critical thinking skills between the two classes ($p = 0.705 > 0.05$). In contrast, there was a significant difference in students' scientific attitudes between the two classes, with a significance value of $0.003 < 0.05$. Therefore, integrating PBL with STAD did not yield a significant difference in students' critical thinking skills, but it did result in a significant difference in students' scientific attitudes compared with the STAD model in learning the Earth Structure topic.

Keywords: Critical Thinking Skills; Earth Structure; Problem-Based Learning; Scientific Attitudes; STAD.

Introduction

21st-century education demands that students possess a set of competencies that enable them to adapt to developments in science and technology. One of the competencies focused on in learning is critical thinking skills, as these skills enable students to analyze information, evaluate evidence, and make logical decisions in solving various problems. In addition to critical thinking skills, science learning is also directed at developing scientific attitudes, such as curiosity, honesty in the face of facts, openness to others' opinions, thoroughness, and responsibility during scientific investigation. Therefore, science learning is not only oriented towards mastering concepts, but also towards developing students' scientific thinking skills and character.

However, the state of science learning in Indonesia indicates that students' critical thinking skills and scientific attitudes still need improvement. The Programme for International Student Assessment (PISA) shows that Indonesian students' scientific literacy skills remain below average among OECD member countries. Indonesia's scientific literacy score was recorded at 393 in 2006, 383 in 2009, 382 in 2012, 403 in 2015, 396 in 2018, and again decreased to 383 in PISA 2022. Meanwhile, the average scientific literacy score of OECD countries in PISA 2022 reached 485 [1]. This condition indicates that Indonesian students still experience difficulties in analyzing problems, connecting concepts with everyday life phenomena, and providing reasons based on scientific evidence. These findings indicate the need to implement learning models that actively involve students in the learning process, enabling the optimal development of critical thinking skills and scientific attitudes.

Education that is relevant to efforts to face the challenges of the times is education that develops competencies and shapes character relevant to those efforts. The education and learning that is developed must be meaningful as a process of empowering critical and creative thinking skills, problem-solving skills, the ability to work with a good work ethic, the ability to research and develop science and technology (IPTEK), and cultivating an independent, responsible, democratic, honest, and moral attitude [2].

Science education, particularly in science subjects, plays a crucial role in shaping students' scientific understanding and critical thinking skills. Critical thinking skills are the ability to analyze, evaluate, and draw logical conclusions from information, which is essential for facing the challenges of today's information age [3]. However, many conventional learning methods still rely on lectures, which often reduce student engagement and hinder the development of students' critical thinking skills [4].

Initial observations at SMP Negeri 2 Mataram indicate that the science learning process is still dominated

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by direct, teacher-directed instruction. Learning activities are largely teacher-centered, leaving students with limited opportunities to discuss, express opinions, and solve problems independently. This situation has resulted in students' low ability to analyze problems and demonstrate scientific attitudes during the learning process. Therefore, a learning model is needed that can provide a more active, collaborative, and problem-solving-oriented learning experience.

One learning method considered capable of developing critical thinking skills is Problem-Based Learning (PBL). This model provides students with the opportunity to learn concepts through contextual problem-solving, encouraging them to identify problems, seek information, analyze data, and develop evidence-based solutions. However, the success of problem-based learning is also influenced by interactions between students during the learning process. Therefore, integrating PBL with cooperative learning strategies is crucial. The Student Teams Achievement Division (STAD) is seen as creating a more active learning atmosphere through group discussions, helping one another understand the material, and shared responsibility for learning outcomes.

The Problem-Based Learning (PBL) model has emerged as an effective alternative for improving students' critical thinking skills. PBL encourages students to actively engage in the learning process by solving real-world problems relevant to their daily lives [5]. With this approach, students not only learn science concepts but are also trained to think critically and creatively in finding solutions.

In addition, integrating STAD (Student Teams-Achievement Division) cooperative strategies into PBL can further enhance learning effectiveness. This cooperative strategy emphasizes cooperation in groups, where students help and support each other to achieve common goals [6]. Previous research shows that the use of cooperative learning strategies can improve students' scientific attitudes, such as curiosity, openness to new ideas, and the ability to work together [7].

Critical thinking skills are students' abilities to analyze information, evaluate evidence, and draw conclusions based on logical reasoning. This ability enables students to identify problems, consider various information, and make appropriate decisions. In addition, scientific attitudes are an important aspect of science education because they reflect how students interact with scientific knowledge and processes. A positive scientific attitude can encourage students to be more active in learning and able to apply the knowledge gained in everyday life [8]. At the Junior High School (SMP) level, especially in grade VIII, the development of scientific attitudes is very important because at this stage students enter the formal operational thinking phase, in which they can think logically, critically, and systematically to understand natural phenomena (9).

Several previous studies have reported that implementing Problem-Based Learning can improve students' critical thinking skills, while the STAD cooperative strategy is effective in enhancing learning activities, cooperation, and learning outcomes. However, most of these studies examine the effects of each model separately. Research integrating Problem-Based Learning with the STAD-type cooperative strategy, while simultaneously measuring its influence on critical thinking skills and scientific attitudes in the Earth Structure material at the junior high school level, remains limited. The research gap (research gap) This is the basis for the need to conduct this research.

Based on the description, this study aims to analyze the effect of a problem-based learning model integrated with the STAD cooperative strategy on the critical thinking skills and scientific attitudes of eighth-grade students of SMP Negeri 2 Mataram on the Earth Structure material. The results of the study are expected to yield an alternative science learning model that effectively develops critical thinking skills while fostering students' scientific attitudes.

Research Methods

This research uses a quasi-experimental method conducted at SMP Negeri 2 Mataram in the even semester of the 2025/2026 academic year. This study aims to analyze the influence of the learning model Problem-Based Learning (PBL) integrated with the cooperative strategy type Student Teams Achievement Division (STAD) on students' critical thinking skills and scientific attitudes on the Earth Structure material. The research design used is a Nonequivalent Control Group Design. Researchers used existing classes without fully randomizing subjects; this design allowed researchers to compare learning outcomes between two groups given different treatments through pretests and posttests.

Research Subjects

The subjects of this study were eighth-grade students of SMP Negeri 2 Mataram. The research sample was determined using purposive sampling, namely selecting samples based on criteria relevant to the research objectives. These considerations are based on recommendations from science teachers and on the characteristics of classes with relatively comparable academic abilities. Based on this technique, class VIII B was selected as experimental class 1 that implemented the model. Problem-Based Learning (PBL) integrated the STAD cooperative strategy, and class VIII E was selected as experimental class 2, which implemented the STAD-type cooperative learning model.

Research Instruments

The research instruments are self-assessment tests of critical-thinking skills and scientific-attitude questionnaires. The critical thinking skills test is structured in the form of multiple-choice questions based on Higher Order Thinking Skills (HOTS), which measures the ability to analyze (C4), evaluate (C5), and create (C6) on the Earth Structure material. The test is given to students before (pretest) and after (posttest) treatment to determine improvement in critical thinking skills. Meanwhile, scientific attitudes were measured using the test administered before and after treatment. The questionnaire was designed based on scientific attitude indicators, including curiosity, cooperation, responsibility, objectivity, and openness to others' opinions. Prior to use in the study, all instruments underwent validity and reliability testing to ensure they were suitable for data collection.

Effectiveness Indicators

In this study, the measurement was based on increases in students' critical thinking skills and scientific attitudes following the model's implementation. Problem-Based Learning (PBL) integrated the cooperative strategy, Student Teams Achievement Division (STAD), and the STAD cooperative learning model. The improvement of both variables was analyzed through a comparison of pretest and posttest results and the calculation of the scores. Normalized Gain(N-Gain) in each class.

In addition, the success of the research is determined by the results of inferential statistical analysis. Before hypothesis testing is conducted, the data are examined using a normality test. Shapiro–Wilk test and Levene's test of homogeneity. Next, the Mann–Whitney test is used at the 5% significance level ($\alpha = 0.05$) to determine whether there is a difference in critical thinking skills and scientific attitudes between treatment 1 and treatment 2 after treatment. The study's success was demonstrated by increases in pretest-to-posttest scores across classes, as well as statistical analyses that provide an overview of the learning model's influence on students' critical thinking skills and scientific attitudes.

Data analysis

The data obtained were analyzed using descriptive statistics and inferential statistics. Descriptive analysis was used to describe the results of the pretest, posttest, and Normalized Gain (N-Gain) values of critical thinking skills and scientific attitudes in experimental class 1 and experimental class 2. This analysis aims to determine the increase in students' abilities after the implementation of the Problem-Based Learning (PBL) model integrated with the Student Teams Achievement Division (STAD) cooperative strategy and the STAD cooperative learning model.

Before hypothesis testing, the data are assessed for normality. Shapiro–Wilk and Levene tests are used to determine whether the assumptions of statistical analysis are met. Based on the results of the prerequisite tests, data that do not meet the parametric assumptions are analyzed using nonparametric tests. Mann–Whitney at a significance level of 5% ($\alpha = 0.05$). This analysis was used to determine whether there were differences in critical thinking skills and scientific attitudes between experimental class 1 and experimental class 2 after being given treatment. The entire data analysis process was carried out using the program IBM SPSS Statistics. The criteria for interpreting N-Gain values, normality test results, homogeneity test, and variance test (Mann–Whitney) are the same as those used in this study.

Results and Discussion

Critical Thinking Skills Results

The results of this study describe students' abilities, especially in critical thinking. Data on students' critical thinking skills were obtained through pretests and posttests. The research data were obtained from two classes: treatment 1 received integrated PBL cooperative learning of the STAD type, while treatment 2 received only STAD-type cooperative learning. The data collected in this study included critical-thinking skills related to Earth's structure. The difference between pretest and posttest scores for both classes is shown in Figure 1 below.

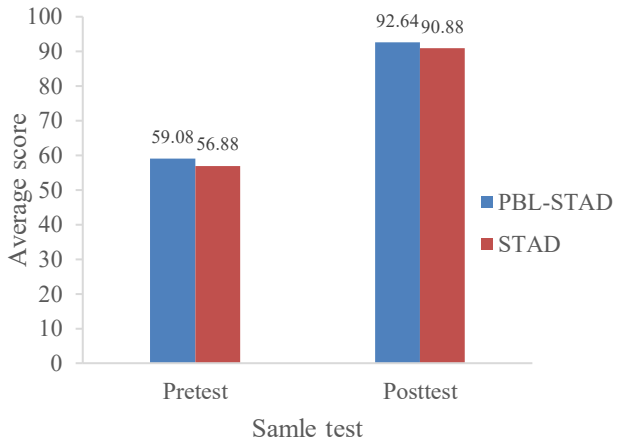


Figure 1. Data on critical thinking skills pretest and posttest scores for the STAD Integrated PBM class and the STAD class

In Figure 1, the critical thinking skills of students in both classes increased after receiving the treatment. In experimental class 1, which applied the Problem-Based Learning (PBL)- integrated cooperative strategy, the Student Teams Achievement Division (STAD), the mean pretest score was 59.08, increasing to 92.64 on the posttest. Meanwhile, in experimental class 2, which implemented the STAD type cooperative learning model, the average pretest score of 56.76 increased to 90.88 on the posttest. The N-Gain analysis showed that treatment 1 increased by 82%, while treatment 2 increased by 79%. Based on the N-Gain interpretation criteria, both classes are included in the effective category, indicating that both the STAD-integrated PBL model and the STAD-integrated PBL model are effective. The STAD model can also improve students' critical thinking skills in the Earth Structure material.

Table 1. Normality and Homogeneity Hypothesis Test

Variables	Data	Normality Test (Sig.)	Information	Homogeneity Test (Sig.)	Information
CTS	Pretest PBL-STAD	0.545	Normal	0.000	Not homogeneous
	Posttest PBL-STAD	0.000	Abnormal		
	Pretest STAD	0.445	Normal		
	Posttest STAD	0.000	Abnormal		
	N-Gain PBL-STAD	0.102	Normal	0.05	Homogeneous
	N-Gain STAD	0.000	Abnormal		

Based on Table 1, the prerequisite test results show that the critical thinking skills data are not entirely normally distributed. The pretest data for experimental class 1 are normally distributed ($p = 0.545 > 0.05$), whereas the posttest

data are not normally distributed ($p = 0.000 < 0.05$). In experimental class 2, the pretest data are normally distributed ($p = 0.445 > 0.05$), whereas the posttest data are not normally distributed ($p = 0.000 < 0.05$). The N-Gain data for experimental class 1 are normally distributed ($p = 0.102 > 0.05$), whereas those for experimental class 2 are not ($p = 0.000 < 0.05$). The homogeneity test results show a significance value of $0.000 < 0.05$, so the critical thinking skills data are declared non-homogeneous. Because the data do not fully meet the parametric assumptions, the difference is tested using the Mann–Whitney test.

Table 2. Mann–Whitney test

Variables	Mann-Whitney U	Z	P-value	Criteria
Critical Thinking Skills	572.500	-1.692	0.705	Ho accepted

The results of the Mann–Whitney test show a U value of 572.500, Z of -1.692, and a significance value of $0.705 > 0.05$. Thus, there is no significant difference in critical thinking skills between students who received STAD-integrated PBL and those who received STAD. However, the absence of a significant difference does not mean that the two learning models do not improve critical thinking skills. Descriptively, both classes still show an increase in the value from pretest to posttest.

The research results are understandable because PBL and STAD both share learning characteristics that actively involve students. PBL provides opportunities for students to learn through problems, conduct investigations, gather information, analyze problems and formulate solutions. Various studies show that these characteristics can support the development of critical thinking skills. A meta-analysis of 30 articles found that PBL is effective in improving critical thinking skills in science learning [10]. PBL can improve students' critical thinking skills in science learning at the junior high school/Islamic junior high school level in Mataram [11]. Research on eighth-grade junior high school students also showed that PBL in the context of socio-scientific issues increased critical thinking skills, with an N-Gain of 0.628 and an effect size of 1.1659 [12]. PBL, integrated with the STEM approach, can improve the critical thinking skills of junior high school students, with an N-Gain of 70.78% [11]. Thus, both theoretically and empirically, PBL has the potential to develop critical thinking skills, but in this study, integrating PBL with STAD has not produced a significant difference compared to STAD alone.

The absence of significant differences in critical thinking skills may also be attributed to the characteristics of STAD, which provide opportunities for students to work in heterogeneous groups, discuss, help one another understand the material, and be responsible for both group and individual learning outcomes. The application of STAD can enhance students' critical thinking skills, as the learning process involves social interaction and collaborative learning activities [13]. The Earth and Solar System material for junior high school students also used the Mann–Whitney test and found that the STAD Student worksheet-assisted learning model can improve critical thinking skills with an N-Gain of 0.57 [14]. STAD combined with a scientific approach can be used to improve the critical thinking skills of junior high school students [15]. In addition, video-assisted STAD can significantly improve students' critical thinking skills [16]. These findings provide an explanation that STAD itself has the potential to develop critical thinking skills. Therefore, when STAD is applied as a comparative treatment, the abilities of the two classes can be relatively close so that the difference between PBL integrated with STAD and STAD alone does not reach the level of statistical significance. The results of this study can also be explained by research showing that PBL's effectiveness in developing critical thinking skills does not consistently yield the same differences across all learning conditions [17]. A systematic review of 24 articles on PBL in Indonesia shows that PBL is widely used to develop critical thinking skills, but the implementation characteristics, materials, media, and supporting strategies vary. Similarly, a meta-analysis on PBL and critical thinking skills shows that the effectiveness of PBL needs to be assessed in relation to the learning context in which it is applied. Therefore, the results of this study, which show no significant difference between STAD-integrated PBL and STAD, do not contradict previous research on the effectiveness of PBL. Previous research has largely shown that PBL can improve critical thinking skills compared to conventional learning, whereas this study compares two active, cooperative models: STAD-integrated PBL and STAD.

Scientific Attitude

This describes students' abilities, especially in scientific attitudes. Data on scientific attitudes were obtained through a questionnaire administered as a pretest and a posttest. The research data were obtained from two classes: treatment 1 received instruction using an integrated PBL-cooperative STAD approach, while treatment 2 received instruction using a cooperative STAD approach only. The data collected in this study included scientific attitude data with 21 statements. Differences in pretest and posttest values for both classes are presented in Figure 2 below.

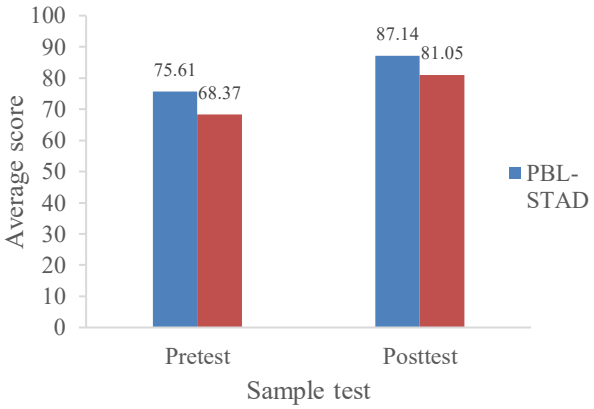


Figure 2. Pretest and posttest scientific attitude value data for the STAD Integrated PBL class and the STAD class

Based on Figure 2, students' scientific attitudes in both classes increased after receiving the treatment. In experimental class 1, which applied the Problem-Based Learning (PBL)- integrated cooperative strategy, Student Teams Achievement Division (STAD), the average pretest score of 75.61 increased to 84.14 on the posttest. Meanwhile, in experimental class 2, which implemented the STAD

cooperative learning model, the average pretest score of 68.29 increased to 80.88 on the posttest. The N-Gain analysis showed that treatment 1 increased by 46%, while treatment 2 increased by 41%. Based on the N-Gain interpretation criteria, both classes were classified as ineffective, indicating that although students' scientific attitudes increased after learning, the magnitude of the increase was not optimal.

Table 2. Normality and Homogeneity Hypothesis Test

Variables	Data	Normality Test (Sig.)	Information	Homogeneity Test (Sig.)	Information
SA	Pretest PBL-STAD	0.01	Abnormal	0.75	Homogeneous
	Posttest PBL-STAD	0.058	Normal		
	Pretest STAD	0.005	Abnormal		
	Posttest STAD	0.000	Abnormal		
	N-Gain PBL-STAD	0.957	Normal	0.086	Homogeneous
	N-Gain STAD	0.027	Normal		

Based on Table 2, the results of the prerequisite test on the scientific attitude variable and the results of the normality test show that the pretest data for the STAD integrated PBL class are not normally distributed with a significance value of 0.010 < 0.05, while the posttest data are normally distributed with a significance value of 0.058 > 0.05. In the STAD class, the pretest data are not normally distributed ($p = 0.005 < 0.05$), and the posttest data are also not normally distributed ($p = 0.000 < 0.05$). Meanwhile, the N-Gain data on scientific attitudes in the STAD-integrated PBL class is normally distributed, with a significance value of 0.957 > 0.05, whereas the STAD class N-Gain data has a significance value of 0.027 < 0.05; thus, based on the Shapiro–Wilk criteria, the data are not normally distributed. The homogeneity test results show that the variance of critical thinking skills data in the pretest and posttest is not homogeneous, with a significance value of 0.000 < 0.05. Meanwhile, the variance of the scientific attitude data indicates homogeneity, with a significance value of 0.750 > 0.05. In the N-Gain data, the results of the homogeneity test for critical thinking skills show a significance value of 0.050, which, based on the criteria used in this study, indicates homogeneity. The N-Gain data for scientific attitudes have a significance value of 0.086 > 0.05, so they are also declared homogeneous. Based on the results of the prerequisite test, which still show non-normally distributed data, especially for critical thinking skills and scientific attitudes, hypothesis testing is conducted using the nonparametric Mann–Whitney test.

Table 3. Mann–Whitney test

Variables	Mann-Whitney U	Z	P-value	Criteria
Scientific Attitude	635.500	-1.047	0.003	H_0 rejected

Based on Table 3, the results of the Mann–Whitney test on the scientific attitude variable show a significant difference between the two classes. Mann–Whitney U = 635.500, Z = -1.047, and $p = 0.003 < 0.05$ indicate a difference in scientific attitudes between students who receive PBL integrated with STAD and those who receive STAD. Thus, H_0 is rejected, and Ha is accepted for the scientific attitude variable. These results indicate that integrating PBL with STAD offers learning characteristics that provide different experiences in the formation of scientific attitudes compared to STAD implemented independently.

These results are strongly supported by research conducted in 2025 on class X students at MAN 2 Mataram [18]. The research used a quasi-experimental design, a scientific attitude questionnaire instrument, and Mann–Whitney analysis. The results showed that the experimental class had an average scientific attitude score of 69, placing it in the high category, while the control class had an average score of 63, placing it in the medium category. The Mann–Whitney test produced an Asymp. Sig. value of 0.003 < 0.05, indicating a significant influence of PBL on students' scientific attitudes. The similarity of these significance values strengthens the findings of this study, even though the research was conducted at different levels and with different materials. This shows that PBL has the potential to provide a stronger learning experience in building scientific attitudes because students are involved in the process of facing problems, seeking information, conducting investigations, and making decisions based on learning outcomes [19].

The results of this study are also in line with those of a study that examined the application of PBL integrated with green chemistry on scientific attitudes [20]. The study obtained a significance value of 0.000 < 0.05 and showed a difference in scientific attitudes between students who received PBL integrated with green chemistry and students who received learning with a scientific approach. In addition, Andriani and Supiah's research on PBL on analytical thinking skills and scientific attitudes is also listed as relevant research in the study of PBL and scientific attitudes [21]. It specifically examined students' scientific attitudes during physics learning using PBL with experimental and project-based methods. Wahyudiati's research also showed a relationship between the application of PBL and critical thinking skills and scientific attitudes in chemistry learning. These results show that PBL is not only oriented towards cognitive aspects but can also provide learning experiences that support the development of affective aspects and scientific attitudes [22-24].

The differences in scientific attitudes between the two classes can be attributed to the PBL stages, which directly provide students with opportunities to confront real-world or contextual problems. When students face a problem, they are required to be curious, seek relevant information, ask questions, consider evidence, discuss, and take responsibility for their decisions. These activities are closely related to the formation of scientific attitudes. In PBL integrated with STAD, these experiences are then reinforced through

heterogeneous group activities, discussions, mutual assistance, presentations, and individual evaluations. Thus, two learning characteristics occur simultaneously: problem-solving through PBL and cooperation and group responsibility through STAD. This combination is thought to provide a more complex learning experience in developing students' scientific attitudes.

On the other hand, STAD also contributes to the development of scientific attitudes by training students to work together, take responsibility, respect others' opinions, and interact in groups. Research on students at SMPN 1 Sakra, East Lombok, showed that STAD made a difference in social skills compared to direct learning and found an interaction between the learning model and scientific attitudes towards social skills [25-26]. Cooperative learning using STAD techniques can significantly improve students' scientific attitudes [27-28]. Research on STAD among students at SMPN 3 Pacitan also reported an increase in scientific attitudes across learning cycles, with the completeness of the affective aspect increasing from 70% in cycle I to 92% in cycle III. These results indicate that STAD itself can support the formation of scientific attitudes. However, in this study, when STAD was combined with the PBL problem-solving stages, statistical tests showed a difference in scientific attitudes compared with STAD alone.

The findings regarding differences in scientific attitudes are also supported by Fiandi's research on the application of STAD in integrated science learning on light. The study showed that using STAD can improve students' scientific attitudes, although differences between the experimental and control classes were not always significant. The research by Sukniyom and colleagues showed stronger results: scientific attitudes after the application of STAD were significantly higher than before the learning. Thus, the results of this study indicate that both models have the potential to foster scientific attitudes, but PBL's emphasis on student-led investigation and problem-solving can provide additional experiences that differentiate the development of scientific attitudes between the two classes.

Overall, the results of the study indicate that PBL, integrated with STAD, and STAD exert different patterns of influence on the two research variables. For critical thinking skills, a significance value of $0.705 > 0.05$ indicates no significant difference between the two classes. This finding is understandable because both models provide opportunities for students to actively discuss, collaborate, analyze information, and solve problems. Previous research on PBL, STAD, and active learning also shows that each model has the potential to support the development of critical thinking skills. Meanwhile, for scientific attitudes, a significance value of $0.003 < 0.05$ was obtained, indicating a significant difference between the two classes. These results are supported by various studies showing that PBL can improve scientific attitudes through problem-solving activities, investigations, discussions, and decision-making, while STAD supports scientific attitudes through group cooperation and responsibility. Therefore, based on the study's results and prior research, Ha is rejected for the critical thinking skills variable, whereas Ha is accepted for the scientific attitudes variable. Thus, PBL integrated with STAD has not shown significant differences compared to STAD in critical thinking skills, but has shown significant differences in students' scientific attitudes towards the Earth Structure material.

Conclusion

Based on the research results, there is no significant difference in critical thinking skills between students who use the STAD-integrated PBL model and those who use the STAD model, as indicated by a Mann–Whitney U test p-value of $0.705 > 0.05$. Meanwhile, there is a significant difference in scientific attitudes between the two classes, with a significance value of $0.003 < 0.05$. Thus, STAD-integrated PBL does not show a significant difference in critical thinking skills but does show a significant difference in students' scientific attitudes toward the Earth Structure material. Based on these results, the STAD-integrated PBL model can be recommended as an alternative science learning model, particularly for supporting the development of students' scientific attitudes through problem-solving activities, discussions, investigations, and group collaboration.

Author's Contribution

Elpana Anisa Sarah: research implementation and manuscript preparation; A. Wahab Jufri and Khairuddin: supervision and manuscript review.

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