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Development of Interactive E-Modules with a Multi-representational Approach to Help Students Analyze the Effect of Heat and Heat Transfer for Grade XI Senior High School

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Abstract: This study aims to develop and determine the feasibility and readability of learning media in Physics E-Modules interactive with a multi-representation approach to help students analyze the effect of heat and heat transfer class IX SMA. This e-module can be accessed online through computers, laptops and smartphones. Research and development uses the ADDIE model. The results showed that the product validation score was 3.53 for content validation and 3.76 for construct validation. The readability test of this E-Module is 96.41%, and it is included in the readability category so that the E-Module can be said to be feasible to use. The results of the validation and readability tests show that the product is feasible to use.

INTRODUCTION

In studying Physics, students are required to think at a higher level and require intellect which causes a high level of difficulty in studying Physics (Istiyono et al., 2019; Malik et al., 2015). Students difficulties in studying Physics are shown from the results of the SMA/MA level exams conducted by students. Based on data from Puspendik Kemendikbud (2019), the results of the SMA/MA level Physics national exam still show the second lowest achievement result after mathematics with an average Physics test score of 46.47. In the questions that measure heat transfer reasoning, only 28% of students managed to answer correctly (Ministry of Education and Culture, 2019). The data is also supported by the results of research conducted to find out the conceptual understanding of high school students regarding the material temperature and heat, in which the understanding of the concept of temperature and heat material is still not good (Azizah et al., 2020; Ni'mah et al., 2019; Silung et al., 2016; Taqwa, Priyadi, et al., 2019; Taqwa, Utami, et al., 2019). This shows that learning Physics on temperature and heat still needs to be improved.

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There are several causes of less than optimal student physics learning, including understanding concepts that are not yet correct, selecting methods that are not appropriate, learning media that are too monotonous, learning environment, and management of learning activities that are still not able to arouse student learning motivation (Sohibun & Ade, 2017; Supardi et al., 2015). In its role to support the learning process, the use of appropriate learning media is one of the factors that influence the achievement of learning objectives properly. This is because learning media has a positive influence in increasing interest in learning and learning outcomes (Supardi et al., 2015; Widodo et al., 2017; Wijoyo, 2018). In addition, learning media is one of the elements that can help students to make it easier to understand abstract material and concepts so that they become concrete and easy to understand (Novitasari, 2016; Solihudin JH, 2018).

In studying Physics, concepts will last a long time if there are various ways of presenting material that are based on the various learning styles of students (Aisyah & S, 2021; Andromeda et al., 2017; Ni'mah, 2016). For example, there are students who more easily understand using verbal representations, there are also students who more easily understand using image representations. If students do not master the concept well, then when given problems related to temperature and heat and students forget the mathematical equations that have been taught, of course students will not be able to solve these problems (Pahini et al., 2014).

In studying Physics, understanding and mastery of material with different representations are needed (Rahmatina et al., 2017; Wati et al., 2019). As in the data on the results of the 2019 Physics national exam, it was also found that questions with graphic interpretation had low achievement results in the subject of temperature and heat with only 35.65% of students answering correctly (Ministry of Education and Culture, 2019). This will not happen if the concept is presented using different representations so that when students forget how to solve problems with one form of representation, students can still find solutions to these problems using other forms of representation (Rohmiati et al., 2017). This process can be explained verbally, mathematically, or in pictorial diagrams or often called multi-representation (Nugroho et al., 2013).

Multi-representation is a way of modeling the same concept using a variety of different formats, whether in the form of words, diagrams, mathematical equations, images, simulations, graphs, and so on (Saputra et al., 2020; Suhandi & Wibowo, 2012). Multirepresentation has three main functions, namely as interpretation, complement, and understanding builder (Finnajah et al., 2016). This variation allows several ways to master a concept. However, not all teaching materials can be used to produce multi-representative explanations. Therefore, we need a learning media that can present material with a multi-representational approach. One of the teaching materials that can be used as media in presenting material in a multi-representational manner is a module (Rahayu et al., 2018; Setyandaru et al., 2017).

The module is one of the important teaching materials to be developed in the learning process to facilitate students and teachers so that the material presented is more easily understood by students (YS Nugroho et al., 2019). There are at least two module functions developed, namely as an additional teaching aid for teachers and as a tool for students to

carry out independent learning (Puspitasari, 2019; Setyandaru et al., 2017). However, so far the method of packaging modules or teaching materials for Physics is still linear, namely only presenting material in the form of concepts, principles, examples of questions and ways of solving them, as well as practice questions and discussions that are of little interest to students (Suwindra & Suswandi, 2014; Zakiyah et al., 2019). This results in students tend to feel more easily bored while studying.

The use of printed modules and electronic modules in the physics learning process has its own advantages and disadvantages. Print modules are considered easier to use without the need for an internet network, but the use of print modules cannot provide a varied display such as displaying videos, animations, and other multimedia products (Puspitasari, 2019). On the other hand, research conducted by Sari(2019)shows that the web-based module that has been developed still has limitations in the format of writing and the use of illustrations. In addition, video illustrations cannot display videos with the form of YouTube links pasted on web pages. These limitations can reduce student learning interest due to the lack of interactive components in the product (Ariyati & Misriati, 2016).

Interactive learning is learning in which there is interaction between students and teachers or students and learning media/resources used to achieve learning indicators (Cahyati et al., 2019; Irwandani et al., 2017a). Interactive learning is a solution that can provide answers to learning that is still classified as traditional, because traditional teacher-centered learning is considered less interactive (Wijoyo, 2018). In creating interactive learning, media is needed that can support interactive learning.

Interactive media can be operated by the user using various control devices, so that the user can operate the media and determine which further options to make (Gunawan et al., 2017). Interactive learning media can also increase students' interest and memory towards Physics subjects (Suhandi & Wibowo, 2012). With interactive media, students get more meaningful learning, because interactive learning media is able to present a more varied learning model (Herkutanto & Soenarto, 2017; Kwok et al., 2016).

In studying abstract material, educators can rely on interactive learning media to make it easier to teach the material (Permana & Damiri, 2014). In this case, the use of media aimed at this development is in the form of interactive modules. The module is said to be interactive if there is active interaction between the module and students, so that interactive modules allow teachers to improvise their learning (Puspitasari, 2019). By using this interactive module, students will be actively involved in learning according to the learning in the 2013 curriculum where there is a demand for a change in learning patterns from teaching centered learning (TCL) to student centered learning (SCL) (Ulandari et al., 2018). The latest 2013 curriculum also requires teachers to be able to utilize technology, information and communication so that learning has efficiency and effectiveness values (Nurmayanti et al., 2015).

The existence of developments in the aspects of Technology, Information and Communication (ICT) makes it easier for humans to access information with unlimited reach in various fields (Fitriyandi, 2013). In the field of education, online learning is a consideration in designing more interactive learning (Engerman & Otto, 2021). In the future, the use of technology for learning media has bright prospects, especially after the

Covid-19 pandemic which also requires each school to carry out independent learning and utilize ICT (Pujilestari, 2020).

In realizing technology-based interactive learning media, E-Modules are a choice of interactive teaching materials that support meeting the needs of technology-based innovative learning (Serevina et al., 2018). E-Modules are technology-based modules and are considered capable of displaying more interactive teaching materials (Irwandani et al., 2017b; Solihudin JH, 2018). E-Modules have advantages over printed modules. These advantages include being more interactive, facilitating navigation, video, audio, images, and even animations can be inserted and can be equipped with an integrated internet evaluation test which can allow automatic feedback to occur immediately (Puspitasari, 2019; Widiana, 2016).

To address the needs of the 4.0 industrial revolution in education, teachers must continue to integrate innovative media to enhance the teaching and learning process (Halili, 2019; Susanti et al., 2019). In improving the quality and ability of teachers in the 4.0 revolution era, internet-based learning of things needs to be improved considering the need to anticipate and think about strategies for things that might happen in the future (Susanti et al., 2019). Various activities also increase students' learning motivation which is expected to affect their learning achievement (Jannah et al., 2018). Based on the background of this problem, the researcher will carry out research with the title "Development of Interactive E-Modules with a Multi-representational Approach to Help Students Analyze the Effects of Heat and Heat Transfer of grade XI" with the aim of developing and knowing the feasibility and legibility of the product.

METHOD

The research design in this study uses research and development methods. This method applies several processes in developing a product. In this study, the product to be developed is teaching materials in the form of interactive E-Modules with a multi-representational approach. The research used uses the ADDIE model (Analyze, Design, Development, Implementation and Evaluation). Based on the steps in product development, the ADDIE model can be used for product development such as teaching materials. The ADDIE development model is considered more rational and complete than the 4D model (Sari, 2017). There are 5 stages of research in the ADDIE design, namely Analyze, Design, Development, Implementation, and Evaluation. Following are the activities at each stage of the ADDIE model research.

Analyze

The analysis phase is carried out with several stages of analysis including performance analysis and needs analysis. Performance analysis is carried out by analyzing data on student learning outcomes through various journals, student achievement and the results of national exam scores. While the needs analysis is carried out to analyze needs, namely reviewing the revised 2013 Curriculum syllabus, in the form of reviewing Core Competencies and Basic Competencies. In addition, reviewing existing products, widely

used teaching materials, learning media used in class, the basis used in product development, and the media/technology used for product development.

Analysis was also carried out by seeking information through direct surveys to see teaching materials that are often used by students, the way teachers teach, and the needs of students at SMAN 9 Malang. From the results of the performance analysis it was found that there were still many students who did not understand the concept of physics in the basic competencies of analyzing the effect of heat and heat transfer. For the results of the needs analysis, students still need teaching materials that are more interactive, considering that the teaching materials that students often use are printed books and teacher summaries. The use of E-Books has been used before, but the E-Books used are not interactive, only in the form of text, pictures and sample questions. In addition, the media used does not yet support the presentation of physics concepts in a different way. From these findings,

Design

After conducting a needs analysis, the researcher designed the product in accordance with the results of the needs analysis by making flowcharts and interactive module program storyboards. That way, the E-Module design can be well organized and product development can be carried out from pre-existing products.

Development

At the development stage, researchers develop products that have been planned at the design stage.The product resulting from this development is an interactive E-Module with a multi-representational approach. There are several components that make up the E-Module, including covers, instructions for use, preface, main menu, material menu, multi-representational material content, evaluation questions, bibliography and about the module.

Implementation

At the implementation stage, the products that have been made are then tested for validity by experts. In testing the validity, it was carried out by giving a questionnaire to the Physics Lecturer at the State University of Malang as an expert validator and two Physics teachers at SMAN 9 Malang as a practitioner validator. Furthermore, the product was tested limited to 15 students of class XI IPA SMAN 9 Malang by providing a readability test questionnaire regarding this interactive E-Module using Google Form.

Evaluation

Evaluation is carried out at the end of each stage by stage in the development of the ADDIE model. At the evaluation stage, the product is evaluated whether it can achieve the objectives of the research, namely to produce interactive E-Module media with a multi-representational approach and determine the feasibility of interactive modules with a multi-representational approach in supporting physics learning in high school. If there are suggestions from experts or from students during the implementation stage, revisions are made so that the resulting product is better. Figure 1 shows a schematic of the ADDIE design stages.

Figure 1. The ADDIE Cycle

Research and Development Data

This study uses 2 types of research data, namely quantitative and qualitative data. Quantitative and qualitative data were obtained from filling out product validation questionnaires, and product practicality test questionnaires. The test subjects in this study included experts in the form of one Physics lecturer, practitioners in the form of two Physics teachers from SMA Negeri 9 Malang, and the trial was limited to fifteen class XI students of SMA Negeri 9 Malang. Quantitative data is in the form of numbers that indicate the feasibility level of the multi-representational interactive module from a questionnaire that has been filled out by experts, teachers and students. This value will then be converted into a number which states the level of validity and a percentage which states the level of product legibility. Qualitative data were obtained from comments or suggestions filled in by experts and students in the questionnaire.

The instrument used to collect data in this study was a questionnaire. There are two questionnaires used, namely the validation test questionnaire and the product practicality test questionnaire. These two questionnaires produce an assessment in the form of quantitative and qualitative data containing comments and suggestions. The product validation questionnaire was filled in by one lecturer as an expert and two teachers as practitioners. The validation test questionnaire is divided into two, namely to assess content validity and to assess construct validity. There are several aspects that are assessed on the validity of the content of this multi-representational interactive E-Module, namely content feasibility, presentation feasibility, and language eligibility. Whereas content validity consists of product operational aspects, cover design, and content design. Validation criteria as shown in Tabel 1.

Table 1. Validation Criteria.

Average of Validation Score (%)	Category
3.26 – 4.00	Valid (without revision)
2.51 – 3.25	Valid enough (slightly revised)
1.76 – 2.50	Invalid (many revisions)
1.00 – 1.75	Invalid (total revision)

For the E-Module readability trial, the respondents came from class XI high school students who had taken the physics subject on temperature and heat. Respondents amounted to 15 students.A product readability test questionnaire was given to determine the practicality level of the interactive E-Module being developed. The product practicality test questionnaire contains several positive statements about the appearance (design), language, and ease of operating the E-Module. Measuring the answers from the product practicality test questionnaire using the Guttman scale.In testing the legibility of the E-Module, data analysis uses the percentage formula with readibility test criteria as shown in Table 2.

Table 2. Reliability test criteria

Validation Score (%)	Category
76 - 100	read
51 - 75	Just Read
26-50	Unreadable
0 - 25	Can not be read

RESULT AND DISCUSSION

The resulting product is an interactive E-Module with a multi-representational approach to help students analyze the effect of heat and heat transfer. This E-Module can be opened on various devices online using a browser that supports the html5 format such as smartphones, computers, laptops and other devices. The presentation of the E-Module is in the form of a link or barcode that can be forwarded to the reader when using it. This E-Module is interactive and has a multi-representational format for presenting the material. The multiple representations presented include verbal representations, image representations, animated representations, video representations, table representations, and graphic representations.

E-Modules can be accessed online. The use of E-Modules can be used by sharing links or E-Modules barcodes to users. The E-Module also combines the Youtube platform for displaying videos, PhET for virtual simulations, Google Forms for practice questions that contain discussions, and Quizizz to monitor student learning evaluation results.

These E-Module sections consist of a cover page that contains the title of the E-Module material, the identity of the E-Module constituent, and a 'start' button. If the 'start' button is selected, it will go directly to the instructions for using the E-Modul. This is so that users are not confused and understand how to use the E-Modul before using it.

Figure 2. E-Module Cover

Instructions for using the module are divided into 3 parts, namely instructions for using the E-Module for teachers, instructions for using the E-Module for students, and navigation instructions. In the teacher's instructions for use, there is a button that connects to the link for opening an account which can be used to retrieve student evaluation data which is directly integrated with student assessment sheets. The results of working on the exercise questions and student evaluations can be monitored through the account, so that the teacher can give assessments to students automatically and monitor the development of student learning outcomes.

Figure 3. Instructions for using the E-Module

This E-Module consists of 7 sub-materials which contain material that contains multi-representational explanations. The multiple representations displayed are in the form of text, images, graphics, videos, and animations. The material presented is adjusted to the existing curriculum in the latest syllabus. The sub-material in this E-Module is based on essential concepts that are important to learn according to learning indicators. The material presented in each sub-material begins with apperception in the form of an intro.

Figur 4. E-Module multi-representation display

Learning activities are not just studying and doing exercises. In some sub-materials there are also virtual practicum activities using a virtual lab. At the end of each sub-material there are examples of questions and practice questions that refer to apperception and achievement indicators.

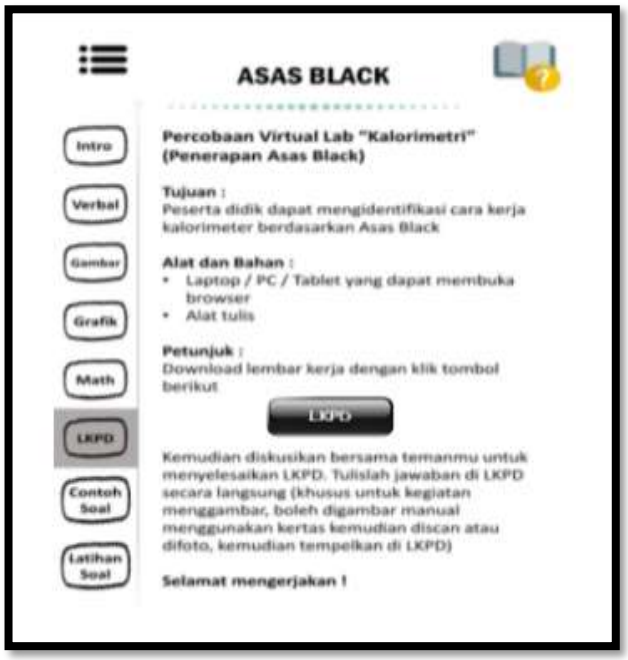

Figure 5. View of page to LKPD

Examples of questions and practice questions are found in each sub-material. Practice questions using the Google Form platform for the process. After students work on the practice questions, the results of the work immediately come out automatically and students can also see scores and feedback in the form of discussion of answers. Student evaluations are presented in the form of quizzes that are integrated with the Quizizz platform. Quizizz accounts can also be accessed by teachers. The teacher can set the display of practice questions and discussions through the accounts in the instructions for use.

Figure 6. View of the page towards the evaluation question

Based on the validity test conducted, the results of content validation analysis were obtained as shown in the following table.

Table 3. Analysis of content validation results

Assessment Aspects	Score	Criteria
Content Eligibility	3.60	Valid
Eligibility of Presentation	3.52	Valid
Language Eligibility	3,47	Valid
Average	3.53	Valid

As for the results of the construct validity test, the results of the analysis are as follows.

Table 4. Analysis of construct validation results

Assessment Aspects	Score	Criteria
Product Operations	3.89	Valid
Cover Design	3.60	Valid
Content Design	3.81	Valid
Average	3.65	Valid

The readability test was limited to 15 students from SMAN 9 Malang, obtaining an average score of 96.41% in the legible category. In the development of this E-Module, the validity and readability test stages were carried out. The validity test phase is divided into 2 components, namely content validation and construct validation. Validation was carried out to expert lecturers and high school physics teachers. Validation aims to find out whether the product development is feasible and to find out which parts of the product need to be repaired/revised.

The results of the analysis for the content validation test are listed in Table 3. From the data shown in Table 3, a content validation score of 3.53 is obtained with the valid category. These results are in line with Wati's research(Wati et al., 2019)who developed a multi-representation e-book by obtaining a content validation score of 3.90 with a valid category. Even so, there are a number of things that still need to be improved in more detailed assessment points. This is because some of these points, if calculated, produce a value of less than 3.26, so revisions/improvements are needed. As in the multi-representation content conformity assessment item.

On the suitability item for multi-representational content, a score of 2.67 is obtained with the category quite valid, so revision is needed. This is because there are still parts of the E-Module sub-material that still use inaccurate multi-representation presentations. Multi-representational display of the table section on the sub-material heat, specific heat, and heat capacity. The presentation of the table representation is still not quite right so that the representation is changed using a graph.

In addition to multi-representational content, there are corrections to unit naming and unit assignment. The use of the abbreviation gram needs to get used to using the letter 'g' instead of 'gr'. In practice questions, there are questions that do not have units, so it is necessary to give units in these questions. Improvements were also made to the practice

questions in Google Form where some mathematical symbols or symbols were still unreadable. In some cases it also shows a different symbol from the symbol that should be used. This happens because not all devices have the same symbol writing format, so the developer needs to convert the question form into an image form so that there are no errors in generating mathematical symbols.

Analysis of the results of the construct validation assessment is presented in Table 4. From the results of the analysis, construct validation has a score of 3.76 and is included in the valid category. Overall, the results of validating this E-Module product have a score of 3.65. The assessment is categorized as valid if the score obtained is more than 3.26 so that this E-Module is included in the valid category. In line with the research conducted by Saputra(Saputra et al., 2020)who developed a multi-representation E-Module product on rectilinear motion material with media validation results of 87% in the very good category.

After conducting the E-Module validation test, the product was revised according to the validator's suggestions. After the product revision, a readability test was carried out on 15 students. The readability test is carried out to determine the readability of the E-Module on various devices. The results of the readability test showed that the average score for each component was 96.41% in the legible category. This is in line with the research and development of multi-representation-based modules for SMA/MA Physics learning conducted by Setyandaru(Setyandaru et al., 2017)with the results of student responses that are classified as positive. This shows that the E-Module is feasible to use from the aspect of readability.

Multirepresentation has a positive impact on increasing students' understanding, especially in understanding Physics. Much was revealed in Taqwa's research with several of his colleagues, both revealing students' difficulties in understanding physics in various representations to learning using a multi-representational approach (Romansyah & Taqwa, 2021, 2023; Saputri et al., 2019; Taqwa et al., 2020; Taqwa, Faizah, et al., 2019; Taqwa et al., 2016; Taqwa & Rahim, 2022). This is because in Physics it is required to be able to explain natural phenomena in various kinds of representations.

CONCLUSION

This research and development has succeeded in producing a product and testing the feasibility of an interactive E-Module with a multi-representational approach to help students analyze the effects of heat and heat transfer in class XI SMA. E-Module is in the form of a web application that can be accessed online using a device that has a web browser. The product gets a validation score of 3.53 for content validation and a score of 3.76 for construct validation. Overall, the product validation score obtained a score of 3.65, which means that this product is included in the valid category. The E-Module readability test obtained a score of 96.41% and included in the readability category. From the results of the validity test scores and readability tests, the E-Module can be said to be feasible to use. It is suggested to conduct further research to determine the effectiveness of the E-Module in helping students analyze the effect of heat and its transfer. In addition, the E-Module can also be developed to run without an

internet network so that it can support learning in locations that have a less stable internet network.

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