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Development of Diagnostic and Remedial Program-Based Interactive Multimedia to Reduce Student's Misconceptions on Geometric Optics

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Abstract- The effort for identifying and overcoming misconceptions of pre-service physics teachers' on geometric optics should be done continuously. Various kinds of misconceptions diagnostic tests were commonly applied by the lectures still in the form of written tests. The weakness of those kinds of tests are the time needed to check the results that quite long so that students cannot know the test results directly. Remedial that commonly applied were still classical and unable to accommodate the differences on students' misconceptions. This research aims to develop diagnostic and remedial program-based interactive multimedia in geometric optics called D&R geometric optics. The study also describes the feasibility of the D&R geometric optics program and also to test the effectiveness of the D&R geometric optics program in identifying and overcoming students' misconceptions on geometric optics. The research design which was conducted was a research and development adapted from Borg and Gall design. The subjects of this study are experts and students. Based on the assessment by the expert validators on three aspects, namely diagnostic questions, media display, and remedial material, it can be concluded that the D&R geometric optics program meets the feasible category. Further, students' assessment in the main field testing, the D&R geometric optics program also categorized as a feasible product to use in learning. Based on product effectiveness assessment, it was found that there is a decrease in the number of misconceptions in both experimental and control classes. In addition, the calculation by using the Mann-Whitney test showed that there were significant differences in mastery of concepts in both classes, with the experimental class was better than the control class.

Keywords: Diagnostic, Remedial, Interactive Multimedia, Misconception, Geometric Optics.

1. Introduction

Geometric optics is one of physics material which concept is difficult to master by students. Several researches have reported that lots of students were still maintaining a low level of concept understanding and alternative concepts that are irrelevant with the scientific concept of geometric optics (Galili&Hazan, 2000; Chen, et al, 2002; Chu, et al., 2009; Kaewkhong, et.al. 2010; Aydin, et al. 2012; Outtara&Boudaone, 2012; Hafizah, et al. 2014). Even learning in a formal context cannot help students to understand concepts accurately, or refine their alternative concepts to be congruent with scientific concepts that are acceptable among the geometric optics experts (Andersson&Kärrqvist, 1983; Goldberg & McDermott, 1986; Goldberg & McDermott, 1987; Fetherstonhaugh&Treagust, 1992; Galili, 1996; Langley, et al. 1997).

Before being involved in a formal learning, students bring certain concepts that they have developed through interaction with events related to geometric optics. With that experience, they develop an intuition and alternative concepts framework about the events on their mind, which are not always correct. Any concept that is irrelevant with scientific concepts is called misconception (Hammer, 1996). Students with misconceptions will think that their answers are correct and they are so sure about it, even if the answers are actually wrong. Misconceptions that are repeated and

maintained consistently will affect the students' learning effectiveness (Hammer, 1996; Wahyuningsih, 2013). Besides, misconceptions can prevent students from understanding and developing concepts in their mind (Kaltakçı&Didiș, 2007; Arslan, et al. 2012; Aydin, et al. 2012).

Misconception among students are not only caused by their experience in interacting with geometric optics-related events, but also by books or even their teachers' mistakes. Misconceptions caused by books take forms of undetailed explanation, unclear use of language, or incorrect description of events related to geometric optics (Gürel & Eryilmaz, 2013). Mistakes by the teachers can be in a form of the teachers' inability in delivering materials, lack of material mastery, inappropriate teaching methods, or attitude in interacting with their students (Suparno, 2005). Pre-service teachers of physics are thus expected to master the geometric concepts well and able to deliver the materials properly. Misconceptions held by physics teacher on geometric optics can lead to their students' misconceptions later, and it should be avoided (Aydin, et al., 2012).

In order to know whether a pre-service physics teacher holds a misconception or not, identification is required. Identifying students' knowledge and difficulty through a series of tests, observations, or projects is called diagnostic (Oyekan, 2013). Diagnostic focuses on three main questions, which students are having difficulties? From the whole materials, which sub materials are understood and which sub materials they find difficult? And what makes it difficult for them on that sub material? (Sukardi, 2011: 228). The data collected through diagnostic can be a basis of needs analysis, and a good source for teachers in revising their methods and teaching content.

Researchers on education have developed several methods for misconception diagnostics. The methods are interview, concept mapping, and various forms of tests (Tsai & Chou, 2002). Interview enables researchers to seek information about a respondent's understanding wholly and deeply, but it takes time and a large number of population is needed for a good generalization (Chen, et al., 2002). Multiple choice test can be applied to a large number of students and is easier to be analyzed, but it cannot reach more deeply into students' idea. The answer could be correct, but the reasons are incorrect (Rollnick&Mahoona, 1999). In solving this problem, students are expected to give their reasons for the answer they chose. Thus, two-tiers or three-tiers multiple choice tests are developed. In two-tiers test, the first tier presents multiple choice items, and the second tier presents choices of reasons for the answers on the first tier (Tsai & Chou, 2002).

Several researches using two-tiers test have found that this kind of test performs well in diagnosing misconceptions (Rollnick&Mahoona, 1999; Chen, et al, 2002; Chandrasegaran, 2007; Chu, et al., 2009; Tüysüz, 2009; Adodo, 2013). However, the two-tiers test cannot determine whether students are holding misconceptions or lacking of knowledge. Distinguishing those two things is really important, because a remedial for students with misconceptions is more difficult than for those who are lack of knowledge (Peşman&Eryilmaz, 2010). Thus, third tier is needed to see how certain the students with their answers on tier one and two, that it can be seen whether the mistakes made by the students are due to misconceptions or lack of knowledge.

The next step after diagnosing misconceptions is giving remedial. Remedial is a clinical learning in which students whose difficulties are given certain topics to achieve the required target (Lien, et al., 2007). The remedial can be conducted in several ways like varying the material delivery, materials simplification, or providing more detailed materials that can help students in solving problems related to the topics being learned (Ogunleye, 2009).

Based on the observations and interviews with some lecturers in FKIP (Faculty of Teachers Training and Education) of Mataram University, it was found that diagnostic and remedial were still conducted in a conventional way. Diagnostic tests were given in a form of paper-based test, in which the test was presented on a piece of paper and the students should give their answer on the given paper. This method of diagnostics is time consuming, it takes time for the lecturer to check the students' answers. The students cannot get the result immediately, that they do not know their lacks in understanding the concepts of geometric optics. Remedial given by the lecturer was still classical, through a repetition of discussion of the materials considered to be difficult by the students in class, without considering various levels of knowledge or ability owned by the students. There were even some lecturers who did not give any remedial at all, due to the limited room, time, and energy.

Diagnostic test can be given through the use of computer. Beside the presentation that is more interesting, computer-based diagnostic tests have some advantages compared to paper-based tests in terms of data collection and analysis (Clariana& Wallace, 2002). Diagnostic tests with computer can diagnose students individually and give the result immediately (Saidah, 2012). Besides, it can help lecturers in giving the result immediately and accurately even if the test involves a large number of students (Demirchi 2006).

One way to give remedial to students is by using computer in a form of interactive multimedia. In interactive multimedia, the contents are in forms of text, audio, video, graphic, animation, and interaction that make learning becomes more interesting. Some processes that are difficult to be done manually can be simulated in interactive multimedia. An abstract concept can be visualized concretely so that it is easier to be understood (Chang, et al., 2008; Chen, et al., 2011; Chen, et al., 2013). Tao (2004) reported that the collaborative physics learning supported by computer multimedia could improve students' understanding of geometric optics especially on the sub topic of shadow forming through lens. It also helped the students' memorization of the concepts to retain longer. Other researches (Zachria& Anderson, 2003; Gunawan, 2008; Chen, et al., 2013) also showed that the use of interactive multimedia in learning could improve students' concepts-understanding and refine students' misconceptions on other physics materials.

Based on the explanation above, this research is aimed at developing an interactive multimedia-based diagnostic and remedial program to help lecturers in identifying and solving misconceptions among students on geometric optics. The program combines both diagnostic and remedial into a single computer program in a form of interactive multimedia which is expected to be helpful in solving the problem of room, time, and energy faced by the lecturers. In addition, the diagnostic and remedial which are presented in an interactive multimedia program is expected to be able to improve students' interest and motivation in diagnosing their own ability and learn independently to acquire the concept of geometric optics accurately.

2. Research Method

The research design which was conducted was a research and development adapted from Borg and Gall design. The procedures performed include collecting information, planning the product, developing preliminary product, preliminary field testing, main product revision, main field testing, operational product revision, and operational field testing. The subjects of this study were experts and pre-service physics teachers. In the preliminary field testing, data were collected from two expert validators using questionnaire. While in the main field testing, data were collected from ten pre-service physics teachers as users using a questionnaire also. The questionnaire results were analyzed using the technique of calculating the mean-score.

In operational field testing, the product was tested experimentally in pre-service physics teachers using pretest-posttest control group design. Operational field testing involved the students of Physics Education at FKIP Mataram University who were taking Optic course and had just been taught about geometric optics. The total was 59 students and then divided into two classes. Experiment class consisted of 30 students and control class consisted of 29 students. The experiment class was treated with the D&R geometric optics program, whereas the control class was treated with the conventional diagnostic and remedial. Both classes got two misconception diagnostic tests (pretest and posttest). The answers from pretest and posttest were divided into four categories based on the categories of *three-tier multiple choice* on Table 1. Each category of answer was analyzed by using mean-score calculation, and then converted into percentage.

Table 1. Categories of Answer on *Three-Tiers Multiple Choice*

Tier One	Tier Two	Tier Three	Category
Correct	Correct	Certain	Understand the concept
Correct	Incorrect	Certain	Misconception
Incorrect	Correct	Certain	Misconception
Incorrect	Incorrect	Certain	Misconception
Correct	Correct	Uncertain	Guessing, lack of confidence
Correct	Incorrect	Uncertain	Not knowing the concept
Incorrect	Correct	Uncertain	Not knowing the concept
Incorrect	Incorrect	Uncertain	Not knowing the concept

(Arslan et al., 2012).

3. Results and Discussion

The product development was begun with a preliminary study that includes literature review and field study. Literature review was conducted by studying some literatures related to geometric optics. The study on previous researches revealed several forms of misconceptions on geometric optics. These misconceptions were confirmed by giving essay tests and informal interviews to physics students. The answers from the students were then analyzed that it was found that the conceptions found among the students are the same with those in the previous researches that had been studied before.

We also studied about the types of misconception diagnostic test such as interview, concept mapping, essay test, multiple choice, and two- and three-tiers multiple choice. We analyzed the advantages and disadvantages of each type. From the intensive study, we decided to employ three-tiers multiple choice test, considering its possibility to distinguish students with a good understanding of concept, students with misconceptions, and students who do not know the concepts. Besides studying the types of diagnostic test, we also studied literatures related to principles of remedial that teachers should give after conducting diagnostic.

Field study was conducted through observation and interview with a physics lecturers who were teaching at Mataram University. Observation was conducted to see the type of diagnostic used by the lecturer in investigating students' ability. The interview was conducted to reveal difficulties faced by the lecturer in conducting diagnostic and giving remedial to the students. The result of this field study showed that the types of diagnostic test employed by the lecturer were essay test, multiple choice, and interview. Those tests were not specifically designed to investigate students' misconceptions, but to merely check students' learning progress and understanding of concept. Whereas remedial of materials considered to be difficult by the students was given in class by repeating the discussion on the materials. Unfortunately, remedial was rarely given due to the problem of room availability, time, and energy.

Literature review on interactive multimedia was conducted by studying several books and previous researches. It was found that interactive multimedia had some advantages that are considered to be a good solution for the aforementioned problem. The principles of diagnostic and remedial can be merged into interactive multimedia. Interactive multimedia enables students to learn independently without the lecturer presence, that the problems of room availability, time, and energy can be solved.

Based on the preliminary study, the development of interactive multimedia-based program for diagnostic and remedial on geometric optics is of great importance. The product specifications are (1) interactive multimedia-based program for diagnostic and remedial on geometric optics is combination into a single multimedia program using Adobe Flash that enables users to open it with a computer (PC or laptop), (2) interactive multimedia-based program for diagnostic and remedial consists of three main sections, namely geometric optics diagnostic test, diagnostics result, and remedial, (3) The result of the diagnostic can be saved and used as a report to the lecturer, and (4) the items in the diagnostic test are presented in forms of text, graphic, and animation. Meanwhile, the

remedial section is presented in forms of animation, simulation, or videos which are featured with narration.

In product planning, we created a storyboard. The storyboard helped us to get an illustration of the product that was going to be developed. Then, we decided the types of misconception that were going to be measured, and then developed diagnostic questions related to geometric optics. There were 26 items of misconception diagnostic developed in the form of three-tiers multiple choice test. Some diagnostic items were taken from previous researches on geometric optics, and some others were developed by ourselves.

The interactive multimedia-based program for diagnostic and remedial on geometric optics (further called as D&R Geometric Optics in this article) consisted of four main frames. The first frame was Main Menu, consisting of overview of the program and several menu buttons. The second frame was Diagnostic Questions, consisting of misconception diagnostic tests on geometric optics. The third frame was the Diagnostic Result, consisting of feedbacks of the students' answers on the diagnostic test. This result can be saved and used as a report to the lecturer. The fourth frame was Remedial, consisting of the explanation of material related to the items answered incorrectly by the students, whether due to misconception or not knowing the concept.

In preliminary field testing, data were collected from two expert lecturers as validators. The product was validated on three aspects, namely diagnostic test, media interface, and remedial material. Based on the validation result on the aspect of geometric optic items, the mean score given by the experts on each indicator ranged between 3.81 – 3.92. Thus, it could be concluded that the geometric-optics diagnostic items were valid on the entire indicators. Scoring indicators employed in the geometric-optics diagnostic items included: 1) The items being assessed are conceptually correct, 2) The items are able to measure the type of misconception, 3) Graphics and information are displayed clearly, 4) The given choices can perform well as distractors, 5) The wording does not lead to a correct answer, and 6) The wording does not lead to ambiguity or misunderstanding.

Then, the expert validation on the aspect of D&R Geometric Optics interface, the mean score given on each indicator ranged between 3.85 – 3.96. Thus, it could be concluded that the D&R Geometric Optics could be categorized as valid on the entire indicators. Scoring indicators employed in validating the media interface included: 1) The graphics chosen are interesting, 2) The graphics chosen are appropriate, 3) The colors chosen are interesting, 4) The colors chosen are appropriate, 5) The texts are appropriate, 6) The text colors are appropriate, 7) The use of language is appropriate, 8) The program is easy to use and operate, and 9) The background sound is interesting.

Lastly, based on the validation on the aspect of remedial material of Geometric Optics D&R Program, the mean score given by the experts on each indicator ranged between 3.85 – 3.92. Thus, it could be concluded that the remedial materials were valid on the entire indicators. Scoring indicators employed in validating remedial materials included: 1) Remedial materials given are conceptually correct, 2) Remedial material uses the appropriate Indonesian language, 3) The use of graphic/animation/simulation is appropriate, 4) The presentation of remedial materials is clear, 5) The presentation of remedial materials is communicative, 6) The remedial materials are congruent with the items being discussed, and 7) The remedial materials can help students in understanding concepts on geometric optics.

Figure 1. Example of Diagnostic-Item Frame Interface

HASIL DIAGNOSTIK

Program Diagnostik dan Remedial
Berbasis Multimedia Interaktif
Optika Geometri

Hasil Diagnostik Pada Hari Rabu, 8 April 2015 / Jam 17 : 20 : 43

Nama : ganda wenang sani
NIM : e1q 011 015
Kelas : fisika b

Honor	Tier 1	Tier 2	Tier 3	Ket.
1	Benar	Benar	Yakin	Cek
2	Salah	Salah	Tidak Yakin	Cek
3	Salah	Salah	Tidak Yakin	Cek
4	Salah	Salah	Yakin	Cek
5	Benar	Benar	Yakin	Cek
6	Benar	Salah	Yakin	Cek
7	Benar	Salah	Yakin	Cek
8	Salah	Salah	Yakin	Cek
9	Salah	Salah	Yakin	Cek
10	Salah	Salah	Yakin	Cek
11	Salah	Salah	Tidak Yakin	Cek
12	Salah	Salah	Yakin	Cek
13	Benar	Salah	Tidak Yakin	Cek

Honor	Tier 1	Tier 2	Tier 3	Ket.
14	Salah	Salah	Yakin	Cek
15	Benar	Salah	Yakin	Cek
16	Salah	Salah	Yakin	Cek
17	Salah	Salah	Yakin	Cek
18	Salah	Benar	Yakin	Cek
19	Salah	Benar	Yakin	Cek
20	Salah	Salah	Yakin	Cek
21	Benar	Benar	Tidak Yakin	Cek
22	Benar	Benar	Yakin	Cek
23	Benar	Benar	Yakin	Cek
24	Salah	Salah	Yakin	Cek
25	Salah	Salah	Yakin	Cek
26	Salah	Salah	Tidak Yakin	Cek

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Figure 2. Diagnostic Result Interface

After revising the product based on the experts' comments and suggestions, the next step was conducting themain field testing that involved ten students as users. The mean score given by the students in respond to the D&R Geometric Optics ranged between 3.50–4.00. Thus, it could be concluded that the interactive multimedia-based program for diagnostic and remedial on geometric optics could be tested further in operational trial. The user students involved in the trial stated that they could understand the instruction on how to use D&R Geometric Optic program clearly, they

were also able to use and run the program based on the instruction given, and they could get the diagnostic result immediately after finishing the test and also get the remedial materials that suited their needs.

In operational field testing, the data were collected from the pretest and posttest result of experiment and control class. The comparison between the pretests of both classes can be seen on Figure 3.

Figure 3. Diagram of Comparison between Pretests of Experiment and Control Class.

Information.

U : Understand the concept G : Guessing (no certainty)
M : Misconception N : Not knowing the concept

From the comparison diagram on Figure 3, it can be seen that the average percentage of students who understand the concepts was still low in both classes, just 19.12% in the experiment class and 18.42 in the control class. Meanwhile, the average result of pretests that belonged to misconception was still high in both classes, it was above 50%. The percentage of students' pretest answers that belonged to guessing (no certainty) was similar in both classes, 2.69% in the experiment class and 3.46% in the control class. Whereas in terms of the category of not knowing the concept, the experiment class was 7.54% higher than the control class.

The comparison between the mean of posttest of both classes can be seen on Figure 4.

Figure 4. Diagram of Comparison between Posttests of Experiment Class and Control Class

Information.

U : Understand the concept
M : Misconception

G : Guessing (no certainty)
N : Not knowing the concept

From the diagram above, it can be seen that the experiment class had an average percentage of concept understanding around 77.8%, increased 58.68% from the pretest. The increase in the experimental was higher than that occurred in the control class which was only 49.48% from the pretest became 67.9%. The percentage of both classes was similar in terms of misconception, 16.81% in the experiment class and 18.42% in the control class. In terms of guessing (no certainty), the percentage of the experiment class was still lower than that of the control class, 1.15% and 4.51% respectively. In terms of not knowing the concepts, the experiment class had an average percentage 4.23%, which was lower than the control class of which percentage 9.00%.

Homogeneity and normality test were conducted towards the posttest data that it was found that the requirement to conduct a discrimination test with t-test was not fulfilled. Thus, in processing the discrimination test for the experiment and control class, nonparametric Mann-Whitney test was employed. The result can be seen on Table 2.

Table 2. Result of Mann-Whitney Test

Categories of Answer	Mann-Whitney U Score	Significance	Conclusion
Understand the concept	304,5	0,047	Different
Misconception	402,5	0,620	Not different
Guessing (No certainty)	254,0	0,002	Different
Not knowing the concept	315,5	0,056	Not different

From the Mann-Whitney test result, it can be concluded that there was a significant difference between experiment and control class in categories of understanding concept and guessing (no certainty). It was shown by the significance scores on those categories which were below 0.05. On the other hand, in the categories of misconception and not knowing the concept, it was concluded that there was no difference between the two classes, because the significance scores were above 0.05.

The findings on this product trial supported some previous researches which stated that students who just learned even in a formal context could hold misconception on geometric optics (Goldberg & McDermott, 1986; Goldberg & McDermott, 1987; Andersson&Kärrqvist, 1983; Fetherstonhaugh&Treagust, 1992; Galili, 1996; Langley, et al., 1997). It was reflected in the misconception percentage on the pretest. Most students were able to memorize formulas related to geometric optics without understanding the very meaning. They experienced events related to geometric events everyday but could not explain the concepts underlying those phenomena.

The result of this research and development proved that the use of three-tiers misconception-diagnostic test was successful in identifying misconceptions among students. This type of diagnostic test was also successful in distinguishing which of the students who had understood the concepts, who were just guessing, and who did not know the concepts at all. The use of interactive multimedia in remedial was also proved to be effective in improving students' concept understanding and lessening misconceptions on geometric optics. With the use of animation, simulation, and videos in the interactive multimedia-based program for diagnostic and remedial, abstract concepts in geometric optics could be presented clearly. This advantage could help the students to understand geometric concepts accurately.

In the experiment class, there were several factors that make misconceptions, no certainty, or not knowing concepts at all could still be found on posttest. First, the students may never used the D&R Geometric Optics program at home. In turn, the students never got any remedial. Some students admitted that they did not use the program at home due to many reasons. Second, it was possible that the contents in the D&R Geometric Optics program were not detailed enough. Third, it was also possible that the material presentation technique was irrelevant with the students' learning styles, that this program could not do much for them. More frequent practicum activities in a real laboratory was really needed to help the students to understand the geometric optics accurately.

4. Conclusions and Suggestions

From the result and discussion above, the interactive multimedia-based diagnostic and remedial program on geometric optics has fulfilled the criteria to be categorized as valid. Besides, the product of this development was also proved to be able to diagnose misconceptions and improve students' concept-understanding or lessen their misconceptions on geometric optics.

This research was conducted based on practicality in the development and application in classroom. Thus, the misconceptions studied in this research were just limited to misconceptions that were thought to be mostly held by the students based on previous researches. For further development, misconceptions to be studied can be broadened by involving all types of conceptions on geometric optics, not just limited to the misconceptions frequently held by students on previous researches.

One of the weakness of this interactive multimedia-based program for diagnostic and remedial on geometric optics is that it was not connected to lecturer's scoring database that the lecturer should do the scoring manually. Due to the weakness, any further development is expected to develop such program in a form of web which is featured with a database system. By doing so, lecturers do not need to do a manual scoring anymore. Besides, by creating such product in a form of web, it will be easier for lecturer to monitor students' learning.

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PREFACE

Assalamu'alaikum warahmatullah wabarakatuh

It is my pleasure to be able to bring the International Conference on Mathematics and Natural Sciences Proceeding to our readers. It took an extra effort, time and patience to accomplish this proceeding and it involved reviewers from all over regions. I personally thank to our reviewers and subsequently apologize for the delay in making this proceeding available for you to read. It is largely due to the inevitably extensive reviewing process and we persist on our initial idea to keep the proceeding both readable and academically meet a higher standard.

This proceeding is presented in six sections: 1) Invited Speakers; 2) Physics; 3) Mathematics; 4) Biology (including pharmacy and agriculture); 5) Chemistry; and 6) General Education. All sections consist of papers from oral and poster presentation in respective subject, including science and science education.

I hope that this proceeding may contribute in science and science education.

Wassalamu 'alaikum warahmatullahi wabarakatuh

Lalu Rudyat Telly Savalas

Chief Editor