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Development of Interactive Physics E-Modules Based on Guided Inquiry on the Material of the Nature of Physics and Occupational Safety for High School Students

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Abstract: The advancement of digital technology in education demands the availability of teaching materials that facilitate independent, interactive, and student-centered learning. In line with the implementation of the Independent Curriculum, the use of digital learning media is an alternative to increase student engagement in the physics learning process, which has traditionally been considered abstract and difficult to understand. This study aims to develop an interactive physics e-module based on guided inquiry on the Nature of Physics and Occupational Safety and to determine its level of validity, practicality, and effectiveness. The study used the Research and Development (R&D) method with a 4D model that includes the define, design, develop, and disseminate stages. The study was conducted at SMA Negeri 8 Jambi City with 35 students of grade X Phase E as subjects. The research instruments were validation sheets from material experts and media experts, questionnaires on teacher and student practicality, and questionnaires on student effectiveness. Data were analyzed descriptively quantitatively using percentages. The results showed that the e-module obtained a very good level of validity with a percentage of validation from material experts of 81.95% and media experts of 89.00%. The practicality level obtained a percentage of 94.7% based on teacher assessments and 87.3% based on student assessments. The effectiveness level reached 89.3%. These results indicate that the interactive physics e-module based on guided inquiry developed meets the criteria of validity, practicality, and effectiveness, making it suitable for use as a learning medium to support the implementation of the Independent Curriculum

Keywords: Attached Growth; Climate Change; Education Learning; Rotating Physics.

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Introduction

Physics education plays a crucial role in shaping students' ability to think scientifically, logically, and critically about the natural phenomena around them. Through physics learning, students are expected to understand scientific concepts, laws, and principles and relate them to natural phenomena and everyday life (Damanik, 2022). Conceptual understanding is at the heart of physics learning because it enables students to rationally explain phenomena, interpret the meaning behind symbols, and connect various concepts in an integrated manner (Ristiani et al., 2025). Therefore, the success of physics learning is measured not only by the ability to complete mathematical calculations but also by the ability to apply concepts contextually and meaningfully (Jumran, 2023).

The implementation of the Independent Curriculum through Minister of Education, Culture, Research, and Technology Regulation Number 12 of 2024 emphasizes student-centered learning, character

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development, scientific reasoning, and critical thinking skills. In the High School Physics Learning Outcomes (CP), students are expected to comprehensively understand physics concepts while developing curiosity and concern for the environment (BSKAP, 2024). To achieve these goals, teachers are required to develop creative, contextual, and student-centered learning.

However, the reality of physics learning in schools still shows various limitations. Based on observations and interviews at SMAN 8 Jambi City, learning is still dominated by the use of textbooks and conventional worksheets, while the use of digital media is still limited. The results of a needs analysis carried out on 35 class Apart from that, 77.1% of students stated that physics learning was still dominated by the lecture method and the use of conventional LKPD. The use of e-modules for the Nature of Physics and Occupational Safety materials has also never been implemented. This condition causes students to tend to view physics as a difficult, abstract subject, and less relevant to everyday life. The results of a needs analysis of 10th grade students showed that most students wanted digital learning media that were interesting, interactive, and easily accessible. In addition, students assessed that guided inquiry-based e-modules could help them better understand the relationship between physics concepts and real-world phenomena.

One approach that can support active learning as required by the Independent Curriculum is guided inquiry. Guided Inquiry is a learning model that places students at the center of learning through directed scientific investigation activities. In this model the teacher acts as a facilitator who provides guidance through guiding questions so that students can discover concepts independently. According to Pedaste et al. (2015), the inquiry stage includes problem orientation, hypothesis formulation, data collection, data analysis, and drawing conclusions. This approach provides students with the opportunity to discover concepts through an investigative process, guided by the teacher as a facilitator. Prasetiyo and Rosy (2021) stated that inquiry learning can train students to formulate questions and solve problems based on their curiosity. Sarifah and Nurita (2023) also emphasized that the guided inquiry model can foster critical thinking skills and student responsibility. Furthermore, Aiman and Meilani (2021) found that the guided inquiry approach significantly improved students' scientific literacy compared to direct learning. These findings are supported by Waode (2023), who stated that guided inquiry learning can improve scientific thinking skills through students' active involvement in the exploration and discovery of concepts.

The integration of the Guided Inquiry model into interactive e-modules allows students to carry out a systematic inquiry process through the available digital features. The presentation of contextual phenomena, learning videos, investigative questions, and reflection activities in e-modules can support each stage of inquiry so that the knowledge construction process takes place more effectively than using conventional teaching materials.On the other hand, developments in educational technology are encouraging the use of digital media in learning. One potential medium is interactive e-modules. Ermawan (2024) stated that e-modules enable students to learn flexibly anytime and anywhere. Maharani (2025) added that the use of videos, animations, and interactive exercises in e-modules can increase student engagement and help them understand abstract concepts. Furthermore, interactive e-modules are considered to support the implementation of the Independent Curriculum because they facilitate independent learning and strengthen students' scientific literacy (Muyassarah et al., 2024).

Although various studies have demonstrated the effectiveness of both guided inquiry approaches and interactive e-modules separately, research integrating the two in developing physics e-modules for the Nature of Physics and Occupational Safety topic remains limited. Most studies focus on the effectiveness of learning models or learning media separately, without combining guided inquiry approaches with digital interactive features in a single learning product. Material on the Nature of Physics and Laboratory Work Safety contains various conceptual and procedural concepts that require visualization and contextual examples. Therefore, presentation in the form of interactive e-modules is considered more appropriate because it is able to integrate text, images, videos, animations and interactive exercises which can help students understand concepts in more depth and increase awareness of laboratory work safety procedures. However, integrating the two has the potential to create a more active, contextual learning experience that is tailored to the characteristics of learners in the digital age.

Based on these conditions, there are three research gaps that need attention, namely: (1) physics learning media in schools are still dominated by printed teaching materials and have not utilized digital e-modules optimally; (2) the guided inquiry approach has been proven effective, but has not been widely applied in the development of e-modules based on the Independent Curriculum; and (3) the development of physics e-modules that integrate digital interactivity with a guided inquiry approach on the Nature of Physics and Occupational Safety is still very limited. Therefore, this study aims to develop a Guided Inquiry-Based Interactive Physics E-Module on the Nature of Physics and Occupational Safety for High School Students. The

product developed is expected to be an interesting, contextual learning medium, and in accordance with the principles of the Independent Curriculum and support improving the quality of physics learning in secondary schools.

Method

Development Procedure

This research is a research and development (R&D) that aims to produce an interactive physics e-module based on guided inquiry on the Nature of Physics and Occupational Safety for high school students. The research was conducted at SMA Negeri 8 Jambi City with 35 students of class X Phase E as research subjects. The development model used is the 4D model (Four-D Model) which consists of four stages, namely Define, Design, Develop and Disseminate. The research stages carried out systematically can be seen in Figure 1.

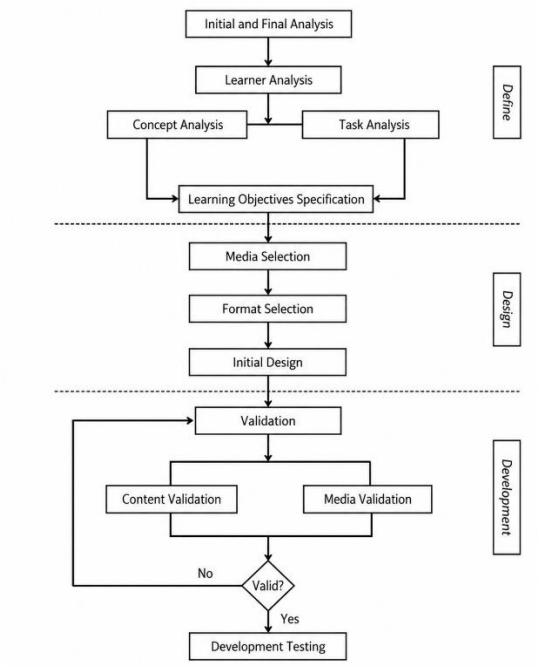

Figure 1. 4D Model Development Procedure

1. The define stage is conducted to analyze the needs, characteristics of students, the curriculum, and learning materials.
2. The design stage involves designing the structure, appearance, and content of the e-module.
3. The develop stage involves product development, validation by subject matter and media experts, product revision, and student trials.
4. The disseminate stage is the stage of disseminating the developed product.

The research instruments used in developing this Guided Inquiry-based interactive e-module consist of several types of instruments adapted to the research objectives. The instrument includes a material expert validation sheet which is used to assess the suitability of the content, language, presentation, and relevance of the material to the Guided Inquiry syntax; media expert validation sheet used to evaluate media display, design, navigation and technical aspects; teacher practicality questionnaire to determine the ease of using e-modules in the learning process; student practicality questionnaire to measure the level of ease of use, readability and clarity of the material presented; and an effectiveness questionnaire used to determine the level of usefulness of e-modules in supporting the learning process. All research instruments were prepared using a four-level Likert scale, namely very good, good, not so good and not good. This scale is used to obtain quantitative data regarding the level of validity, practicality and effectiveness of the product being developed so that it can be used as a basis for determining the suitability of e-modules as a physics learning medium.

An effectiveness questionnaire is given to students after using the e-module. The questionnaire consists of three assessment aspects, namely aspects of appearance, presentation of material, and benefits of using e-modules. Each aspect is measured using positive statements with a Likert scale of 1–4. The assessment results are then analyzed using percentages to determine the level of effectiveness of the product being developed.

Result and Discussion

Define

The definition phase aims to identify learning needs and problems as a basis for developing interactive e-modules. This phase includes a pre-post analysis, student analysis, task analysis, concept analysis, and specification of learning objectives. The initial analysis results indicate that physics learning at SMA Negeri 8 in Jambi City has implemented the Independent Curriculum, supported by media such as PPT, LKPD, and learning videos. However, there is no interactive e-module available to support independent and interactive learning. Furthermore, students still have difficulty connecting everyday life phenomena with the physics concepts they are learning.

Analysis of student characteristics shows that students have fairly good initial abilities and are accustomed to using digital technology, but are more interested in visual, interactive, and contextual learning media. This condition indicates that the development of digital media based on guided inquiry is in accordance with student learning needs. Task analysis produces learning activities in the form of observation of

phenomena, analysis of case studies, discussions, answering guiding questions, and drawing conclusions. Meanwhile, concept analysis maps the material on the Nature of Physics, which includes physics as a product, process, and scientific attitude, as well as material on Laboratory Work Safety, which includes safety rules, hazard symbols, and personal protective equipment.

Based on the analysis, learning objectives were formulated to enable students to understand the nature of physics and laboratory safety, relate everyday phenomena to physics concepts, and apply scientific thinking through a guided inquiry approach. The results of this define stage served as the basis for designing the interactive e-module.

Design

The design phase aims to transform the results of the needs analysis into an initial design for an interactive e-module. This phase includes instrument design, media selection, format selection, and interactive feature design. Evaluation instruments are designed according to Learning Outcomes (CP) and Learning Objectives (TP) to measure conceptual understanding and support student inquiry activities. Based on student characteristics and school conditions, the chosen media is a flipbook-based interactive e-module because it is easily accessible via smartphones or laptops and is able to integrate various multimedia elements such as images, videos, animations, and interactive navigation.

The e-module format is structured following the syntax of guided inquiry, which includes problem formulation, hypothesis formulation, information collection, hypothesis testing, and conclusion drawing. The e-module structure consists of a cover page, main menu, user manual, concept map, learning activities, evaluation, glossary, bibliography, and developer profile. The design results produce a storyboard and e-module interface equipped with interactive navigation features, contextual materials, supporting videos, inquiry-based activities, and evaluation in the form of a QR Code-based educational game through the Wordwall platform. This design is then used as the basis for product development in the next stage.

The development of the interactive e-module in this study was designed by integrating all stages of the Guided Inquiry model into the learning activities presented. The problem-orientation stage is realized through the presentation of contextual physics phenomena in the form of images, videos, and illustrations, aimed at arousing students' curiosity about the material being studied. Next, students are guided to formulate problems through provocative questions formulated based on the observed phenomena. In the hypothesis formulation stage, students are given the opportunity to put forward tentative conjectures as predictions regarding the problem being studied.

The data collection stage is facilitated through the provision of learning materials, supporting videos, additional information sources, and exploratory activities that enable students to obtain relevant information to address the proposed problems. The information obtained is then used in the hypothesis testing stage through various investigative activities, discussions, exercises, and case analyses provided in the e-module. The results of this analysis then serve as the basis for students to draw conclusions based on the evidence and data gathered during the learning process.

The systematic application of Guided Inquiry syntax in this e-module aims to create a student-centered learning experience while encouraging their active involvement in the knowledge construction process. Through these stages, students not only gain a conceptual understanding of the Nature of Physics and Laboratory Safety but also develop critical thinking, problem-solving, and scientific skills required in the implementation of the Independent Curriculum.

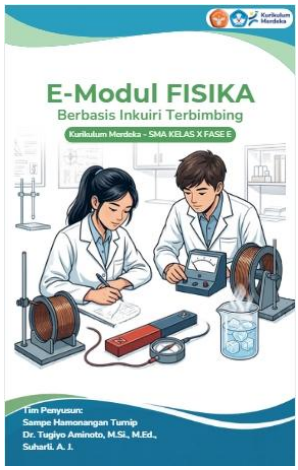

Figure 2. Module Cover

Figure 3. Main Menu Page

Develop

Material Expert Validation

Material validation was conducted by a material expert from the Physics Education Study Program at the University of Jambi. The validation activity aimed to assess the appropriateness of the content, the suitability of the material, and the quality of the presentation of the developed e-module. The results of the material expert's assessment are presented in Table 1 and Figure 4.

Table 1. Data from the Results of the Subject Matter Expert Validation Questionnaire

Aspect	Average	Category
Curriculum	83,3%	Very Valid
Material	80,0%	Valid
Grammar	76,7%	Valid
Evaluation	86,7%	Very Valid
Guided Inquiry	85,0%	Very Valid
Media and Presentation	80,0%	Valid
% Average	**81,95%**	**Very Valid**

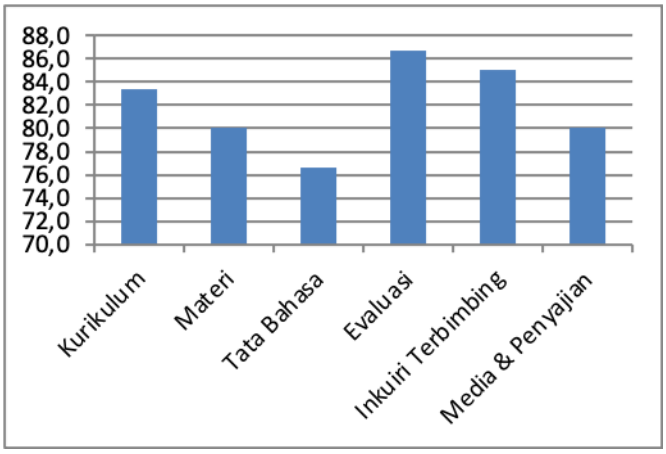

Figure 4. Graph of Material Expert Validation Results

The results of the validation by material experts indicate that the developed e-module has met the standards of content suitability and conformity with the applicable curriculum, with an overall average of 81.95%, which is included in the very valid category. In more detail, the aspects of curriculum, evaluation, and guided inquiry received very high scores, indicating that the e-module is aligned with learning outcomes and is able to encourage students' scientific thinking processes. Meanwhile, aspects of material, grammar, and media and presentation are in the valid category, which indicates that there is still room for improvement, especially in the clarity of wording and strengthening the presentation of concepts for easier understanding. Overall, these results indicate that the e-module is suitable for use in terms of scientific substance, but can still be refined in the aspects of language and presentation to be more optimal in supporting the learning process.

Media Expert Validation

Media validation aims to assess the quality of the appearance, design, navigation, and technical aspects of the developed e-module. The results of the media expert validation are presented in Table 2 and Figure 5.

Table 2. Media Expert Validation Questionnaire Results Data

Aspect	Average	Category
Cover View	88,0%	Very Valid
Technical	90,0%	Very Valid
% Average	**89,00%**	**Very Valid**

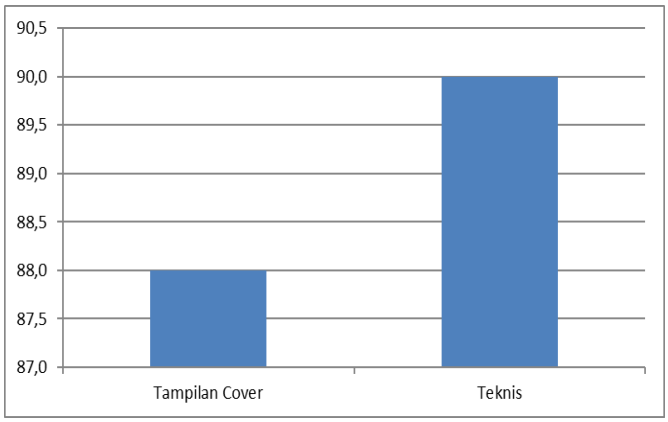

Figure 5. Media Expert Validation Results Graph

The results of media expert validation show that the e-module has excellent design quality and technical aspects with an average of 89.00% in the very valid category. The cover display and technical aspects received high ratings, indicating that the visual design, layout, and navigation of the e-module are attractive and easy to use by users. This is important because the media aspect plays a role in increasing learning comfort and student engagement when using the e-module. With these results, it can be concluded that visually and technically the e-module is suitable for use without significant obstacles, and is able to support the achievement of learning objectives through a more interactive and interesting presentation.

Teacher Practicality Level

A practicality test was conducted by physics teachers to determine the level of ease of use of the e-module in the learning process. The practicality assessment included aspects of content suitability, language use, appearance, and completeness of the e-module components. The results of the teachers' practicality assessment are presented in Table 3 and Figure 6.

Table 3. Data from the Teacher Practicality Level Questionnaire

Aspect	Average	Category
Content Eligibility	86,7%	Very Valid
Use of Language	93,3%	Very Valid
Appearance	100,0%	Very Valid
Component Completeness	96,7%	Very Valid
% Average	**94,7%**	Very Valid

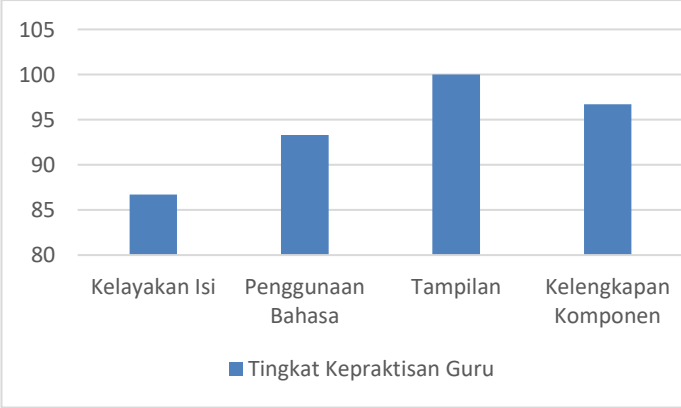

Figure 6. Graph of Teacher Practicality Level Results

The results of the practicality test by teachers indicate that the e-module is very practical to use in the learning process with an average of 94.7% in the very valid category. The high scores in all aspects, especially the display and use of language, indicate that the e-module is easy to understand, systematic, and does not present difficulties for teachers in the classroom implementation process. In addition, the completeness of the components that are rated very high indicates that the e-module has fully provided all learning needs so that it can be used directly without much modification. This shows that the e-module is not only appropriate in content, but also practically effective in supporting the teacher's role as a learning facilitator.

Level of Student Effectiveness

An effectiveness test was conducted on students to determine the effectiveness of the developed e-module in supporting the learning process. The effectiveness assessment included aspects of the e-module's appearance, material presentation, and benefits for students. The results of the student effectiveness assessment are presented in Table 4 and Figure 7.

The results of the student effectiveness test indicate that the e-module has a high level of effectiveness in supporting the learning process with an average of 89.3% in the very valid category. The material presentation aspect received the highest score, indicating that the material was delivered coherently and easily understood, thus helping students in building conceptual understanding. In addition, the appearance and benefits aspects also received the very good category, indicating that the e-module was able to attract learning interest and provide a meaningful learning experience. Thus, the e-module not only functions as a source of information, but also as a medium that supports increasing student understanding and learning motivation.

Table 4. Data from the Questionnaire Results on the Level of Student Effectiveness

Aspect	Average	Category
Appearance	87,3%	Very Valid
Presentation of Material	90,7%	Very Valid
Benefit	90,0%	Very Valid
% Average	**89,3%**	Very Valid

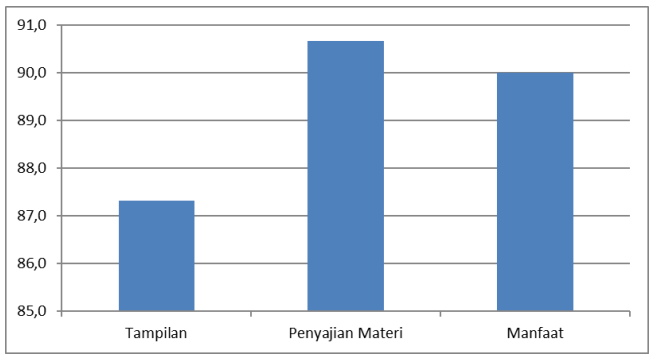

Figure 7. Graph of Results of Student Effectiveness Level

Student Practicality Level

A practicality test was conducted with students to determine the level of ease of use of the e-module in learning activities. The practicality assessment included aspects of appearance, language readability, ease of use, material clarity, and learning activities contained within the e-module. The results of the practicality assessment are presented in Table 5 and Figure 8.

Table 5. Data from the Questionnaire Results on the Level of Student Practicality

Aspect	Average	Category
Appearance	85,3%	Very Valid
Language Readability	87,4%	Very Valid
Ease of Use	87,8%	Very Valid
Clarity of Material and Activities	88,2%	Very Valid
% Average	**87,3%**	Very Valid

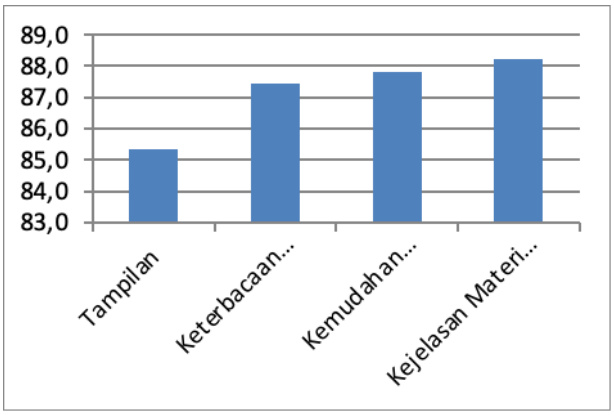

Figure 8. Graph of Results of Students' Practicality Level

The results of the student practicality test showed that the e-module was easy to use and understand in learning activities with an average of 87.3% in the very valid category. The aspects of ease of use and clarity of material received high scores, indicating that students did not experience difficulties in accessing or understanding the contents of the e-module. In addition, the readability of the language and learning activities presented were also considered very good, indicating that the e-module was designed according to the developmental level of students. Overall, this shows that the e-module is practical, communicative, and able to support student learning independence more effectively.

Disseminate

The dissemination stage is the dissemination stage of a product that has been declared valid, practical, and effective based on expert validation and student trials. At this stage, the interactive physics e-module based on guided inquiry was introduced and disseminated on a limited basis to physics teachers and students at SMA Negeri 8 Jambi City as the primary users of the product. Dissemination was carried out by providing access to the e-module in digital form so that it could be used as a learning medium for the Nature of Physics and Occupational Safety materials. In addition, the development results were also conveyed to physics teachers as consideration in the use of digital learning media that support the implementation of the Independent Curriculum. The dissemination stage aims to introduce the developed product to users and obtain input for further development. Although dissemination is still carried out on a limited scale, research results indicate that the developed e-module has the potential to be implemented in other schools with similar student characteristics.

Conclusion

Based on the results of the research and development that has been carried out, a product was obtained in the form of an interactive physics e-module based on guided inquiry on the material of the Nature of Physics and Occupational Safety for high school students. The development was carried out using a 4D model that includes the stages of define, design, develop, and disseminate. The results of the validation by material experts showed a percentage of 81.95% with a very valid category, while the validation by media experts obtained a percentage of 89.00% with a very valid category. The results of the practicality test by teachers obtained a percentage of 94.7% with a very valid category, while the practicality test by students obtained a percentage of 87.3% with a very valid category. In addition, the results of the effectiveness test by students showed a percentage of 89.3% with a very valid category. Based on these results, it can be concluded that the interactive physics e-module based on guided inquiry that was developed meets the criteria of validity, practicality, and effectiveness so that it is suitable for use as a learning medium on the material of the Nature of Physics and Occupational Safety to support the implementation of the Independent Curriculum and increase student involvement in the physics learning process.

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