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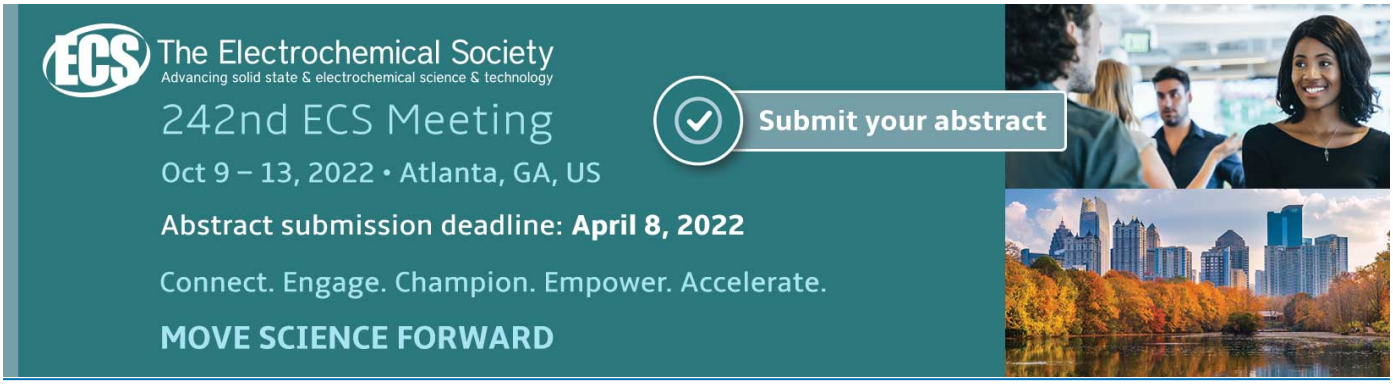

Flipped classroom using e-module to improve understanding of light concepts: needs analysis of e-module development to empower scientific explanation

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Abstract. This study aims to determine the effectiveness of the flipped classroom using e-module to improve understanding of the light concept, analyze the trend of increasing student concept understanding, and analyze the weaknesses of e-module instructional activities. This research method is the concurrent embedded mix method. The research design is a one-group pretest-posttest design. The subjects involved 22 students of IAIN Palangka Raya and Hamzanwadi Selong University. The sample was selected by cluster random sampling. Quantitative data were collected using a two-tier test. Qualitative data were collected through interviews and observations. Quantitative data analysis technique using t-test. Qualitative data were analyzed descriptively qualitatively. The results showed that: 1) There was a significant increase in student's conceptual understanding after the implementation of the flipped classroom using e-module, 2) The trend of increasing concept understanding in the low category was 18%, the medium category was 68%, and 14% in the high category, and 3) The weakness of this e-module is that there are no hand-on and scaffolding-oriented instructional activities to empower explanations. scientific in elaborating concepts.

1. Introduction

The learning process is a process of delivering messages from the source of the message to the recipient of the message. The process of delivering this message can be done synchronously and asynchronously [1]. So that the use of technology becomes a very important consideration to improve the effectiveness and quality of the learning process [2]. Besides that, the curriculum based on the Indonesian National Qualifications Framework emphasizes problem-solving using Science and Technology.

Utilization of technology in learning can use the flipped classroom learning strategy, namely learning that minimizes direct teaching from the teacher, but maximizes indirect teaching with material support that can be accessed anytime by students [3]. The flipped classroom gives students to prepare for lessons by watching videos, listening to broadcasts, reading articles, discussions, or group work [4]. The flipped classroom is an instruction that used accessed at home before entering class, the classroom becomes a place to solve problems and develop concepts [5].

Technology-based learning strategies that can be used by educators in the learning process in the current digitalization era to increase the activeness and independence of students are flipped classrooms using e-modules. Through e-module, educators can share material synchronously or asynchronously. The advantage of the e-module is that it is equipped with audio, video, images, and

animations that can help students elaborate concepts in learning. The flipped classroom strategy using e-modules is indispensable in online learning in the era of the COVID-19 pandemic, especially in physics teaching materials [6], [7].

Diagnostics of students' initial concepts need to be done before learning begins as a reference for designing teaching materials that suit the needs of students. Low initial concept understanding causes students to have difficulty connecting other concepts related to the concept being studied [8]. Like the case of fiber optic material, because fiber optic material is closely related to the concept of light, an inventory of trends in understanding the concept of light is very important before teaching fiber optic material. The results of research by Yoanita & Akhlis (2015) show that the lowest level of understanding of the concept of light occurs in indicators of knowing the definition, nature of light, and understanding the conditions for the process of reflection and refraction of light [9].

The results of a preliminary study conducted by researchers on the trend of understanding the concept of light among students of IAIN Palangka Raya and Hamzanwadi Selong University showed that 50% of the items about the concept of light were not understood by students. Many indicators of understanding the concept of light that are still not understood by students include the concept of changes in the magnitude and direction of refractive rays when passing through a medium that has a different refractive index, conditions for the occurrence of critical angles, conditions for total internal reflection, and the meaning of the mathematical equation for attenuation of light waves.

The results of a preliminary study on the trend of understanding the concept of light are used as a basis for researchers to develop e-modules. After learning through flipped classrooms using e-module, it is hoped that there will be an increase in understanding of the concept of light. This study, in addition to measuring the increase in student's conceptual understanding after learning through flipped classrooms using e-modules, but also taking inventory of the causes of student difficulties in answering questions of understanding concepts, and evaluating the weaknesses of instructional activities in e-modules as consideration for compiling instructional activities on e-modules. The next step is to empower students' scientific explanations. To train students to be able to make the right decisions based on information and data, students need to be trained to argue using scientific explanations.

2. Methods

This research was conducted by using the exploratory sequential design [10]. In this study, qualitative research is a large part of this research and quantitative data is used as data to support research results. The research design is a one-group pretest-posttest design. The subjects of this study involved 22 students of IAIN Palangka Raya and Hamzanwadi Selong University. The sampling technique is cluster random sampling, which is a sampling technique where a researcher divides the population into several separate groups, then from these clusters, several samples are chosen randomly. Quantitative data were collected through a test instrument for understanding the concept of light in the form of multiple-choice and answer reasons. Qualitative data about the reasons why students had difficulty answering certain light concepts were collected through interviews. Qualitative data on instructional weaknesses in the e-module were collected through document observations and student activities in the learning process. Obtained from the results of interviews. The quantitative data analysis technique uses a t-test to measure the effect of flipped classroom treatment using e-modules to improve students' understanding of the concept of light. Before the t-test, the analysis prerequisite test was conducted, namely the normality test and data homogeneity. Qualitative data were analyzed descriptively qualitatively using normalized gain [11].

Table 1. Criteria for Normalized Gain Score

Criteria	Percentage Level of Mastery
gain ≥ 0.7	High
$0.3 \leq$ gain < 0.7	Medium
gain < 0.3	Low

Qualitative data analysis to describe the trend of increasing student understanding of concepts, mapping the indicators of questions that are still difficult to answer by respondents. The concept map of this research as shown in Figure 1.

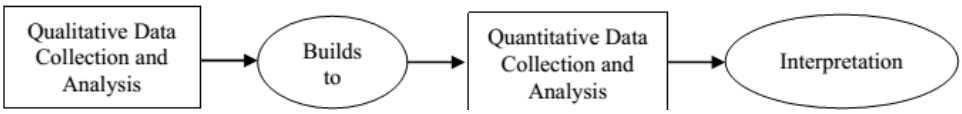

Figure 1. The concept map of research

3. Result and Discussion

3.1. Effectiveness of flipped classroom using e-module to improve understanding of the concept of light

The results of the analysis prerequisite test consist of the results of the normality test in Table 2 and the homogeneity of the data in Table 3.

Table 2. Tests of Normality

	Kolmogorov-Smirnov		
	Statistic	df	Sig.
Post-test	.146	22	.200
Pre-test	.200	22	.022

The significance value (p) of the post-test data on the Kolmogorov-Smirnov test is 0.2 (p > 0.05), so the post-test data is normally distributed. The significance value (p) of the pre-test data on the Kolmogorov-Smirnov test was 0.02 (p < 0.05), so the pre-test data were not normally distributed
.

Table 3. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.793	1	42	.378

The significance value of the test of homogeneity of variances is 0.37 (p > 0.05), so the pre-test and post-test data variances are the same or homogeneous.

The results of descriptive data analysis of data containing the mean, number of samples, standard deviation, and standard error of the mean are shown in Table 4.

Table 4. The Results of Descriptive Data Analysis

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Post-test	66.5909	22	17.20924	3.66902
	Pre-test	36.1364	22	17.85736	3.80720

T-test analysis was conducted to see the significance of the difference between the pre-test and post-test data. The significance of these differences as a way to test the effect of the flipped classroom assisted by e-module on increasing students' understanding of concepts. The results of the t-test are shown in Table 5.

The significance value (2-tailed) was 0.000 (p < 0.05). So that the results of the pre-test and post-test experienced a significant change. Based on the descriptive statistics in Table 3, shows that the average pre-test is 36.13 and the average post-test is 66.59, so it is proven that the post-test is higher. The results of this study are in line with the results of research by Nafaida, Halim & Rizal (2015)

showing a significant difference between students' understanding of the light refraction concept before and after the application of the phet-based module [12]. E-modules are effective in conveying an overview of the required material [13]. The e-module is effectively flipped classroom-oriented in increasing student motivation and learning outcomes [14]. Students show higher confidence in their ability to achieve the specified goals after completing the e-module [15]. The survey results have shown that students find the learning experience more comfortable, interesting and effective, and very comfortable given the much greater activity expectations in flipped classroom-oriented e-module learning[16].

Table 5. Paired Samples Test

Paired Differences		t	df	Sig. (2-tailed)
95% Confidence Interval of the Difference				
Lower	Upper			
22.71710	38.19199	8.185	21	.000

The advantage of the flipped classroom is that students have the opportunity to learn independently and working together to solve problems in class [3]. The advantage of the flipped classroom are 1) have a strong factual knowledge base, 2) understand facts and ideas in a coherent and organized manner, and 3) organizes new learning in a way that aids retrieval and application [17]. Flipped classroom learning can allow students to relate new content to their schemas [18]. Flipped classrooms can promote independent learning and improve social connectedness and student performance [19],[20], [21]. The results of Mok's research (2014) show that student feedback about flipped classroom learning is generally very positive with many respondents considering it effective and useful for learning [22]. The flipped classroom must be presented cognitively and practically, teacher skills in designing material using various equipment and to transform the material with a learning management system [23], [24].

3.2. The trend of increasing students' understanding of light concepts

The trend of increasing students' light concepts after being taught through a flipped classroom assisted by e-modules can be seen in Figure 2.

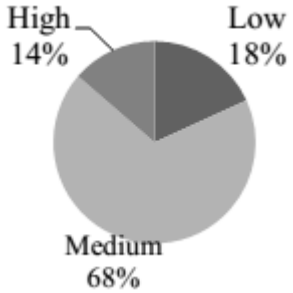

Figure 2. The trend of increasing student concept understanding.

The increase in students' understanding of concepts after the implementation of the flipped classroom using e-modules was mostly in the moderate category as much as 68%. while the increase in understanding of concepts in the high category is very small, namely 14%, so it is necessary to refine the flipped e-module so that most of the increase in understanding the concept of light can increase in the high category. But on the other hand, the Flipped Classroom strategy-oriented e-module can reduce the increase in understanding the concept of light with a low category of only 18%.

The data from the analysis of the achievement of each indicator of understanding the concept of light after being taught through flipped classroom using e-module is shown in Figure 3.

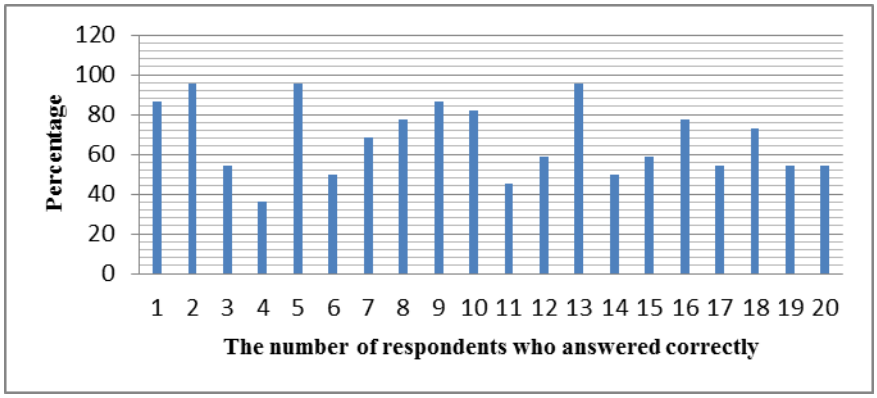

Figure 3. Achievement of indicators of understanding the concept of light.

The concepts that respondents still find difficult after being treated using e-modules are question number 4 (only 36% could answer correctly), question number 11 (only 45% could answer correctly), question number 6, and 14 (only 50% can answer correctly).

Question number 4 deals with interpreting the meaning of the representation of the direction of the rays, the correct concept that the direction of the rays is a representation of the direction of wave propagation because the direction of the rays is in the same direction as the direction of wave propagation. Questions and samples of student answers in question number 4.

Question: The direction of the rays is a representation of….
An example of a student's scientific explanation of the answer claim to question number 4 is:

- The direction of wave propagation is a representation of the direction of the rays.
- Because the direction of the ray is always perpendicular to the direction of ray propagation.

Question number 4 only 1 student is correct out of 22 respondents on the pre-test because only 22% of respondents believed that the wavefront was a plane perpendicular to the direction of wave propagation. After learning using e-modules there was an increase in the number of students who were able to answer question number 4 as many as 8 students. The scientific explanation for the claim for the answer to question number 4 does not yet refer to the structure of the scientific explanation in the form of claim, evidence, reasoning, and rebuttal, but only consists of claim and reasoning.

Question number 11 deals with giving an example of a critical angle representation, the correct concept that a critical angle is an angle of incidence that produces an angle of refraction of 90^o to the normal line or parallel to the interface between the two mediums. Questions and samples of student answers in question number 11.

Most of the students incorrectly answered question number 11 on the pre-test because 56% of respondents thought that the angle of incidence was greater than the critical angle when the refracted ray was parallel to the boundary plane of the medium. After learning using e-modules, there was no significant increase in critical angle concept understanding because there was only 1 student who answered correctly. The scientific explanation claims the second and third answers are less precise. The first trend of scientific explanation meets the three structures of scientific explanation, namely claim, evidence, and reasoning, but the rebuttal component has not yet emerged.

Question: The critical angle in Figure 4 is shown by….

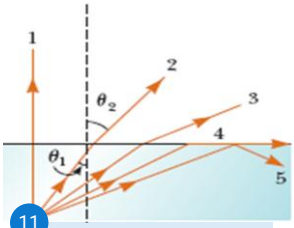

Figure 4. The propagation of light from a dense medium to a less dense medium in problem number 11

An example of a student's scientific explanation of the answer claim to question number 4 is:

- The critical angle is the angle of incidence that produces an angle of refraction of 90° or the angle of the incident ray from a denser medium to a less dense medium whose angle of refraction is parallel to the boundary between the two media. So from the figure, the critical angle is shown in Number 4

Question number 6 deals with making inferences from diffuse reflection events, the correct concept that angles of incidence and angle of reflection are equal because Snell's law of reflection still applies. Because the plane is not flat so that the normal line position of each plane segment is not the same so that the direction of the angle of incidence and reflection of each segment of the plane is not the same, but each segment of the plane angle value of the angle of incidence is equal to the angle of reflection. Questions and samples of student answers in question number 6.

Question: The statement that is incorrect about reflection in Figure 5 is….

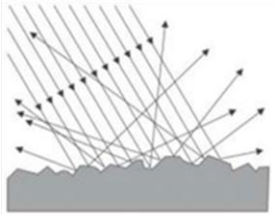

Figure 5. The diffuse reflection in question number 6

An example of a student's scientific explanation of the answer claim to question number 6 is:

- Because each segment of the roughness of the plane has its normal line direction. So, even though the direction of the rays is irregular, Snell's law still applies to every segment of the roughness of the plane.
- Diffuse reflection is a reflection that occurs when a light source falls on an object with a rough surface so that light is reflected in all uncertain directions.

Some students were wrong in answering question number 6 on the pre-test because 89% of respondents agreed that the angle of incidence and angle of reflection was not the same on an uneven plane. Respondents assume that Snell's law does not apply to an uneven plane because it is imagined with a random light direction due to the uneven surface of the plane. They do not realize that the normal lines on the uneven plane are not in the same direction. After learning using e-module there was an increase in the number of students who were correct as many as 4 people. The first trend of scientific explanation meets the three structures of scientific explanation, namely claim, evidence, and reasoning, but the rebuttal component has not yet emerged. The second and third scientific explanations do not meet the structure of scientific explanations.

Question 14 deals with identifying the conditions for total internal reflection to occur, the correct concept that the conditions for total internal reflection to occur if (1) light comes from a denser

medium to a less dense medium ($n_1 > n_2$), and (2) the angle of incidence must be greater than the critical angle ($i > \theta$). Questions and samples of student answers in question number 14.

> Question: If n represents the index of refraction, i represents the angle of incidence, and θ represents the critical angle, then total internal reflection occurs if….
> An example of a student's scientific explanation of the answer claim to question number 6 is:
> - Total internal reflection only occurs if the light is directed from a medium with a certain refractive index to a medium with a lower refractive index, if $n_1 > n_2$ it will result in Sin θ > 1
> - The refractive index is not equal and the angle of incidence is equal to the critical angle

Some students were wrong in answering question number 14 on the pre-test because the sub-chapter had not been taught by the teacher while studying at high school. Question number 14 can only be answered correctly by 4 students in the pre-test. After learning using e-module there was an increase in the number of students who were able to answer correctly as many as 7 students. The scientific explanation given to support the claimed answer is not correct. The first reason is wrong in the equation Sin > 1, the second reason is wrong in the statement that the angle of incidence is equal to the critical angle.

The indicators of understanding the concept of light that is still difficult for students after being treated with an e-module oriented flipped classroom are (1) Interpreting the meaning of the representation of the direction of light, (2) Providing examples of critical angle representations, (3) Making Snell's law inferences from diffuse reflection events, and (4) Identifying the conditions for total internal reflection to occur.

3.3. Weakness Analysis of Material-Oriented E-modules

Indicators interpreting, giving examples, inference, and identification need to be improved again through appropriate learning activities. Indicators identify, infer, interpret, and provide examples related to decision-making skills through scientific explanations supported by information and data. The weakness of this e-module is that there are no hands-on activities and concept elaboration to train students' scientific explanation skills. Therefore, the e-module needs activities that bridge the hands-on activities through the inquiry learning model and concept elaboration to empower scientific explanations through argumentation structure scaffolding.

Research by Hsu, Chiu, Lin, & Wang (2015) on the Argumentative Scientific Inquiry System with structured argumentation scaffolding shows that there is a significant increase in scientific explanation skills [25]. Guided inquiry can improve students' conceptual understanding of light concepts [26]. Thus, to achieve a balance in achieving conceptual understanding and scientific explanation skills, in the next flipped classroom-oriented e-module development, it is necessary to consider guided inquiry accompanied by argumentation scaffolding.

4. Conclusion

There is a significant difference in student's understanding of light concepts after the implementation of the flipped classroom using e-module. The trend of increasing understanding of the concept of light in the low category is 18%, the medium category is 68% and the high category is 14%. Scientific explanation to support the claim of answers to questions do not meet the structure of scientific explanations in the form of claims, evidence, reasoning, and rebuttal, but only includes claim answers and reasoning. The weakness of this e-module is that there are no hands-on and scaffolding-oriented instructional activities to train students' scientific explanations in elaborating concepts. The implication for improving this e-module is to consider guided inquiry learning models and argumentation scaffolding techniques.

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