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The Impact of the E-Learning Module on Remediation of Misconceptions in Modern Physics Courses

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Abstract

The misconception in mastering physics concepts occurs in basic physics and is also found in advanced physics, such as Modern Physics or Quantum Physics. Efforts to remediate misconceptions have been done manually or offline but are often constrained at too long an interval between identification activities and remediation actions. Through the advancement of online learning systems, E-learning media, these obstacles can easily be overcome. This article will discuss one way of remediation using Moodle-based E-Learning modules. A total of 2 classes (45 students) were randomly selected for the experimental group and two classes (64 students) for the control group. The experimental group used a representative module based on E-Learning as a remediation treatment, while the control group used a conventional module. The results of the validation of the material and the design of the E-Learning modules were obtained as very feasible to use. Data collection uses a two-tier Modern Physic Diagnostic Test or MPDT (Modern Physic Diagnostic Test) of 30 items combined with the CRI (Certainty of Response Index) index. It is carried out twice, namely before and after treatment. The N-Gain normality analysis results showed the percentage of misconception reduction was more significant in the experimental group than in the control group. Important note obtained by implementing E-Learning is more appropriate to be used simultaneously between conventional face-to-face and E-Learning.

Keywords: : misconception, module, e-learning, quantum physics, modern physics

INTRODUCTION

Misconception research, especially misconception in the field of physics, has been studied since the 70s (Cronbach 1970; Champagne et al. 1980; Carey 1985; Clement 1982), covering three main stages, namely (a) Development of diagnostic test instruments (Treagust 1988; Halim et al. 2009b; Karunia & Rinaningsih 2013; Halim et al. 2016; Halim et al. 2017; Halim et al. 2018a; Halim et al. 2018c; Halim et al. 2020a; Resta et al. 2020), (b) Identification and Analysis of causes of misconception (Halim et al. 2019; Saputri et al. 2011; Halim et al. 2020b), and (c) Remediation of misconceptions (Zukhruf et al. 2016; Junike et al. 2016; Putra et al. 2016). The term remediation or restoring misconceptions has been used with various types of words by education experts, including the use of the term fighting or to combat (Martinez et al. 2013; Styer 1996) and the antidote to the misconception (Styer 1996; Baxter & Amory 2004), overcoming or overcoming misconceptions used in educational research (Halim et al. 2011; Tarmizi et al. 2017; Zainuddin et al. 2020), avoiding or to prevent and oppose or challenge misconceptions (Kose 2008; Pekmez 2010; Yang & Senocak 2013; Zainuddin et al. 2020), the elimination or eradicating of misconceptions (Ammons & Eickman 2011; Mansournia 2018). Overall, these terms, even though they have different meanings and meanings, the purpose and purpose are still the same, namely to deal with or eliminate students' misconceptions.

Throughout history, the handling of misconceptions among students has been used with various learning activities, including using the "idea confrontation" strategy (Licth 1991), using a teaching strategy consisting of two stages. First, students are reminded about the initial concepts they hold, and second, students are involved in conceptual conflicts that conflict with the students' initial ideas (Foster 2012; Tzu 2010). Other experts use the remediation process based on the conceptual change model (O'Leary 1997; Rohmah et al. 2020). Some experts also use the analogy approach to reduce misconceptions (Brown 1993; Fast 1997). They are using conceptual change models in quantum concepts (Vosniadou & Verschaffel 2004; Fardanesh 2006; Hewson et al. 1998).

The use of computers (offline) for remediation of misconceptions has been carried out, including the effect of computer-assisted teaching on remedying deceptions (Gürbüz & Birgin 2012), on students' conceptual development (Gürbüz 2007), and construction of an online learning system for decimal numbers through the use of cognitive conflict strategy (Huang et al. 2008). While the use of computer-supported collaborative learning strategies for helping students acquire self-regulated problem-solving skills (Lazakidou & Retalis 2010; Halim et al. 2016), computer-aided misconception-based intelligent tutoring and exercise generation (Lee 1988), to correct misconceptions and to improve understanding of correlation (Liu et al. 2010) and to correct preservice teachers' misconceptions about the operators of division (Saputra et al. 2013). Furthermore, computers have also been used for diagnostic and remedial learning tests (Tirosh et al. 1990), cognitive diagnostic adaptive testing: effects on remedial instruction as empirical validation (Mizayanti et al. 2020), and remediation misconception by incorporating a web-assisted physics program (Demirci 2005).

While the use of E-learning technology (online) is still used so far for the implementation of learning and evaluation, for example, used for learning media (Hung 2010; Irwandi et al. 2018; Chiral et al. 2018), learning evaluation instruments (Wang 2010 ; Al-Junda 2017; Shute & Rahimi 2017), measuring student learning outcomes (Islamiyah & Lilis 2016; Adam et al. 2013), measuring students' language and metacognitive skills (Dalia 2017), evaluating distance learning with E-Learning (Al-Junda 2017; Wang 2007), and online student activity assessment (Shute & Rahimi 2017; Elena 2018; Vida & Brigita 2014; Nurmalia et al. 2020). Related to the use of mastery studies of concepts and misconceptions, E-learning has been used for the development of two-tier diagnostic test instruments (Halim et al. 2018c) and three-tier (Resta et al. 2020). While remediation using web modules or E-learning has been carried out in several concepts, including the ecological concept (Hidayatun et al. 2015) and the photoelectric effect (Halim et al. 2018c). Weaknesses of the research, where the remediation process is only in the form of text or narrative explanations without being supported by other forms of presentation such as animated or realistic videos.

The diversity of forms of presentation or multi representative during the remediation of misconceptions is very important because students have the different background knowledge and ability of reason (Kohl 2007; Hasbullah et al. 2019; Ernawati et al. 2020; Razali et al. 2020). Therefore, through this current research, a misconception concept remediation package will be applied in the form of an E-learning module integrated with the PhET simulation media for the wave-particle dualism concept E-RemMis package. This package has been developed in previous studies (Halim et al. 2018c). There are several advantages of the E-RemMis package, including test participants will know the test results or feedback after answering all the test items, including concepts that are misunderstood and concepts that have been correctly understood. The implementation of the E-RemMis package is based on a combination of several previous models, including; empirical studies of E-Learning (Chiral et al. 2018), theories and techniques of E-Learning (Berman 2006), development of an integrated Geogebra E-Learning module (Halim et al. 2020c), development of four-tier diagnostic tests (Hakim et al. 2012), and the development of E-Learning diagnostic tests (Halim et al. 2018c; Resta et al. 2020). There are three advantages and remediation problems that will be solved through this research, namely; overcoming the lateness of students knowing the results of remediation, overcoming geographic factors (space and time) for the implementation of misconception remediation, and overcoming delays in the remediation of concepts that are misunderstood by test takers.

RECEARCH METHODS

Research Design

This research uses a quantitative approach with a quasi-experimental method, and the design chosen is The Matching-Only Pretest-Posttest Control Group Design. According to Fraenkel's view, quasi-experimental research is "A quasi-experiment is an empirical interventional study used to estimate the causal impact of an intervention on target population without random assignment" (Fraenkel, et al, 2012). The control group and the experiment group were randomly selected from 4 classes taking Modern Physics classes. The experimental group will be taught by using a multi-representative E-learning module (X). In contrast, the control group is given the concept module of the photoelectric effect and the Compton effect manually in PPT and Word (C).

Population and Sample of Research

The study was conducted on students majoring in Physical Education at the Teaching and Education Faculty, Syiah Kuala University. The selected population comprises all students taking Modern Physics as many as four classes or 109 people. The sample selection technique uses a comprehensive sample approach from the entire population. Two categories are randomly selected to be an experimental group of 46 students and two locales for a control group of 64 students.

Collection of Data

Data was collected using a two-tier diagnostic test instrument in the concept of Modern Physics or known by the abbreviation MPDT (Modern Physic Diagnostic Test) developed by researchers as many as 30 items. The basis for these tests' development refers to several previous studies that have developed and used the same test (Halim et al. 2018c; Halim et al. 2009b; Halim et al. 2020a; Yusrizal & Halim 2009; Hasan et al. 1999). The content of the test is related to Modern Physics material which is currently running lectures, including those related to the concept of the Photoelectric Effect, there are 12 items, related to the Compton Effect there are four items, related to electron diffraction there are ten items and related to wave-particle dualism there are four items. Before this instrument is used, it is first given to material experts to test the content's validity and test the limited sample. According to the research design, data collection was carried out in two stages, before the treatment or pre-test, and after the treatment or post-test, both for the experimental or control group.

Data Analysis

Data collected were ordinal discrete forms from the results of a two-tier multiple-choice diagnostic test combined with the CRI index. Data analysis was performed using Excel or using a descriptive statistical approach based on right / wrong answers in the first stage and CRI index writing in the second stage. The first stage data are in the form of choices A, B, C, and D, while the choice in the second stage is the CRI index in the form of numbers from 0-5. The excel page in sheet (1) is arranged in the form of raw data, as shown in TABLE 1 used to raw input data from the first stage (A, B, C, and D) and the second stage data (Halim et al. 2009b).

On the same excel page but sheet (2) is used for data analysis by changing the first correct answer/correct step with "0" and with "1", while the data from the second stage remains with a number from 0-5. Data analysis for the data of two-tier diagnostic test results refers to the CRI index table (Certainty of Response Index) or respondents' certainty index answers that have been used by previous researchers (Hakim et al. 2012; Wati et al. 2020).

TABLE 1. Sample of excel page for data analysis based on CRI indexs (Halim et al. 2009b)

No	**1**		**2**		**3**		**4**		**..**	**..**	**total**
Keys	**A**	**CRI**	**C**	**CRI**	**D**	**CRI**	**B**	**CRI**			**Answers**
Students											
14-00101	B	4	A	3	**D**	5	A	2			
14-00102	.	.	.	.	.	.	.	.			
14-00103	.	.	.	.	.	.	.	.			
14-00104	**A**	3	**C**	5	C	2	D	3			
14-00105	.	.	.	.	.	.	.	.			

Respondent (student) response patterns are divided into two categories, namely correct answers with a low CRI index (<2.5) and high CRI index (<2.5). For a low CRI index, the respondent guesses the answer and happens to think right (lucky guess), while for a high CRI index, the possibility of the respondent understands the concept being asked. Both answer patterns are wrong with low and high CRI indexes. If the answer is wrong and the CRI index is low (<2.5), then the respondent is still less likely to understand the concept being asked. If the answer is wrong and the CRI index is high (> 2.5), then the respondent may perceive misconceptions on the concept being taught (Halim et al. 2009b; Zainuddin et al. 2020; Hakim et al. 2012).

RESULTS AND DISCUSSION

Results of Pilot Test

Two-tier diagnostic test instruments on the concept of Modern Physics or MPDT were given to experts for validity testing and also tested on limited samples. The trial results and the validity of the MPDT instrument it was found that 26 items were valid and four items were invalid with the results of the validity of the two-tier diagnostic test instrument obtained by r_{xy} = 0.40 with the reliability coefficient or Alpha Cronbach = 0.703. In other words, the 30 items in the test have a high correlation between items, and all items can be trusted and support the measurement. The items are to measure the level of misunderstanding of concepts in students taking Modern Physics courses (Hakim et al. 2012; Mizayanti et al. 2020: Halim et al. 2009b).

E-Learning Module Validation Test Results

Based on the results of these calculations, the average score of the results of validation by media experts and material experts on multi-representative e-learning learning modules can be seen in the following TABLE 2. Based on TABLE 2 the percentage results of the validation of the material and media design E-learning module based on multiple representatives from all aspects obtained values of 87.67% and 81%. This value is stated that the material and media design of multiple representative-based E-learning modules that are used are very strong criteria, meaning that the media is very appropriate to be used to reduce misconceptions in Modern Physics courses. Module validation technique and the results obtained are not much different from those obtained by previous researchers (Yusruzal and Halim 2009; Hasja et al. 2020).

TABLE 2. Content Validation and Media Design of Multiple Representative-Based E-Learning Modules

Validation							**Mean**	**Decision**
Content Experts				**Design and Media Experts**				
Content Feasibility	Presentation of Content	Validation Assessment	Contents of the Multiple Representative Module	Format and display	Layout outline	Packaging and learning activities		
85 %	86 %	88 %	93 %	79 %	83%	81%	84.5%	Very good

Analysis of Modern Physics Misconceptions

The data collection results of students' misconceptions in this study used a two-tier test diagnostic test instrument equipped with the Certainty of Response Index (CRI) method. The effectiveness of the use of E-Learning modules in reducing student misconceptions in Modern Physics learning can be seen from the reduction in the percentage of misconceptions experienced by students in the experimental and control classes and differences in Gain Normalization (N-Gain).

Experiment Class N-Gain Value

Based on the misconception data analysis results, the average N-Gain score obtained in the experimental class is lower than the control class that is -0.01 and 0.03. These results indicate that multi-representative E-Learning modules can overcome students' misconceptions in modern physics courses. The acquisition of an average N-Gain score on each item can be seen in FIGURE 1.

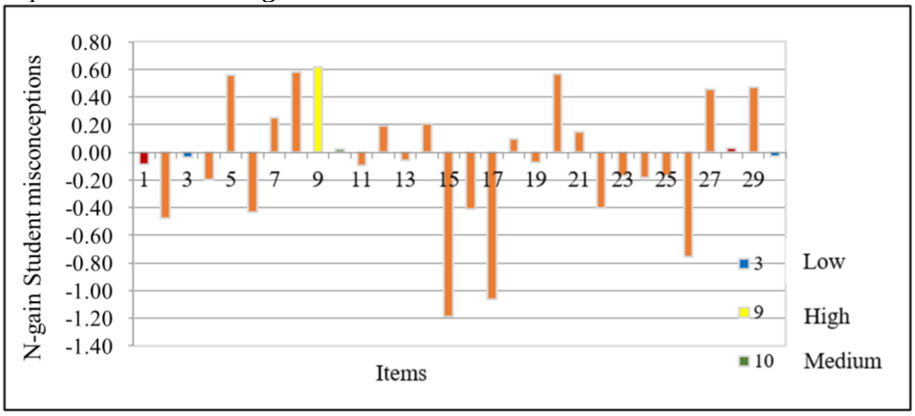

FIGURE 1. Reduction of Misconception after Treatment in the Experiments Group

The data in the graph in FIGURE 1 is N-Gain data for negative and positive. Negative N-Gain data means a reduction in misconceptions for modern physics concepts in problems 2, 4, 6, 11, 15, 16, 17, 22, 23, 24, 25, and 26. Approximately 84% of stimulus problems are related to understanding concepts or misconceptions in the cognitive domain C1 through C3. Only 16% of the stimulus is related to formulas and calculations or misunderstandings in the cognitive domain C4 through C6. This means that remediation of misconceptions using multi-representative E-Learning modules is only useful for the category of misconceptions in the cognitive realm of C1 through C3. For example, problem number 17, related to the electron diffraction experiment by Davisson Germer. Students to answer question 17 only need an understanding of interference and diffraction and how they are related. So the required knowledge to answer these questions lies in the realm of C2 (understanding). Remediation of misconceptions in this domain is enough to show a video about the Davisson Germer experiment, as shown in the multi-representative E-Learning module. Other questions have done the same thing. Besides that, positive N-Gain data gives the meaning that the concepts in problems 5, 7, 8, 9, 12, 14, 20, 27, and 29 are still misunderstood by students, especially related to the understanding of kinetic energy on the photoelectric effect (no.9). About 67% of the stimulus from these questions is related to the relationship between variables in the form of equations. About 33% of inspiration from these questions is related to the relationship between variables in the form of narration. This means that the remediation applied in this study is that using multi-representative E-learning modules is still not effective, especially for abstract concepts (photon kinetic energy, etc.).

Based on the graph in FIGURE 1, it can also be seen that the lowest N-Gain score is in item 3 and 30, that is - 0.03. These results indicate that only 14% of students experience misconceptions on these items. Next on item 10 is the N-gain misconception of 0.02. These results suggest that 33% of students experience misconceptions about these questions. In contrast, the acquisition of the highest misconception N-Gain score occurred in item 9, which was 0.62. These results indicate that 86% of students experience misconceptions on these questions. The sound of the problem can be seen in item 9. In item 9, the emergence of misconceptions is due to students not yet understanding the meaning of the photoelectric effect experiment graphs, so students cannot operate the data listed on the graph into equations to determine the metal plate threshold energy (these results indicate that the use of E-Learning. It is not appropriate to use concepts that contain multiple representations. This result follows (Jong et al. 1999) findings that providing assignments with simulations can improve student performance on an aspect called the intuitive knowledge test. In addition, (Moser et al. 2017) also revealed that metacognitive strategies can be useful for students during physics-based learning simulations. The factors that cause students' misconceptions are their intuition, mathematical form, local language factors and definition restrictions (Saputri et al. 2011) and Bell and Joe (besides Bell and Joe 2006) states that computer simulations will only involve students in discussions about how the model is used in science and the limitations that the model has and how it differs from reality. Further research also shows that if the concept of e-learning is better provided with a perspective approach so that the reach will be phenomenal (Elango et al. 2008).

Rosenberg's research (2001) revealed that e-learning, aside from having weaknesses, also had weaknesses, including the learning process tending towards training rather than education and the tendency to neglect academic or social aspects between students. Therefore, overcoming this learning can be combined between e-learning with conventional understanding called blended teach (Hermawanto et al. 2013). Furthermore, Prasart et al (2014) revealed that e-learning courses should not be used alone but must be mixed between face-to-face and e-learning for the right solution.

Control Class N-Gain Test Results

Based on the data obtained, the N-gain test results in the control class are 0.03. These results indicate that students experience misconceptions in understanding the concepts of modern physics. The acquisition of an average N-Gain score on each item can be seen in FIGURE 2.

Based on the graph, it can be seen that the lowest N-Gain score is in item 18, which is - 0.05. These results indicate that 77% of students experience misconceptions about these items. Furthermore, items 2, 5, 9, 21, and 25 obtained N-Gain misconceptions of 0.02. These results indicate that 40% of students experience misunderstandings on these questions. Simultaneously, the acquisition of the highest misconception N-Gain score occurred in item 17, which is 0.46. These results indicate that 86% of students experience misconceptions about these questions. The sound of the problem can be seen in item 17. In item 17, the emergence of a misconception is caused by students not yet understanding the concepts generated from Davisson Germer's experiment. The emergence of these misconceptions can be caused by the lack of time allocation, which causes the implementation of learning and presentation is limited because the teacher, as far as possible, set the time so that the learning process is following the indicators of achievement. These results indicate that instructional media is indispensable to explain abstract concepts into a reality that can provide convenience to students to practice logic skills with simulations and attractive multimedia displays. As revealed by Sonya and Kem (2015), highly interactive software is used to describe intrinsically preferred subjects by students who have the low spatial ability. Therefore, one of the media that can be used in visualizing physical material, especially in abstract concepts, is a virtual laboratory. Virtual laboratories are presented in the form of computer-based software (Sari et al. 2016).

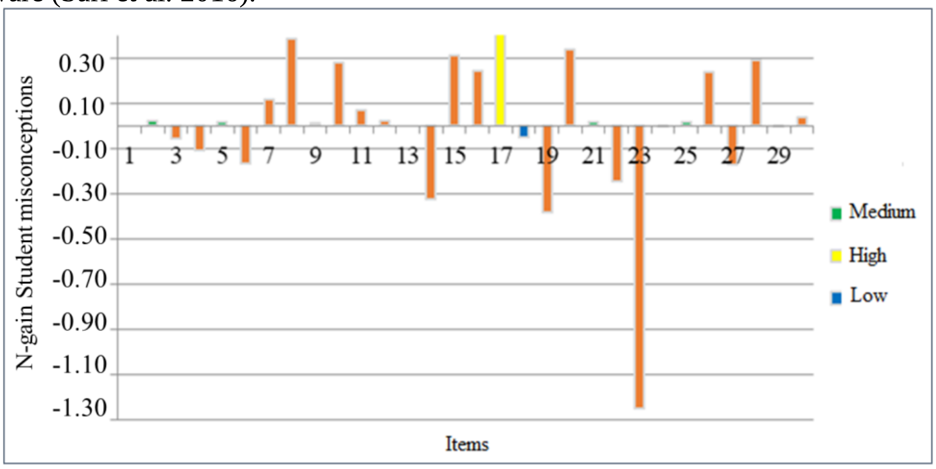

FIGURE 2. N-gain Control Class Misconception

E-learning can often be seen as a more varied learning approach, which may experience an increase that is difficult to obtain success. Like traditional learning environments, success with e-learning depends on the instructor and the learner himself (Berman 2006). Besides that, the findings of Hidayatun et al. (2015) showed that the application of e-modules based on Problem-Based Learning could reduce misconceptions on ecological material.

E-Learning Module Effectiveness Against Misconception Reduction

The effectiveness of using E-Learning modules in physics learning is oriented to changing students' misconceptions, which are determined based on the percentage of students whose mediated misconceptions and the number of misconceptions on the items. Based on the analysis results described above, we obtain a difference in the percentage of misconceptions on each item for the experimental and control classes, as shown in FIGURE 3.

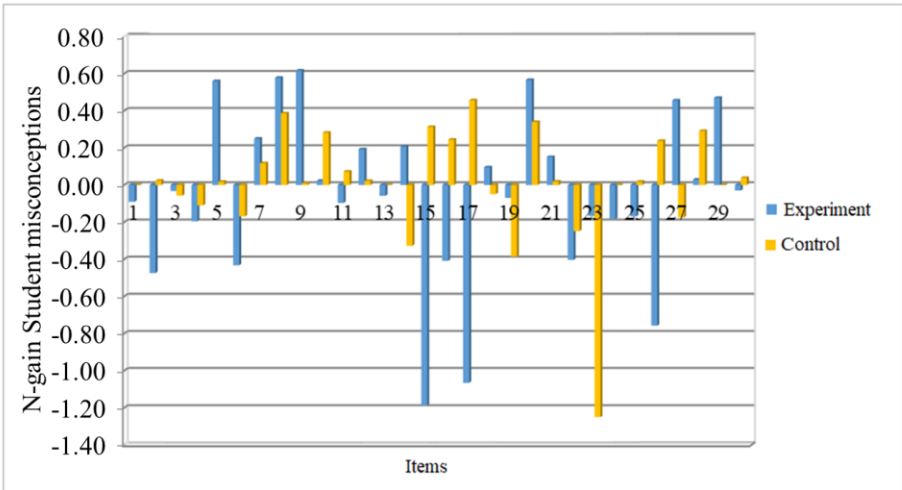

FIGURE 3. Difference of N-Gain Misconceptions for each Item of the Problem

Based on FIGURE 3, the difference of N-Gain misconceptions on each item for each class shows the characteristics of E-Learning in learning Modern Physics. The difference in the percentage of most dominant misconceptions between the two types is in items 4, 12, 14, 21, 27, 29, and 30. The lowest percentage in the control class is in items 12, 21, 27, 29, 30, and five. They are related to calculations through graphs and the operation of data into formulas. The highest percentage of misconceptions is in items 4 and 14. Both items are associated with the concept of the photoelectric effect and the Davisson Germer experiment. These results indicate that students with learning without E-Learning are better able to solve problems of modern physics in calculations through formulas or calculations through graphics. However, students who are taught without E-Learning still experience misconceptions related to a theory or concept in modern physics. While in the experimental class, the opposite occurred. The lowest percentage was in items 4, 14, and the highest was in item 12, 21, 27, 29, and 30. These results indicate that students taught through E-Learning succeeded in understanding concepts and theories found in modern physics courses but still have problems solving problems both in calculation problems using formulas and calculation problems through graphs. Based on the results of the misconception analysis described above, it can be concluded that not all physics concepts, in particular, can be done through E-Learning learning.

E-learning is only able to facilitate abstract concepts and does not need to be solved mathematically. These results are consistent with what was reported by Palmira and Džeraldas (2016) that students involved in real physics laboratories with simple traditional devices could attract and focus their attention. Furthermore, Sheard et al. (2003) also revealed that teachers could obtain feedback on student learning experiences through face-to-face interactions with their students, allowing ongoing evaluations of their teaching programs in conventional teaching environments. However, when students study in an electronic environment, informal monitoring is not possible. Students prefer to capture rich lectures for learning, and the availability of their college attendance does not always have a negative impact (Pale et al. 2013). Therefore the analysis of the structure of learning materials used in E-Learning must focus on developing students' critical thinking to engage in learning consistently and independently (Vida and Brigita 2015).

SUMMARY

Based on the study results, it can be concluded that overall the items obtained by students' misconceptions about learning modern physics can be overcome through the use of E-Learning. Whereas, if seen from the concepts in the article accepted, not all of these concepts can be radiated using E-Learning. The use of E-Learning is very effective to be used to describe specific and abstract concepts. But the use of E-Learning is not appropriate to be used for ideas that contain multiple representations. The factors that cause students' misconceptions are their language intuition and mathematical form. In the two-tier diagnostic test questions, you should use problems in the form of selected responses equipped with reasons for choosing an answer to minimize guessing answers and find out the error.

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