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Original Research Article

Enhancing students' scientific attitudes with a problem-based learning model integrated green chemistry

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ABSTRACT

Enhancing scientific attitudes through education by incorporating green chemistry principles is essential, so that students can explore new ideas and information about chemistry concepts while considering environmental sustainability. This has the potential to change chemistry learning to be more meaningful. This study aims to determine the influence of the problem-based learning (PBL) model integrated with green chemistry on students' scientific attitudes. This research is a quasi experiment research with pretest-posttest control group design. The participants were XI MIPA class students who were randomly selected. The data collection method used scientific attitude questionnaire as an instrument. Data analysis includes n-gain test and hypothesis testing using t test. The results showed a sig value of 0.000 (0.000 < 0.05) and tcount of 5.136 ($t_{count} > t_{table}$). This indicates that there is a significant difference in scientific attitudes between students who follow the PBL-green chemistry learning model and students who follow learning with a scientific approach. The existence of this difference indicates that the PBL-green chemistry model has a positive influence in improving students' scientific attitudes.

Introduction

Education is an important aspect in determining the quality and survival of a nation. Education is one of the indicators of a nation's progress (Fajra et al., 2020; Wicaksana & Sanjaya, 2022). Education at each level from primary to higher education must provide every student with the opportunity to acquire the knowledge, skills and values essential to prepare them for the global competition that is getting tougher every day (Sudjimat et al., 2021). Meaningful education is considered an essential educational goal and a necessity in facing the challenges of the 21st century. Meaningful learning outcomes have a great opportunity to produce a quality learning process, in both the cognitive, affective, and psychomotor aspects (Ozyer & Altinsoy, 2023). The three aspects of competence are interrelated to produce qualified and independent graduates.

The independent curriculum has now been developed. The development of an independent curriculum focuses more on the content and competencies of students and the empowerment of student character (Ernawati & Rahmawati, 2022; Lubaba & Alfiansyah, 2022). In this context, the promotion of students' scientific attitudes is one of the most important goals. Scientific attitudes lead students to act rationally, consistently, and objectively in dealing with a problem. This attitude is characterized by curiosity, objectivity, honesty, open-mindedness and logic (Sugrah et al., 2023). Science learning can facilitate students to understand nature and phenomena related to research and investigation so as to foster scientific attitudes (Erdugan, 2020). Scientific attitudes in learning activities can provide facilities for students to learn by not being passive and independent. This attitude includes the desire to continue learning, to seek answers for questions, and not to be afraid of making mistakes (Murningsih et al., 2016). Students who have a high scientific attitude will have fluency in thinking so that they will be motivated to always achieve and have a strong commitment to achieving success and excellence (Pascaeka et al., 2023).

Fostering students' scientific attitudes is an important goal of the school curriculum which can be determined by the learning atmosphere, student and teacher skills, and the quality of learning (Fitriani et al., 2020). Scientific attitudes are affective aspects that are very important in people's lives because they can shape personalities that allow individuals to make rational considerations in decision making. However, based on the results of research by Firdaus & Darmadi (2017), it shows that Indonesian students have a weak scientific attitude. It is in line with the findings of previous studies which prove that students' scientific attitudes are still in the low category (Rosita & Bahriah, 2016; Kusherawati et al., 2020). This low scientific attitude is partly due to the lack of scientific attitude training and ineffective learning strategies that only focus on improving students' ability to understand textbooks (Fitriani et al., 2020). The survey results show that 39% of educators have difficulties in developing students' scientific attitudes due to habitual factors, interaction time with students, and general practical thinking (Calik & Karatas, 2019; Yildirim & Dogru, 2023). Learning in schools generally only emphasizes cognitive aspects without paying attention to the development of scientific attitudes (Sudarmini et al., 2015).

Chemistry learning does not encourage students' scientific attitudes because it focuses more on memorizing material than on meaningful and relevant learning (Driana et al., 2021). Teachers emphasize more on providing definitions, concepts, or principles of learning materials (Wildan et al., 2019). Therefore, there is a need for a learning innovation that focuses on empowering students' scientific attitudes. One of the ways to empower scientific attitudes is by using a problem-based learning (PBL) model integrated with green chemistry. The PBL model is a learning model that is in accordance with the concept of an independent curriculum, where this learning model uses the principle of problem solving which is related to environmental or human health problems (Redhana & Suardana, 2021). Arends (2012) divides the syntax of the PBL model into five steps consisting of 1) orienting students to the problem, 2) organizing students to learn, 3) guiding individual and group investigations, 4) developing and presenting work, 5) analyzing and evaluating the problem-solving process. These steps are designed to actively involve students in learning, so that they not only understand the material in depth but also develop scientific attitudes through a structured learning process.

The integration of green chemistry prinsiples in the PBL-model not only teaches students to solve problems but also to consider environmental impacts and choose solutions that are environmentally friendly and sustainable. This helps students develop their sensitivity to the environment and a better scientific attitude. PBL-Green Chemistry model is one of the complete learning strategies in presenting cognitive, affective, and psychomotor dimensions (Nuswowati et al., 2017; Sudarmin, et al., 2019). Learning with the green chemistry approach includes cognitive and affective aspects, which its application triggers positive changes in students' attitudes towards chemistry lessons and increases their motivation to learn more about it (Fauziah et al., 2019).

According to the description above, the positive character contained in the PBL-Green Chemistry learning model is assumed to be able to shape students' scientific attitudes. Therefore, the effort made in overcoming these problems is to apply the PBL-Green Chemistry model in empowering students' scientific attitudes. This study aims to determine the influence of PBL-Green Chemistry learning model on students' scientific attitudes in learning chemistry.

Materials and Methods

This research is a quantitative approach. The research method used is quasi experiment with pretest-posttest control group design. Such a research design uses an experimental group and a comparison group (control class) that are measured and observed before and after treatment. The treatment given was in the form of applying the PBL model integrated with green chemistry for the experimental class and the scientific approach for the control class. This research design is presented in Table 1.

Table 1. Research design

Class	Pretest	Treatment	Posttest
Experiment	Y_1	X_1	Y_2
Control	Y_1	X_2	Y_2

Description:
X_1 - Treatment with PBL-Green Chemistry;
X_2 - Treatment with Scientific Approach
Y_1 - Pretest Scientific Attitudes
Y_2 - Posttest Scientific Attitudes

Sample and Population

The population in this study were students of class XI MIPA SMAN 1 Tualang. The research sample was selected using random sampling technique which is a sample selection technique carried out randomly selected based on the population that has been determined (Noor et al., 2022). The sampling obtained two classes, namely XI MIPA 3 as the control class and XI MIPA 4 as the experimental class. The experimental class totaled 35 students, while the control class totaled 37 students. The experimental class was treated using the PBL model integrated Green Chemistry and the control class was given treatment using learning with scientific approach.

General Procedure

This study used a non-test instrument in the form of a scientific attitude questionnaire that had been validated by experts previously. The scientific attitude questionnaire was compiled and developed by researchers based on the results of synthesizing aspects of scientific attitudes according to several experts (Olasehinde & Olatoye, 2014; Astutik & Prahani, 2018; Kustijono et al., 2018; Adebusuyi et al., 2020; Fitriani et al., 2020; Mayangsari et al., 2020). The items in the scientific attitude questionnaire cover the aspects of: 1) curiosity, 2) critical thinking, 3) open-mindedness, 4) honesty, 5) responsibility, 6) cooperation, 7) sensitivity to the environment. Completion of the questionnaire is based on a Likert scale with categories of strongly agree, agree, doubt, disagree, and strongly disagree with a score range of 1-5. This questionnaire was given at the beginning (pretest) and end (posttest) of the study, both in the experimental and control classes.

The scientific attitude questionnaire instrument was trialed before the research was carried out to determine the validity and reliability. This questionnaire was given to 166 students of class XII MIPA who were students outside the sample of this study. This validity test uses the Quest program. The validation results show that the 33 questionnaire statement items are valid and can be used for research data collection. The reliability of the questionnaire instrument obtained is 0.82 which is in the good category.

Data Analysis

Data obtained was in the form of pretest-posttest scores of students' scientific attitudes. The pretest-posttest data were analyzed by calculating the n-gain score. The results of the n-gain calculation obtained are then categorized based on Table 2.

Table 2. N-gain score categories

Average Gain	Category
$0.70 < g \leq 1.00$	High
$0.30 < g \leq 0.70$	Medium
$0.00 < g \leq 0.30$	Low

Hypothesis testing is carried out to determine whether there is a significant influence of the independent variable on the dependent variable. Hypothesis testing in this study used the t-test with the help of IBM SPSS Statistics 27 software. Before the t-test analysis, normality and homogeneity tests were first carried out.

Results and Discussion

Data on students' scientific attitudes were obtained from pretest and posttest scores of scientific attitude questionnaires in experimental and control classes conducted at the beginning and end of the study. The description of the results of the scientific attitude questionnaire score can be seen in Table 3.

Table 3. N-gain score categories

Description	Experiment Class		Control Class	
	Pretest	Postest	Pretest	Postest
Max Score	151	162	143	160
Min Score	117	146	115	137
Average	134.17	155.86	125.80	148.11

Table 4. Results of N-gain test

Class	N	N-gain	Category
Experiment	35	0.71	High
Control	37	0.58	Medium

Table 3 showed that experimental class students who applied PBL-green chemistry had higher pretest and posttest results of scientific attitudes than students in the control class who applied the scientific approach. This research data is in the form of pretest-posttest differences (n-gain score) of students' scientific attitudes in experimental and control classes in chemistry learning. The N-gain test was conducted on the difference in pretest-posttest scores in the experimental and control classes. The N-gain test results showed a considerable effect of the model on improving students' scientific attitudes before and after treatment in both classes. The statistical description of the pretest-posttest difference data (n-gain score) of students' scientific attitudes is summarized in Table 4.

The N-gain test results in Table 4 indicate that the N-gain score in the class with the application of the PBL-Green Chemistry model is 0.71 which is included in the high category. Whereas the control class with the application of the scientific approach has N-gain score 0.58 which is in the medium category. The difference in N-gain scores in the two classes indicates that the application of the PBL-Green Chemistry model is effective in improving students' scientific attitudes than the scientific approach. The improvement of students' scientific attitudes in detail can be seen through the comparison of the average difference in scores for each aspect, as shown in Fig-1.

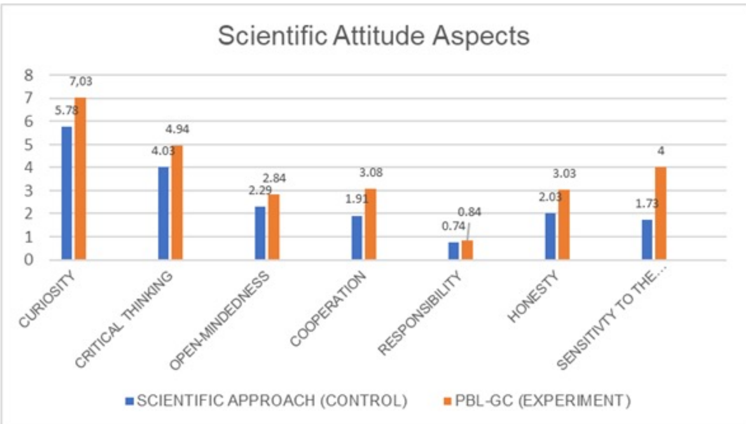

Fig-1. Comparison of average gain score for each aspects of students' scientific attitude

Fig-1 showed that the average difference in pretest-posttest scores (gain score) of each aspect of scientific attitude in the experimental class was higher than in the control class. These results are in line with the research of (Rohaeti et al., 2020) which found that the average score of each aspect of students' scientific attitudes in the experimental class was higher than in the control class. The graph shows that the highest average difference between the experimental and control classes lies in the aspect of curiosity, with a value of 7.03 in the experimental class (PBL-Green Chemistry model) and 5.78 in the control class (scientific approach).

The curiosity aspect has three indicators, namely asking about things that have not been understood, enthusiasm for learning, and enthusiasm in finding answers. The PBL-Green chemistry model provides opportunities for students to analyze environmental or human health problems through problem orientation syntax. According to (Jamaluddin et al., 2024), exposure to topics or problems that are close to students' lives will create a new atmosphere in learning that can increase student motivation to find out solutions to environmental or human health problems presented. In this syntax, it is carried out by stimulating students' curiosity, which is the teacher and students asking questions about the problems presented so that there is good interaction in learning. Through this question and answer, the teacher can explore the knowledge that students have about the problem given. Students get more attention and more active because they are given the opportunity to express their opinions. This is in line with the statement of Fitriani et al. (2020) that the problem orientation stage focuses on the curiosity of students. Curiosity encourages questions, which then triggers the search for information and action, and results in new discoveries (Hasanatin & Rohaeti, 2021).

The critical thinking aspect consists of three indicators, namely not mixing facts with opinions, analyzing questions given by the teacher, and expressing opinions related to findings that are different from theory. The questionnaire results on this aspect gave a satisfactory score. These results are in line with the learning process in the classroom, where students can ask questions, give statements, and show a critical attitude during discussions and presentations. This proves that the PBL-Green Chemistry model can shape scientific attitudes, especially in the critical thinking aspect.

Scientific attitudes in the aspect of open-mindedness have several indicators such as accepting criticism and suggestions from friends, and appreciating the findings/opinions of friends. The PBL-Green Chemistry model provides opportunities for students to work together and openly accept opinions or suggestions from other students. The application of problem-based learning models can have an impact on students in the form of self-confidence, the ability to work independently, learn to accept and argue, the ability to analyze, and learn to share with others (Palennari, et al., 2023; Jamaluddin et al., 2024).

In the aspect of cooperation attitude, there are two indicators, namely actively participating in the group and helping group members who are having difficulty. The attitude of student cooperation can be seen when conducting experiments and group discussions. The attitude of responsibility obtained the lowest score of the other aspects, namely with a value of 0.84 in the experimental class and 0.74 in the control class. This needs further learning emphasis from the responsibility aspect. The indicators in the scientific attitude aspect are honesty, such as not manipulating data and doing assignments and tests honestly. Honest attitude is shown by students in recording data from observations that match what is obtained and when doing their worksheets.

The latest scientific attitude aspect is sensitive to the environment. This environmentally sensitive attitude is trained through the syntax of guiding investigations, where at this stage students carry out green chemistry-oriented practicum using materials that are easily encountered by students in everyday life. In this learning, students carry out practicum to prove the truth of the answers to the problems contained in the worksheets, students must have a sense of environmental sensitivity such as being responsible for using tools and materials when doing practicum. This can be seen in the learning process, where when the practicum is finished, students clean the laboratory and the tools and materials used. Students also put the tools and materials back to their initial place.

The changing scientific attitude of students after learning suggests that a person's attitude is not static but can undergo changes due to the learning process, and attitudes can change due to the conditions and influences given (Erdugan, 2020; Maison, et al., 2020).

Before testing the hypothesis using the t-test, the data were first tested for normality and homogeneity. The normality test was conducted with the Shapiro-Wilk test on two groups of gain score data of scientific attitudes of experimental and control class students with the assistance of IBM SPSS Statistics 27. The results of normality testing are presented in Table 5.

Table 5. Normality test result

	Class	Sig.
N-gain Score	PBL-GC	0.917
	Scientific Approach	0.216

Table 6. Homogeneity test result

	F	Sig.
N-gain Score	0.163	0.688

Based on Table 5, the signifance value obtained on the experimental and control class data is 0.917 and 0.216, respectively. The sig value is > 0.05, which means that both data groups are normally distributed. After knowing that both groups of data are normally distributed, the homogeneity test is carried out with the F-test. The F-test results show that F_{count} is 0.163 and F_{table} is 3.980. This shows that $F_{count} < F_{table}$ so it is known that the data is homogeneous. In addition, data homogeneity can be proven by looking at the sig value. The sig value obtained is 0.688 > 0.05, which means that the two groups of data are homogeneous. The results of the homogeneity test are summarized in Table 6. If the data is declared normally distributed and homogeneous, hypothesis testing can be done using the Independent Sample T-test. Testing was carried out using the IBM SPSS Statistics 27 application with a significance level of 5%. The results of hypothesis testing can be seen in Table 7.

Table 7 shows that tcount is 5.136 and a sig value is 0.000. The ttable value is known to be 1.667 so that 5.136 > 1.667 (tcount > ttable) and sig 0.000 < 0.05 which means that H0 is rejected. These results indicate that there is a significant difference in scientific attitudes between students who are taught the PBL learning model integrated with green chemistry and students who are taught with a scientific approach. This indicates that the application of the PBL-green chemistry learning model has a positive impact on the scientific attitudes of students in the experimental class. Experimental class students who use the PBL-green chemistry model build their own discoveries to foster scientific attitudes and are adapted to real life, so that students can form scientific attitudes in themselves as characters in chemistry learning.

Table 7. Scientific attitude t-test result

		t-test for Equality of Means						
							95% Confidence Interval of the Difference	
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
N-gain score	Equal variances assumed	5.136	70	.000	.11388	.02218	.06966	.15811
	Equal variances not assumed	5.195	62.144	.000	.11388	.02192	.07006	.15770

These results are similar to the research of Sakliressy et al. (2021) that problem-based learning has a positive influence on improving students' scientific attitudes. Andriani & Supiah (2021) also stated that there were differences in scientific attitudes in experimental class students who used a problem-based learning model with control class students due to problem-based learning demanding student activeness in finding and proving the truth of the solution to the problem presented.

The findings of this study are reinforced by Wahyudiati (2022) in her research revealed that the PBL learning model has a major contribution in improving students' scientific attitudes as evidenced by the high effective contribution given by the learning model. Direct involvement of students in the learning process will foster and shape scientific attitudes in themselves. As stated by Zulirfan et al. (2018) in their research that student-centered learning can develop each dimension of scientific attitudes compared to teacher-centered learning.

The integration of green chemistry in chemistry learning through stimulating environmental problems and experimental activities can increase students' curiosity and sensitivity to the environment (Chavarria & Alquisira, 2021). According to Sakliressy et al. (2021) experimental activities can train students' cooperation, accuracy, honesty, accuracy, and responsibility. This is in line with Grangeat (2016) which shows that students get positive results on scientific attitudes and concept mastery through experimental activities.

The application of PBL model integrated with green chemistry created positive changes in students' motivation and attitude in learning chemistry (Fauziah et al., 2019). Kolopajlo (2017) argues that the concept of green chemistry is not only an enhancer but also carries a motivational function, so that the application of green chemistry in learning can involve and improve the affective side of students. Sakliressy et al. (2021) in their research revealed that when students have learning motivation in themselves, they will indirectly try to process learning so that they can hone their scientific attitudes. This is in line with Liou (2020) which states that students who have high learning motivation are able to solve problems without giving up easily even though there are difficulties in the process. The problem-solving process in PBL integrated with green chemistry requires an attitude of curiosity, critical thinking, open-mindedness, honesty, responsibility, cooperation, and environmental sensitivity. This scientific attitude of students is trained in every meeting so that if it is done continuously, the values of science will be internalized and can influence students' attitudes to be more in line with scientific attitudes.

Conclusion

The results showed that problem-based learning (PBL) integrated with green chemistry has a positive influence in improving students' scientific attitudes. This approach incorporates the principles of green chemistry into the learning process that involves students in solving real problems related to the environment and using environmentally friendly chemicals. The results showed a significant difference in students' scientific attitudes between the experimental and control classes, with a significance value of 0.000 < 0.05 and a $t_{count} > t_{table}$ value (5.136 > 1667). The N-gain test results showed that the average n-gain in the experimental class was 0.71 which was in the high category. While the average n-gain of the control class was 0.58 which was categorized as moderate. This research emphasizes the importance of embedding green chemistry principles into chemistry learning to improve students' scientific attitudes, concern and involvement in environmental sustainability that has the potential to change chemistry learning to be more meaningful.

Conflict of Interests

The author declares that there is no conflict of interest in this research and manuscript.

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