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Integrated Renewable Energy E-Module PBL Model with Smartphone to Improve Students' Creative Thinking and Communication Skills

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ABSTRAK

Perkembangan IPTEK adalah ciri dari abad 21 yang menuntut siswa memiliki keterampilan 4C. Studi pendahuluan menunjukkan keterampilan berpikir kreatif dan komunikasi siswa masih kurang. E-modul energi terbarukan terintegrasi model PBL dengan smartphone menjadi aspek yang penting untuk menunjang peningkatan keterampilan berpikir kreatif dan komunikasi siswa. Penelitian ini bertujuan untuk menentukan validitas dan praktikalitas dari e-modul. Pengembangan dalam penelitian ini mengacu pada model desain Hannafin dan Peck. Objek penelitian berupa e-modul energi terbarukan terintegrasi model PBL dengan smartphone. Instrumen dalam mengumpulkan data yang dipakai yakni lembar angket uji validitas dan praktikalitas. Teknik untuk menganalisis data yang dipakai yakni statistik deskriptif. Berdasarkan analisis data yang dilakukan didapatkan dua hasil penelitian. Hasil penelitian yaitu, validitas e-modul dengan nilai 0,80 serta praktikalitas penggunaan e-modul menurut guru dan siswa dengan nilai 92,86 dan 86,40. Hasil penelitian menyimpulkan bahwa e-modul energi terbarukan terintegrasi model PBL dengan smartphone valid dan praktis kategori baik sekali digunakan dalam menunjang proses pembelajaran fisika.

ABSTRACT

The development of science and technology is a characteristic of the 21st century, requiring students to have 4C skills. Preliminary studies show that students' creative thinking and communication skills still need to improve. The renewable energy e-module integrated with the PBL model with smartphones is an important aspect that supports improving students' creative thinking and communication skills. This research aims to determine the validity and practicality of the e-module. The development in this research refers to the Hannafin and Peck design model. The research object is a renewable energy e-module integrated with the PBL model and a smartphone. The instrument used to collect data was a validity and practicality test questionnaire. The technique for analyzing the data used is descriptive statistics. Two research results were obtained based on the data analysis carried out. The research results are the validity of the e-module with a value of 0.80 and the practicality of using the e-module according to teachers and students with a value of 92.86 and 86.40. The research results concluded that the renewable energy e-module integrated with the PBL model with a smartphone was valid and practical in terms of being very good for supporting the physics learning process.

1. INTRODUCTION

The science and technology development has helped developments in human life various fields. The science and technology development is currently something that piques the public's interest including in the education field. The science and technology development in the education in world has resulted in many innovations to support the process of learning (Fındıkoğlu & İlhan, 2016; Simanjuntak & Budi, 2018). The rapid science and technology development has brought about a turn in the paradigm of learning in the world of education which is marked by a shift in digital learning. The science and technology development characterizes the 21st century and influences the global order of life (Jayadi *et al*., 2020; Yeni *et al*., 2014). Thus, to deal with the science and technology development humans are necessary to possess skills of 21st century. The 21st is distinguished by globalization and competition. The skills of 21st century are skills that a person needs to succeed in facing increasingly complex challenges, especially to achieve success in life (Mufit *et al*., 2020; Novita, 2023; Sawitri *et al*., 2021). Human life in the twenty-first century is undergoing

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major changes that differ from the preceding century's order of life. The 21st century demands student skills to be ready to face the challenges that exist (Asrizal *et al*., 2020; Jayadi *et al*., 2020). The skills of 21st century have become basic skills that students must have today. There are four skills that are important for students to master, which are known as the 4C skills. These skills includinng skills of critical thinking, creative, communication and collaboration (Maulidah, 2021; Widya et al., 2022). The importance of 4C skills in the 21st century is due to increasingly fierce competition for human resources.

One of the 21st century that important for students to have is skills of creative thinking. Students' projects, particularly those containing diverse forms of everyday life difficulties, need them to use creative thinking abilities in assessing problems, finding ideas, and arguing (Hwang et al., 2015; Maulidah, 2021). In relevan with creative thinking skills, students must also have skills of communication. The skills of communication are abilities to communicate new concepts, ideas, knowledge, and information to others using voice, writing, symbols, drawings, graphics, or numbers (Yu(Feriyanti, 2020)lianti & Handayani, 2021). Through the skills of creative thinking and communication that are owned, it will be able to achieve educational goals by the demands of the independent learning curriculum.

As an answer, the independent learning curriculum is provided to the intense competition for human resources globally in the 21st century. The presence of the independent curriculum complements the previous curriculum (Indarta *et al*., 2022; Nurohmah *et al*., 2023). Education has a strategic role in forming qualified, creative, and competitive human resources. The presence of the independent learning curriculum is the government's way to increase the quality and quality of education in a better direction. Learning in the independent learning era involves conditions that are independent in fulfilling the goals, approach, materials and learning evaluation for both teachers and students (Indarta et al., 2022; Sudirtha et al., 2021). The independent learning concept that has been developed into a curriculum has relevance to 21st century learning because it is more concerned with the needs of students. The autonomous learning curriculum requires teachers and students to be more creative and imaginative in order to increase the learning quality (Mairizwan et al., 2022; Rivalina, 2015). Thus, the curriculum in independent learning is one of the curricula that can overcome the educational crisis and can adapt to the times (Ariga, 2023; Nurohmah et al., 2023; Wahid & Hamami, 2021).

In essence, educational efforts are an investment in the future of a nation for the progress of the Indonesian nation. Indonesia's investment in education is through sustainable development. One aspect that needs to get full attention in sustainable development is the environmental and energy aspects. The problems faced by Indonesia in the environmental and energy fields are dependence on dwindling fossil energy reserves, limited access to energy for the community, and the development of renewable energy which is constrained by technological mastery and low financing. The problem of limited access to energy requires an effort to reduce dependence on fossil energy. For example, by developing renewable energy sources or changing our behavior in using energy, which is the of the world education respons in preparing students to have wise behavior in consuming energy (Caraka & Ekacitta, 2017; Khotimah, 2017). The curriculum plays an important role in efforts to awaken students to care more about the environment. One of the subject matter that studies energy and the environment is physics.

Learning physics is learning by developing reasoning and analysis. Through physics, almost all issues related to nature can be understood (Ewar et al., 2023; Malina et al., 2021). The physics learning approach stresses providing direct experience in order to acquire competences to scientifically examine and analyze the natural surrounds. Physics education is built on the notion of active learning, which allows pupils to maximize their potential (Baepler et al., 2014; Theobald et al., 2020). Physics learning is important in life for everyday to meet human needs through problem solving. The process of solving problems requires a relevant learning model called the Problem Based Learning model (Astuti, 2019; Purnomo et al., 2022).

The efforts made by the government, schools, teachers and other parties do not break the fact that the conditions in the field have not described the expected conditions. This is known from an initial study was done at a public high school in the Padang city. The initial study was done to determine students creative thinking and skills of communication as seen from tests of students creative thinking and skills of communication through learning with the PBL model. The think in creative and communication skills of class X students results of a public high school were in the less category with an average of 56.07 and 55.24. These results are supported based on the results of the initial test results by giving questions to students it was found that creative thinking of students skills had an score in average of 52.79 in the category was less. The profile of creative thinking of students skills, namely 55.38%, is included in the category was sufficient. This is because no companion book hones creative thinking. Based on interview results it was give that only a few students had good communication skills when learning physics took place in each class (Almuharomah et al., 2019; Dona & Syafriani, 2022; Putri et al., 2022).

Starting from the ideal conditions and real conditions that have been described, it was found that there were problems with creative thinking of students and communication skills. It is important to make efforts to overcome this problem. One of the solutions to solve this problem is to develop an integrated e-module PBL model with a smartphone to increase creative thinking of students and communication skills. The e-modules development with the integration of PBL or e-modules to increase creative thinking skills or communication skills has been studied by several previous researchers. Module development with PBL integration valid and feasible to use in learning physics. E-module physics can be used easily in learning physics to increase creative thinking of students skills. The development of the e-module further states that the Ethno-STEM based e-module assisted by Canva which is integrated with the Gordang Sambilan musical instrument can improve students' communication skills (Aji et al., 2017; Aprilia & Anggaryani, 2023; Putri et al., 2022).

The research was done is not similar from research before. This study has three differences from previous studies. The first difference is that the e-module is integrated with the PBL model by utilizing ICT, especially smartphones. The second difference is that e-modules are developed to increase creative thinking of students and communication skills. Third, the developed e-module contains material on renewable energy and its use in real world problems. This research also has a novelty, namely in the form of an electronic module by utilizing the application of Flip PDF Professional which creates interactive e-modules by including multimedia like as images, video, audio, hyperlinks, and others. The e-module can be used with a smartphone so that it can be used anytime and anywhere.

The first theoretical research the e-module is relevant to the solution provided. The electronic modules are one of the learning aids that can be used by teachers and students in the learning process. E-modules are electronic versions of modules that be accessed and used via electronic devices such as computers, laptops, tablets, or even smartphones. E-modules can make it more easy for students to learn independently, and help students understand the concept of material whether or not there is a teacher (Asrizal *et al*., 2022; Fahlevi & Asrizal, 2021; Saprudin *et al*., 2021). E-modules are modules in digital form, consisting of text, images, or both which contain digital electronic material accompanied by simulations that can and are appropriate for use in learning (Arnila et al., 2021; Rahayu & Sukardi, 2021). One way to make e-modules is to use the Flip Pdf Professional application. Flip PDF Professional is a feature-rich flipbook creator with a page edit capability that allows you to create interactive book pages by incorporating multimedia like as photographs, video, audio, hyperlinks, and so on.

The second theoretical reasearch is related to solutions, namely the model of problem-based learning known as the PBL model. The PBL model is a learning model that can be used to help kids expand their mindsets and become more active and creative (Aji *et al*., 2017; Roza *et al*., 2022; Widura *et al*., 2021). The PBL model allows students to take an active role in the process of seeking information, solving existing problems, being responsible for the assignments given and being able to associate a physics concept with events in their lives. Through problem-based learning, students experience a process of learning by actively solving problems through structured stages and at the learning students ending are expected to produce a particular product (Muhdana, 2020; Winoto & Prasetyo, 2020). The PBL model will make learning activities more enjoyable, increase learning interactions and students become directly involved in the process of mastering the material. Student involvement in learning increases creative thinking of students and communication skills (Amalia et al., 2014; Kokotsaki et al., 2016).

The third theoretical research deals with solutions, namely the use of smartphones in learning. Smartphones are mobile phones that can use and function like computers. Smartphones are a type of media that can transmit information quickly through their internet facilities (Rismayanti *et al*., 2022; Simanjuntak & Budi, 2018). Smartphones can connect humans over long distances with supporting facilities such as SMS, chat, as well as telephone and Viber. The function of a smartphone is not only for texting and calling, However, users can freely install programs, add functions, or adjust as they see fit. Smartphones also have many benefits among students, this is because smartphones are also learning media that are multi-media in nature, which means they can be used for various purposes including technology-based learning resources (Annisa et al., 2022; Arnila et al., 2021). Smartphone learning allows a variety of media for engagement that can be tailored to individual preferences.

The e-module used integrated with the PBL model with smartphone will increase creative thinking of students and communication skills because they implement real-world problems. The integrated e-module PBL model is following 21st century learning which demands skills of creative thinking and communication. Based on the problems background that have been described, it can be argued that this research needs to be done. The research purpose is to reveal the validity and practicality of the renewable energy e-module integrated with the PBL model with smartphone to increase creative thinking of students and communication skills.

2. METHOD

The research was done is Research and Development (R&D). Research and development is a type of research that is used in the manufacture of a particular product and is tested for the validity of the product (Elfeky et al., 2020; Santi et al., 2022). The R&D purpose in education is not to develop or test theories, but to create useful goods for use in schools. The research was done using the Hannafin & Pack design model in product manufacturing. Hannafin and Peck's model is a learning design model whose presentation is simple and doesn't take long. This development model have three stages, namely needs analysis, design, development and implementation (Ningsih et al., 2022; Wahyuni et al., 2021). The first phase of the research is needs and context analysis. The activities that have been carried out in this phase are analyzing the problems of using ICT in physics learning, analyzing student characteristics, analyzing objectives of learning and analyzing learning arrangements. The use of ICT in learning analysis, namely regarding the use of ICT in learning physics, the use of ICT in physics learning materials, the use of ICT in physics learning media, and the ICT in assessment used. Analysis of student characteristics regarding background, learning interest, learning attitudes, learning motivation and learning styles of student. Analysis of objectives of learning related to differences in ideal objectives of learning with objectives of learning used by the teacher based on the operational verbs used. Analysis of learning settings related to opening activities, content and closing of learning used by the teacher in The process of learning occurs.

The second phase of research is the PBL model design integrated renewable energy e-module with a smartphone. Activities that have been carried out include the design of e-modules. The applications used in making this e-module are Microsoft Word and Flip PDF Professional applications. The material chosen in this e-module is physics material for phase E, namely renewable energy and its utilization. The e-module is designed with a learning model in it, namely the problem based learning model. This stage also designed the instruments needed to produce prototypes. The structure of the e-module is cover, introduction, instructions for use, learning outcomes, core parts and closing. The design of this e-module will be made interactive, such as providing pictures, videos, Kahoot! links, and Google form links for evaluation.

The third phase of research is Development and Implementation. This activity is carried out after the e-module has been designed. In the development and implementation stages, validity and practicality tests are conducted for the e-module perfection. The product validation test purpose to reveal whether the product developed has been declared valid by experts manner that it is easy for use by students in learning. The following step is to put the product through its paces. The product practicality test aims to find out that the product is practically used in learning.

This study used instruments for data collection in the shape of sheets for validation questionnaire and sheets for practicality questionnaire. Data analysis techniques in this study used descriptive statistics to analyze validity and practicality. Statistical analysis is displayed in graphical form. Product validity was conducted by 3 experts who were lecturers of physics at FMIPA UNP. The validation questionnaire sheet instrument of product consist of 5 components, known as substance of material, display of visual communication, design of learning, utilization of software, and integrates PBL model. Practicality analysis can be obtained by dividing the value of the components obtained by the many components and then multiplying by one hundred. The practicality questionnaire sheet instrument of product consist of 5 components, known as useful, easy to use, appealing, clear, cost effective, and integrates PBL model. The practicality e-module categories shown in Table 1.

Table 1. The Practicality e-Module Categories

Intervals	Categories
81 – 100	Very Good
61 – 80	Good
41 – 60	Sufficient
21 – 40	Not Good
0 – 20	Fail

3. RESULT AND DISCUSSION

Result

The research results got after doing a needs analysis are product design or design. The product being developed is an integrated renewable energy e-module with a PBL model with a smartphone to increase creative thinking of students and communication skills. The integrated renewable energy e-module PBL model with smartphones is designed based on the structure of writing practical guides for module materials of teaching, namely titles, research guides, must be attained competencies, supporting information, exercises, worksheets (LK), and evaluations. The developed renewabsle energy e-module PBL

model with smartphones can be presented as attractively as possible to facilitate and motivate students to research physics anywhere and anytime. The appearance of the renewable energy e-module on a smartphone shown in Figure 1.

(a) (b)

Figure 1. (a) E-Module Cover Design, (b) E-Module Main Menu

Renewable energy e-modules are integrated with PBL models and smartphones, at the beginning there is a cover and main menu. The e-module cover display contains the SMA logo, the independent learning curriculum logo, the UNP logo, title, author, phase, semester and name of the institution and year of manufacture. The title section explains the material to be studied, namely renewable energy material. This e-module is provided for students of high school in class X in phase E of semester 2. The cover displays sentences written in English and is made as attractive as possible by balancing the colors. The cover of the e-module also contains images of solar panels and windmills which represent the renewable energy material to be studied. The e-module main menu display contains a table of contents for the e-module. Learning activities have objectives of learning, material descriptions, summaries, worksheets, practice questions, and evaluations, as well as feedback responses. Worksheets are integrated with the PBL model to increase communication skills. The practice questions are packaged in creative thinking skills essay questions. Evaluation of learning is given an objective question test related to renewable energy material and is packaged in Kahoot! as well as Google Forms. Evaluation questions are given answer keys at the end of the e-module as a form of feedback to students.

The PBL model integrated renewable energy e-module with smartphones is enhanced with comments and suggestions by experts. Revisions were made in accordance with comments and suggestions from experts. The comments and suggestions from experts on the renewable energy e-module integrated with the PBL model with smartphones are related to practice questions that still don't describe questions for creative thinking. The next suggestion is that evaluation questions are adjusted to the objectives of learning to be achieved. Another suggestion is regarding the PBL syntax, it is better to make teacher activities and student activities, and in the preface, it is stated that the e-module is integrated with the model of PBL to increase creative thinking of students and communication skills.

The next action is to make increase ments to the e-module based to the validator's comments and suggestions. In general, improvements were made to minimize the deficiencies of the integrated renewable energy e-module PBL models with smartphones. Improvements made are finding and making practice questions that according to the components skills of creative thinking. The next improvement is to make evaluation questions that are following the objectives of learning achieved. The last improvement is making student and teacher activities in the PBL model syntax, as well as increasing the preface by including information that the renewable energy e-module is integrated with the PBL model and aims to increase creative thinking of students and communication skills.

Renewable energy e-modules are integrated with the PBL model with smartphones before being used through the validation stage. The purpose of this validation stage is that the renewable energy e-module is integrated with the PBL model and the smartphone used by students is valid. The integrated renewable energy e-module PBL model with smartphones was validated by 3 validators from UNP physics lecturers. The validity results of the integrated renewable energy e-module PBL model with smartphone were acquired from the product evaluation from validator using the validation questionnaire sheet

instrument. The validation questionnaire sheet instrument of product consist of 5 components, known as substance of material (MS), display of visual communication (VC), design of learning (LD), use of software (US), and integrated PBL model (IM). The validation analysis results of the integrated renewable energy e-module model PBL with smartphones shown in Figure 2.

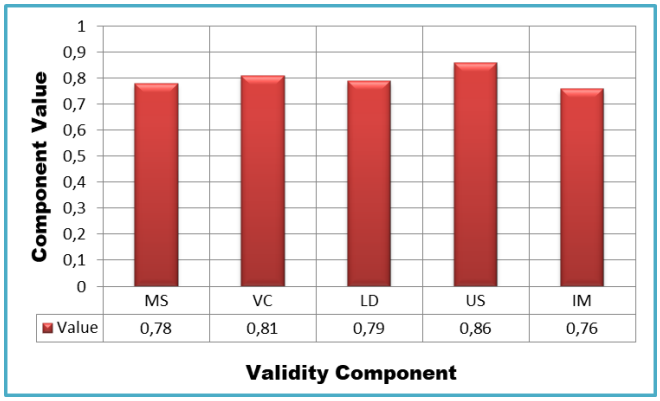

Figure 2. Component Validity Results

Based on the data analysis in the figure, The each component fluctuates score, with the lowest value being 0,76 and the maximum value being 0,86. According to experts, the value of the validation test findings on the integrated renewable energy e-module PBL model with smartphone may be assessed by calculating the value in average of all components for assessment. According to experts, the value in average of validation findings of the integrated renewable energy e-module model PBL with cellphones is 0,80. The material substance is the initial component, and it consists of four indicators: veracity, material coverage, presentability, and readability. The value in average given by the validator for the material substance indicator is 0,78 in the category was valid. The second component is the display of visual communication which is similar to the e-module appearance. The visual communication display validation results have an average of 0,81 category was valid. The validation results show that the renewable energy e-module integrated with the PBL model with a smartphone may make it simple for students to use the e-module by providing a clear navigation display, readable text display, learning media, and proportional color combinations, and has previously done so has media such as pictures or pictures. can encourage pupils to learn physics.

The third component is learning design which consists of 10 indicators. Learning design indicators are title, introduction, research guide, CP, supporting information, exercises, worksheets, evaluation, glossary, and bibliography. The validation results for learning design have an average of 0,79 in the category was valid. The fourth component is the software used (US) which consists of 5 indicators with a value in average of 0,86 which is in the category was valid. The validation results show that the use of software in the renewable energy e-module is integrated with the PBL model and a smartphone makes it more easy for users to use the e-module. The fifth component is the integrated PBL model which consists of 5 indicators with a value in average of 0,76 in the valid category. The validation results show that overall the renewable energy e-module contains the integrated PBL model well. Based on the validity results, we can got conclusion that the developed e-module renewable energy integrated PBL model with smartphones is valid for use in optimizing physics learning.

After being validated, a renewable energy e-module is integrated with the PBL model and a practicality test. According to the teacher, the test for practicality of the integrated renewable energy e-module with the PBL model and smartphone was carried out on 3 class X physics teachers at one of the public high schools in the Padang city. The teacher practicality test results were got from the practicality test sheet instruments analysis. The practicality test instrument is in the shape of a questionnaire on the use of renewable energy e-modules integrated with PBL model and smartphone. The sheet of practicality test instrument from to the teacher have 6 components. These components include useful (UF), easy to use (EU), appealing (AL), clear (CL), cost effective (CE), and integrated PBL model (IM). Analysis of the component of practicality according to the teacher shown in Figure 3.

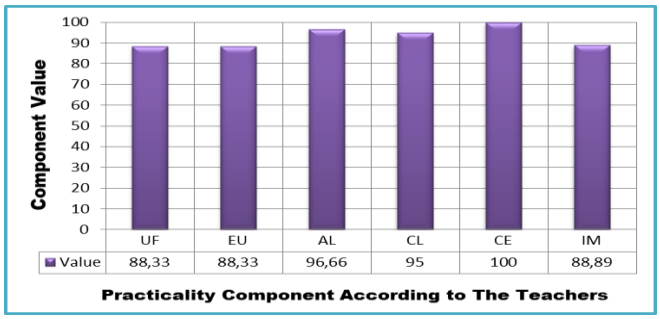

Figure 3. The Practicality Component Results from Teacher

Based on data analysis on the image of the practicality component from to the teacher, value were obtained in the range of 88 to 100. The value in average of the component of practicality from teacher was 92.86, which was in the category was very good. The value given by the teacher to the practicality test sheet instrument states that the renewable energy e-module integrated with the PBL model with smartphones is practically used in learning physics. First, the useful component consists of 5 indicators. Useful indicators consist of being useful for teachers to achieve learning goals, beneficial for teachers in teaching better, beneficial for teachers to accelerate mastery of the material, beneficial for teachers in increasing creative thinking and communication skills, and beneficial for teachers in mastering renewable energy material. The value in average of the useful component is 88.83 in the category was very good. Second, the easy to use component consists of 5 indicators. The indicators are to make it more easy for teachers to teach renewable energy material, make it more easy for teachers to control learning activities, make it more easy for teachers to understand renewable energy material, make it more easy for teachers to increase creative thinking and communication skills, and make it more easy for teachers to teach renewable energy material in real-world situations. The value in average of the easy to use component is 88.33 in the category was very good.

The third component, namely appealing with an average of 96.66, is in the category was very good. The appealing component has 5 indicators. The indicators of the appealing component consist of attractive covers and templates, attractive composition of images and colors, proportionally sized titles of material and sub-material, linking learning material to the real world, and increasing creative thinking and communication skills. Fourth, the clear component analysis results with an average of 95.00 are in the category was very good. The results for data analysis show that the e-module is very clear in its presentation. Fifth, the cost effective component has 5 indicators. Cost effective component indicators consist of e-modules that do not require expensive costs, can be used repeatedly, are practical and easy to carry because they are stored on a smartphone, and can be used anytime and anywhere. The cost effective component data analysis results have a value in average of 100.00 in the category was very good. Sixth, the integrated PBL component with an average of 88.89 is category was very good. The results for data analysis show that the designed renewable energy e-module already integrates the PBL model. Based on the practicality results according to the teacher, we can got conclusion that renewable energy e-modules with smartphones are practically used by teachers to support the process of learning in physics.

The practicality test of the PBL model integrated renewable energy e-module with smartphones according to students was carried out on 35 class X students at one of the public high schools in the Padang city. The student practicality test results were got from the practicality test sheet instruments analysis. The practicality test instrument is in the shape of a questionnaire on the use of renewable energy e-modules integrated with PBL models and smartphones. The sheet instrument of practicality test according to students consists of six components. These components include useful (UF), easy to use (EU), appealing (AL), clear (CL), cost effective (CE), and integrated PBL model (IM). Analysis of the component of practicality from teacher shown in Figure 4.

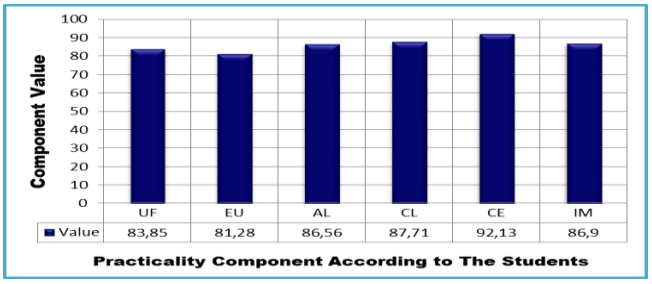

Figure 4. Practicality Results According to Students

Based on data analysis on the image of the component of practicality according to students, values were obtained in the range of 81 to 93. The value in average of the component of practicality according to students was 86.40 which was in the category was very good. The scores given by the students on the practicality test sheet instrument stated that the renewable energy e-module integrated with the PBL model with smartphones was practically used in physics learning. First, the useful component consists of 5 indicators. Useful indicators consist of being useful for students to achieve learning goals, beneficial for students in learning better, beneficial for students to accelerate mastery of the material, beneficial for students in increasing creative thinking and communication skills, and beneficial for students in mastering renewable energy material. The value in average of the useful component is 83.85 in the category was very good. Second, the easy to use component consists of 5 indicators. The indicators are to make it more easy for students to learn renewable energy material, make it more easy for students to control learning activities, make it more easy for students to understand renewable energy material, make it more easy for students to increase creative thinking and communication skills, and make it more easy for students to learn renewable energy material with real-world situations. The value in average of the easy to use component is 81.28 in the category was very good.

The third component, namely appealing with an average of 86.56, is in the category was very good. The appealing component has 5 indicators. The indicators of the appealing component consist of attractive covers and templates, attractive composition of images and colors, proportionally sized titles of material and sub-material, linking learning material to the real world, and increasing creative thinking and communication skills. Fourth, the clear component analysis results with an average of 87.71 are in the category was very good. The results for data analysis show that the e-module is very clear in its presentation. Fifth, the cost effective component has 5 indicators. Cost effective component indicators consist of e-modules that do not require expensive costs, can be used repeatedly, are practical and easy to carry because they are stored on a smartphone, and can be used anytime and anywhere. The cost effective component data analysis results have a value in average of 92.13 in the category was very good. Sixth, the integrated PBL component with an average of 86.90 is category was very good. The results for data analysis show that the designed renewable energy e-module already integrates the PBL model. Based on the practicality results according to students, we got conclusion that the renewable energy e-module is integrated with the PBL model with practical smartphones for students to support the physics process of learning.

Discussion

There are two results achieved in this research, namely the validity and practicality results of the integrated renewable energy e-module PBL model with smartphones. The development of an integrated renewable energy e-module with the PBL model with smartphones based on a needs analysis found that the use of ICT was not optimal in teaching physics in schools. This is not relevan with the demands of the 21st century, because the science and technology development is a feature of the 21st century (Jayadi *et al*., 2020; Yeni *et al*., 2014). The creative thinking and communication skills of class X students at one of the public high schools in the city of Padang are low. The lack materials of teaching that contain creative thinking of students and communication skills is one of the triggers for this to happen. Materials of teaching such as e-modules are important to develop to increase creative thinking of students and communication skills (Almuharomah et al., 2019; Dona & Syafriani, 2022; M. A. F. Kurniawan et al., 2023). The first result achieved in the research is related to product validity. The product being developed is a renewable energy e-module integrated with the PBL model with a smartphone. Validity comes from the word validity which means validity or the way it should apply. Product validity is a process for testing the validity of products developed through the provision of assessments by several experts (Firmonia et al., 2020; W. S. S. J. Kurniawan, 2022). The assessment component in the validity instrument must be relevant and consistent with the theory used in the preparation of the e-module (Dona & Syafriani, 2022; Laili, 2019). The validity of e-modules was generally assessed by 3 experts by reviewing five components based on experts, namely material substance, visual communication display, learning design, use of software, and the integrated PBL model (Malina et al., 2021; Sukareni & Sukmana, 2021). E-module is said to be valid if it meets the standard value of the validation component. E-modules can be said to be valid if they meet the criteria of good or very good in the e-module component and are following learning indicators (Aryawan et al., 2018; Izhar et al., 2022). Based on the data it can be concluded that the validity of the product from the assessment given by experts is very good and the product can be used in optimizing the physics process of learning.

The two studies results are the practicality of integrated renewable energy e-modules with PBL models and smartphones. The practicality of the integrated renewable energy e-module PBL model with smartphones is assessed by product users, namely teachers and students. The instrument of practicality test consists of five components to measure the level of product practicality, namely useful, easy to use,

appealing, clear, cost effective, and integrated PBL model. The practicality instrument used is a practicality questionnaire for teachers and students. The practicality test is carried out by practicing the product in the field and asking product users to fill out a practicality questionnaire. Data analysis on the practicality questionnaire stated that the value of each component was in the category was very good. This is in accordance with the opinion (Mardian *et al*., 2022; Muhammad *et al*., 2022) that teaching material is said to be practical if the teaching material can be used easily by teachers and students in learning. The existence of real-world facts and problems presented in the e-module will make it easy for students to relate to learning contexts. This states that the smartphone-based integrated renewable energy e-module is practical for use in physics learning.

The results showed that the renewable energy e-module integrated with the PBL model with a smartphone can be used as a learning resource in physics learning. The PBL model integrated renewable energy e-module with smartphones has been tested for validity. This is also relevan with research was done by (Asrizal *et al*., 2022; Rismayanti *et al*., 2022; Simanjuntak & Budi, 2018) which states that valid e-modules can be used to support the process of learning. After being validated, the e-module is tested for practicality on e-module users, namely teachers and students (Muhammad *et al*., 2022; Widya *et al*., 2022). The research results stated that the renewable energy e-module integrated with the PBL model with a smartphone is valid and practical to use in the physics process of learning for class X SMA.

The research was done has findings, namely developing an integrated e-module PBL model with a smartphone to increase creative thinking of students and communication skills. The PBL model is integrated into the e-module in the worksheet to increase students' communication skills. The developed e-module has creative thinking exercises that aim to increase creative thinking of students skills. E-modules can be accessed via smartphones making it more easy for users to research anywhere and anytime. Perfect research results are things that are not easy to realize when carrying out research. The research was done has several limitations. The first limitation is that the developed e-module only contains material on renewable energy and its use. This is due to the researchers' limited time in developing the e-module, which is only one semester. The second limitation is that the research stages are carried out from validation tests to product practicality tests. This is due to the limited research time is very short.

4. CONCLUSION

Based on the research and discussion results, two conclusions can be put forward. First, the validity value of the renewable energy e-module integrated with the PBL model with smartphones is in the category was very good. The PBL model integrated renewable energy e-module with smartphones has 5 components. The validity component consists of material substance, visual communication display, learning design, use of software, and integrated PBL model which is in the category was very good. Second, the value of the practicality of the use of integrated renewable energy e-modules with the PBL model with smartphones according to teachers and students is in the category was very good. The PBL model integrated renewable energy e-module with smartphone has 6 components. The component of practicality consists of useful, easy to use, appealing, clear, cost effective, and integrated PBL models which are in the category was very good. Thus, it can be concluded that the renewable energy e-module integrated with the PBL model with smartphones is valid and practical to increase creative thinking of students and communication skills in optimizing physics learning.

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