Problem-Based Learning Modules with Socio-Scientific Issues Topics to Closing the Gap in Argumentation Skills

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ABSTRACT
Problem-Based Learning (PBL) modules based on the topic of socio-scientific issues are behaved to be effective to improve argumentation skills. This aim of the research was to look at the effectiveness of PBL modules on the topic of socio-scientific issues, in order to empower argumentation skills for students with high and low achievements. Method was used the 2x2 factorial design. Samples of this research were participants of the twelfth-grade students of senior high schools in Surakarta. Cluster of random sampling technique was used to determine the samples, and the samples were divided into two groups, namely the control group using conventional modules and the experimental group using PBL modules. Each sample group was divided into two groups base on high and low achievements. The instrument used to obtain the data on argumentation skills was an essay test. The results showed that the application of PBL-based modules is more effective in improving students' argumentation skills than conventional modules and the PBL-based module can minimize the gap in argumentation skills in students with high and low academic achievements.
Keywords: argumentation skills, PBL-based module, socio-scientific issues, academic achievement.

INTRODUCTION
The development of science and technology in the 21st century produced more challenging in the competition of human experts that is inseparable from the role of the quality of education could promote more competitiveness (Ana *et al*., 2019). Educational experiences have been changes and the developments in educational sciences require qualified human resources with various skills (Wüstenberg *et al*., 2014). One of the necessary skills is the argumentation skill (Evagorou and Osborne, 2013). Argumentation skills are ability of people to construct data and information which can eventually produce strong and precise ideas (Cetin, 2014).

These skills are essential in the academics activities (Abdollahzadeh *et al*., 2017) especially for developing, evaluating and validating knowledge (Weng *et al*., 2017). Argumentation skills contribute to improving conceptual understanding more deeply (Aydeniz and Ozdilek, 2016) and allowing students to be more active in the learning process by providing opportunities to share, reflect, and revise their ideas with others (Cavlazoglu and Stuessy, 2018). Empowering argumentation skills could also allow students to develop their communication skills (McNeil *et al*., 2016) and improve scientific literacy (Kaya, 2013). According to Toulmin (2003), argumentation skills consist of six aspects, there were: claim, data, warrant, backing, qualifier, and rebuttal. The category of argumentation skills can be divided in four categories consisting of: level 1 (an argument containing a claim with a simple structure); level 2 (an argument consisting of a claim and data); Level 3 (an argument consisting of claims supported with data, warrant, or backing, but not containing rebuttal); Level 4 (level 3 is added by one or more rebuttals) (Garcia *et al*., 2013).

Studies on mastering students' argumentation skills in Indonesia showed apprehensive results. This can be seen from Indonesia's achievements in the Trends in International Mathematics and Science Study (TIMSS) in 1999, 2003, 2007, 2011 and 2015. Indonesian students' ranking is almost at the bottom list. This results indicate that Indonesian students are not accustomed to solving problems which require the aspects high-order thinking such as reasoning, application, analysis and evaluation (Mullis *et al*., 2015). This argumentation skill study was

carried out through a written test. It shows that the students' argumentation skills were at level one by 17.8%, in which the arguments given by the students only contained simple claims. The students were at the second level by 3.35%, in which the arguments given by the students were supported by data without the support of warrant and backing. The results of the preliminary test showed that the rebuttal aspect had not developed and there were gaps in argumentation skills among students.

The gap in argumentation skills among the students with different academic achievements was needed to be addressed. Academic achievement is one indicator that is important in assessing student learning progress (Tabbodi *et al.*, 2015). Student academic achievement can be classified into high low achievement (Ozguc and Cavkaytar, 2015). There are several factors influencing the students' academic achievements; among others are family characteristic, intellectual level, psychological characteristic, classroom climate and learning duration (Budsankom *et al.*, 2015). The gap in academic achievements between high achievement (HA) and low achievement (LA) students can be reduced, if LA students are given sufficient time to learn according to their needs and abilities. The difference in speed in receiving learning becomes one of the factors that causes the gap between HA and LA students because of the same duration of learning in the classroom.

Argumentation skills do not arise naturally in most people. This would be depends on the environment and practice (Mcneill, Alez-howard *et al.*, 2017). Argumentation skill empowerment can be integrated in the classroom learning system (Manz, 2015). One way to empower argumentation skills in the classroom is to integrate socio-scientific issues (SSIs) in the learning process (Christenson, 2014; Åkerblom and Lindahl, 2017; Pitiporntapin and Sadler, 2016). SSIs is characterized by two important elements, namely the relationship of science content and social interests (Genel and Topçu, 2016; Topçu et al., 2017) that are complex, open, and controversial (Lindahl and Lundin, 2016), thus providing opportunities for students to conduct evaluations (Sadler *et al.*, 2016) and discussions (Tidemand and Nielsen, 2017) in finding and identifying concepts or principles learned (Potter and France, 2018). The issues presented in the learning process are daily problems (Yu *et al.*, 2014) which are not structured or complex that leads to multiperceptions (Rosli *et al.*, 2013) and will encourage representation that will support the claim so that a good argument is formed (Namdar and Shen, 2016). The more contextual the problem is presented, the better the learning takes place (Ridlo, 2014).

Teachers have an important role in providing an effective learning environment, but the level of student argumentation does not depend solely on how the teacher engages students in the advancement of thinking skills. One way to empower argumentation skills is to use modules that consider the history, theory and perspective of argumentation in learning in advance (Archila, 2014). Modules which can be used to empower argumentation skills must contain learning materials that package a multi-perspective problem that is tied to social, economic, political and ethical or moral aspects so that SSIs are the suitable topic to be integrated in the learning module (Morris, 2014).

The problem-solving process needs to be integrated in learning because it is an important key in science learning (Williams, 2018) and is an crucial factor for students in adjusting their behaviour in dealing with a problem (Yigiter, 2013). A module that contains components of problem identification, analysis of learning problems and issues, discovery and reporting, presentation of solutions and reflections, as well as an overview, integration and evaluation is called Problem-Based Learning (PBL) module. The PBL module is one form of reading literature with instructions focused on the learning process and learning content. The use of PBL-based modules can accommodate students to identify problems, define and represent problems, explore possible strategies or solutions, act on selected solutions, and examine and evaluate outside classroom learning (Kuzle, 2017; Niss, 2018).

The argumentation skills can be empowered through ill-structured problem which is used as a trigger in the PBL syntax (Tawfik, 2017; Fang *et al.*, 2018). The learning process is packaged in the form of an investigation of a socio-scientific issue as outlined in the module so that students are encouraged to collect and analyse data to build evidence-based explanations (de Sá Ibraim and Justi, 2016). Students can deliver arguments based on their initial knowledge to connect past experiences with new situations when given the opportunity to learn with problem solving (Cheng *et al.*, 2018).

Therefore, it is necessary to conduct a research to determine whether PBL-based modules on the topic of socio-scientific issues can significantly reduce the gap in argumentation skills between HA and LA students and are more effective than conventional modules. The aims of this research were to find out: (1) how PBL-based modules with the topic of socio-scientific issues influence argumentation skills compared to conventional modules; (2) what is the effect of the academic achievement on argumentation skills; and (3) whether the PBL-

based module with the topic of socio-scientific issues is more effective to close the gap of argumentation skills between HA and LA students than the conventional module.

RESEACH METHOD

Research Design

The aim of this study was to examine the effectiveness of PBL-based biology modules on students' argumentation skills, the effect of academic achievement on students' argumentation skills, and the interaction between modules and academic achievement on argumentation skills. Prior to this research, PBL-based module product development on the SSIs topic had been carried out with reference to the research and development (R & D) method (Borg and Gall, 2003). SSIs topics used in this research include recombinant DNA, cloning, IVF and hybridoma techniques. The independent variables are the PBL-based biotechnology module and conventional module. The dependent variable is the students' argumentation skills. The moderator variable is the level of student academic achievement. The level of student academic achievement was chosen as the moderator variable due to different levels of academic achievement in each class. Based on the variables involved and the objectives to be achieved, the design of this research was used a 2x2 factorial design (Creswell, 2012). The design of this research is presented in Table 1.

Table 1. *Application of PBL-based Module with 2X2 Factorial Design*

		Module	
		PBL (X_1)	Conventional (X_2)
Learning Achievement	High (Y_1)	$X_1 Y_1$	$X_2 Y_1$
	Low (Y_2)	$X_1 Y_2$	$X_2 Y_2$

X_1 : PBL-based module
X_2 : Conventional module
Y_1 : High achievement
Y_2 : Low achievement
$X_1 Y_1$: Argumentation skills of HA students using PBL-based biotechnology modules
$X_1 Y_2$: Argumentation skills of HA students using conventional modules
$X_2 Y_1$: Argumentation skills of LA students using PBL-based modules
$X_2 Y_2$: Argumentation skills of LA students using conventional modules

Participant

The research populations were at senior high schools in Surakarta. The samples used were 214 twelfth-grade students majoring in science in the second semester of 2018/2019. Sampling was conducted by intact group technique to determine two groups of sample classes. Class XII Science 2 was chosen as the control class (using conventional modules) and XII Science 7 as the experimental class (using PBL-based biotechnology modules). The students in each sample class were grouped into two, HA and LA, based on daily test average scores. The illustrations of the research samples can be seen in Table 2.

Table 2. *Sample Distribution*

Classes	∑HA	∑LA	Treatment	Daily Test Average Score
Control	10	10	Conventional Module	LA: 44-60; HA: 68-86
Treatment	10	10	PBL-Based Module.	LA: 45-59; HA: 69-84

Instrument

The instrument of data collection in this research was a written test prepared using the rubric of argumentation skills according to Toulmin (2003), which consists of 6 aspects: (1) claim, (2) data, (3) warrant, (4) backing, (5) qualifier, and (6) rebuttal. The instrument has been validated by expert before being used for collecting data of students' argumentation skills.

Data Analysis Technique

The data were analysed using the ANCOVA test with a significance level of 0.05 with pretest scores as covariates (Ary *et al*., 2010). Least Significant Difference (LSD) test was used to measure the difference in the average value of the variables. The data analysis techniques used were descriptive statistical and inferential statistical analyses. Descriptive statistical analysis is used to describe or explain the collected data about the profile of students' argumentation skills and the level of academic achievement in applying PBL-based biotechnology modules and conventional modules. Inferential statistical analysis is used to analyse the data from the results of the argumentation skills test.

FINDINGS

Results of Biotechnology Module Development Based on Problem Based Learning

The PBL module was developed according to the PBL syntax and the aspects of argumentation skills visualized on the objectives, material, activities and evaluation questions to empower students' argumentation skills. The PBL syntax can encourage students to empower higher thinking processes so that the PBL-based biotechnology module has the potential to enable argumentation skills training. The following was the module developed by the PBL syntax:

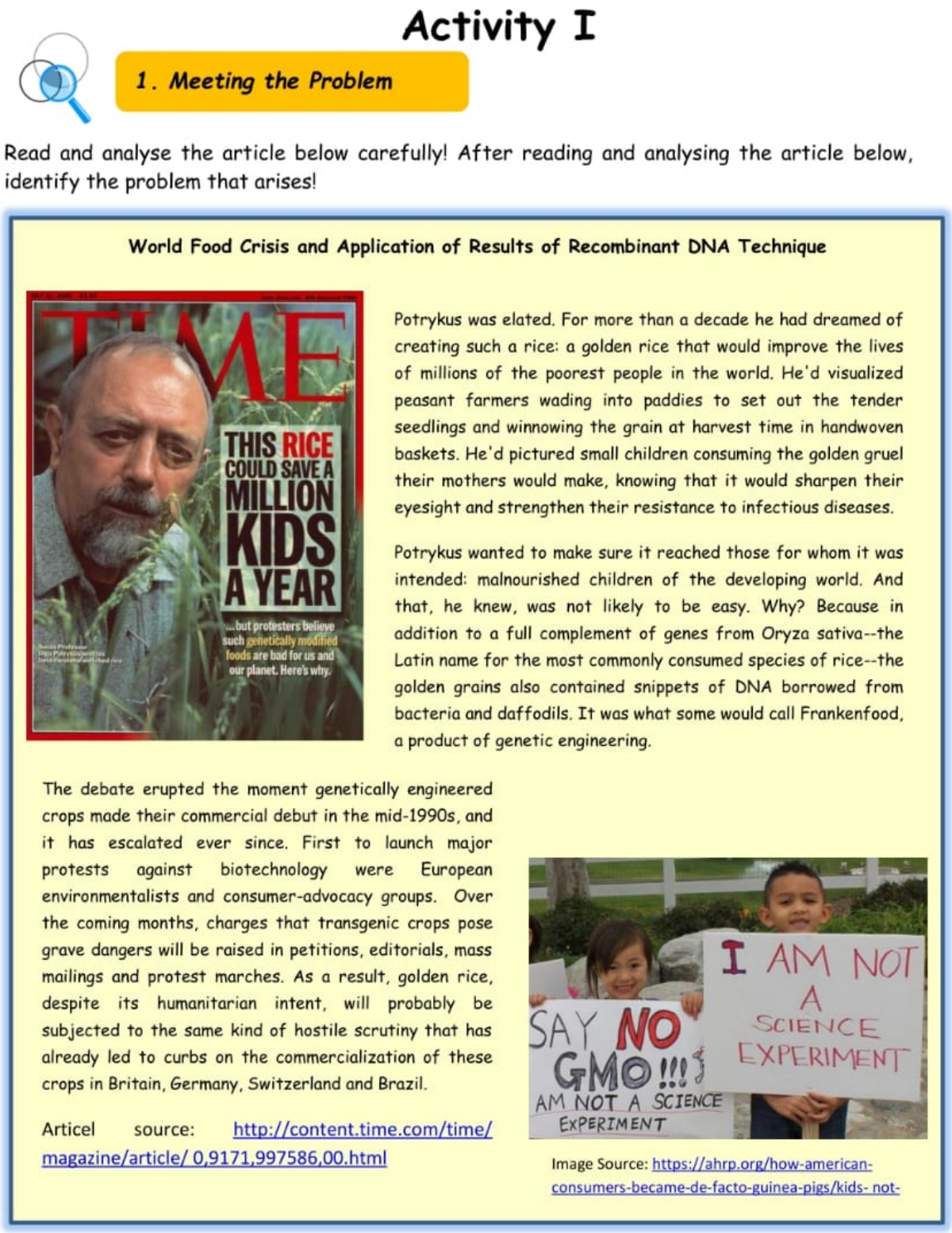

Figure 1. Meeting the Problem Stage in the PBL-based module

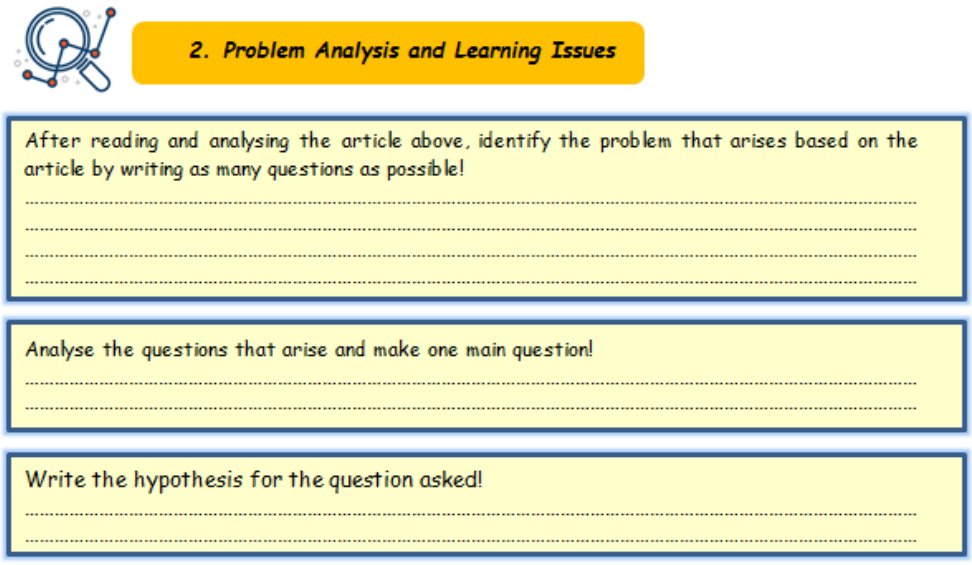

Figure 2. Problem Analysis and Learning Issues Stage in the PBL-based module.

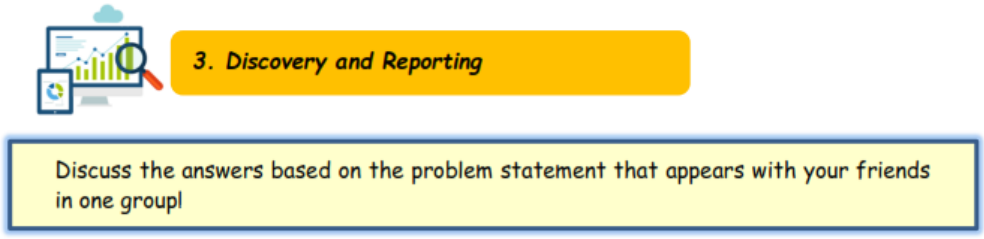

Figure 3. Discovery and Reporting Stage in the PBL-based module.

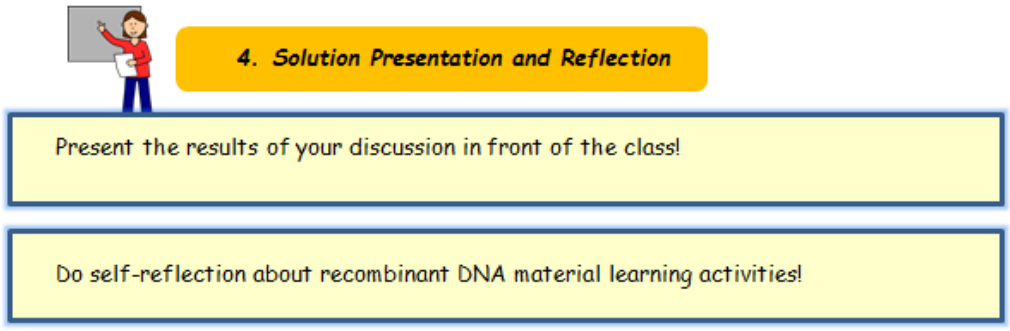

Figure 4. Solution Presentation and Reflection Stage in the PBL-based module.

The activities expected from the students are visualized in Table 3.

Table 3. *Activities Student in the Learning Process*

PBL Syntax	Activities in Module	Student Activities
Meeting the problem	Students are stimulated with the socio-scientific issues related to biotechnology.	Identifying the problems raised in the module.
Problem Analysis and Learning Issues	Students are directed to ask relevant questions to build meaningful relationships between prior knowledge and key concepts.	Proposing possible explanations or hypotheses to solve problems.
Discovery and Reporting	Students are directed to have discussions.	Discussing and exchanging information and correcting each of the ideas that arise.
Solution Presentation and Reflection	Students are directed to present in front of the class and reflect on learning	Presenting and reflecting on the solutions found.

The Results of PBL-Based Biotechnology Module Application towards Argumentation Skills for Students with High and Low Achievement

The SPSS 24 program was used to analyse the data and results showed that based on the results of the normality test, the value of the students' argumentation skills is 0.076, which means the sample from the population of twelfth-grade science students is normal. The homogeneity test resulted in the *p* value of 0.598, which means that the data of students' argumentation skills have the same or homogeneous variants. The results of the covariance analysis of data on argumentation skills in the module, academic achievement and interaction between modules and academic achievement can be seen in Table 4.

Table 4. *ANCOVA Test Results on Student Argumentation Skills*

Source	Type III Sum of Squares	Df	Mean Square	F	P
Corrected Model	[78,801] A.	4	19,700	12,919	.000
Intercept	46,471	1	46,471	30,475	.000
Pre	29,329	1	29,329	19,233	.000
Modules	44,992	1	44,992	29,504	.000
Achievement	3,659	1	3,659	2,400	.130
Modules * Achievement	.012	1	.012	.008	.930
Errors	57,946	38	1,525		
Total	564,928	43			
Corrected Total	136,747	42			

a. R Square = .576 (Adjusted R Squared = .532)

Table 4 shows the significance of module variation with a value of p <0.0001, less than the alpha value of 0.05 (<0.05), which means the application of different modules significantly influences students' argumentation skills. Table 5 visualizes the analysis results the different effects of the modules on argumentation skills.

Table 5. *The Effect of the Module on Argumentation Skills Student at 12th grade*

Modules	Pre-test Average	Post-test Average	Differences	Average Corrected	Notation
PBL	0,492	4,018	3,526	4,451	A
Conventional	1,076	2,406	1,330	2,010	B

Table 5 shows that the PBL-based modules on the socio-scientific topic has significant effect compared to conventional ones. The PBL-based biotechnology module has an average argumentation skill of 4.451, which is higher than the conventional module does of 2.010. It indicates that the group of students using PBL-based biotechnology modules has higher argumentation skills compared to that using conventional modules. The results of the analysis of differences in academic achievement on argumentation skills are visualized in Table 6.

Table 6. *The Difference in the Effect of Academic Achievement on Argumentation Skills*

Academic Achievement	Pre-test Average	Post-test Average	Differences	Average Corrected	Notation
High	0,970	3,928	2,958	3,550	A
Low	0,631	2,346	1,715	2,911	B

Table 6 shows that the score for corrected argumentation skills in HA students is 3.55 and LA students 2.911. These results indicate that the HA student group has better argumentation skills than the LA student group. The LSD test results, as shown in Table 7, exhibits the interaction between the learning module and academic achievement and its effect on students' argumentation skills.

Table 7. *LSD Test Results Confirm the Interaction of Learning Module with Academic Achievement on Argumentation Skills*

Interactions	Pre-test Average	Post-test Average	Differences	Average Corrected
Conventional – Low	0,750	1,620	0,870	1,708
Conventional – High	1,500	3,428	1,928	2,312
PBL – Low	0,439	3,526	3,087	4,114
PBL – High	0,528	4,345	3,807	4,789

Table 7 shows HA and LA students who learned using PBL-based modules have higher argumentation skills than those using conventional modules. LA students who learned using PBL-based modules seem to improve their argumentation skills more effectively than those using conventional modules. PBL-based modules on socio-scientific issues succeeded in improving LA students' argumentation skills at almost the same level as HA students' skills even though the average score did not exceed the average score of HA students. The following are the examples of student answers to recombinant DNA topics in four levels of argumentation categories. Another research shows that learning with PBL will make students face additional challenges, which has a positive effect on students' argumentation skills (Wecker and Fischer, 2014). These were the examples of the student answers in the DNA recombinant topic in four different level of argumentation.

Level 1 : "I disagree."

Level 2 : *"No, because the bacteria Agrobacterium tumefaciens, has been inserted by anti-pest genes so that the composition of amino acids in Agrobacterium DNA also changes which then makes it non-poisonous to plants. Instead, Agrobacterium tumefaciens has the ability to insert or release anti-pest genes into the DNA of kapok plants."*

Level 3 : *"I disagree, because the cause of the tree not attacked by pests is that it has been infected by the cry gene originating from the soil bacteria, Bacillus thuringiensis. Agrobacterium tumefaciens, in this case, is used as a vector because it has the property of being able to join / infiltrate DNA genes from plants."*

Level 4: *"I disagree. Agrobacterium tumefaciens is a vector used to transform plants. This bacterium can transfer genes into plant genomes through explants either in the form of leaf discs or other parts of plant tissues that have high regeneration potential. The bacteria from the type of plasmid Ti are stripped of their virulence (disarmed), so that the plant cells transformed by Agrobacterium tumefaciens and which are capable of regenerating will form a genetically engineered healthy plant. The Kapok tree does not contain harmful bacteria. The tree is only inserted with the Cry gene from Bt. The gene only attacks certain types of insects and is not harmful to humans, so the tree is suitable for planting."*

The research focuses on improving argumentation skills and minimizing the gap in argumentation skills between HA and LA students by using PBL-based modules with SSIs topics. The results showed that the application of PBL-based modules had a significant effect on students' argumentation skills. Table 6 shows that PBL-based modules improve argumentation skills more effectively than conventional modules. In other words, students using PBL-based modules have higher argumentation skills than those using conventional modules.

Also, the research findings correspond with the research of Christenson dan Chang Rundgren (2015) which shows that the topic of GMOs can improve students' argumentation skills. Biotechnology material on the genetic technology topic can improve the students' argumentation skills and understanding of content Sadler *et al*. (2016). PBL-based modules with SSIs topics have a large contribution to empower the argumentation skills found in each stage of learning. Students will be triggered to carry out learning activities and construct knowledge during the learning process (Cetin *et al*., 2019).

PBL steps stimulate the student to find solutions by developing argumentation skills in group discussions. At the meeting the problem stage, students are faced with problems in the form of socio-scientific issues that trigger them to make ideas as solutions to problems which are a temporary claim. The use of ill-structured problems gives different effects to students in constructing content knowledge to be more in-depth, holistic and structured (Kim and Clariana, 2016). SSIs that are used as triggers in learning increase students' active participation throughout learning using PBL-based modules (Demiral and Cepni, 2018). Students are motivated to identify claims that are socially accepted critically, and then strengthen with supporting ideas or refute them with evidence (Braund *et al*, 2013).

In the problem analysis and learning issues stages, students formulate a problem based on their initial claim (Fadzil, 2017). At this stage, students practice thinking of evidence and reasons as hypotheses or temporary answers to answer the problem formulation they are raising. Students can obtain data, warrant and backing at the stage of discovery and reporting. The activities of direct experimental discovery or discussion of literature can help them build their knowledge and improve negotiations among group members. Evidence in the form of data and reasons for findings and negotiations will be used to support claim.

The module activities in the solution presentation and reflection stage improve the aspect of rebuttal because at this stage students experience cognitive conflict from the discussion process. Each group reports and presents the

results of group discussions to other groups in a classic way so that there is discussion between groups. During the discussion, students are faced with various claims. They are asked to bring evidence and alternative reasons to reject other claims or alternative claims submitted by other groups.

Student assignments require the student to reach decisions that guide them in making rebuttal (Eemeren *et al*., 2013). This requires students to engage in a deep learning process, including articulating evidence for counterargumental and rebuttal possibilities. The higher rebuttal value can be an indication that students learn to see problems from different perspectives. At this stage, claims arise in the form of conclusions or decisions (Kim *et al*., 2015). Claims that appear at the final stage are actual claims because they have been supported by correct and logical data, warrant, backing and rebuttal to solve problems.

PBL involves utilizing intelligence from within individuals, groups of people and the environment for meaningful, relevant, and contextual problem solving (Serevina and Sari, 2018). Learning takes place in a process where students working together in groups of 4-5 people to solve problems (Selcuk, 2015). This is consistent with the statement Solbes *et al* (2018) that science learning must have meaning in social interactive processes.

The development of group activities and the use of contextual situations are the conditions needed to improve argumentation skills. The learning process with PBL allows students to discuss and make decisions about a problem well (Kan'an, 2018). Students build a system of meaning and understanding of facts through their interactions with their friends (Erdogan, 2019), thus triggering them to find a lot of information and improve the quality of argumentative processes (Torres and Cristiancho, 2018). This is in line with the research results which show that the argumentation skills of LA students who experience learning using PBL-based modules improve even higher at almost the same level as HA students even though the average score does not exceed that of HA students. The improvement of academic performance can be observed from the increase in the score of the argumentation skills from the pre-test to the post-test activities.

Social environment is one of the learning facilitators, where everyone has a 'zone of proximal development' which means that there is a gap between individual abilities that can be reduced by getting help from his more capable colleagues (Prayitno *et al*., 2017). An important aspect of scaffolding is when problems are very complex, students can ask for help from their friends in one group. Scaffolding through peer tutors provides more study time for LA students.

Module characteristics also allow LA students to independently learn outside of class hours. Sufficient time to study about SSIs can improve LA students' academic performance. The module characteristics consist of self-instruction, self-contained, stand alone, adaptive and user friendly (Prawita *et al*., 2019). 1) Self instruction means that with modules the students can learn independently and they do not depend on others; 2) Self-contained means that the required learning material is contained in a module that aims to provide the opportunity for students to learn the learning material completely because the learning material is arranged as one complete unit; 3) Standalone means that the module does not depend on teaching materials or other media or does not have to be used together with teaching materials and other media; 4) Adaptive means the module has a high adaptability to the development of science and technology; 5) User friendly (familiar) means that every instruction and information exposure that appears on the module is helpful and friendly to the user. User friendly includes using language that is simple, easy to understand, and uses commonly used terms.

CONCLUSION

Based on the above findings, it can be concluded that PBL-based modules on SSIs were believed more effective in improving students' argumentation skills rather than conventional modules for both HA and LA students. This is based on ANCOVA test results on student argumentation skills shows the significance of module variation with a value of $p < 0.0001$. The use of PBL-based modules can minimize the gap in the argumentation skills between LA and HA students because it allows students to produce scaffolding with peer tutors. In addition, they have more time outside the formal learning hours.

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