



Students' Scientific Argumentation Ability on Optical Instrument Material Through PBL-STEM with E-Authentic Assessment

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Abstract. Optical instruments are considered complex and abstract and students still find it difficult to understand them. However, this material important because the phenomenon is often encountered in everyday life and is taught from elementary school to university level. Practicing scientific argumentation can increase students' understanding of the phenomena they experience and shape students to be able to provide structured scientific explanations. Meanwhile, the PBL-STEM model with E-AA is still not widely applied to this material. The aim of this research is to investigate the effect of PBL-STEM with E-AA to support the improvement of scientific arguments on optical instrument material . This research uses mixed *methods* with an *experimental embedded design* . Students make miniature technology in the form of simple loupe and binoculars at the end of the lesson. Research was conducted on 36 eleventh grade high school students in the city of Malang , Indonesia . The instrument for obtaining quantitative data is in the form of 6 essay questions on the Scientific Argumentation Test on Optical Instruments, while the instrument for obtaining qualitative data is in the form of interviews. Quantitative data were analyzed using the Wilcoxon test, N-gain and effect size , while qualitative data were analyzed through the steps of exposure, reduction, coding, data presentation and conclusions . The research results showed that PBL-STEM with EAA had a significant effect on increasing students' scientific argumentation , from level 2 during the pretest to level 3 during the posttest with a category that was almost close to moderate . Practical implications in schools also show a medium effect . The levels of scientific argumentation in sub-materials from highest to lowest level are microscopes, eyes and glasses, and cameras, respectively . Overall, students still have difficulty making scientific arguments because they do not understand the components of scientific argumentation well, especially the aspects of warrant and rebuttal . It is recommended that future research add an "Art" aspect to the STEM approach so that the AI component is more developed.

Keywords: optical instruments, scientific argumentation, PBL-STEM model

1 Introduction

Optical instruments are important material in learning physics so this material is introduced from elementary school to the university level because its applications are often

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found in everyday life so students need to understand the concept of optical instruments well [1]. Optical instrument material is part of basic physics which discusses light, the concept of reflection and refraction of light as well as the formation of images in lenses and mirrors which are interesting topics for problem solving, but many students still find it difficult to solve problems in geometric optics material [2], [3]. Besides that, optical instrument material related to the phenomenon of reflection and refraction of light is considered complex and abstract [4], so that optical instrument material is difficult to understand. Students' difficulties in optical instrument material include difficulties in carrying out experiments on optical instruments, difficulty illustrating the incident and reflected rays in reflection and refraction and students have difficulty understanding phenomena and their application in everyday life [5]. Practicing scientific argumentation (SA) can increase students' understanding of natural phenomena and help improve students' understanding of the material. A learning that includes scientific arguments is able to direct students to understand natural phenomena and form students to provide structured scientific explanations [6].

Science learning that applies scientific arguments has many uses, including developing critical skills, increasing students' contextual understanding and increasing academic achievement [7]. Thus, scientific argumentation has an important role and is an essential skill in science learning [8], [9]. Scientific argumentation is an interactive process in forming an explanation where someone makes a statement or responds to another person's statement with the evidence obtained [10], [11]. Toulmin *argumentation pattern* (TAP) is a pattern for viewing scientific arguments where TAP suggests important constructions in argumentation in the shape of *claim*, *data*, *backing*, *warrant*, and *rebuttal* as important constructions in argumentation [12].

In learning, models are needed to support increasing scientific argumentation skills. PBL-STEM is a learning model that supports the improvement of scientific argumentation by providing meaningful learning through the integration of skills, knowledge and concepts [13]. PBL is synonymous with learning that focuses on problem solving so that it can improve learning outcomes [14], [15]. PBL directs students to express problems, collect and analyze data where students are trained to make statements, supporting evidence and interpret them in discussions [16]. The STEM approach to learning improves students' critical thinking skills, problem solving abilities, communication skills and creativity [17]. Additionally, the STEM approach trains students how to solve problems by linking the material and practices involved in scientific argumentation [18]. However, PBL STEM learning requires a lot of learning time [19], [20].

In this research, the shortcomings of PBL-STEM learning in the classroom were done by doing *Authentic assessment*. This assessment is an assessment carried out by teachers on aspects of attitudes, knowledge and skills in accordance with basic competencies, core competencies and graduate competency standards [21]. Several studies show that this assessment is a solution that can cover these weaknesses other electronic-based learning [22]. This *authentic assessment* is online or electronic based (ea *authentic assessment*) so that teachers can provide faster *feedback on student learning outcomes*. According to [23], [24] online assessments make the learning process more effective and efficient. However, PBL - STEM learning is equipped with e- *authentic*

Table 1. The scientific argumentation of basic framework

L. Level	Characteristics of Argumentation
1	Simple arguments in the form of claim vs counter-claim or claim vs claim
2	Arguments consisting of claims with the data, warrants or backing but without rebuttal
3	Arguments with a series of claims or counter-claims with the data, warrants, or backing which are sometimes accompanied by weak rebuttals
4	Arguments with a claim with several clearly identifiable objections
5	Extensive arguments with more than one rebuttal

assessment It is still rarely used to generate scientific argumentation skills on optical instrument material .

This research imposes the PBL-STEM learning method with *e- authentic assessment* to upgrade students' scientific arguments on optical instruments. The aim of this research is to determine the level of students' scientific argumentation on optical instrument material by applying PBL-STEM with *e- authentic assessment*.

2 Method

This research uses mixed methods with an *experimental embedded design* [25]. Research was conducted on 36 eleventh grade high school students in the city of Malang, Indonesia. The data obtained is in the form of qualitative and quantitative data from the pre-test results and then given treatment in the form of learning using the PBL-STEM model with EAA. Next, a post-test was carried out to obtain more qualitative and quantitative data. The instrument for obtaining quantitative data is with the appearance of SA essay-test questions, while the instrument for obtaining qualitative data is in the form of interviews. The pretest and posttest given in the form of SA essay questions were developed consisting of 6 questions which were declared valid.

Pre-test and post-test activities are carried out with a written test within 90 minutes supervised by the subject teacher in order to obtain the desired results. The data obtained in this test is quantitative data from students' answers to questions. Quantitative data was analyzed using the Wilcoxon test, N-gain, and effect size. In addition, students' scientific arguments are classified into several levels of student scientific argumentation, based on the basic framework for analyzing scientific arguments with the *Toulmin argumentation pattern* (TAP) which includes *claim (C)*, *data (D)*, *warrant (W)*, *backing (B)*, and *rebuttal (R)* [12] according to table 1. Qualitative data was analyzed through the steps of exposure, reduction, coding, data presentation and conclusions.

PBL has five syntaxs, namely orienting students to problems, organizing students to learn, helping students independently or in groups , developing and presenting work results , analyzing and evaluating the results of problem solving [26], [27], while STEM is a learning approach that integrates *Science, Technology, Engineering and Mathematics* into a complete learning with the aim of developing students' knowledge and skills comprehensively [28], [29]. Learning is by *e-authentic assessment* is to help effective and efficient learning.

Table 2. Student pre-test and post-test results on scientific argumentation

Statistics	Pretest	Posttest	Wilcoxon-Test	N-Gain	D-Effect Size
the number of students	36		0.000	0.27	0.61
minimum	0	20			
maximum	10	36.67			
mean	3.15	28.05			

Table 3. Percentage of students' scientific arguments on each question

Student AI Level	Q1		Q2		Q3		Q4		Q5		Q6		Average	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Lv 1	3%	78%	36%	67%	8%	72%	8%	100%	11%	22%	0%	75%	11%	69%
Lv 2	3%	22%	6%	33%	0%	28%	0%	0%	6%	28%	0%	22%	2%	22%
Lv3	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	0%	3%	0%	9%
Lv 4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Lv 5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
No Answer	94%	0%	58%	0%	92%	0%	92%	0%	83%	0%	100%	0%	87%	0%
Sub material	Reflective properties and refraction of light		Eyes and glasses		Lup	Camera	Microscope	Binoculars						

3 Result and Discussion

PBL STEM learning with EAA was carried out in 4 meetings where this learning was carried out in 2 PBL STEM cycles with EAA. In the first meeting, students learn the properties of reflection and refraction with mirrors and lenses, eyes and glasses and cameras. In the first meeting, students do practical work using convex lenses to analyze the properties of images formed by eye lenses and cameras.

Data analysis was carried out with the aim of comparing student test result data on the pre-test and post-test, which means the data is paired because it was taken from the same students before and after being given treatment (PBL-STEM with EAA). The results of the students' pretest and post-test SA data were analyzed quantitatively with descriptive statistics and difference tests using the Wilcoxon test (non-parametric) and looked at the influence of the n-gain and d-effect . The results of data analysis are shown in table 2.

Based on table 2, the Wilcoxon test results show that Asymptotic significance. (2-Tailed) of 0.000 ; 0.05, which means there is a significant difference in scores between the pre-test and post-test. The table also shows that the average score of students' SA skills has increased. The escalation in the results of students' SA skills between pretest and posttest is based on an n-gain of 0.27, which means there is a significant effect that is almost close to medium , the effect size test results also show a value of 0.61 which is in the medium category [30], [31]. Can it be was concluded that the combination of PBL-STEM learning with EAA could improve students' SA skills on optical instruments. The results of this research are supported by previous research, namely that PBL with STEM helps improve SA skills [11], [32], although this study did not include EAA. This means that this research we conducted, namely PBL-STEM which includes EAA, is more complex and therefore more promising in facilitating increased student SA.

The following table presents students' work on each sub-chapter of material in 6 test question numbers.

Table 3 exposes that during the pretest most of the students still did not answer, but during the posttest there were no students who did not answer or express their scientific arguments. It also appears that on average, students at each level of SA experienced an increase in the pretest during the post-test. The average SA ability before giving PBL-STEM learning with EAA was still very weak, shown by the highest average pretest achievement of students still at level 2 with a percentage of only 2%. However, after being given learning, students at level 2 increased to 22%. Students' SA achievement was highest at level 3, namely from 0% at pretest to 9%. When interviewed, the majority of students stated that they "don't know how to make good scientific arguments". This means that students find it difficult to make scientific arguments because they do not understand the components of SA [33].

After being given PBL-STEM learning treatment with EAA, students who were at level 1 of SA were dominant in question number 4 with the camera sub-material at 100%. Students at this level have SA patterns in the form of *claims*, *data*, *claims* with inaccurate *data*, or students are only able to make one component of a scientific argument. When interviewed, the majority of students gave the statement "I don't understand the principle of what camera is used, I only know that the camera applies the principle of refraction".

Students who are at level 2 of SA are dominant in question number 2 with the eye and glasses sub-material at 33%. Students at this level have a pattern of SA which consists of *data claims*, *backing claims* and *data claims* with inaccurate *warrants*, or students are not yet able to make SA components other than claims and data. When interviewed, the majority of students who were at level 2 gave the statement that "based on the phenomenon in the question about pedestrians who said the view on the surroundings became blurry so I concluded that the pedestrian was farsighted."

Students who are at level 3 of SA are dominant in question number 5 with the microscope sub-material at 50%. At this level, students' SA patterns take the form of data claims accompanied by backing, data claims accompanied by warrants. From the interview results, the majority of students stated that "in the question it was stated that Akbar needed a microscope with a magnification of 100 times to observe bacteria. Akbar only has a lens with an ocular lens magnification of 10 times, an objective lens of 10 times." "Because of the magnification of the microscope = $M_{ob} \times M_{ok}$, $10 \times 10 = 100$ I think Akbar can observe bacteria with the lens he has." Table 3 exposes that the percentage of students who did not answer during the posttest decreased and became 0% or there were no students who did not answer. This implies that there is an influence that the compound of PBL-STEM learning with E-AA can improve students' SA skills on optical instruments. Research [34], [35] shows that problem-based learning (PBL) can help improve SA skills.

From Table 3 it also appears that students are still not able to reach levels 4 and 5 of SA. This means that none of the students' answers to the questions include backing and rebuttal aspects of the scientific arguments they make. This is because students find it difficult to create backing and objections to the rebuttal. Research [11] shows that students who only reach level 3 of SA have difficulty in making *backing* and rebuttals in *rebuttaal*. Scientific arguments do not include a *rebuttal aspect* because students are less able to analyze the relationship between concepts and each other to refute *claims*

and tend to just answer questions without being able to refute *claims* with different explanations [6], [7], [36]. To be able to improve SA skills at a better level, students must be trained more in the engineering design process (EDP) in STEM. Because learning using a STEM approach with EDP aspects can help improve scientific arguments [18], [37]. The aspect of designing prototypes in STEM is also able to support students in explaining the relationship between one concept and another [38]. Adding Art to STEM can increase student involvement in improving various cognitive skills and abilities [39].

4 Conclusion

Based on the results of research on the application of PBL-STEM with E-AA, it shows a significant increase in scientific arguments on optical instrument material among the pre-test and post-test scores. The results of an effect size calculation are in the medium category. However, students' scientific arguments have not yet reached level 4 and level 5. Students do not know how to make good scientific arguments and have difficulty making scientific arguments because they do not understand the components of scientific argumentation. It is recommended that future research add an "Art" aspect to the STEM approach so that the AI component is more developed

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