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E-learning based on "problem-based learning" as optical instrument learning complement: Efforts to grow the high order thinking skills

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ABSTRACT

This study aims to develop e-Learning based on "problem-based learning" as optical instrument learning complement to grow the High Order Thinking Skills (HOTS). This study used the model of research and development (R & D) with the development model of Borg & Gall. The instruments used in this study were questionnaires and cognitive tests with questions at the HOTS level. The questionnaire was used to collect the data from the expert review and trial results, while cognitive tests were used to collect the data on the abilities of the students HOTS with indicators analyzing, evaluating and creating. Validation results according to experts in terms of material is 85% and the design is 85% with very good criteria. The results of observations of students' responses to products score is 87% with very good criteria. The N-gain test results of students high-level thinking skills or HOTS in the experimental class for analyzing indicators (0.74) were higher than the control class (0.24), for evaluating indicators (0.76) higher than the control class (0.52), while for indicators creating (0.96) higher than the control class (0.27). The results of the study showed that e-Learning based on problem-based learning was effective to foster students' HOTS.

1. Introduction

The curriculum of 2013 requires learning High Order Thinking Skills to familiarize students with higher-order thinking. The Ministry of Education begins to implement international standards on Computer-Based National Exams, both for Mathematics, Literacy and Natural Sciences, namely those that require high reasoning, or High Order Thinking Skills (Ariyana et al., 2018). In line with that, in the 21st century learning framework shows that the learning process is not enough just to increase knowledge, but is equipped with critical and creative abilities, strong character and supported by the ability to use ICT (Partnership Of 21st Century Skills, 2008).

The results of observations were done with the students and the teachers in three high schools in Pringsewu District stated that; First, the learning process that takes place has not stimulated the students to think higher, 75% of teachers only use teacher center method and do the exercise. The teacher must be first follower of the pace of innovation, so that the students can be motivated to make a change (Wang et al, 2018). Second, is the reading culture of students being very lacking, 83% of students prefer to open social media and play games during their free time. This data is in line with the findings of UNESCO (2012), only one in 1,000 Indonesian people prefer to read. Third, the type of question given by the teacher has not stimulated them to think higher, 63% of teachers provide physics questions at C1-C3 levels. This statement was reinforced by monitoring the supervision and Guidance of Post-High School Learning Evaluation (EHB) conducted by the Directorate of High School Development, most of the high school teachers in compiling items tend to only measure Low Order Thinking Skills (LOTS) (High Order Thinking Skills Question Preparation Module, 2015).

Basic competencies (KD) at HOTS level have not been properly learned, one of which is optical instrument material. KD of optical instruments have KKO analyze and create works. There are several reasons that underlie this. First: optical instrument are the materials that are classified as difficult. This is supported by research conducted by Agnes et al. (2015); Gaili & Hazan (2000); Chang, et al. (2007) stated that the students still experience misconceptions in the

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concept of shadow formation, the nature of shadows on mirrors, and the working principle of some optical instrument. Students who lack understanding of how light travels will have difficulty describing Shadow formation and explaining the nature of shadows such as distinguishing virtual or real shadows (Hadžibegović and Sliško, 2013; Colin et al, 2010). The second is the lack of time allocation to learn materially and study its application in life.

Based on these problems, the solution given is to use e-Learning as a "face-to-face" learning complement. E-Learning can be used to enrich teaching materials (enrichment) in blended learning Lewis (2002). E-Learning is a learning activity that involves technology for the presentation of Shute and Towle (2003). Without digital technology to facilitate communication between stakeholders, in sharing pictures, stories, and good relationships, it will not work (Khier and Khalil, 2018). With information technology, students can access the teachers and the learning resources over time moreefficiently (Liao, et al., 2014). Two of the highest rated advantages of e-Learning are 1) flexibility at times and places (Macpherson et al, 2004), 2) ease in teaching materials (Yaghoubi, 2008).

E-Learning must be in accordance with the objectives of physics learning, namely students are able to analyze the problems, have the problem-solving skills and be able to apply in their lives. Problem Based Learning (PBL) models present real-life, open, and multifaceted problems for students to discuss, analyze, and solve (Enger et al, 2002). The problems presented in PBL are effective daily problems that can stimulate the students to obtain the sufficient information, activate initial knowledge, and directing their learning correctly (Hung, 2008). Furthermore, the PBL model helps to improve the development of lifelong learning skills in an open, reflective, critical mindset and active learning (Margetson, 2006). By utilizing the problem as a trigger for learning and interactivity, the potential of technology can be fully utilized (Nurdiansyah & Fahyuni, 2016). Online problem-based learning can meet the objectives and be benefits (Lopez-Ortiz, 2006). Online PBL implementation helps to increase the use of technology and high-level thinking skills (Şendağ & Odabaşi, 2009). This study has two purpose, the first is to develop PBL-based e-Learning as a complementary learning to support face-to-face learning, especially optical instrument material. Second, applying learning by using PBL-based e-Learning as a complement to optical instrument material to foster the High Order Thinking Skills of students.

2. Method

The procedure of this research is done by adapting the steps of the research and development model according to (Gall et al, 2003). The development procedure can be seen in Fig 1.

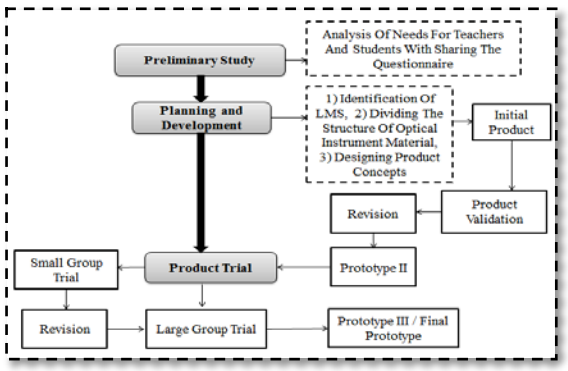

Fig 1. The Development Model (Gall, et al. 2003)

2.1. The Research Design

The product trial design uses pretest-posttest with control group design (Setyad, 2006) can be seen in Table 1.

Table 1
Trial Design

Group	Pretest	Dependent variable	Postest
E	Y1	X1	Y2
K	Y3	X2	Y4

Note:
X1: Treatment in the form of blended learning (face to face and e-Learning)
X2: Treatment in the form of conventional learning (face to face)

The students high-level thinking skills test data using questions at HOTS level, in the form of quantitative data seen from the pretest and posttest scores of students.

2.2. Sample Selection

The sampling technique uses a purposive sampling technique, schools are chosen based on researchers' considerations regarding the quality and location of the school. Sample research to obtain data needs analysis, researchers involved 126 students and 3 teachers in three high schools throughout Pringsewu District, Lampung, to fill out the questionnaire. The product trials in this study involved 54 students of XI IPA at SMAN 1 Pardasuka Pringsewu Regency, with 27 students of XI IPA 1 learning face-to-face and using PBL-based e-Learning as learning complement while the XI IPA 2 class consisted of 27 students studying face to face only. Both classes use a scientific approach during face-to-face learning.

2.3. The Research Instrument

The research instrument uses questionnaires and questions about optical instrument material. The questionnaire was used to collect the data on needs analysis in the field, test data on content / material & design validation, and student response data. Essay questions are used to see the students' high-level thinking skills with indicators of analyzing, evaluating and creating. This type of essay is deliberately chosen so that it can be seen how the students' abilities are actually based on the description of the answers given. Before being used, all the research instruments have been tested for validity and reliability.

2.4. Data Analysis

The results of PBL-based e-Learning validity was analyzed by calculating the average score of each validator, then interpreting the average score percentage using interpretations based on Riduwan (2014) in Table 2.

Table 2
Interpretation of Validation Score (Percentage)

Percentage	Criteria
80,1% - 100%	Very Good
60,1% - 80%	Good
40,1% - 60%	Medium
20,1% - 40%	Low
0,0% - 20%	Very Low

The effectiveness of e-Learning as a complementary learning physics to students using an analysis of the average N-gain score is then interpreted using Meltzer (2002) classification as presented in Table 3.

Table 3
N-Gain classification

Average Gain normalized	Classification
N-gain > 0,7	High
0,3 ≤ N-gain ≤ 0,7	Medium
N-gain <0,3	Low

Data analysis was also supported by a t-test consisting of paired sample t test to determine the increase in the value of the pretest with posttest in the experimental class and the independent sample t test to determine the difference in average posttest values in the experimental class and control class.

3. RESULTS

After conducting a preliminary study and obtaining the data on the needs analysis for students and teachers, the steps for preparing PBL-based e-Learning are arranged. In the planning stage the first step is to identify the Learning Management System (LMS) that fits your needs.

Schoology is a website that combines e-Learning and social networking (Aminoto and Pathoni, 2014). The similarity between Schoology and other tools (Facebook Launch, and Breaking the waves) is that they are all easy to use (Depict, 2014). Using e-learning with Schoology is more beneficial than using moodle because it does not require hosting and management Schoology is more user friendly (Natalia et al. 2015). Schoology features such as; Course, Groups, Resources, Recent Activities that contain it; Assigment, Quiz, Discussion, Attandance (attendance), Analityc etc. (Yuliyanto and Imaduddin, 2014). Based on this, the LMS used is Schoology because its use is easy, the application is not heavy, the features in it can be used to support online learning, then schoology can be accessed through smartphones so that it has higher flexibility.

The second step is to divide the material structure according to the indicators of achievement that will be achieved at each meeting. Based on the needs map that has been compiled on the KD optical instrument, it is concluded that e-Learning is arranged in 4 meetings to reach the KD. The structure of the optical instrument material based on the curriculum of 2013 is presented in Table 4.

Table 4
Optical Instrument Material Structure Based on Curriculum of 2013

Time	Material	Sub material
The First Meeting	Eye	Parts of the eye and their functions Power of eye accommodation The process of forming shadows on normal eyes
	Eye defects	Various types of eye defects Characteristics of myopia, hypermetropy, presbyopia and astigmatism The process of forming shadows on myopia, hypermetropy, presbyopia and astigmatism defects
	Sunglasses	The Function of glasses Lens strength in myopic, hypermetropy, presbyopic eye defects The process of forming shadows after using glasses on myopia, hypermetropy, presbyopia and astigmatism defects
The Second Meeting	Magnifying glass	Function of Magnifying glass The process of shaping the shadow is faded when the eyes accommodate and do not accommodate Enlargement of shadow in the eyes when the eyes accommodate and do not accommodate
	Camera	Parts of the camera and their functions The process of forming a shadow on the camera The difference in how the eyes work with the camera
The Third Meeting	Microscope	Microscope parts and their functions Magnification of the microscope when the eye accommodates and the eyes do not accommodate The process of forming a shadow on a microscope when the eyes accommodate and the eyes do not accommodate
The Fourth meeting	Binoculars	Various binoculars Parts and functions of star, earth, stage, reflections and periscope binoculars Enlargement of shadows on binocular earth stars and the stage The process of forming shadows on star binoculars, earth, and the stage when accommodating and not accommodating

The third step is the design of PBL-based e-Learning concepts as a complement that will be developed can be seen in Fig 2.

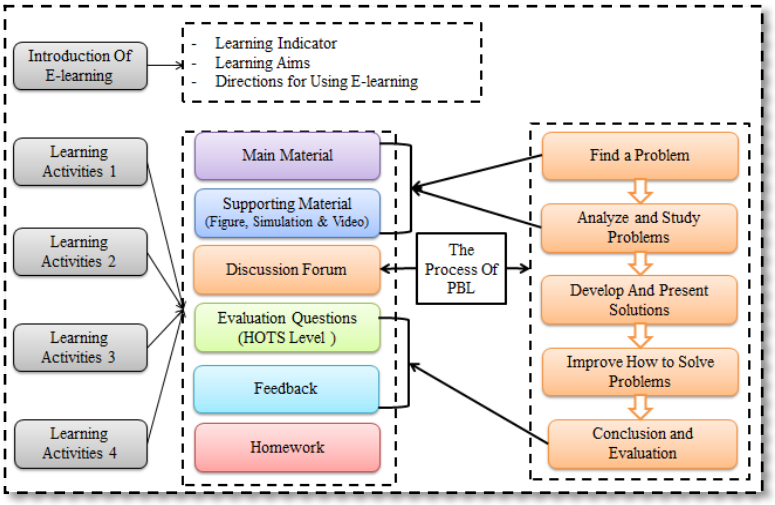

Fig 2. The Development Product Concept

At the development stage, PBL-based e-Learning products are produced as complementary learning of optical instrument. The results of the data analysis state that PBL-based e-Learning is feasible to be used as a learning tool to grow HOTS students, after the content and design validity was carried out by 3 Expert Lecturers and 2 Expert Practitioners. The results of the assessment of expert content validity and design validity for PBL-based e-Learning as a complement can be seen in Table 5.

Table 5
Expert Test Assessment Results

Validator		Test Type	Score	Qualitative Statement
Expert validator	D1	Content validity	69%	Valid
		Design validity	76%	Valid
	D2	Content validity	91%	Very Valid
		Design validity	94%	Very Valid
	D3	Content validity	97%	Very Valid
		Design validity	85%	Very Valid
Expert Practitionair Validator	P1	Content validity	78%	Valid
		Design validity	76%	Valid
	P2	Content validity	91%	Very Valid
		Design validity	92%	Very Valid
The Average		Content validity	85%	Very Valid
		Design validity	85%	Very Valid

The product trial in the experimental class was carried out using the blended learning method, which combines face-to-face learning with online learning (Yen and Lee 2011). Online learning (e-Learning) is done as a complement or complement that serves to strengthen students' understanding of the material that has been obtained face to face. Face-to-face learning uses a scientific approach. Students can access main and supporting material such as; 1) picture, the presence of images in learning activities will give new nuances. It can be a stimulant or a stimulant during learning activities (Adinata et al., 2015); 2) simulations, students give a greater positive response to moving images / simulations compared to still images (Agustina et al, 2017); 3) videos, integrating video clips in multimedia can improve students' perceptions of important information and motivation for learning (Ljubojevic et al, 2014), on e-Learning as a reference in finding information.

The implementation of e-Learning uses a problem-based learning model, PBL in question is found in the discussion forum program developed, discussion forums are designed in the presence of a problem based on phenomena in everyday life, this problem will be discussed by students. Cho and Jonassen (2002) show online discussions as long as the problem-solving activities can automatically be recorded and are useful to be feedback. After conducting discussions, students will conduct an evaluation by working on the questions at the HOTS level. HOTS questions enter the cognitive level C4, C5, C6 (Anderson and Kratwohl, 2001) at the end of each e-Learning learning. Evaluation questions are complemented by feedback on correct answers and wrong answers so students know where the errors are quickly, efficiently and effectively. The revision feedback method is superior compared to the self-revision method (Ratopo et al. 2015). Last is downloading home tasks. The overall online evaluation can improve the students' ability to formulate learning needs, choose meaningful learning activities, and complete learning tasks (Kicken, 2009).

The results of student responses after obtaining the e-Learning treatment of PBL as a complement were found to have an average percentage of 87% which means that it is qualitatively very good. The following is the breakdown of student responses in Fig 3.

The effective aspects are based on content/content in e-Learning such as: main material and supporting material can help students access the concepts needed in exploring deeper material, discussion forums and evaluation questions can stimulate high-level thinking of students. The overall effort to combine face-to-face learning, viewing multimedia and online discussions received a positive response (Khine and Lourdasamy, 2003). Furthermore, Thompson and McDowell (2019) stated that the majority of students (76.4%) in online learning and in blended learning (64%) felt self-confidence increased.

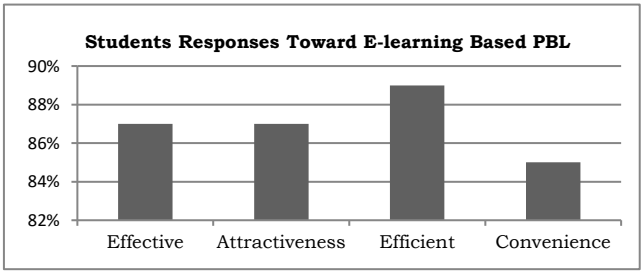

Fig 3. Student Response to e-Learning based PBL

The aspect of attractiveness is based on the teacher's observation when learning is carried out, either face to face or online, where the enthusiasm of students responds to online discussions very well. Learning strategies that use e-learning media in physics learning can increase the students' interest in learning well (Sulisworo and Agustin, 2017). Blended learning allows the students to become more involved in the learning process and more motivated and, as a result, increase their commitment and perseverance (Donnelly, 2010; Wang et al., 2009; Woltering et al., 2009; Yen and Lee, 2011).

Efficient aspects based on e-Learning can improve the quality of learning, achievement, and foster high-level thinking that is relaxed with the students able to associate the concepts with the reality (everyday life). In line with Woltering's research, (Woltering et al, 2009) student satisfaction was much higher when using blended learning (PBL). In line with that, Sulisworo and Agustin (2017) revealed that there was a high increase in learning outcomes for students learning by using e-Learning. Lastly, the facilitation aspect was based on systematic presentation so students could manage their own learning.

To determine the increase in the value of the pretest with posttest using the n-gain test and statistical hypothesis testing using paired sample t-test. The average value of the results of the n-gain test in the experimental class and the control class can be seen in Table 6.

Table 6
N-Gain Test Result

Class	The Highest Score	The Lowest Sciore	Pre Test Average	Post Test Average	N-Gain Average
Experiment	86	40	48,2	71,6	0,84
Control	80	42	50	55,7	0,29

Based on Table 6, it can be seen that the experimental class N-Gain is much higher than the control class so that it can be concluded that HOTS increases the students in high criteria. While the graph of the average N-Gain of each student's HOTS indicator is set out in Fig 4.

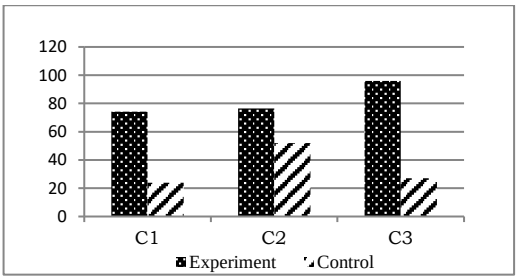

Fig 4. The Graph of Calculation of NS Gain Aspects of HOTS

Note:

C1 = Analyze, C2 = Evaluate, C3 = Create

The results of the analysis of thinking skills at the first level were analyzing with the n-gain experimental class (0.74) higher than the n-gain control class (0.24). The ability to analyze has been trained in the learning process using e-Learning through discussion forums, namely by providing images, students are directed to find a problem from the image then be able to analyze by explaining the solutions and answers to these problems. Problems can trigger curiosity, inquiry, and thinking in a meaningful and powerful way of analyzing Tan et al. (2009). Furthermore (Ramos, 2013) emphasizes that analysis and evaluation is a skill that is associated as a step to solve a problem. The following are examples of student discussion and answer questions found in Fig. 5a and 5b.

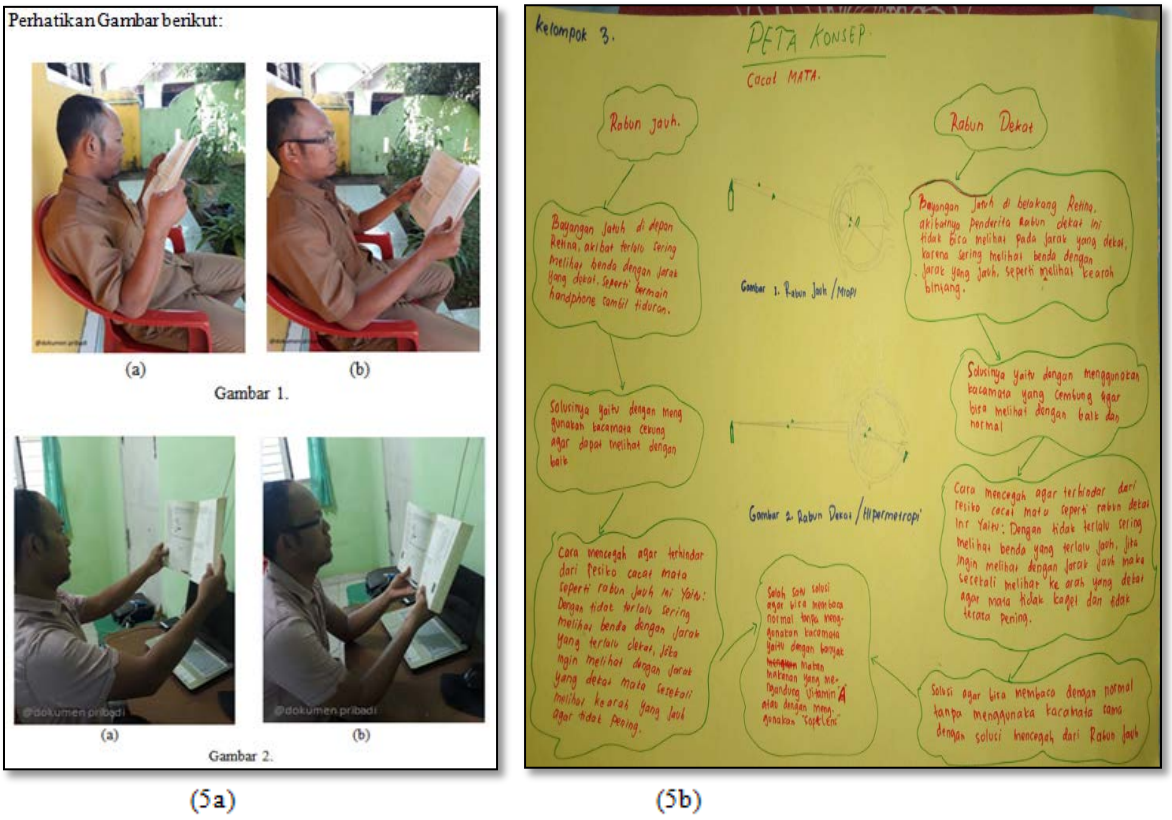

Fig (5a). Problem at Discussion Forum 1, **(5b).** The Student Answers

The high-level thinking aspect evaluates with the n-gain experimental class (0.76) higher than the n-gain control class (0.52). The increase in scores obtained is because in learning students are given the opportunity to evaluate the answers from friends or other groups, discuss each other give responses and answers to the problems presented. Online discussion forums allow the students to get feedback immediately if they encounter the difficulties, and online platforms also allow them to read and comment on assignments posted by their colleagues (Khine and Lourdasamy, 2003) help them clarify the problems encountered in each teaching unit (Tsai and Tang, 2017).

The last high-level thinking skills are aspects of creation with n-gain experimental class (0.96) higher than the n-gain control class (0.27). The increase in scores obtained is because in e-Learning learning, the problems presented are designed so students can explore the answers they will express by creative thinking. The creative process is seen as a change in perception, or seeing a combination of new ideas, new relationships, new meanings, or new applications that have never been felt before (Tan et al. 2009). Questions or problems are made based on phenomena in everyday life so that it becomes a stimulus for students to develop their answers. Utilizing real life problems as a stimulus for students to think critically and solve problems and achieve important knowledge and concepts from material (Masek and Yamin, 2011). There was a significant increase in the experimental class compared to the control class, one of which was because experimentally the students practiced making simple binoculars in groups. Project learning can have a positive influence on creative thinking skills (Arifah et al. 2018)

The increase in the value of a high-level thinking skills test is in line with the increase in the average value of evaluation questions which exercises each end of e-Learning activities. The following is the average value of evaluation questions in Fig 6.

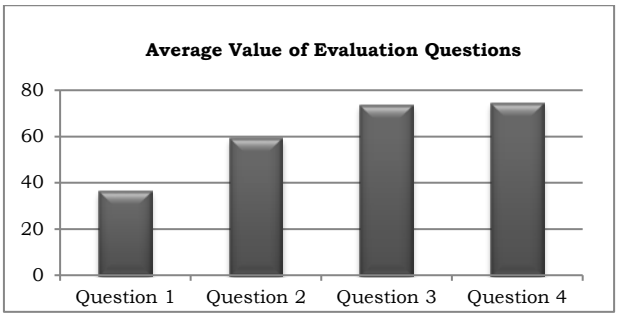

Fig 6. Average Value of Evaluation Questions for Each E-Learning Meeting

Increasing the value of the pretest and posttest in the experimental class can also use the statistical hypothesis test using paired sample t-test can be seen in Table 7.

Table 7
The Result of Paired Sample T-Test Betwen Pretest and Postest

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	postes - pretes	23,407	4,290	0,826	21,710	25,104	28,351	26	0,000

The results of statistical hypothesis testing using paired sample t-test obtained a Sig value of 0.000 <0.05, it can be concluded that significantly the posttest value after using the developed product is higher than the pretest value before using the developed product. While the difference in average gain values in the experimental class and control class is done by statistical hypothesis testing using the Independent Sample T-Test can be seen in Table 8.

Table 8
the Average Gain Difference Test Result Betwen Experimental and Control Classes

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
N-Gain	Equal variances assumed	,020	,887	8,786	53	,000	52,124	5,933	40,225	64,024
	Equal variances not assumed			8,784	52,869	,000	52,124	5,934	40,221	64,027

The results of statistical hypothesis testing using Independent Sample T-Test obtained a Sig value of 0.000 <0.05, it can be concluded that there is a difference between the average gain values in the experimental class and the control class, or significantly the average gain value of the experimental class using the product developed higher than the average value of the gain of the control class that does not use the product of development.

The results of data analysis showed that the overall aspects of high-level thinking skills in the experimental class were higher than the control class. This is supported by Nalatia et al. (2016) e-Learning learning program with school can be used as a learning enrichment that is very interesting, easy to use, useful, and effective to teach the concept of rigid body dynamics and train students to learn independently. Next is Suyatna, et al. (2017) The use of visual media in physics learning can improve the student learning outcomes. The e-Learning environment provides an easy access to learning materials, both authentic designed, and also facilitates peer-to-peer communication via e-mail, facilitated forums, internet-based resources and tools has the potential to improve learning outcomes through integration with PBL (Murphy, Ness & Pelletier, 2001).

The findings in this study that e-Learning based on "problem-based learning" as optical instrument learning complement can foster high-level thinking skills of students. Empirical studies on PBL online have found positive effects on learning outcomes in addition to fostering a positive attitude towards problem solving, but also helping students improve their ability to effectively and rationally apply information and experience to real life challenges, then students can increase their learning autonomy, thinking critical and creative thinking, which can significantly contribute to improving lifelong learning skills (Tsai and Tan, 2017). PBL effectively encourages student thinking and enhances students' high-level thinking skills, especially in reasoning skills (Silver, 2004). The e-Learning system can improve critical thinking skills (Putra and Sudarti, 2015).

4. Conclusion

Based on the description above, it can be concluded that e-Learning based on problem-based learning- has been successfully developed as an optical instrument learning complement to grow HOTS students of class XI who can support face-to-face learning. E-Learning based on problem-based learning as a supplement contains the main material, supporting materials such as simulation and video images, discussion forums, feedback and homework. It is also equipped with evaluation questions at the HOTS level which can be used to train HOTS students' thinking. It also can foster high-level thinking skills of students, especially in optical instrument material. The results of the N-gain test of high-level thinking skills of the students in the experimental class (0.84) were higher than the control

class (0.29).

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