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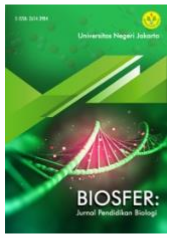

Biodiversity with problem-based learning: impact on quality of students' scientific argumentation

Yenny Anwar*, Rita Rahmayanti, Ermayanti

Biology Education, Faculty of Teacher Training and Education, Universitas Sriwijaya, Indonesia

*Corresponding author: yenny_anwar@fkip.unsri.ac.id

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A B S T R A C T

This study aims to determine the effect of problem-based learning (PBL) on the scientific argumentation of class X students at Senior High School in Indralaya, Indonesia, on biodiversity education. The research method was quasi-experimental with a non-equivalent control group research design. This research was conducted in class X-science-3 (n=33) as an experiment and X-science 4 (n=33) as a control at Senior High School in Indralaya, Indonesia. The data collection instrument was a test question that included scientific argumentation skills in essay questions and recorded class discussions. Data on writing scientific arguments are analyzed using cohesion and coherence, sentence effectiveness, concept correctness, critical analysis of problems and problem-solving. Data on the ability of scientific argumentation in writing and oral are also analyzed based on Toulmin's claim, data, warrant, backing, rebuttal, and qualifier. Furthermore, based on the Toulmin aspect, the students' quality level of scientific argumentation is determined. The result showed that the level of argumentation quality of students who applied the PBL model was mainly at level 3, while the control class was mainly at level 1. The effect being studied is significant. The PBL can significantly influence the ability of scientific argumentation in class X students at senior high school in Indralaya, Indonesia.

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INTRODUCTION

The ability of scientific argumentation is the basis of students in acting, thinking, and communicating. Students must become familiar and proficient in successfully navigating the science classrooms (Anwar, 2019; Howard & McNeill, 2016; Saracaloglu et al., 2011). The main part of science is learning to be involved in various important aspects, including formulating questions, describing mechanisms, and constructing arguments (Haris et al., 2012; National Research Council, 2012). Science learning should not only emphasize memorizing concepts but also have to equip students with life skills such as interpersonal intelligence development, intrapersonal intelligence, communication skills, creativity, thinking scientifically, criticize, have decision-making skills, and have the skill of creating an argument (Rustaman, 2016; Nabilah et al., 2019; Saracaloglu et al., 2011).

The argumentation in the learning process is shown by communicating information obtained from learning activities between students and students with teachers, thus important that the teacher make a concerted effort to cultivate a classroom in which argumentation is practiced, promoting dialogic interactions among students (Driver et al., 2000; Handayani, 2017; Howard & McNeill, 2016). But sometimes, the communication process becomes hampered because not all students can express their opinions verbally and be passive. The lack of student activity in finding data independently is a major factor in the students' low skills to express arguments, lack of knowledge of any relevant theory or concepts often restricts students' ability to reason effectively (Driver et al., 2000; Mahardika, 2015; Osborne et al., 2004). Students' arguments are still in simple statements without scientific reasons and evidence. It cannot be said as the expected scientific argumentation in the science process (Pritasari et al., 2016).

The scientific argumentation used by a scientist is to connect the evidence (data) obtained by a statement (claim) that is formed and strengthened with warrants, backings, qualifiers and rebuttal) This aspect should appear in arguments as scientific argumentation (Howard & McNeill, 2016; McNeill et al., 2006; Toulmin, 1979). Based on the aspects of Toulmin that appear, then the level of quality of the students' argumentation will be determined. These aspects of Toulmin will later be seen in the ability of students to convey arguments both oral and writing. Writing ability is a person's ability to convey messages and communicate with writing. Students are expected to make a good paragraph of argumentation. It can stimulate critical thinking (Widyastuti, 2018; McNeill & Krajcik; 2009). The ability of students to make paragraph arguments will be seen based on aspects, cohesion and coherence, sentence effectiveness, concept correctness, critical analysis of problems and problem-solving. These aspects are needed in making a good quality of argumentative paragraph (Johnson, 1992; Karadeniz, 2017)

Based on interviews with Biology subject teachers in Senior High School in Indralaya, Indonesia class X Science tend to be passive when discussing and only accepts the material presented. In contrast, the learning process takes interaction and communication. This response indicates students' lack of understanding in thinking critically and making evidence-based arguments (Ristanto et al., 2020; Howard & McNeill, 2016; Mcghee, 2015). For these reasons, more research needs to be done on identifying and implementing effective and efficient strategies that facilitate the development of scientific argumentation skills in learning science.

Science learning includes biology learning, has scientific reasoning activities about explaining, experimenting, and using the environment as an object and resource for learning (Erduran & Jiménez-Aleixandre, 2008). One of the materials that study environmental problems is biodiversity learning material. Biodiversity has become a crucial educational topic, enforced by the conference of Rio in 1992 (Gaston and Spicer, 2004; van Weelie and Wals, 2002;

Randler, 2008). A crucial aspect of competence in biodiversity is correctly identifying species in their natural habitat; therefore, basic knowledge about animal or plant species has been targeted as an important aspect for learning and understanding biology (Pfeiffer et al., 2008; Gaston and Spicer, 2004). Unfortunately, the learning outcomes obtained by students on Biodiversity material only reached 60% classical completeness, below the classical completeness standard, namely 85% (Ulimaz, 2015). Also, the scientific argumentation skills of students who apply guided inquiry in Physics are at a moderate level with a percentage of 52.38% (Mahardika, 2016).

The ability of argumentation in science learning is still low because learning has not led students to participate in learning actively (Mubarok et al., 2016; Mcghee, 2015). The alternative solution chosen to support students' activeness is to apply the PBL model. PBL gives freedom to students to learn according to their interests and concerns (Mubarok et al. 2016; Mcghee, 2015; Dastgeer & Afzal, 2015). So that with PBL students are intensively and actively involved and make students continue to find out and solve problems (Arends, 2012; Khusnayain et al., 2013; Mubarok et al. 2016). Through PBL, students develop and present their work, this stage requires students to be able to argue after doing p; this solving. In PBL learning that presents contextual problems to be studied so that students can arouse the desire to learn independently and do problem-solving (Mcghee, 2015; Nurhadi, 2004; Izzaty, 2006). PBL increases student argumentation, because it trains students to learn independently in finding solutions to the problems being studied (Astuti., 2019; Pritasari et al., 2016). PBL also invites students to argue, because this learning design exposes students to be able to do problem-solving (Khusnayain et al., 2013; Mcghee, 2015). PBL also can improve the ability of scientific argumentation in learning Physics, because PBL models train students to answer contextual problems through investigation, development, and presentation of work, as well as discussions (Mubarok et al. 2016). Unfortunately, Mubarok et al. (2016) research has not analyzed how stages of PBL can improve quality of students' scientific argumentation skills, yet there has been no research applied to biology learning. Based on the description above, it is deemed necessary to research the effect of PBL on the ability of scientific argumentation students. This study aimed to determine the effect of Problem Based Learning on the ability of scientific students in Biodiversity learning material.

METHODS

Research design

The research design is using quasi-experiment with forms nonequivalent control group design. This design has a control group to set an external variable that affects the implementation of research (Sugiyono, 2012). This research design has an initial test (pretest) before approval and a final examination (posttest) after treatment. The variables in this study are PBL as an independent variable and the ability of scientific argumentation of students as the dependent variable.

Table 1.
Quasi-experimental with nonequivalent control group design.

Learning Strategies	Grade Point	
	Pretest	Posttest
PBL	O_1	O_2
Conventional	O_3	O_4

Population and Sample

The research subjects were 33 students of class X science in Senior High School in Indralaya, Indonesia. This research was conducted in class X Science 3 (n=33) as an experiment and X Science 4 (n=33) as control. The sample selection in this study uses the purposive sampling technique, namely, taking sample members from the population based on certain considerations (Sugiyono, 2012). Considerations are made based on interviews with Biology class X science teacher in Senior High School in Indralaya, Indonesia and based on the average value of daily tests of the previous learning material. This study was conducted in class X Science 3 as an experiment and X Science 4 as control at Senior High School in Indralaya, Indonesia. There is no different average value in the previous learning material.

Instrument

Data collection on scientific argumentation ability consists of 4 argumentative essay questions, student worksheets, and recording of class discussions. The ability to write scientific arguments in this study is the ability to write arguments according to linguistic rules such as cohesion and coherence, sentence effectiveness, concept correctness, critical analysis of problems and problem-solving. This aspect is used to see students' ability to write arguments in learning biology material biodiversity. The quality of scientific argumentation is determined from the elements of the emerging Toulmin Argumentation Pattern (TAP), which will later be converted based on the Erduran et al. (2004) method analysis framework in Table 2. This instrument has construct validity because it is based on theory, and statements follow the measured aspects of Toulmin, especially emphasizing rebuttal as an indicator of significant aspects of the quality of the argument. (Fraenkel et al., 2012; Erduran, 2007). Assessments of reliability test conducted obtained agreement more than 80% (Osborne et al., 2004)

Table 2.
The analytical framework of quality argumentation

Level	Criteria
5	The argument presents an expanded argument with more than one clear rebuttal.
4	the argument presents an argument with a clear argument and has multiple claims and counterclaims.
3	The argument contains an argument with a series of claims or counter claims with data, guarantor, or weak backing and weak rebuttal.
2	the argument includes an argument form one claim again other claims with data, guarantor or support but does not contain a rebuttal.
1	the argument includes an argument with a simple claim against a claim that contradicts (counterclaim) or a claim against the other claims.

Furthermore, argumentation research is carried out with a rubric that serves as a guideline for scoring based on the fulfillment of several criteria for the results of the arguments worked out by students (Rahmawati, 2014). The argument score criteria are listed in Table 3.

Procedure

The research procedure was divided into three stages: the preparation stage, the implementation stage, and the completion stage. In the preparation stage, there are activities such as identifying problems, preparing learning tools, preparing instruments, school observations, sample selection, and administering research permits. Furthermore, at the sample implementation stage, a pretest is given, treatment is given, a questionnaire is given to the students, and posttest is given. There are several stages in the implementation of PBL, namely, orienting students to problems, organizing students to learn, guiding individual and group investigations, developing, and presenting work, analyzing, and evaluating the problem-solving process (Arends, 2012). Finally, at the completion stage, activities such as processing and analyzing data from the students' scientific argumentation are carried out, discussing, and summarizing the results of research in the form of reports.

Table 3.
Score Criteria for Argumentation

Assessment criteria	Category	Score
Argument sheet not filled	Students are declared not to argue	0
The arguments issued have to do with statements and learning material	The students' arguments are not arranged	1
Arguments that can be clearly identified as claims and warrant	The students' arguments are arranged poorly	2
Arguments contain data or supporting evidence, and some are identified as backing	The students' arguments are arranged quite well	3
The argument contains refutation and conclusion, which can be identified as rebuttal and qualifier	The students' arguments are arranged well	4

Data Analysis Techniques

The data analysis technique used in this study was a statistic using SPSS version 23. In the written test, the students answered questions, then calculated the ability of scientific argumentation, which includes writing scientific arguments and the quality of scientific arguments based on Toulmin's Argument Pattern (TAP) and categorized according to the criteria of value standards. Then, compare the scientific argumentation abilities of the experimental class and the control class. Then the data were analyzed using a t-test to determine the significance of the effect of PBL on the ability of scientific argumentation. The t-test on SPSS version 23 is carried out if the data is normally distributed and homogeneous. This test is carried out by comparing the value of the results of the scientific argumentation ability of control and experimental with the criteria if the probability (significance)> 0.05.

RESULTS AND DISCUSSION

The data analyzed from this study was the score of students' abilities of scientific argumentation, students' responses, and learning implementation observation data. The data obtained in this study are the test data before treatment (pretest) and the test data after treatment (posttest). Students' achievement at pretest and posttest can be seen in the profile of the ability to write scientific arguments shown in Figure 2.

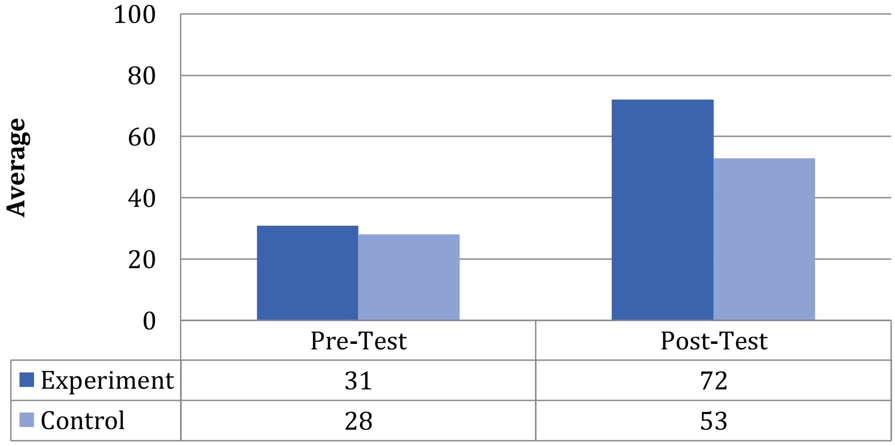


Figure 2. Results of the Argument Writing Ability

The ability to write argumentation tests indicates an average difference in the two classes. Figure 2 shows that the experimental class is better than the control class. The average obtained by the two classes is then categorized into five categories, which are very good, good, sufficient, less, and failed based on aspect argument writing ability such as cohesion and coherence, sentence effectiveness, concept correctness, critical analysis of problems and problem-solving. The ability to write arguments in control and experimental classes is listed in Table 4.

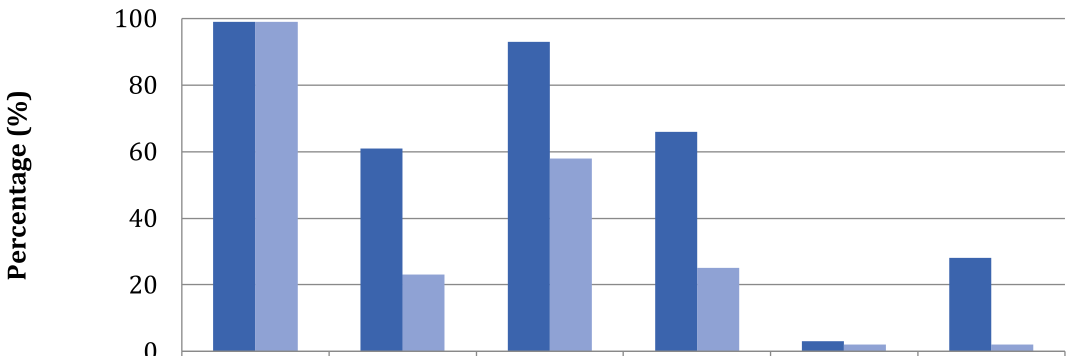
Table 4.
Aspect Writing Ability Test Results

Aspect Ability to Write Arguments	Class	Meeting days		Average	Criteria
		I	II		
Cohesion and Coherence	Experiment	3.23	3.42	3.33	Excellent
	Control	2.24	2.90	2.57	Fair
Sentence Effectiveness	Experiment	3.02	3.27	3.14	Good
	Control	2.12	2.64	2.38	Fair
Concept Correctness	Experiment	3.14	3.27	3.20	Excellent
	Control	2.18	2.49	2.33	Fair
Critical Analysis of Problems	Experiment	2.41	2.60	2.50	Fair
	Control	1.47	1.94	1.71	Poor
Problem Solving	Experiment	2.12	2.45	2.29	Fair
	Control	1.43	1.79	1.61	Poor

PBL implementation was conducted in 2 meetings. Describe the differences in biodiversity at the level of genes, species, and ecosystems, present observational data through literature review on biodiversity at genes, species, and ecosystems. The first meeting discussed the role of humans in efforts to conserve biodiversity in Indonesia and designed breakthroughs or creative ideas about efforts to conserve biodiversity in Indonesia. Table 3 shows that the test results in the ability to write arguments in the experimental class are better than the control class, both in the twice meetings. This can be seen from the five aspects of writing arguments based on scores obtained by students. Students in the experimental class who apply PBL are better at writing arguments because, with PBL, students are required to solve problems, find solutions, and communicate problem-solving. One factor that causes differences in the average value of the ability to write the argumentation of the experimental class and the control class is the contribution of constructivist perspectives, contributions in the form of actualizing the values of self-experience so that students provide solutions to problems and facilitate the writing of arguments.

Conclusion These results support the statement that students' essay writing argumentation skills that apply PBL are better than those who do not apply PBL (Jumariati & Sulistyo, 2017). PBL is an effective model than conventional lecture methods for teaching essay writing to intermediate-level students and improving writing skills. In the fourth phase of PBL, students develop and present their work; this stage requires students to argue after solving problems (Dastgeer & Afzal 2015). When students develop and present their work in class discussions, students provide mutual advice in delivering good arguments. It causes the ability to write students' arguments in the experimental class better.

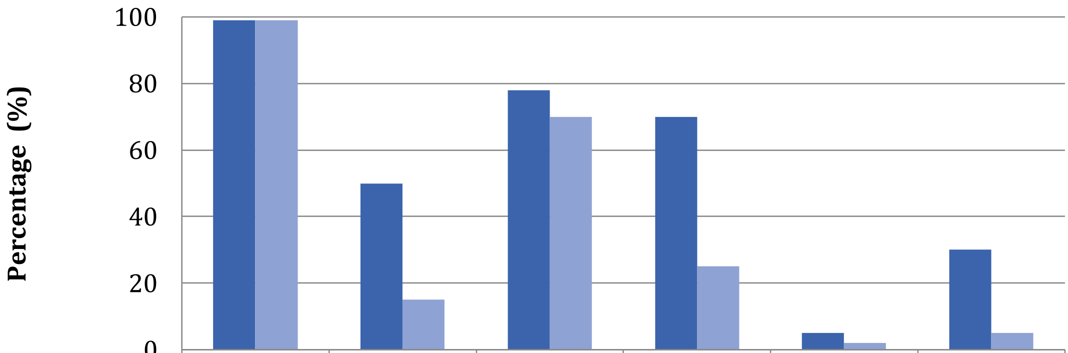
Written test of scientific argumentation ability was obtained from posttest as many as four essay questions. Then assessed based on the TAP, which includes six aspects, namely aspects of claims (statements), data (evidence), warrant (guarantee), backing (support), rebuttal (refutation), a qualifier (justification). The results of the scientific argumentation ability tests analysis are shown in Figure 3.



	Claim	Data	Warrant	Backing	Rebuttal	Qualifier
Experiment	99	61	93	66	3	28
Control	99	23	58	25	2	2

Figure 3. Scientific Argumentation in Writing

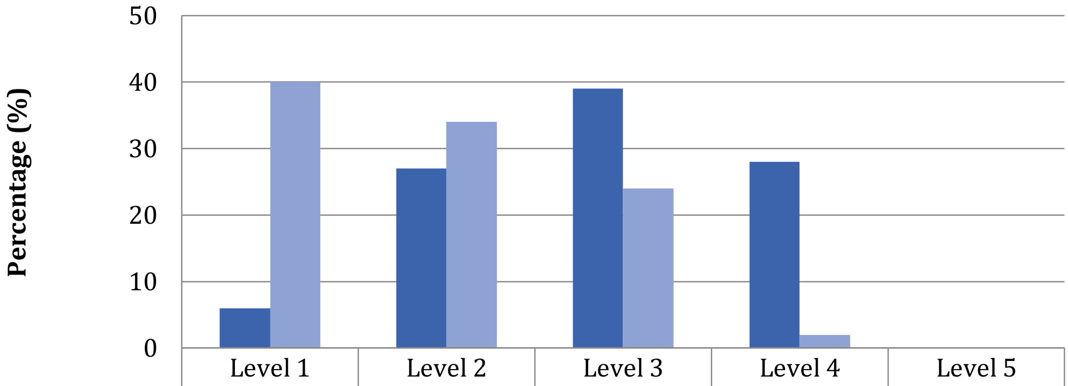
The test results of the ability of scientific argumentation about TAP show the average difference in the second class, which can be seen in Figure 3, which shows the experimental class is better than the control class. In the experimental class claims 99%, 61% data, warrant 93%, 66% support, 3% rebuttal, 28% qualifications. In the control class obtained a percentage of 99% claims, data 23%, warrants 58%, support 25%, rebuttal 2%, qualification 2%. This data shows that PBL students are better at discussing scientific arguments based on TAP aspects. In the experimental and control class, students can make claims with a percentage of 99%. However, in other aspects such as data, warrant, backing, and rebuttal, the percentage of aspects in experimental class students is better than the control class. To assess the ability of scientific argumentation verbally based on aspects of TAP in the experimental class and the control class, shown in Figure 4.



	Claim	Data	Warrant	Backing	Rebuttal	Qualifier
Experiment	99	50	78	70	5	30
Control	99	15	70	25	2	5

Figure 4. Scientific Argumentation in Oral

The results of the written scientific argumentation ability test based on the TAP show differences in the average of the two classes. Figure 4 shows that the experimental class is better than the control class. In the experimental class 99% claims were obtained, 50% data, 78% warrant, 70% backing, 5% rebuttal, 30% qualifier. In the control class obtained a percentage of 99% claim, 15% data, 70% warrant, 25% backing, 2% rebuttal, 5% qualifier. The data shows that PBL students are better at writing scientific arguments based on TAP aspects. In the experimental and control class, students can make a statement (claim) with a percentage of 99%. However, in other aspects such as data, warrant (statements that link data with claims), backing (statements that support warrant), a qualifier (statement of justification), and rebuttal (rebuttal), the percentage of aspects that appear to students in the experimental class is better than control class. The results of scientific argumentation according to the TAP in writing and orally are categorized into the level of argumentation. The results of the analysis are shown in Figure 5.



	Level 1	Level 2	Level 3	Level 4	Level 5
Experiment	6	27	39	28	0
Control	40	34	24	2	0

Figure 5. Quality of Scientific Argumentation

The percentage of aspects of scientific argumentation shows that there are differences between written and oral scientific arguments in experiment and control classes. The ability of verbal scientific argumentation is superior to scientific argumentation in writing. This is because PBL learning uses problem-solving that requires students to find data to support students' arguments. Good quality in arguments is based on delivering the data to support the claim (Howard & McNeill, 2016; McNeill et al., 2006; Mcghee, 2015). This is consistent with Anwar et al. (2019) research that backing and rebuttal appear more verbally because, during the discussion, students are encouraged to make objections to claims and warrants based on supporting data.

There are several stages in the implementation of PBL, namely, orienting students to problems, organizing students to learn, guiding individual and group investigations, developing and presenting work, analyzing and evaluating the problem-solving process (Arends, 2012). The first stage of PBL helps students solve problems; the claiming aspect will appear at this stage. PBL allows students to solve problems and develop knowledge (Sanjaya, 2008; Arends, 2012; Khusnayain et al., 2013). The second and third stages of PBL become the stage for students to collect data, information, theories, and concepts relevant to the problem; at this stage data aspect will appear. PBL encourages students to understand concepts by solving problems so that students can give aspirations and interactions (Putra, 2013; Dastgeer & Afzal, 2015). The fourth phase of PBL, the step of students communicating the work. The data, warrant, backing, and rebuttal aspects will appear through this stage. The fourth phase in PBL requires students to discuss and clash in arguments causing more significant backing and rebuttal aspects to the ability of scientific argumentation verbally than in writing (Sanjaya, 2008; Belland et al., 2011; Mubarok et al. 2016). In the fifth stage, PBL becomes the stage for students to argue and justify the arguments that have been presented. At this stage, students display the rebuttal and qualifier aspects. Based on Figure 3 and Figure 4, aspect rebuttal and qualifier is low, relevant with Erduran (2007) that perceived the presence of rebuttal as a significant indicator of quality argumentation.

Based on Figure 5, it can be seen that students who apply PBL the quality of scientific argumentation are mostly at level 3, while the control class is mostly at level 1. This shows that the quality of the argumentation in the class implementing PBL is better. Because the PBL model facilitates students in arguing. In the PBL model, students work in groups and need communication, problem-solving, and collaboration skills (Loman & Finkelstein, 2000). In the fourth phase, developing and presenting the work becomes one of the phases in PBL that can develop students' argumentation abilities both verbally and in writing. In this phase, students communicate the work in the form of reports that have been made to classmates. In this phase, there is a discussion in solving problems and collaboration skills that can improve students' argumentation abilities. With PBL, students are encouraged to perform scientific process skills, such as formulating hypotheses, determining variables, determining procedures, collecting data, discussing data, analyzing, and drawing conclusions (Wulandari & Shofiyah 2018). All of these skills foster the ability to think and argue. The implementation of PBL model can increase curiosity, pleasure in answering problems and can improve students' communication skills to be very good (Nabilah et al., 2019).

The constraints experienced by researchers while conducting research on the application of PBL require high concentration because there is a lot to be prepared in presenting learning activities. This research also requires a lot of energy to apply the PBL learning model to see scientific arguments. The things that are done to overcome these obstacles are that researchers prepare to teach materials and maintain energy before researching to focus and concentrate on carrying out learning activities.

CONCLUSION

PBL learning model has a significant effect on scientific argumentation in Biodiversity learning material. This is supported by an increase in the average value of writing arguments and the ability to argue based on TAP aspects both in writing and oral. Also, writing argumentation skills include cohesion and coherence, sentence effectiveness, concept truth, critical analysis of problems, and problem-solving. The application of the PBL model can improve students 'scientific argumentation abilities because the stages in the PBL model facilitate students' argumentation. Learning using the PBL model allows students to learn independently in constructing their knowledge, analyzing complex problems and real-life problems, working together in small groups, and becoming skilled in making effective and accurate communication both verbally and non-verbal. This study directs that PBL in biodiversity learning can improve students' scientific arguments through PBL stages. As consideration for further research development, it is necessary to think of an appropriate method to develop each aspect of scientific argumentation, especially the rebuttal and qualifier aspects.

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