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Quality of Student Scientific Argumentation Through the Application of Problem-Based Learning With Flipped Classroom Approach

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Abstract: This research is quantitative research with a descriptive method that aims to analyze and compare the quality of students' scientific arguments in experimental class 1 which is applied by the PBL model through Flipped Classroom approach with experimental class 2 which applies the PBL model only. Instruments to measure students' scientific argumentation skills are essay questions. The quality of the students' arguments was analyzed based on the completeness of the components and the strength of the arguments. Analysis of the completeness of students' argumentation components aims to determine the level of students' argumentation which consists of 5 levels. The strength of the students' arguments was analyzed and categorized into three categories, namely weak, moderately strong, and strong. The results showed that students' scientific argumentation skills based on the completeness of the argument components in both classes experienced a significant increase. Most of the students in both classes have level 3 argumentation skills, meaning that students can make claims accompanied by complete supporting grounds. Based on the analysis of students' argument strength, experimental class 1 showed better argument quality than experimental class 2 where the percentage of students with strong argument strength in experimental class 1 was higher. Therefore, it can be concluded that the application of PBL with Flipped Classroom approach can improve the quality of students' scientific arguments.

Keywords: Flipped Classroom; PBL; Scientific Argumentation

Introduction

The era of the 21st century demands the acceleration of students in developing the skills needed to be able to contribute actively to social life in society. There are four important skills in the 21st century that need to be continuously developed and trained in students, namely critical thinking skills in problem-solving, creative thinking in innovation, communication, and collaboration skills (Kemendikbud, 2016). Communication skills are an important aspect of learning science. The purpose of learning science should involve students in scientific discussions, not just mastering concepts (Diniya, D., et al., 2021). In academic discussions, students communicate by expressing their opinions and arguments on issues. Submit supporting evidence to justify their arguments so that a clearer conceptual understanding emerges while other students resist, express doubts, and search for alternative answers (Faize et al., 2018). Argumentation is a social, rational, and scientific activity where there is a dialogue process between two or more individuals to produce claims or statements that are justified with the support of scientific evidence (Putri, 2018). Argumentation is important to be trained because it can improve students' ability to understand concepts, critical thinking, scientific investigation, cognitive processes, and the achievement of scientific literacy (Kusdiningsih et al., 2016).

Several studies have shown that students' skills in scientific argumentation are still low. Average student

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scores based on Putri survey results (2017) as a whole is 24.7 out of a maximum score of 48 for students' scientific argumentation skills on heat and global warming material, this is in a low category. Based on an analysis of student's answers, students can provide evidence to support claims based on everyday experience but most of the evidence is inadequate in terms of both quality and quantity. Students also have difficulty providing inferences that explain logical relationships between data and claims. Another important aspect of argumentation, backing, can take the form of principles, laws, concepts, or theories that support the reasoning. The overall average of student responses indicates that students struggled to support their point of view. The findings of Pritasari et al. (2016) reinforce that students' arguments are only simple claims without being supported by strong evidence and justification. Students can make accurate claims related to the problem but still find it difficult to provide sufficient evidence and reasons to support the justification of the claims made (Putri, 2018).

A student's poor scientific reasoning ability can be caused by many factors, including: a lack of student participation in scientific discussions. While most teachers use demonstration methods in learning science, students are required to conduct their own experiments to gather evidence in the form of data that support claims on scientific issues (Pitorini et al., 2020). Student-centered learning models need to be applied to train students' abilities in scientific argumentation. One of them is the *Problem Based Learning* (PBL) model with *Flipped Classroom* approach. Authentic problems become the basis of the PBL model. The first phase in PBL is the orientation of students to problems, the teacher raises problems that can cause cognitive conflicts and student interest, and can use short videos in the form of illustrations of real problems such as pollution, environmental damage, rare natural phenomena, and so on. This phase can train students in making claims or statements related to problems (Arends, 2008). However, if the video playback is carried out in class and accompanied by investigation activities in the form of experiments in the third phase in PBL, it will be less than optimal because experimental activities require quite a lot of time and maximum supervision from the teacher. This can be overcome by collaborating the PBL model with *Flipped Classroom* approach, where assignments *online* are done before the learning session in class (Rahmawati et al., 2016). The first phase in PBL can be moved to the home via *Flipped Classroom* approach.

Application of the PBL model in science learning has been shown to be able to develop students' scientific argumentation skills such as the following results of Pritasari et al. (2016) research which showed students' skills in generating claims, collecting evidence, and including justifications continued to develop over three learning cycles with PBL. The application of the PBL model with practicum also improves students' skills in written argumentation (Tarigan, 2015). The application of *Flipped Classroom* has also been proven to increase the learning independence and academic achievement of students (Asiksoy & Ozdamli, 2015). The use of digital technology through learning videos that can be accessed by students whenever and wherever according to their needs can improve students' understanding of learning materials (Gonzalez-Gomez et al., 2016). Through videos containing interesting scientific phenomena, it is hoped that it can improve students' ability to think; and issue ideas and opinions so that they can indirectly develop students' skills in scientific argumentation.

The improvement of students' skills in scientific argumentation is of course not only measured by the high average score of students' argumentation but also needs to be assessed in terms of the quality of the arguments. Research is still rare that analyzes the quality of students' arguments, mostly only measuring the increase in students' argumentation skills quantitatively (Jewaru et al., 2021). The quality of students' arguments can be assessed from two aspects, namely the completeness of the argument components and the strength of the arguments. Therefore, students' scientific arguments need to be analyzed qualitatively to find out trends in the level of students' arguments and the strength of students' arguments to make it easier for teachers to improve the quality of learning to improve the quality of students' scientific arguments. It is deemed necessary to conduct a study entitled Quality of Student Scientific Argumentation through the Application of *Problem-Based Learning* with *Flipped Classroom* Approach. The purpose of this study was to assess the quality of students' scientific argumentation in experimental class 1, which applied problem-based learning through flipped classroom, and experimental class 2, which applied problem-based learning without flipped classroom.

Method

This research is quantitative research with a descriptive method that aims to systematically describe facts and characteristics of the population in a factual and accurate manner, in this case analyzing and comparing the quality of students' scientific arguments in two different classes (Sudjana & Ibrahim, 2007). The population in this study were all eighth-grade students in one of the public junior high schools in Argamakmur, North Bengkulu in the even semester of the 2021/2022 academic year which consisted of 10 classes. The research sample consisted of two classes, namely experimental class 1 and experimental class 2 which were taken through *purposive sampling technique*, namely selecting samples based on certain considerations because the selected samples were adjusted to the needs where students in one class had at least one communication tools or media that can access the video. In experimental class 1, learning with the *Problem Based Learning* (PBL) model was applied through *Flipped Classroom* approach, while in experimental class 2 only the *Problem Based Learning* (PBL) model was applied.

The difference in treatment in the two classes only lies in the time and place of giving the video as a medium to orient students to the problem in the first stage of the PBL model whereas, in experimental class 1, the video is accessed by students through *YouTube*, then students are given a worksheet to do individually after watching the video at home. This is an implementation of the *Flipped Classroom* while in experimental class 2, at the beginning of learning after the preliminary activity, the teacher-oriented students to the problem through video shows.

The instrument to measure students' scientific argumentation skills is by using essay questions, totaling 6 questions on Substance Pressure material and its application in everyday life. The questions have been tested for validity, reliability, discriminatory power, and level of difficulty and have met the criteria for valid and reliable questions. Questions are given at the beginning before learning (*pre-test*) and after the completion of learning (*post-test*). Each question consists of 4 questions that contain argumentation components, namely claims, data, justification, and support. The following is one of the arguments tested.

Figure 1. Footprints on the snow ground

The Figure 1 is of two pairs of the same person's footprints wearing different shoes. The person was walking on the ground covered by snow. From the figure 1, is there a difference in pressure produced by the two pairs of shoes on the snowy ground? If so, how are they different? Provide evidence that can support your answer in part a! Explain the relationship of the evidence you put forward with your answer in part a! Write down the explanation or theory that underlies your answer!

The quality of students' arguments was analyzed based on the completeness of the argument components and the strength of the arguments. Analysis of the completeness of students' argumentation components aims to determine the level of students' argumentation and is analyzed using the rubric developed by Dawson and Venville (2009) which is contained in Table 1.

Table 1. Student Argument

Level	Description
1	Only contains *claim*.
2	Contains *claims* and *data*, and/or *warrants*.
3	Contains *claim, data, warrant*, and *backing/qualifier/rebuttal*.
4	Contains *claim, data, warrant, backing*, and *qualifier/rebuttal*.
5	Contains all components of argumentation: *claim, data, warrant, backing, qualifier,* and *rebuttal*.

The strength of students' arguments on the written test was analyzed using the rubric developed by Supriatna (2016) from Zohar & Nemet (2002) as presented in Table 2.

Table 2. Rubric for Assessment of Scientific Argumentation Ability Through Argument Strength

Level	Description
4	*Logical claims*, supported by *grounds* (*data, warrant, backing* true* and relevant
3	*Logical claim*, supported by some *grounds* (*data, warrant, backing* valid and relevant Or; Some *claims'* have logical *grounds* (*data, warrant, backing* true* and relevant
2	Some *claims*, supported by some *grounds* (*data, warrants, backing* valid and relevant
1	*backing*) is true*, but *grounds* are irrelevant. Or; *Claims* are logical, but *grounds* (*data, warrant, backing*) are incorrect* and irrelevant. Or; *The claim* is illogical, but the *grounds* (*data, warrant, backing*) are true and relevant. Or; *The claim* is illogical, and the *grounds* (*data, warrant, backing*) are untrue and irrelevant. Or; *Claim* is not supported by *grounds*

*) Determination of 'correct' is based on the validity of the concept and the rationality of the answers contained in the basis for submitting the *claim (grounds: data, warrant, backing*).

After all students' answers were analyzed, the average score obtained by students was categorized based on the value interval with a standard deviation (SD) which was divided into three categories of argumentative strength, namely weak, moderately strong, or strong.

Table 3. Classification of Strength of Arguments

Classification	Interval
Strong	$X > M + 1\,SD$
Moderately Strong	$M - 1\,SD \leq X \leq M + 1\,SD$
Weak	$X < M - 1\,SD$

(Arikunto, 2006)

The classification is based on a normal distribution which is divided into three categories, where the strong classification includes the score above, which includes the moderately strong category is the score that lies between to, and which is included in the weak category is a score that is below. M is the mean score obtained and SD is the standard deviation. Then, the number of students who fall into the category of each level and the strength of the argument then calculated in percent using the formula proposed by Purwanto (2010) as follows.

$$NP = \frac{R}{SM} \times 100\ \% \quad (1)$$

NP = The percent value sought or expected
R = The raw score obtained (in this study the number of students who appeared at each level and the strength of the argument determined)
SM = The ideal maximum score expected (in this study the number of students in a specified class)

Result and Discussion

Level of Student's Scientific Argument

To determine the quality of an argument, a student's argument can be analyzed in two aspects, namely the aspect of the completeness of the argument component and the strength of the argument. The components of the student's arguments identified to consist of claims, data, justifications, and supports. Based on the aspect of completeness of the argument components, students' arguments are grouped into levels 1 to level 5 based on the modified rubric developed by Dawson and Venville (2009) (Table 1). The results of the initial data analysis of students' scientific argumentation abilities based on the completeness of the argument components can be seen in the following diagram.

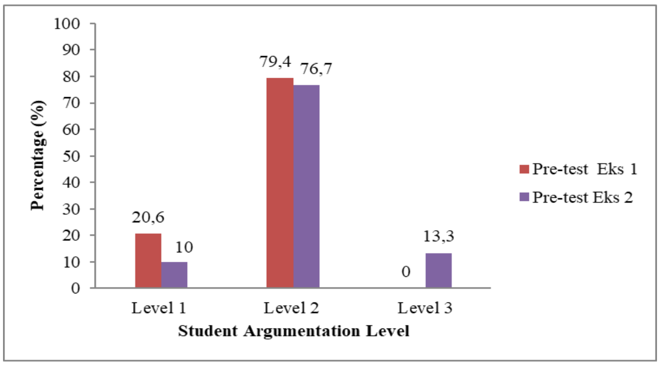

Figure 2. Completeness of the Argument Components of Both-Class Students (*Pre-test* Data)

Based on the data in Figure 2 it is known that 20.6% of experimental class 1 students and 10% of experimental class 2 students have level 1 argumentation skills, which can make claims or statements. The arguments of students in both classes are dominated by level 2, which is 79.4% of experimental class 1 students and 76.7% of experimental class 2 students, meaning that students can make claims accompanied by data and/or there is justification. Only 13.3% of students in experimental class 2 have level 3 argumentation skills, namely being able to make claims with complete supporting grounds (data, justification, and support).

The data obtained are followed by the results of the initial observation of the students' argumentative abilities obtained, where students already can make claims, but students' claims are still simple. Students also have difficulty connecting the data with the claims submitted and students still have difficulty providing a basis to support the claims. This is because students are not familiar with scientific argumentation questions and the teacher's lacks special attention in developing students' scientific argumentation skills.

After being given treatment, both classes were then given a *post-test* to measure the increase in students' scientific argumentation skills. The results of the final data analysis of students' scientific argumentation abilities based on the completeness of the argument components are presented in Figure 3.

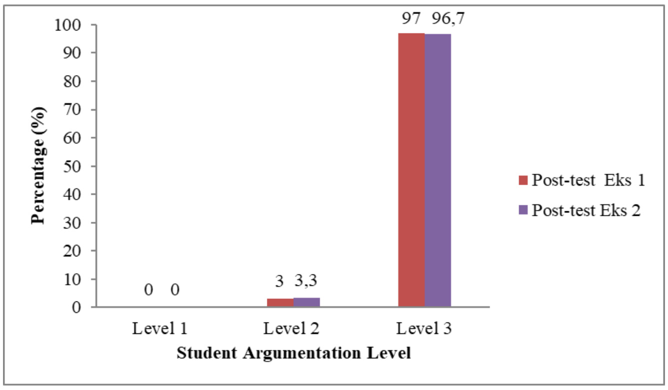

Figure 3. The Completeness of Both-Class Student's Argument Components (*Post-test* Data)

Based on the data in Figure 3 it can be seen that students' scientific argumentation abilities are based on the completeness of the argument components in both classes experienced a significant increase. Most of the students in both classes, namely 97% of experimental class 1 and 96.7% of experimental class 2 students had level 3 argumentation skills, meaning that students were able to make claims accompanied by complete supporting grounds (data, justification, support). The decline in the argumentation ability of level 1 students is very significant, whereas in experimental class 1 and experimental class 2 there are no students whose argumentation skills are at level 1. Meanwhile, for level 2, there are still 3% of students in experimental class 1 and 3.3% of students in experimental class 2 who have argumentation skills at that level.

Strength of Student's Scientific Argument

The strength of the student's argument is assessed from the validity of the concept, rationality of the answer, and the relevance between the claims submited and the basis for supporting claims (data, justification, and support). Strong arguments are characterized by relevant and specific justifications to support conclusions with accurate scientific proofs of concept while weak arguments are characterized by the absence of scientific knowledge considerations or scientific knowledge considerations but are inaccurate, non-specific and imprecise (Zohar & Nemet, 2002). Therefore, the rubric developed by Supriatna (2016) is used to analyze the strength of students' arguments as presented in Table 2. The categorization of argument strength is divided into three, namely strong, moderately strong and, weak. Based on the data, the average score (M) obtained is 2.64 and the standard deviation (SD) is 0.72. The summary of the results of the initial data analysis of students' scientific argumentation abilities based on the strength of the argument can be seen in Figure 4.

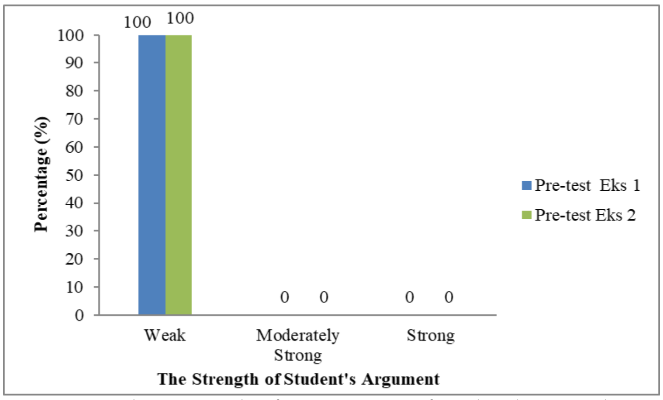

Figure 4. The Strength of Arguments of Both-Class Students (*Pre-test* Data)

The results of the initial data analysis of students' argumentative abilities, are based on the aspect of the strength of argument, weak arguments are the arguments produced by students in both classes. For as many as 100% of experimental class 1 and experiment 2 students, the strength of the arguments is in the weak category, meaning that the claims and the basis for supporting claims (data, justification, and support) are not yet valid (in terms of concepts), and the basic supporting claims put forward by students are irrelevant to the claims so that does not substantiate the claims made. As in the example argument below, "oil pressure is greater than water pressure (*claim, logical but not true*) because oil is slippery than water so the pressure is greater (*justification, irrelevant*)". The answer is almost the same in the following example argument, "water pressure is greater than oil pressure (*claim, logical and true*) because water is more liquid while oil is sticky (*justification, irrelevant*)".

The strength of the student's argument which is dominated by the weak category is a natural thing because students have not received substance pressure lessons and students answer questions based on the initial knowledge they have, this knowledge can come from their daily experiences or from previous lessons that may be related to the material studied. After being given treatment with PBL model learning in both classes, it is expected to improve the quality of the arguments put forward by students. The summary of the results of the final data analysis of students' scientific argumentation abilities based on the strength of the argument can be seen in Figure 5.

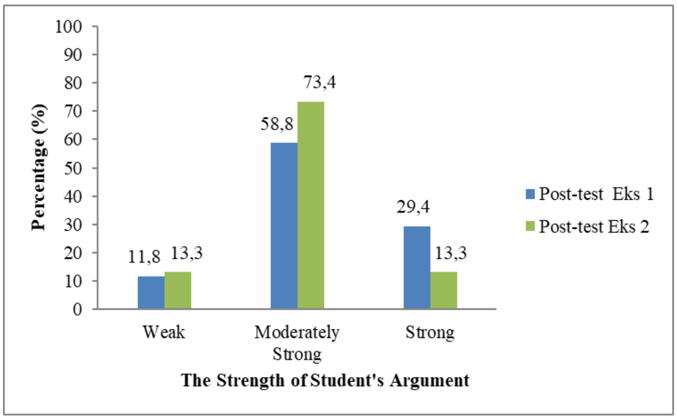

Figure 5. Strength of Arguments of Both-Class Students (*Post-test* Data)

Based on the data in Figure 5, after being given treatment, the percentage of students with strong and strong argument categories experienced a significant increase, while for the weak category, the percentage of students in both classes decreased which is significant where there are 11.8% of students in experimental class 1 and 13.3% of students in experimental class 2 whose argument strength is in the weak category.

The data in Figure 5 shows that the strength of students' arguments is dominated by the fairly strong category (58.8% of students in experimental class 1 and 73.4% of students in experimental class 2). This fairly strong category shows that students can make logical claims and are supported by some true and relevant supporting grounds (data, justification, and support). For example, in the following student argument, "the pressure of shoe B is greater than the pressure of shoe A (*a logical and true claim*), the proof is that the footprint of A's shoe is not deep in the snowy ground (*the evidence is true and supports the claim*), so the footprint of B's shoe has greater pressure (*justification partially support the claim*), the factors affecting the solids pressure are surface area and depth (*the support provided is correct and partially supports the claim*)". This student's argument is categorized as strong enough because the supporting basis (data, justification, and support) does not fully support the claims submitted.

The category of the strength of the strong argument in both classes experienced a significant increase were in the *pre-test*, there were no students whose arguments were in the strong category, while in the *post-test* it rose to 29.4% of experimental class 1 students, and 13.3% of experimental class students 2 whose arguments fall into the strong category. A strong argument is built on the components of an argument that are scientifically valid and relevant to each other, for example in the following example of an argument "the pressure on the shoes in Figure B is greater than the shoes in Figure A *(a logical and correct claim),* from the figure it can be seen that the shoe in picture B is deeper than picture A *(the evidence is true and fully supports the claim)*". The shoe pressure in Figure B is greater so that it leaves a deeper imprint while the shoe pressure in Figure A is smaller so it leaves a less deep footprint *(the justification fully supports the claim)*. Factors that affect the amount of pressure in a solid are compressive forces and surface area. The toe surface area of the shoe in figure B is smaller resulting in greater pressure, the toe surface area of the shoe in figure A is larger resulting in less pressure, the surface area is inversely proportional to the pressure *(the theory given is correct and fully supports the claim)*.

When viewed from the completeness of the argumentation component, the initial data on students' argumentation ability is dominated by level 2, meaning that students can make claims accompanied by data and/or there is justification. This is following by the results of Herawati's (2015) research that most of the students' arguments fall into the level 2 category, meaning that students can submit claims that are equipped with data and/or there is justification. The results of Venville & Dawson's (2010) research involving 30 Australian students (aged 12-17) from several different schools also showed that most of the students (75%) expressed low-level arguments consisting only of claims or only claims and data while justification, support, and, *qualifiers* appear infrequently.

The final data on students' argumentation skills showed a significant increase, where almost all of the students' arguments were in the level 3 category, meaning that students were able to make claims accompanied by complete supporting grounds (data, justification and support). The increasing knowledge of students after learning concepts can lead to an increase in the number of students who can include data and make justifications in arguing (Antonio, RP., & Prudente, M.S., 2021). According to Putri (2018), learning with the PBL model can increase students' knowledge to improve student's ability to argue.

The strength of the arguments of students in both classes also increased in the category of quite strong and strong. For the category of weak arguments, both classes experienced a decrease. The increase in the strength of students' arguments can be caused by learning activities. The habit of expressing true and logical evidence, reasons, and other supports can be trained to students in learning activities so teachers must consider the types of activities and students' cognitive abilities to support their argumentation abilities (Klahr et al., in Varma, 2014).

Based on the analysis of students' argument strength, experimental class 1 showed better argument quality than experimental class 2 where the percentage of students with strong argument strength in experimental class 1 was lower than in experimental class 2 while the percentage of students with strong argument strength in experimental class 1 was higher. compared to the experimental class 2. This subtle difference can be caused by almost the same treatment in the two classes. The PBL learning model was applied to both classes, the difference in treatment only lies in the provision of videos where the experimental class 1, the video was observed by students at home along with video worksheets that must be filled out after watching the video which is the application of the *Flipped Classroom* while in the experimental class 2, the video is observed in class and students are not given a video worksheet.

The application of the *Flipped Classroom* through the provision of videos and video worksheets at home has a positive impact on students where videos can train students to make claims or statements related to problems. This is reinforced by the results of the questionnaire that 100% of students agree with doing the LKPD after watching the video, training their thinking skills in predicting the cause of the Substance Pressure phenomenon. When suspecting the cause of a phenomenon, students will make a claim or statement and include reasons that support the claim. Bringing interesting and authentic scientific phenomena into the classroom, educational video technology makes the process of research and investigation more interactive, allowing students to ask questions about the video they are watching. (Anggreni, N. K. S., & Suniasih, N. W., 2021).

The results of this study indicate that the application of learning in both classes can improve the quality of students' scientific arguments. This is due to a series of learning processes experienced by students. The learning process begins by orienting students to the problem through video media. After watching the video, students are given the opportunity to express their opinions regarding the problems in the video, then students will formulate problems and establish hypotheses, and test their hypotheses through group investigations. According to Tan (2003), in this phase students are trained to submit claims or statements from the results of their thoughts related to problems.

Evidence or data to support claims can be obtained by students from investigation activities through a practicum in groups. After students carry out practical work on the phenomena they are investigating and collect sufficient data, students provide explanations and solutions. In this phase, the teacher encourages the free exchange of ideas and full acceptance of the various ideas that arise (Arends, 2008). Through PBL students in groups will discuss intensively so that verbally they will ask each other, answer, criticize, correct and clarify any concepts or arguments that arise in the discussion (Steck et al., 2012). Warrants or justification explaining the relationship between claims and data, or an explanation of how the data support claims, may develop at the stage of presentation of the work. The ability to reason includes the ability to explain and justify scientifically proven statements (Kurniawati et al., 2022).

At the stage of presenting the work, a representative of the group explains the solution to the problem. Teachers are responsible for guiding class discussions. This class discussion aims to find the best explanation and solution to the problem so that all students can understand it correctly. Class discussions allow students to refine or revisit their views from different perspectives. Because students tend to be more motivated and learn when they are given the opportunity to share and deepen discussions (Atwood et al., 2010 in Waldrip et al., 2013). In this phase, the teacher can also train students' ability to think or argue.

Several research results have also proven that applying the PBL model in science learning can improve the quality of students' arguments, including according to Pritasari et al. (2016) where students' ability to make claims, including evidence and justifications, continues to grow over the three learning cycles. This statement is also supported by the results of previous research by Tarigan (2015) that the application of practicum-based PBL can improve students' written argumentation skills in science learning. The results of research by DeJenger (2012) also show that students' argumentation skills increase through an inquiry-based learning model. Several studies (Tarigan, E. A., & Rochintaniawati, D., 2015; Pritasari et al., 2016) show that PBL can improve students' argumentation skills, and students are more active during the learning process.

Conclusion

Based on the research data, the application of learning in both classes can improve the quality of students' scientific arguments assessed from the completeness of the components and the strength of the arguments. Based on the analysis of students' argument strength, experimental class 1 showed better argument quality than experimental class 2 where the percentage of students with strong argument strength in experimental class 1 was lower than in experimental class 2 while the percentage of students with strong argument strength in experimental class 1 was higher. compared to the experimental class 2. Therefore, it can be concluded that the application of *Problem Based Learning* with *Flipped Classroom* can improve the quality of students' scientific arguments.

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