JPPIPA 10(11) (2024)

Jurnal Penelitian Pendidikan IPA

Journal of Research in Science Education

http://jppipa.unram.ac.id/index.php/jppipa/index

Development of Global Warming E-Module Integrated with PBL Model and Ethnoscience to Promote Students' Environmental Literacy

Mutiara Nurul Fitri[1], Asrizal[1*], Rose Amnah[2], Hidayati[1], Emiliannur[1], Helma[3]

[1] Department of Physics, Mathematics and Natural Science Faculty, Universitas Negeri Padang, Padang, Indonesia.
[2] Department of Mathematics and Science Education, Faculty of Education, University Malaya, Malaysia, Malaysia.
[3] Department of Mathematics, Mathematics and Natural Science Faculty, Universitas Negeri Padang, Padang, Indonesia.

Received: September 03, 2024
Revised: October 13, 2024
Accepted: November 25, 2024
Published: November 30, 2024

Corresponding Author:
Asrizal
asrizal@fmipa.unp.ac.id

DOI: 10.29303/jppipa.v10i11.9059

Abstract: Information and communication technology (ICT) in the 21st century is experiencing rapid development in the field of education. Education in the 21st century requires students to master 21st century skills and themes. One of the themes that students must master is environmental literacy. Based on the initial study conducted, students' environmental literacy is still low. One of the solutions provided to support the improvement of environmental literacy is the development of global warming e-module integrated with problem based learning model and ethnoscience to promote students' environmental literacy. The purpose of the study was to investigate the validity and practicality of the e-module. Product development refers to the Hannafin and Peck research and development model. The technique used in data analysis is descriptive statistics. Based on data analysis, two research results were obtained. First, the validity test results were 91.8 with a very good category. Second, the results of practicality according to teachers and students are 95.7 and 85.2 in the excellent category. The results concluded that the global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy is valid and practical and can be used in supporting the physics learning process.

Keywords: E-module; Environmental literacy; Ethnoscience; PBL model

Introduction

The development of information and communication technology (ICT) in the 21st century has experienced very rapid development. The development of ICT in the 21st century has a huge impact in various fields, especially in the field of education (Widya et al., 2022) The rapid development of ICT has made changes in the world of education (Simanjuntak et al., 2018; Wang, 2022). Education in the 21st century requires students to have literacy skills, skills and attitudes, as well as mastery of technology (Asrizal et al., 2022; Asrizal & Utami, 2021; Mu'minah, 2021). Responding to the challenges of ICT development, students are required to have various 21st century skills.

The 21st century skills are essential to prepare learners for global challenges. The 21st century skills that must be mastered are critical thinking, creative, communication, and collaboration skills (Astuti et al., 2019; Kim et al., 2019; Santos, 2017). These skills play a central role in preparing individuals to face a dynamic future. 4C skills are very important in the 21st century, because the competition for human resources is increasingly fierce in mastering competencies. These competencies have not had a wide impact on students if

How to Cite:
Fitri, M. N., Asrizal, Amnah, R., Hidayati, Emiliannur, & Helma. (2024). Development of Global Warming E-Module Integrated with PBL Model and Ethnoscience to Promote Students' Environmental Literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8276–8289. https://doi.org/10.29303/jppipa.v10i11.9059

they are not accompanied by mastery of 21st century themes (Isnaeni et al., 2023).

The importance of the 21st century theme lies in its ability to prepare individuals for global challenges. According to the Partnership for 21st Century Skills, in addition to the 4C skills, the 21st century theme must also be mastered. The themes of the 21st century that must be mastered are global awareness, financial literacy, economics, business and entrepreneurship, awareness as citizens, health literacy, and environmental literacy (Baroya, 2018; Menggo, 2022). Mastery of the 21st century theme is very important for the success of students (Chairunnisak, 2020). Mastery of these themes aims to equip students with comprehensive insights so that they can understand and contribute to the solution of global problems. Therefore, the importance of mastering the theme of the 21st century in 21st century learning.

One of the important themes of the 21st century that must be mastered by students is environmental literacy. It is important for students in 21st century learning to master environmental literacy (Indriyani & Wahyuni, 2021; Sari et al., 2021). Environmental literacy aims to prepare students who have a deep understanding of environmental problems and can overcome environmental problems well (Ainin & Asafri, 2023; Kusumaningrum, 2020). This environmental literacy-oriented education will help create a generation that is more sensitive, proactive, and ready to face global environmental problems. Environmental literacy skills in students can also help in achieving the 4C skills (Sari et al., 2021). Therefore, the education curriculum must be able to adapt and ensure that the theme can be integrated effectively in the learning process in order to create competent human resources in facing global challenges.

The Independent curriculum is here to answer the challenges of fierce competition for human resources globally in the 21st century. The Independent curriculum provides relevant, innovative, and comprehensive learning. The Independent curriculum also focuses on developing students' competencies and skills in accordance with the needs of the 21st century (Nasution, 2021; Thana & Hanipah, 2023). According to the Ministry of Education and Culture, the characteristics of the Independent curriculum in the learning process are that it can develop soft skills and character of students, focus on essential material and delve into basic competencies in literacy and numeracy, differentiated learning according to students' abilities, and student-centered learning (Fajri & Andarwulan, 2023; Wiguna & Tristaningrat, 2021).

The Independent curriculum gives rise to new innovations in learning by utilizing the development of information and communication technology (ICT). The use of ICT in learning can be carried out by educators through infrastructure, tools, learning facilities, and teaching materials. An educator must understand and technology to deliver subject matter to students (Faux-Nightingale et al., 2022) of the uses of ICT in learning can be applied to teaching materials in the form of electronic modules or better known as e-module (Effendi & Wahidy, 2019). E-module as teaching materials play an important role in ensuring effective learning because they can help students who have difficulty understanding the lesson (Suastrawan et al., 2021; Wijaya & Vidianti, 2019).

E-module is the development of digital-based module arranged sequentially or systematically that can be used or accessed online so that students can use them independently anywhere and anytime (Sari et al., 2021). The advantage of the e-module is that the e-module is equipped with images, sounds, animations, videos, and questions that can be accessed using electronic devices. E-modules are also very practical, durable, and not susceptible to damage (Ardianto et al., 2024; Fujiarti et al., 2024). E-modules also support students' independence in learning and make learning more interesting and interactive (Cynthia et al., 2023; Noer et al., 2021; Suastrawan et al., 2021).

E-modules can be combined with learning models, methods, and approaches. The development of electronic module can be combined with learning models that can support more optimal student learning activities (Safitri et al., 2023; Yani et al., 2020). One of them is the problem based learning (PBL) model. PBL is a learning process that exposes students to real-life problems that they must solve and solve validly through group discussions (Buhungo et al., 2023; Putri et al., 2023). The use of the PBL model can make students learn independently. PBL leads to an independent learning process to solve a problem (Hidajat, 2023). Because in this PBL, students will be involved in the form of participation that they do, namely discussing, presenting, asking questions, and answering in the learning process (Haque & Nurbatra, 2023; Safitri et al., 2023)

E-module can also be combined with ethnoscience. Ethnoscience is a learning approach that links actual public knowledge with scientific knowledge. Ethnoscience is knowledge that is typical of a certain cultural group (Chibuye & Sen, 2024). Ethnoscience learning can be connected with the local culture and wisdom of the local environment. Learning with ethnoscience can also increase and have a positive influence on 21st century communality (Sari et al., 2023). Culturally or tradition-based learning is able to build the ability to collaborate, think critically, sense of nationality, socio-cultural awareness, leadership, concern for the environment, and curiosity (Hikmawati et al., 2020; Hikmawati et al., 2021).

The reality on the ground has not yet depicted ideal conditions. The results of an initial study conducted at State Senior High School Number 2 in Padang Panjang show that students' environmental literacy is still low. The average result of students' environmental literacy was 55.3 in the sufficient category. The value of students' environmental literacy from each indicator, namely in the cognitive indicator, was at 45.0 with the category of less. The results of the affective and behavioral indicators were at 60.4 with the sufficient category. These results show that students' environmental literacy is still low. Students' environmental literacy is still low for cognitive indicator components, enough to be good for attitude and behavior indicators (Siddiq et al., 2020; Susanti & Nupus, 2022; Yulianti & Kusumaningrum, 2021).

Another finding found in the field is that there are still students who are caught throwing garbage in the sewers, in flower gardens, and in flower pots. In addition, students also use two-wheeled vehicles to school on average. Of course, this will increase the amount of CO_2 produced. The use of various types of fossil fuels or BBM makes a major contribution to increasing the concentration of greenhouse gases, especially CO_2. It is one of the greenhouse gases that causes global warming (Pratama, 2019). This problem is related to environmental literacy in affective indicators and students' behavior towards the environment. According to data from the Central Bureau of Statistics (2018), Indonesia's environmental indifference index in 2018 was 0.51, indicating that indifference is quite high or awareness still shows a low number (Siddiq et al., 2020). This shows the problem that should be solved so that students' environmental literacy can increase.

Based on the ideal conditions and real conditions found in the field, there is a problem of low environmental literacy among students. An innovative solution to overcome this problem is to develop an integrated e-module of the PBL model with ethnoscience known as ethno-PBL to promote students' environmental literacy. The integration of PBL models in learning can help students to solve physics problems that are close to real life (Hayati & Asrizal, 2023). The PBL model also has an effect in improving environmental care attitudes and environmental literacy (Amin et al., 2020; Anggraini et al., 2022; Aufa et al., 2021). The use of ethnoscience-based module can develop students' attitudes towards environmental conversion (Utari et al., 2021). Ethnoscience-based learning can build environmental awareness in students (Rahman et al., 2023).

The novelty of the research compared to previous research. The novelty of the research is that the product developed is an electronic module (e-module) integrated with the PBL model, ethnoscience approach, and environmental literacy skills. Previous research has not developed by integrating the three. Previous research developed e-modules integrated with one or two of the three. Some have developed integrated PBL models, integrated ethnoscience, and environmental literacy only. No one has integrated the whole. This research will combine them into an integrated e-module. This research makes a new contribution in promote students' environmental literacy by combining technology, PBL models, and ethnoscience approaches, which have not been discussed in previous studies. So it can be concluded that the novelty of this research is the combined use of technology (e-module), learning model (PBL), and integration of local knowledge (ethnoscience) which are all focused on developing students' environmental literacy.

Researchers are interested in developing an integrated e-module of the PBL model with ethnoscience to promote students' environmental literacy at this time. This interest arises because research is carried out by integrating the PBL model with ethnoscience in modules that are digitally packaged through Canva and Heyzine software. The research aims to investigate the validity and practicality of the global warming e-module integrated with problem based learning model and ethnoscience to promote students' environmental literacy.

Method

The type of research is research and development or often called Research and Development (R&D). R&D has the aim of validating and developing new products, where validation means pre-existing products and development means updating existing products or creating new products (Sugiyono, 2019). The research and development model used is the Hannafin & Peck model which consists of three phases, namely the needs analysis, design, development and implementation phases. The first phase of this research is needs analysis. Activities carried out are related to the analysis of problems in the use of ICT in physics learning, problems in the use of teaching materials in physics learning, problems in the implementation of PBL and ethnosaisn models in learning, analysis of student characteristics, and analysis of student environmental literacy.

The second phase of this research is the design phase. The design that will be made e-module integrates the PBL model with ethnoscience. The material selected in this e-module is class X phase E material, namely global warming. Researchers designed the e-module using Canva and Heyzine flipbook. The structure of the e-module in this study is based on the practical guide for the preparation of learning e-module (Kemendikbud, 2017). The structure of the e-module developed is cover,

preface, table of contents, glossary, introduction, learning activities, evaluation, answers and scoring guidelines, bibliography, and appendices.

The third phase of this research is development and implementation. The e-module that has been designed is then validated by three FMIPA lecturers from the Department of Physics at Universitas Negeri Padang. E-modules that have been validated are improved if there are weaknesses and shortcomings in the e-modules. Improvements are made in accordance with the inputs submitted by the validators and after revision will be tested to teachers and students to find out the practicality of the e-module. More clearly, the Hannafin and Peck model can be seen in Figure 1.

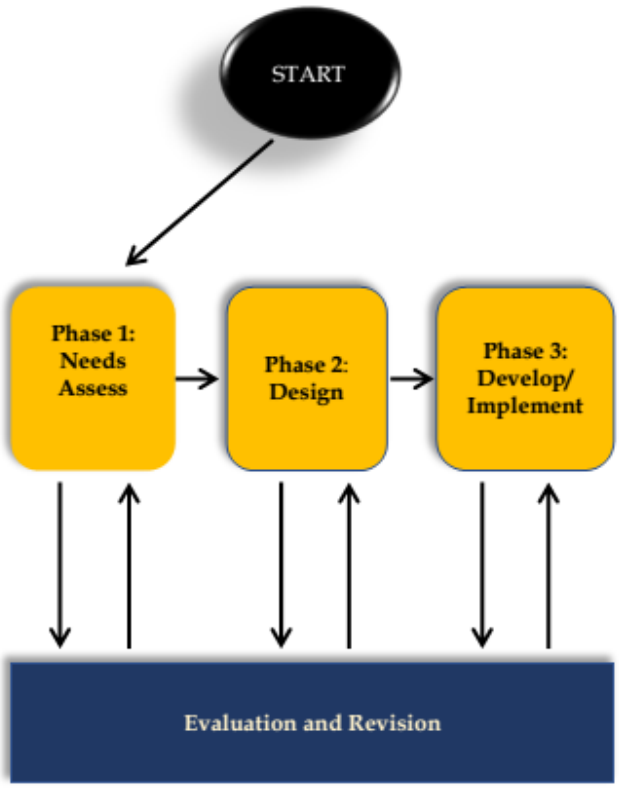

Figure 1. Hannafin and peck development model

The instruments used to collect data for this research are validity and practicality questionnaire instruments. The data analysis technique for validity and practicality is descriptive statistics. The data from the analysis is displayed in the form of a graph format. The validity questionnaire instrument consists of six components, namely the substance of the material, the design of learning, the display of visual communication, the use of software, the integration of the PBL model, and the integration of ethnoscience. The wide instrument of the practicality questionnaire is divided from seven components, namely benefits, ease of use, attractiveness, clarity, learning time efficiency, PBL model integration, and ethnoscience integration. Validity and practicality analysis can be obtained by dividing the value of the components obtained by the number of components and then multiplying by one hundred percent. The categories of validity and practicality of the e-modules are shown in Table 1.

Table 1. Criteria for Validity and Practicality of E-Module (Arikunto, 2015)

Interval (%)	Category
80-100	Very good
66-79	Good
56-65	Enough
40-55	Less
30-39	Fail

Result and Discussion

Result

This research is a continuation of the previous research and development stage at the needs analysis stage. The results of the research obtained after conducting a needs analysis are product designs. After the product is completed, the validity and practicality of the product is tested. So, the results obtained in this study are the results of the validity test and the practicality test results of the e-module. The product developed is global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy. E-module designed in accordance with the practical guidelines for the preparation of learning e-module (Kemendikbud, 2017). The structure of the e-module is cover, introduction, table of contents, glossary, introduction, learning activities, evaluation, answers and scoring guidelines, bibliography, and appendices. The e-module was created with the help of Canva and Heyzine applications. Overall, the e-module on global warming integrates with PBL model and ethnoscience to promote students' environmental literacy, incorporating both the PBL model and ethnoscience.

The global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy can be presented as attractively as possible so that it makes it easier and motivates students to learn physics anywhere and anytime. E-module is interesting because it is integrated with the PBL model, integrated with ethnoscience, and integrated with environmental literacy. Integrated e-module with the PBL model combine e-module with the syntax of the PBL model. Integrated e-module with ethnoscience combine e-modules with the local wisdom of West Sumatra. Integrated e-module with the environment combine e-module with cognitive, affective, and behavioral indicators of environmental literacy. The following is a display of the integrated global warming

e-module of the PBL model and ethnoscience to promote students' environmental literacy can be seen in Figure 2.

The global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy before being used, the validation stage is carried out so that the e-module used is valid. Validity is the process of giving an assessment by experts to test the validity or validity of a product (Firmonia et al., 2020). Validation is carried out using a validation instrument sheet. The assessment components in the validation instrument must be relevant and consistent in accordance with the theory used in the preparation of the e-module (Dona & Syafriani, 2022; Nazifah & Asrizal, 2022).

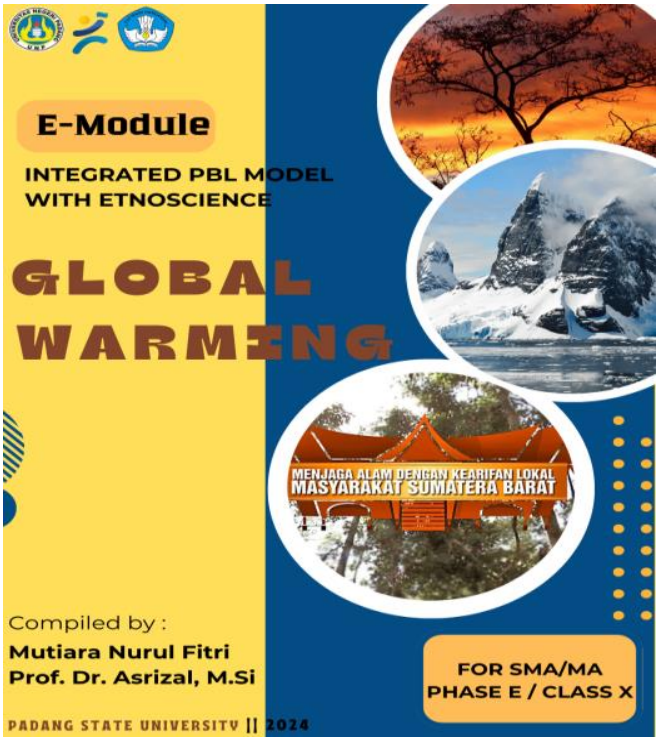

Figure 2. E-module cover

The global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy was validated by three physics lecturers at Universitas Negeri Padang. The validation results were obtained from product assessments by validators using the validation questionnaire instrument. The validation questionnaire instrument contains six components, namely material substance (MS), learning design (LD), visual communication display (VC), software utilization (SU), integrated PBL model (IM), and integrated ethnoscience (IE). The results of the analysis of the validity component can be seen in the Figure 3.

Based on the data analysis in Figure 3, it can be stated that the results of the product assessment carried out by experts through the substance components of the material, learning design, visual communication display, software utilization, PBL model integration, and ethnoscience integration as a whole are very good. The validation percentage on each indicator was obtained in the percentage range of 85.8 to 100.0. The highest percentage is in the ethnoscience integration component, which is 100.0 in the very good category. The lowest percentage in the software utilization component is 85.8. Despite the lowest presetanse, the software utilization component is still in the very good category.

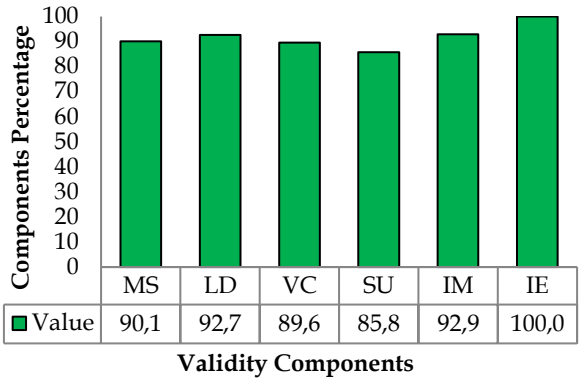

Figure 3. Results of validity components

The first validation component is the substance of the material. Material substance indicators consist of four indicators, namely truthfulness, depth, concency, and readability. The average percentage of material substance indicators provided by validators is 90.1, categorized as very good. The e-module that was made contained a very good substance of the material. The second component in the validation instrument is learning design. The components of the learning design consist of ten indicators, namely cover, introduction, table of contents, glossary, introduction (learning outcomes, learning objectives, time allocation, instructions for using e-modules, learning activities (KB) containing learning objectives, material descriptions, summaries, assignments, worksheets, exercises, and self-assessment), evaluation, answer keys and scoring, bibliography and appendices. The average percentage of learning design indicators given by validators is 92.8, which is categorized as very good. E-module made with a very good learning design.

The third component in the validation instrument is the visual communication display. The components of the visual communication display consist of six indicators, namely navigation, letters, media, color, video, and layout. The average percentage of visual communication display indicators given by validators is 89.6 in the very good category. The e-module that was made contained the visual communication display very well. The fourth component in the validation instrument

is the use of software. The software utilization component consists of three indicators, namely interactivity, the use of supporting software such as Canva, Microsoft Word, Heyzine, Google Form, and Google Drive, and originality. The average percentage of software utilization indicators given by validators is 85.8 in the very good category. The e-module that was created has made good use of the software.

The fifth component in the validation instrument is the integrated PBL model. The components of the PBL model are divided into five indicators, namely student orientation to problems, organizing students to learn, guiding individual or group investigations, developing and presenting work results, analyzing and evaluating the problem-solving process. The average percentage of PBL model integration indicators given by validators is 92.9 in the very good category. This means that the e-module made has been integrated with the PBL model. The sixth component of the validation instrument is the integration of ethnoscience. The ethnoscience component consists of seven indicators, namely Prohibited Forests, Tropical Rainforests, Nagari Forests, Prohibited Forests, Customary Forests, Andaleh Wood, and Forbidden Pool/Fish. The average percentage of ethnoscience penetration indicators given by validators is 100 in the very good category. The e-module are made to integrate ethnoscience very well.

The average percentage of the six components of the validation of the integrated global warming e-module of the PBL model with ethnoscience is 91.8. This means that the value of the validity of the integrated global warming e-module of the PBL model with ethnoscience validated by three experts or validators is in the category of very good or valid. E-modules can be said to be valid if they meet the criteria of good or very good in the components of the e-module (Izhar et al., 2022). Based on the validity results, the integrated global warming e-module of the PBL model with ethnoscience is valid and can be used to support the learning process. This is in line with research Syahputra et al. (2022) that valid e-module can be used to support the learning process.

After the validity test, the global warming e-module integrated with the PBL model and ethnoscience was tested for practicality. Practicality aims to see whether the developed product is practical to use in the learning process (Pakaya et al., 2023). The practicality test was conducted on teachers and students. The results of the analysis were obtained from the practicality questionnaire. The components of the practicality questionnaire according to teachers include usefulness (UF), ease of use (EU), attractiveness (AC), clarity (CL), learning time efficiency (TE), PBL model integration (MI), and ethnoscience integration (EI). The analysis of the practicality component according to the teacher can be seen in the Figure 4.

Based on Figure 4, it can be stated that the results of the assessment of the use of global warming e-module products integrated with the PBL model and ethnoscience assessed by teachers starting from the components of benefits, ease of use, attractiveness, clarity, time efficiency, integration of PBL models, and integration of ethnoscience are very practical. The percentage of practicality of each indicator is in the range of 91.7 to 100. The highest value is in the ethnoscience integration component, which is 100 with a very good practicality category. The lowest percentage was in the time efficiency component with a value of 91.7. Although the time efficiency component is the lowest value, the time efficiency component is still in the excellent practicality category.

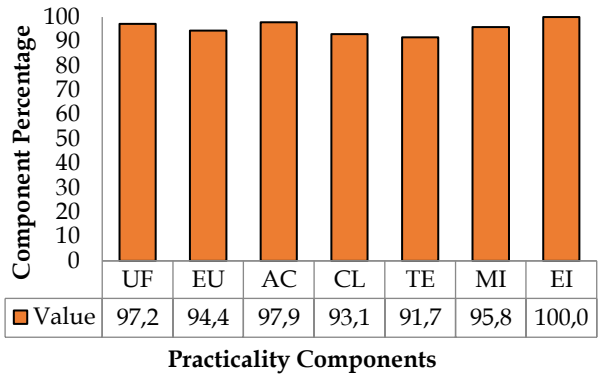

Figure 4. Practicality result according to teachers

The first component of practicality according to teachers is benefits. The benefits component has indicators, namely helping teachers to achieve learning objectives, being able to teach better, accelerating mastery of material, understanding material that is connected to daily life problems, knowing local wisdom that is in accordance with the material, and training students' environmental literacy. The average percentage of the benefit component indicator is 97.2 with a very good category. This shows that the global warming e-module integrated with the PBL model and ethnoscience is useful for teachers in the process of teaching physics material.

The second component on the instrument of the practicality test sheet according to the teacher is easy to use. The easy-to-use component has indicators, namely making it easier for teachers to teach global warming physics material, controlling student learning activities, linking material with real problems, introducing local wisdom, facilitating students' environmental literacy, and the ease of teachers in teaching global warming material. The average percentage on the ease component indicator is 94.4 in the excellent category. This shows

that the global warming e-module integrated with the PBL model and ethnoscience makes it easier for teachers to teach physics.

The third component on the instrument of the practicality test sheet is attractiveness. Indicators of the attractiveness component are attractive covers, attractive image and video compositions, attractive color combinations in content templates, attractive color combinations, interesting contexts, linking material to real world life, linking material to ethnoscience, and equipped with environmental literacy. The average percentage on the attractiveness component indicator is 97.9 in the excellent category. These results indicate that e-module is interesting to use in the learning process.

The fourth component on the instrument of the practicality test sheet is clarity. The clarity component is clear pictures and videos, clear learning objectives, clear commands, clear legible fonts, clear material, and clear activities and work instructions. The average percentage on the clarity component indicator is 93.1 in the excellent category. This shows that the global warming e-module integrated with the PBL model with ethnoscience is very clear in terms of presentation.

The fifth component on the instrument of the practicality test sheet is the efficiency of learning time. The learning time efficiency component is efficient learning time, learning at the student's pace, can be used repeatedly, quickly understanding the material, and saving learning time. The average percentage on the learning time efficiency component indicator is 91.7 in the excellent category. This shows that the global warming e-module integrated with the PBL model and ethnoscience can streamline learning time.

The sixth component on the instrument of the practicality test sheet is the integrated PBL model. The integrated components of the PBL model include learning activities using the PBL model, problems presented in accordance with the application in everyday life, instructions and instructions directed at students, guiding students in problem solving, facilitating the presentation of work, providing reflection for students, increasing student activeness, and guiding environmental literacy. The average percentage on the integrated indicators of the PBL model is 95.8 in the excellent category. This shows that the global warming e-module integrated PBL model and ethnoscience has integrated the PBL model well in the designed e-module.

The seventh component on the instrument of the practicality test sheet is integrated ethnoscience. The ethnoscience component includes connecting learning with local wisdom, introducing relevant local wisdom, encouraging students to appreciate local culture, motivating students to learn about local wisdom, encouraging students to find out about local wisdom, and encouraging students to learn local wisdom. The average percentage on the ethnoscience integrated indicator is 100 in the excellent category. This shows that the global warming e-module integrated PBL model with ethnoscience has integrated ethnoscience in the designed e-module.

The average percentage of the practicality component according to the teacher is 95.7. This means that the percentage given is in the excellent practicality category. The results of the value given by the teacher can be concluded that the practicality of the product from the teacher's point of view is already at a very good practicality. This shows that the product in the form of global warming e-module integrated PBL model with ethnoscience can be used in optimizing the physics learning process at school.

Practicality of global warming e-modul integrated with PBL model and ethnoscience according to students. The components of the practicality questionnaire according to students consist of usefulness (UF), ease of use (EU), attractiveness (AC), clarity (CL), learning time efficiency (TE), PBL model integration (MI), and ethnoscience integration (EI). The analysis of the practicality component according to the students can be seen in the Figure 5.

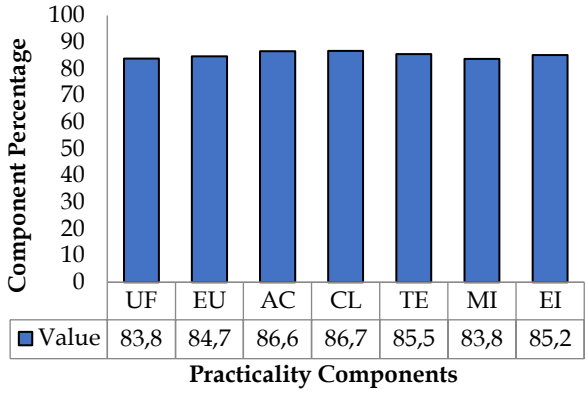

Figure 5. Practicality result according to students

Based on Figure 5, it can be described the results of the assessment of the use of global warming e-module products integrated with the PBL model and ethnoscience assessed by students. The percentage of practicality of each component is in the range of 83.8 to 86.7. The highest percentage is in the clarity component, which is 86.7 with a very good practicality category. The lowest percentage was on the integration of the PBL model with a percentage of 83.8. Although the PBL model integration component is the lowest value, the PBL model integration component is still in the excellent practicality category.

The first component on the instrument of the practicality test sheet according to students is the benefits. The benefits component has indicators that can

be used by students as a reference in learning, achieving learning objectives, motivating students in learning, efficient student learning time, increasing student independence in learning, helping students understand material that is connected to everyday life, helping students know local wisdom, and training students' environmental literacy. The average percentage of the benefits component is 83.8 in the excellent category. This shows that the global warming e-module integrated with the PBL model and ethnoscience is useful for students in the learning process.

The second component on the instrument of the practicality test sheet according to students is easy to use. The easy-to-use component has indicators, namely making it easier for students to understand the material, controlling learning activities, can be used by students anywhere and anytime, connecting material with life in the real world, knowing local wisdom, and training students' environmental literacy. The average percentage of easy-to-use components is 84.7 in the excellent category. This shows that the global warming e-module integrated with the PBL model and ethnoscience makes it easy for students in the learning process.

The third component on the instrument of the practicality test sheet according to students is attractiveness. The components of attractiveness include an attractive cover, interesting composition of images and videos and according to the material, interesting color combinations of content templates, interesting color combinations, interesting contexts to read, linking material with real world life, linking material with local wisdom and linking material with environmental literacy. The average percentage of the attractiveness component is 86.6 in the excellent category. This shows that the presentation of global warming e-module integrated with the PBL model and ethnoscience is interesting and can support student physics learning.

The fourth component on the instrument of the practicality test sheet according to students is clarity. The clarity component includes clear images and videos, clear learning objectives, clear commands, clear legible fonts, clear material, and clear activities and work instructions. The average percentage of the clarity component is 86.7 in the excellent category. This shows that the global warming e-module integrated with PBL model and ethnoscience is clear and can be used in physics learning.

The fifth component on the instrument of the practicality test sheet is the efficiency of learning time. The learning time efficiency component includes efficient learning time, learning according to ability, can be used repeatedly, quickly understanding the material, and saving learning time. The average percentage of the learning time efficiency component is 85.5 in the excellent category. This shows that the global warming e-module integrated with the PBL model and ethnoscience makes learning time efficient.

The sixth component on the instrument of the practicality test sheet is the integrated PBL model. The PBL component includes learning activities using the PBL model, the problems presented are in accordance with the application in everyday life, help identify problems, practice finding solutions to problems, practice making written ideas in solving problems, and practice making reports on solution activities. The average percentage of integrated components of the PBL model is 83.8 in the excellent category. This shows that the global warming e-module integrated with the PBL model and ethnoscience has integrated the PBL model in the e-module.

The seventh component on the instrument of the practicality test sheet is integrated ethnoscience. The ethnoscience component includes connecting learning with local wisdom, introducing relevant local wisdom, motivating learning local wisdom, encouraging finding out local wisdom, helping connect science and local wisdom, and encouraging learning local wisdom. The average percentage of ethnoscience integrated components is 85.2 in the excellent category. This shows that the global warming e-module integrated with the PBL model and ethnoscience has integrated ethnoscience in the e-module. The average percentage of the practicality component according to students is 85.2. This means that the percentage is in the excellent practicality category.

Discussion

The results achieved in this study were two in accordance with the research objectives. The two results are the results of the validity and practicality of the global warming e-module integrated with the PBL model with ethnoscience to promote students' environmental literacy. The first result achieved in this study is validity global warming e-module integrated with the PBL model with ethnoscience to promote students' environmental literacy. The validity of e-modules is reviewed from the components of material substance, visual communication display, software utilization, learning design, integrated PBL model, and integrated ethnoscience.

The validity of the developed product was tested by experts to obtain the validity level of the e-module. The results of data analysis from the validity questionnaire state that the value of each component is very good category. Based on the validity results, the integrated global warming e-module of the PBL model with ethnoscience is valid. A valid e-module can be used to support the learning process. Several previous studies have stated that valid e-modules can be used to support

the learning process (Asrizal et al., 2021; Triani & Asrizal, 2023; Syahputra & Mustika, 2022). So, the global warming e-module integrated with the PBL model with valid ethnoscience can be used and can optimize the learning process.

The second result of this research is the practicality of global warming e-module integrated with the PBL model with ethnoscience to promote students' environmental literacy. The results of the scores given by students can be concluded that the practicality of the product from the students' point of view is already at a very good practicality. This shows that the product in the form of global warming e-modules integrated with the PBL model and ethnoscience can be used to optimize the physics learning process. Practical e-module that can be used in the learning process (Erita, 2022; Yanto et al., 2023; Yusuf et al., 2024).

The results of data analysis from the practicality questionnaire stated that the value of each component was in the excellent category. Practicality refers to the condition of teaching materials developed that are attractive and easy to use by users (teachers and students) in the learning process under any conditions (Firmonia et al., 2020). Practicality refers to the condition where the developed learning module can be used easily by students so that learning becomes interesting, meaningful, fun, and valuable and can increase student creativity (Pakaya et al., 2023).

Based on the analysis of global warming e-module integrated with the problem-based learning model and ethnoscience to promote students' environmental literacy, the e-module is valid and practical with excellent category. The developed e-module can be used as support in the learning process. Previous research that supports the results of this study is that physics e-module integrated with PBL and ethnoscience models can improve students' 21st century skills (Fitri & Asrizal, 2023). E-module based on PBL can improve students' science process skills (Serevina et al., 2018). STEM-integrated PBL physics electronic module can improve students' critical thinking skills (Adhelacahya et al., 2023). Development of physics e-module based on PBL can improve higher order thinking skills (Pane et al., 2021).

Several other previous studies that support the results of this study. Research produced ethnoscience based e-module that are valid, practical, and effective in improving kayuh baimbai character and can be used in learning (Putri et al., 2023). Local wisdom-based e-modules can improve students' cultural and civic literacy (Latif & Talib, 2021). The development of ethnoscience integrated e-module can improve students' concept understanding (Puspaningrum et al., 2022). Ethnoscience based e-module are suitable for use in improving students' critical thinking skills (Fadilah et al., 2024). The use of PBL e-module based on wetland environment can improve students' critical thinking skills and environmental care attitudes (Aufa et al., 2021). The black soybean ethnoscience based integrated project-based learning module can improve students' science process skills (Anggrella & Sudrajat, 2024).

The results concluded that the global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy is valid and practical. E-module can be used in supporting the physics learning process (Abdullah et al., 2024; Asrizal et al., 2021; Daulay & Asrizal, 2024; Nazifah & Asrizal, 2022; Triani & Asrizal, 2023; Virijai & Asrizal, 2023). So that valid and practical e-modules can be used in the learning process and optimize students' physics learning process.

Conclusion

Based on data analysis, two research results were obtained. First, the validity test results were 91.8 with a very good category. E-modules with a very good validity level indicate that the teaching materials have been tested for feasibility and validity. Second, the results of practicality according to teachers and students are 95.7 and 85.2 in the excellent category. E-modules with a very good level of practicality indicate that digital teaching materials are easy and practical to use in the learning process. The results concluded that the global warming e-module integrated with PBL model and ethnoscience to promote students' environmental literacy is valid and practical and can be used in supporting the physics learning process.

Acknowledgments

Thank you to: First, the experts from the physics department at Universitas Negeri Padang for serving as validators during the validation test. Second, the principal and vice principal of State Senior High School Number 2 in Padang Panjang for granting permission to conduct the research. Third, the teachers and students of State Senior High School Number 2 in Padang Panjang for their participation as practitioners in the practicality test.

Author Contributions

M. N. F., contributed in conceptualizing the research idea, developing the product, collecting data, analyzing data, and writing the article. A., as a supervisor who managed the research activities from conceptualizing the research idea to writing, reviewing, and editing the article. R. A., H., and E., who have provided suggestions and input to the development of global warming e-modules integrated with the PBL model with ethnoscience in implementation of research. All authors have read and approved the published version of the manuscript.

Funding
This research did not receive any external funding.

Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this article.

References

Abdullah, Herdini, & Putri, T. S. (2024). Validity and Practicality of E-Module Based on Phenomenon Based Learning Using Articulate Storyline on Material Colligative Properties of Solutions. *Jurnal Penelitian Pendidikan IPA*, *10*(2), 764–775. https://doi.org/10.29303/jppipa.v10i2.5837

Adhelacahya, K., Sukarmin, S., & Sarwanto, S. (2023). Impact of Problem-Based Learning Electronics Module Integrated with STEM on Students' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(7), 4869–4878. https://doi.org/10.29303/jppipa.v9i7.3931

Ainin, D. T., & Asafri, H. (2023). Improving Environmental Literacy through Primary Education: Preparing Students as Environmental Advocates. *PPSDP: International Journal of Education*, *2*(Special Issue), 110–118. https://doi.org/10.59175/pijed.v2i2.114

Amin, S., Utaya, S., Bachri, S., Sumarni, & Susilo, S. (2020). Effect of Problem-Based Learning on Critical Thinking Skills and Environmental Attitude. *Journal for the Education of Gifted*, *8*(2), 743–755. https://doi.org/10.17478/jegys.650344

Anggraini, N., Nazip, K., Amizera, S., & Destiansari, E. (2022). Penerapan Model Problem Based Learning Berbasis STEM Menggunakan Bahan Ajar Realitas Lokal terhadap Literasi Lingkungan Mahasiswa. *BIOEDUSAINS: Jurnal Pendidikan Biologi dan Sains*, *5*(1), 121–129. https://doi.org/10.31539/bioedusains.v5i1.3589

Anggrella, D. P., & Sudrajat, A. K. (2024). Development of an Integrated Project-Based Learning Module Based on Black Soybean Ethnoscience to Improve Students' Science Process Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3038–3045. https://doi.org/10.29303/jppipa.v10i6.5855

Ardianto, W., Destiniar, & Mulbasari, A. S. (2024). Pengembangan E-Modul Bangun Ruang Kerucut Berbasis Etnomatematika Kelas V. *INNOVATIVE: Journal of Social Science Research*, *4*(4), 8469–8481. Retrieved from https://j-innovative.org/index.php/Innovative/article/view/10026

Arikunto, S. (2015). *Prosedur Penelitian: Suatu Pendekatan Praktik*. PT. Rineka Cipta.

Asrizal, A., & Utami, A. W. (2021). Effectiveness of Mechanical Wave Learning Material Based on ICT Integrated CTL to Improve Students Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *7*(4), 632–641. https://doi.org/10.29303/jppipa.v7i4.837

Asrizal, Desnita, & Darvina, Y. (2021). Analysis of Validity and Practicality Test of Physics Enrichment E-Book Based on CTL and Enviromental Factor. *Journal of Physics: Conference Series*, *1876*(1), 1–8. https://doi.org/10.1088/1742-6596/1876/1/012034

Asrizal, Yurnetti, & Usman, E. A. (2022). ICT Thematic Science Teaching Material With 5E Learning Cycle Model to Develop Students' 21st-Century Skills. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 61–72. https://doi.org/10.15294/jpii.v11i1.33764

Astuti, A. P., Aziz, A., Sumarti, S. S., & Bharati, D. A. L. (2019). Preparing 21st Century Teachers: Implementation of 4C Character's Pre-Service Teacher through Teaching Practice. *Journal of Physics: Conference Series*, 1–8. https://doi.org/10.1088/1742-6596/1233/1/012109

Aufa, M. N., Rusmansyah, R., Hasbie, M., Jaidie, A., & Yunita, A. (2021). The Effect of Using E-Module Model Problem Based Learning (PBL) Based on Wetland Environment on Critical Thinking Skills and Environmental Care Attitudes. *Jurnal Penelitian Pendidikan IPA*, *7*(3), 401–407. https://doi.org/10.29303/jppipa.v7i3.732

Baroya, E. H. (2018). Strategi Pembelajaran Abad 21. *As-Salam: Jurnal Ilmiah Ilmu-Ilmu Keislaman*, *I*(1), 101–115. Retrieved from https://journal.stai-yamisa.ac.id/index.php/assalam/article/view/28

Buhungo, T. J., Supartin, S., Arbie, A., Setiawan, D. G. E., Djou, A., & Yunus, M. (2023). Learning Tools Quality of Problem-Based Learning Model in Contextual Teaching and Learning Approach on Elasticity and Hooke's Law Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1092–1098. https://doi.org/10.29303/jppipa.v9i3.3127

Chairunnisak. (2020). Implementasi Pembelajaran Abad 21 di Indonesia. *Prosiding Seminar Nasional Teknologi Pendidikan Pascasarjana UNIMED*, 351–359. Retrieved from https://digilib.unimed.ac.id/id/eprint/38770/

Chibuye, B., & Sen, I. (2024). Integration of Local Knowledge in The Secondary School Chemistry Curriculum-A Few Examples of Ethno-Chemistry from Zambia. *Heliyon*, *10*(7), 1–15. https://doi.org/10.1016/j.heliyon.2024.e29174

Cynthia, C., Arafah, K., & Palloan, P. (2023). Development of Interactive Physics E-Module to Improve Critical Thinking Skills. *Jurnal Penelitian*

Pendidikan IPA, *9*(5), 3943–3952. https://doi.org/10.29303/jppipa.v9i5.2302

Daulay, H., & Asrizal. (2024). Design of Digital Teaching Material of Sustainable Lifestyle Theme Integrated Ethno-PjBL for Independent Curriculum Learning. *JPPIPA: Jurnal Penelitian Pendidikan IPA*, *10*(7), 3866–3879. https://doi.org/10.29303/jppipa.v10i7.8252

Dona, P., & Syafriani. (2022). Validitas E-modul Fisika Berbasis SETS (Science, Environment, Technology, and Society) untuk Meningkatkan Kemampuan Berpikir Kreatif Peserta Didik Kelas X SMA. *Jurnal Penelitian Pembelajaran Fisika*, *8*(2), 113–121. https://doi.org/10.24036/jppf.v8i2.115741

Effendi, D., & Wahidy, D. A. (2019). Pemanfaatan Teknologi dalam Proses Pembelajaran Menuju Pembelajaran Abad 21. *Prosiding Seminar Nasional Pendidikan Program Pascasarjana Universitas PGRI Palembang*, 125–129. Retrieved from https://jurnal.univpgri-palembang.ac.id/index.php/Prosidingpps/article/view/2977

Erita, S. (2022). Development of an E-Module for Learning Mathematics Based on a Scientific Approach to Help The Online Learning Process. *International Journal of Trends in Mathematics Education Research*, *5*(4), 411–416. https://doi.org/10.33122/ijtmer.v5i4.170

Fadilah, A. M., Muhlisin, A., & Ismawati, R. (2024). Development of an Ethnoscience-Based Integrated Science Module with RIAS Learning Model to Improve Students' Critical Thinking Ability. *Phenomenon: Jurnal Pendidikan MIPA*, *13*(2), 264–282. https://doi.org/10.21580/phen.2023.13.2.16931

Fajri, T. A. Al, & Andarwulan, T. (2023). Implementation of the Merdeka Curriculum in Indonesia: Challenges and Opportunity. *Journal of Educational Innovationn*, *10*(2), 204–212. Retrieved from https://erudio.ub.ac.id/index.php/erudio/article/view/634

Faux-Nightingale, A., Philp, F., Chadwick, D., Singh, B., & Pandyan, A. (2022). Available Tools to Evaluate Digital Health Literacy and Engagement with Ehealth Resources: A Scoping Review. *Heliyon*, *8*(8), 1–6. https://doi.org/10.1016/j.heliyon.2022.e10380

Firmonia, N. A., Asrizal, A., & Mufit, F. (2020). Pengembangan Bahan Ajar Fisika Materi Fluida Terintegrasi Literasi Baru dan Bencana untuk Meningkatkan Hasil Belajar Siswa Kelas XI. *Pillar of Physics Education*, *13*(1), 9–16. Retrieved from https://ejournal.unp.ac.id/students/index.php/pfis/article/view/8054

Fitri, A. D., & Asrizal. (2023). Development of Physics E-Module Integrated with PBL Model and Ethnoscience to Improve Students' 21st Century Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10610–10618. https://doi.org/10.29303/jppipa.v9i12.5877

Fujiarti, A., Meilania, D. K., Angraeni, M., & Umah, R. N. (2024). Literatur Review: Pengaruh Penggunaan E-Modul Terhadap Hasil Belajar Siswa Sekolah Dasar. *Jurnal Jendela Pendidikan*, *4*(01), 83–89. https://doi.org/10.57008/jjp.v4i01.694

Haque, M. R., & Nurbatra, L. H. (2023). The Use of Problem-Based Learning to Enhance Student Participation. *Edulingua: Jurnal Linguistics Terapan dan Pendidikan Bahasa Inggris*, *10*(2), 41–52. Retrieved from https://ejournal.unisnu.ac.id/JE/article/view/5037

Hayati, H. S., & Asrizal, A. (2023). Need Analysis to Develop Global Warming E-Module Integrated Problem Bases Learning Model to Improve Students' 21st Century Skills. *Physics Learning and Education*, *1*(2), 108–116. https://doi.org/10.24036/ple.v1i2.23

Hidajat, F. A. (2023). A Comparison Between Problem-Based Conventional Learning and Creative Problem-Based Learning on Self-Regulation Skills: Experimental Study. *Heliyon*, *9*(9), 1–12. https://doi.org/10.1016/j.heliyon.2023.e19512

Hikmawati, H., Suastra, I. W., & Pujani, N. M. (2020). Ethnoscience-Based Science Learning Model to Develop Critical Thinking Ability and Local Cultural Concern for Junior High School Students in Lombok. *Jurnal Penelitian Pendidikan IPA*, *7*(1), 60. https://doi.org/10.29303/jppipa.v7i1.530

Hikmawati, H., Suastra, I. W., Suma, K., Sudiatmika, A. A. I. A. R., & Rohani, R. (2021). Effect of Problem-Based Learning Integrated Local Wisdom on Student Hots and Scientific Attitude. *Jurnal Penelitian Pendidikan IPA*, *7*(Special Issue), 233–239. https://doi.org/10.29303/jppipa.v7ispecialissue.1118

Indriyani, S., & Wahyuni, E. (2021). Literasi Lingkungan dan Kesadaran Lingkungan: Potensi dan Tantangan dalam Pendidikan Abad 21. *Prosiding Seminar Nasional Pendidikan 2020*, 239–245. Retrieved from https://www.researchgate.net/publication/353016532_literasi_lingkungan_dan_kesadaran_lingkungan_potensi_dan_tantangan_dalam_pendidikan_abad_21

Isnaeni, C., Puspa, S., Nur, D., Rahayu, O., & Parhan, M. (2023). Transformasi Pendidikan Abad 21 dalam Merealisasikan Sumber Daya Manusia Unggul Menuju Indonesia Emas 2045. *Jurnal Basicedu*, *7*(5), 3309–3321.

https://doi.org/10.31004/basicedu.v7i5.5030

Izhar, G., Wardani, K., & Nugraha, N. K. (2022). The Development Enviromental Literacy Media Learning for Elementary School Student. *Journal of Innovation in Educational and Cultural Research*, *3*(3), 397–404. https://doi.org/10.46843/jiecr.v3i3.116

Kemendikbud. (2017). *Panduan Praktis Penyusunan E-Modul Pembelajaran*. Direktorat Pembinaan SMA, Ditjen Pendidikan Dasar dan Menengah.

Kim, S., Raza, M., & Seidman, E. (2019). Improving 21st-Century Teaching Skills: The Key to Effective 21st-Century Learners. *Research in Comparative and International Education*, *14*(1), 99–117. https://doi.org/10.1177/1745499919829214

Kusumaningrum, D. (2020). Pengembangan Environmental Literacy Instrument Ranah Kognitif untuk Siswa Sekolah Dasar di Kabupaten Malang. *JPDI (Jurnal Pendidikan Dasar Indonesia)*, *5*(2), 45–51. https://doi.org/10.26737/jpdi.v5i2.2204

Latif, N. S., & Talib, A. (2021). Development of Ethnomathematics E-Modules Based on Local Wisdom to Improve Students' Cultural and Civic Literacy. *International Conference on Educational Studies in Mathematics (ICoESM 2021)*, *611*(ICoESM 2021), 112–120. Retrieved from https://www.atlantis-press.com/proceedings/icoesm-21/125965711

Menggo, S. (2022). Strengthening 21st-Century Education Themes in ELT Material for ESP Students. *VELES: Voices of English Language Education Society*, *6*(1), 25–40. https://doi.org/10.29408/veles.v6i1.4979

Mu'minah, I. H. (2021). Studi Literatur: Pembelajaran Abad-21 Melalui Pendekatan STEAM (Science, Technology, Engineering, Art, and Mathematics) dalam Menyongsong Era Society 5.0. *Prosiding Seminar Nasional Pendidikan*, 584–594. Retrieved from https://prosiding.unma.ac.id/index.php/semnasfkip/article/view/654

Nasution, S. (2021). Assesment Kurikulum Merdeka Belajar di Sekolah Dasar. *Prosding Seminar Nasional Pendidikan Dasar*, *1*(1), 135–142. Retrieved from https://journal.mahesacenter.org/index.php/ppd/article/view/181

Nazifah, N., & Asrizal, A. (2022). Development of STEM Integrated Physics E-Modules to Improve 21st Century Skills of Students. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2078–2084. https://doi.org/10.29303/jppipa.v8i4.1820

Noer, A. M., Putri, E. N., Rery, R. U., Anwar, L., & Tarawi, O. (2021). The E-Module Development of Reaction Rate Based on Guided Inquiry as Independent Teaching Materials. *Journal of Physics: Conference Series*, *1806*(1). https://doi.org/10.1088/1742-6596/1806/1/012176

Pakaya, S. Y. C., Dama, L., Hamidun, M. S., Nusantari, E., Baderan, D. W. K., & Katili, A. S. (2023). Development of Problem-Based Learning Modules on Environmental Pollution Materials to Improve Student Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 7803–7809. https://doi.org/10.29303/jppipa.v9i10.4323

Pane, A. N., Andra, D., & Wayan Distrik, I. (2021). The Development Physics E-Module Based PBL-Integrated STEM to Improve Higher-Order Thinking Skills on Static Fluid Material. *Journal of Physics: Conference Series*, *1796*(1), 1–6. https://doi.org/10.1088/1742-6596/1796/1/012086

Pratama, R. (2019). Efek Rumah Kaca terhadap Bumi. *Buletin Utama Teknik*, *14*(2), 120–126. Retrieved from https://jurnal.uisu.ac.id/index.php/but/article/view/1096

Puspaningrum, A. K., Sumarni, W., & Sudarmin. (2022). Desain E-Modul Larutan Elektrolit-Nonelektrolit Multirepresentasi terintegrasi Etnosains untuk Meningkatkan Pemahaman Konsep. *Journal of Chemistry in Education*, *11*(1), 37–43. Retrieved from https://journal.unnes.ac.id/sju/index.php/chemined/article/view/48234

Putri, M. E., Ahda, Y., Anhar, A., & Putri, D. H. (2023). Effect of Problem-Based Learning Models and Prior Knowledge toward Critical Thinking Skills on Human Digestive and Circulatory System. *Jurnal Penelitian Pendidikan IPA*, *9*(5), 3905–3914. https://doi.org/10.29303/jppipa.v9i5.3697

Putri, M. R., Suryajaya, S., & Sholahuddin, A. (2023). Pengembangan E-Modul IPA Topik Getaran, Gelombang dan Bunyi Berbasis Etnosains untuk Meningkatkan Karakter Kayuh Baimbai. *Journal of Banua Science Education*, *3*(2), 85–97. https://doi.org/10.20527/jbse.v3i2.165

Rahman, A. A., Santosa, T. A., Nurtamam, M. E., Widoyo, H., & Rahman, A. (2023). Meta-Analysis: The Effect of Ethnoscience-Based Project Based Learning Model on Students' Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 611–620. https://doi.org/10.29303/jppipa.v9i9.4871

Safitri, R., Hadi, S., & Widiasih, W. (2023). Effect of the Problem Based Learning Model on the Students Motivation and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7310–7316. https://doi.org/10.29303/jppipa.v9i9.4772

Santos, J. M. (2017). 21st Century Learning Skills: A Challenge in Every Classroom. *Ijemr (International Journal of Emerging Multidisciplinary Research*, *1*(1),

31–35. https://doi.org/10.22662/ijemr.2017.1.1.031

Sari, E., Awal, R., Martalasari, M., & Pandia, D. A. (2023). Profil Literasi Lingkungan Peserta Didik SMAN 3 Adiwiyata dan SMAN 16 Non Adiwiyata di Rumbai. *Bio-Lectura: Jurnal Pendidikan Biologi*, *10*(2), 265–272. https://doi.org/10.31849/bl.v10i2.16272

Sari, I. R., Jufrida, J., Kurniawan, W., & Basuki, F. R. (2021). Pengembangan E-Modul Materi Suhu dan Kalor SMA Kelas XI Berbasis Ethnophysics. *Physics and Science Education Journal (PSEJ)*, *1*(1), 46–59. https://doi.org/10.30631/psej.v1i1.697

Sari, M., Afandi, & Marlina, R. (2021). Pentingnya Literasi Lingkungan dalam Pembelajaran Abad 21. *Prosiding Seminar Nasional Pendidikan 2020*, 685–689. Retrieved from https://www.researchgate.net/publication/353016105_pentingnya_literasi_lingkungan_dalam_pembelajaran_abad_21

Serevina, V., Sunaryo, S., Raihanati, R., Astra, I. M., & Sari, I. J. (2018). Development of E-Module Based on Problem Based Learning (PBL) on Heat and Temperature to Improve Student's Science Process Skill. *TOJET: The Turkish Online Journal of Educational Technolog, 17*(3), 26–36. Retrieved from https://typeset.io/papers/development-of-e-module-based-on-problem-based-learning-pbl-le7odjij6y

Siddiq, M. N., Supriatno, B., & Saefudin, S. (2020). Pengaruh Penerapan Problem Based Learning Terhadap Literasi Lingkungan Siswa SMP pada Materi Pencemaran Lingkungan. *Assimilation: Indonesian Journal of Biology Education*, *3*(1), 18–24. https://doi.org/10.17509/aijbe.v3i1.23369

Simanjuntak, B. R., Desnita, & Budi, E. (2018). The Development of Web-Based Instructional Media For Teaching Wave Physics on Android Mobile. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *4*(1), 1–10. https://doi.org/http://doi.org/10.21009/1

Suastrawan, K. E., Suardana, I. N., & Sudiatmika, A. A. I. A. R. (2021). The Effectiveness of Science E-Modules for Class VII Junior High Schools Based on Socioscientific Issues to Improve Students' Critical Thinking Skills. *Journal of Science Education Research*, *5*(2), 1–9. https://doi.org/10.21831/jser.v5i2.42877

Sugiyono, S. (2019). *Metode Penelitian Pendidikan (Pendekatan Kualitatif, Kuantitatif, dan R&D)*. Bandung: Alfabeta.

Susanti, W., & Nupus, D. H. (2022). Analisis Profil Literasi Lingkungan Siswa SMP pada Pembelajaran. *Report of Biological Education*, *3*(1), 11–16. https://doi.org/10.37150/rebion.v3i1.1608

Syahputra, H., & Mustika, D. (2022). Validitas Bahan E-Module Berbasis Android pada Operasi Count Fractional Kelas V SD. *IJoIS: Indonesian Journal of Islamic Studies*, *3*(2), 163–171. https://doi.org/10.59525/ijois.v3i2.114

Thana, P. M., & Hanipah, S. (2023). Kurikulum Merdeka: Transformasi Pendidikan SD untuk Menghadapi Tantangan Abad ke-21. *Prosiding Konferensi Ilmiah Dasar*, *4*, 281–288. Retrieved from http://prosiding.unipma.ac.id/index.php/KID

Triani, F., & Asrizal, A. (2023). Development of Basic Electronics E-Modules Integrated with Problem Solving Models to Improve Students' Mastery of Concepts and Creative Thinking. *Jurnal Penelitian Pendidikan IPA*, *9*(Special Issue), 88–94. https://doi.org/10.29303/jppipa.v9ispecialissue.5880

Utari, R., Andayani, Y., Savalas, L. R. T., & Anwar, Y. A. S. (2021). Pemanfaatan Hasil Pengembangan Modul Kimia Berbasis Etnosains untuk Menanamkan Sikap Konservasi Lingkungan di Sekolah MAN 2 Lombok Tengah. *Jurnal Pengabdian Magister Pendidikan IPA*, *4*(1), 92–97. https://doi.org/10.29303/jpmpi.v4i1.593

Virijai, F., & Asrizal, A. (2023). Development of Ethnophysics-Based Augmented Reality Assisted Digital Teaching Material for 21st Century Learning. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9200–9209. https://doi.org/10.29303/jppipa.v9i12.4583

Wang, X. (2022). An Overview of ICT and Educational Change: Development, Impacts, and Factors. *Journal of Contemporary Educational Research*, *6*(8), 1–8. https://doi.org/10.26689/jcer.v6i8.4191

Widya, W., Yusmanila, Y., Zaturrahmi, Z., & Ikhwan, K. (2022). Praktikalitas E-Module Berbasis Model Creative Problem Solving (CPS) untuk Materi Fluida Dinamis Terintegrasi Keterampilan Abad 21. *Edukatif: Jurnal Ilmu Pendidikan*, *4*(4), 5700–5707. https://doi.org/10.31004/edukatif.v4i4.3313

Wiguna, I. K. W., & Tristaningrat, M. A. N. (2021). Langkah Mempercepat Perkembangan Kurikulum Merdeka Belajar. *EDUKASI : Jurnal Pendidikan Dasar*, *3*(1), 17–26. https://doi.org/10.55115/edukasi.v3i1.2296

Wijaya, J. E., & Vidianti, A. (2019). The Effectiveness of Using Interactive Electronic Modules on Student Learning Outcomes in Education Innovation Course. *ICOPE: International Conference on Progressive Education*, *422*, 86–89. https://doi.org/10.2991/assehr.k.200323.096

Yani, Y. P., Hardeli, H., Oktavia, B., & Kurniawati, D. (2020). Development of an Integrated E-Module of Scientific Literacy and Video Demonstration Using a Problem-Based Learning Model for High School Students on Acids and Bases. *Jurnal Penelitian*

Pendidikan IPA, *8*(2), 452–462. https://doi.org/10.29303/jppipa.v8i2.1306

Yanto, F., Diliarosta, S., Azhar, A., Primasari, M., & Syukri, D. (2023). Development of Science Learning E-Modules Using the PBL Model eith Ethnoscience Approach. *Journal for Re Attach Therapy and Developmental Diversities*, *6*(9s), 1070–1079. https://doi.org/10.33394/jp.v10i2.7130

Yulianti, V., & Kusumaningrum, D. (2021). Analisis Keterampilan Literasi Lingkungan Siswa SD di Kecamatan Turen Tahun Pelajaran 2019/2020. *Primary Education Journal*, *1*(1), 10–20. https://doi.org/10.33379/primed.v1i1.694

Yusuf, F. M., Solang, M., Latjompoh, M., Katili, A. S., Ibrahim, M., & Pobela, W. S. (2024). The Practicality of E-Modules Based on Problem-Based Learning (PBL) on The Human Respiratory System in Class XI (Senior High School 1 Tilango). *IJSRA: International Journal of Science and Research Archive*, *12*(2), 1316–1320. https://doi.org/10.30574/ijsra.2024.12.2.1382