Development of e-Module for Independent Learning of Physics Material Based on Independent Curriculum

Najmi Asfiya, Pakhrur Razi*, Hidayati, and Silvi Yulia Sari

Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Padang, Indonesia
Email: najmiasfya@gmail.com (N.A.); fhrrazi@fmipa.unp.ac.id (P.R.); hidayati@fmipa.unp.ac.id (H.); silviyuliasari@fmipa.unp.ac.id (S.Y.S.)
*Corresponding author

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***Abstract*—Independent curricula are implemented to create a pleasant education and to liberate students from excessive dependence on traditional teaching methods of an instructive nature. The independent learning of the students becomes the main focus of this curriculum. Therefore, there is a need for supporting material. It does not only provides material, but it can also contribute to increasing the students' learning independence. However, the teaching material from the existing physics materials have not supported independent learning and have not been properly displayed. The research aims to develop e-modules for physics materials that facilitate independent learning on an independent curriculum. This research is part of educational design research that refers to the plomp development model using a descriptive approach in processing the data obtained. Validity and practicality tests are carried out to see the eligibility of e-module. The validity was tested through two stages: one-to-one and small groups. Based on validity at the self-evaluation stage, the average score was 98.88%. The validity test at the expert review stage is carried out on five aspects: material substance, learning design, appearance (visual communication), use of software, and learning independence. The average value of each aspect were 0.89, 0.92, 0.81, 0.79, and 0.89, respectively. The practicality test was conducted through two stages: one-to-one and small groups. Theaverage practicality score was 97.75% and 87.35% for teacher and student responses at the one-to-one practicality test. The average practicality score was81.15% for small group practicality tests with very practical categories. From the qualification test performed, the average values in the category are acceptable. Students and teachers can consider this e-module as one of the physics lessons on an independent curriculum.**

***Keywords*—e-module, independent curriculum, independent learning, physics**

I. INTRODUCTION

The COVID-19 pandemic has a large worldwide influence on education [1]. One of them is learning loss, which leads to the failure to achieve the goal of learning. Learning loss is caused by less effective learning through remote learning [2]. Learning loss is defined as a condition in which students' knowledge and skills are reduced compared to achievements in the previous period [3]. This is proved by the students' deficient Higher Order Thinking Skilss (HOTS) ability [4]. It turns out that not only Indonesia is experiencing this condition, but other countries are also experiencing it [5]. Much effort has been applied to ensure that learning activities continue. There are various learning alternatives, such as distance learning using e-learning [6] or Zoom meetings. However, the use of learning alternatives still has a low level of efficiency, which is only 40% [7]. It cannot be denied that distance learning has its challenges for both teachers and students [8].

Government efforts to address learning losses are by implementing a new curriculum tailored to the situation and needs [9]. Indonesian government has changed the current curriculum from the 2013 Curriculum to an independent curriculum from July 12, 2022. The main factor in curriculum exchange in Indonesia is caused by learning losses [10]. The independent curriculum presents learning material more simply and focuses on essential knowledge [11]. As a result, the learning material that previously existed in the 2013 curriculum but in the independent curriculum was removed and replaced with other learning material.

The independent curriculum is project-based and requires character and soft skills traits adapted to the school's character. Furthermore, the development of essential competencies (literacy and numeration) is vital in this curriculum [12]. This aligns with the 21st-century curriculum, which also provides students with opportunities to learn and develop various literacy skills in various scientific fields [13]. The independent curriculum focuses on the autonomy and independence of students. Developing learning independence can be an effective solution to overcoming learning losses [14].

Independence demonstrates a belief in the ability of one to solve problems without the special help of others [15]. Independent learning does not mean learning independently or learning on their own, but learning on their own initiative, with or without the assistance of other appropriate person to make important decisions in meeting their learning needs [16]. Independent learning can enhance creativity, problem-solving, leadership, communication, and innovation [17].

Physics is the most essential of the natural sciences because it could provide a fundamental conceptual and theoretical foundation for the further development of technology and other scientific disciplines [18]. In essence, learning physics does not only contain theories or formulas to be memorized but also concepts that must be understood in depth [19]. In the material on global warming and environmental pollution, there will be many concepts that students must understand. Not only that, students also have to analyze their environment to see how global warming and environmental pollution occur. To support learning activities, of course, teaching materials are needed that are by the independent curriculum, which demands students' learning independence and can explain concepts on global warming and environmental pollution by linking them to problems in the surrounding environment.

Physics teaching materials in the independent curriculum

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to restore students' learning independence have not been widely developed. Based on preliminary research which was carried out through interviews with teachers from senior high schools in Padang City, the material on environmental pollution in the handbook provided by Indonesia's Ministry of Education, Culture, Research, and Technology has not been explained properly. And in the global warming material, the problems presented are not yet close to students. Fulfillment of teaching materials for teachers and students, especially material on global warming and environmental pollution, must be carried out immediately. Remember that this material must reach the students. If not, then existing learning outcomes have not been achieved properly.

An effort can be made to solve this problem by developing teaching materials. The teaching materials developed not only meet the needs of teaching content based on an independent curriculum but can also facilitate students' independent learning. A suitable teaching material to facilitate independent learning in an independent curriculum and also to meet the learning demands of students is an e-module.

E-modules are student learning resources that can be used in digital form and are organized according to the purpose and preferences of the students [20]. E-modules can be opened at anytime and anywhere [21], capable of overcoming learning space and time constraints, can increase student motivation [22], and make students comfortable learning with various multimedia that can be in the e-module [23]. The main characteristic of e-modules is independent teaching resources that are arranged systematically in simple language and presented in learning activity units [24] for independent learning needs [25].

E-modules can improve the efficiency of time for students to study learning materials, provide solutions to students to use information and communications technology wisely, increase students' initiative in the learning process [26], provide space for the students to learn independently [27], and encourage student literacy to find information from a variety of sources on their own [28].

In connection with the above exposure, the core objective of this study is to develop teaching materials for physics lessons that support the independence of learning based on an independent curriculum. The e-module developed will pass the eligibility test to be ready to be used. The development of this e-module uses a Plomp development model consists of three stages: preliminary research, development or prototyping phase, and assessment phase. However, this study is limited to the development phase. From three stages of research on this model, this study goes to the second stage of development.

II. Method

A. Research Approach

The type of research conducted is educational design research that develops research-based solutions to complex problems in educational practice [29]. The module's development follows the Plomp development model because it is more flexible than other models [30]. This development model consists of preliminary research, development phase (prototype phase), and evaluation phase [29]. This study is limited to the development phase.

The research was carried out between February 9, 2023, and September 21, 2023. With details of each phase of its research, the preliminary research was carried out from February 9, 2023, until April 1, 2023. In the development phase, the prototype design phase will be carried out from April 2, 2023, until July 21, 2023, and the remaining time will be for the formative evaluation phase and analysis of the results.

Information gathering at the preliminary research stage was carried out through interviews with physics teachers from SMAN 2 Padang, the SMAN 10 Padang, and the SMA Pembangunan Laboratorium Universitas Negeri Padang. The subjects in this research were six experts to validate the product. The one-to-one practicality test was provided to three students with low, medium, and high abilities [31] and one teacher from the first-grade semester one at SMAN 2 Padang, the SMAN 10 Padang, and the SMA Pembangunan Laboratorium Universitas Negeri Padang. The small group phase practicality test was conducted at the SMA Pembangunan Laboratorium Universitas Negeri Padang, consisting of nine students divided into three groups [32], each group representing students with low, medium, and high abilities.

Table 1. Plomp development model research procedure

Preliminary research		**Review of literature** **Analysis of physics learning needs for teachers through interviews**
Development (prototyping phase)	Prototype I	Initial development results
	Prototype II	Self-evaluation
		Revised
	Prototype III	Expert review
		One-to-one
		Revised
	Prototype IV	Small groups
		Revised

Fig. 1 despicts the suggested model's architectural diagram.

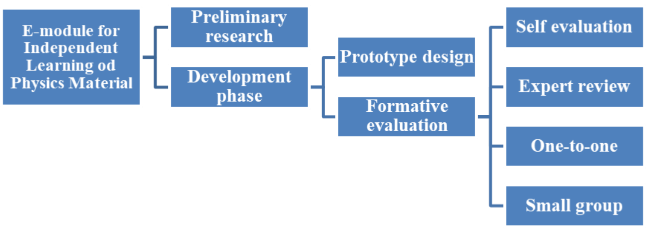

Fig. 1. Architecture of the Plomp development model.

B. Data Collection

At each stage, the research procedure requires data collection instruments. The research instruments for each stage can be found in Table 2.

The instruments used in the development phase use an open questionnaire with a Likert scale. The purpose of using a questionnaire is to collect data from respondents. At the self-evaluation stage, the questionnaire used was modified by Tessmer [33]. From the expert review stage until the small groups stage, the questionnaire used was modified from the previous research [34].

Table 2. Data collection instruments

Preliminary research phase	Analysis of physics learning needs for teachers	Physics teacher interview guidelines and teaching materials
Development (prototyping phase)	Self-evaluation	Self-evaluation instrument
	Expert review	Validity instrument
	One-to-one	One-to-one student practicality instrument
		One-to-one teacher practicality instrument
	Small groups	Small groups instrument

The data obtained using the data collection instrument is then analyzed. The results of teacher interviews are analyzed using a qualitative descriptive approach. Through this approach, the results of the interview are described, interpreted, and made informative. Descriptive results at an early stage can help gain insight into concepts and find new problems [35]. In the formative evaluation phase, a descriptive approach is used to explain the validity and practicality [36] of the e-modules that have already been developed.

The instrumental practicality results obtained through one-to-one and small group evaluation are analyzed using the Eq. (1) [37].

$$x_i = \frac{\sum s}{s_{max}} \times 100\% \quad (1)$$

Description:
x_i = Value of questionnaire for each aspect
$\sum s$ = Number of scores given to practice
s_{max} = Maximum score for each aspect

The $\sum s$ value is obtained from the total number of scores given by the practices for the assessed aspects. The s_{max} value is derived from each category present in each aspect. The maximum score for each category on each aspect is 4, and the minimum score is 1.

The value range of instrument analysis results in practicality between 0%–100%. Table 3 provides the practicality criteria for e-modules [38].

Table 3. Practicality criteria of e-modules using the likert scale

No	Percentage (%)	Category
1	81%–100%	Very practical
2	61%–80%	Practical
3	41%–60%	Practical enough
4	21%–40%	Less practical
5	≤ 20%	Not practical

The validation instruments' results are gathered through the self-evaluation stage and the expert review stage. Validation via the self-evaluation stage is analyzed with Eq. (1), with validation criteria presented in Table 4 [39].

Table 4. Practicality criteria of e-modules using the likert scale

No	Percentage	Category
1	81%–100%	Very practical
2	61%–80%	Practical
3	41%–60%	Practical enough
4	21%–40%	Less practical
5	≤ 20%	Not practical

Validation through the expert review phase is analyzed with Aiken's V validity formula [40].

$$V = \frac{\sum s}{n(c-1)} \quad (2)$$

Description:
V = Index of agreement on item validity
s = r-l_o
l_o = Lowest score that can be given by the validators
$\sum$s = Total s
r = score given by the validators
n = Number of validators
c = The Number of categories selected validators [27]

The maximum score that can be given by the validators for each category is 4, and the minimum value (l_o) is 1. The s value is obtained using the value given by each validator minus 1 (l_o).

There are four categories that validators can select to evaluate statements on the validator leverage sheet. The validator selection categories are divided into four with details, as shown in Table 5.

Table 5. Categories of evaluation of validator responses

Score	Category	Indicator availability percentage (%)
1	Strongly disagree	0–25
2	Disagree	26–50
3	Agree	51–75
4	Very agree	76–100

The maximum score that a validator can give is 4 with the art category agree, and the minimum score is 1 with the category strongly disagree. The Number of experts required as validators at this stage is six. Validity criteria at the expert review stage using Aiken's V scale [41].

Table 6. E-module validity criteria using Aiken's V scale

Aiken's V scale	Category
V < 0.78	Invalid
V ≥ 0.78	Valid

The lowest result obtained from the validation instrument analysis is 0.00. If the value is 0.00, then each validator gives a score on the same statement with the lowest score. If the score is 1.00, then every validator pays the same claim with the highest rating.

Revisions made at each stage are based on the value of each category obtained. It is also based on suggestions and comments received.

III. Result

A. Preliminary Research

Preliminary research is also known as the phase of needs analysis. Researchers conducted a review of the literature and analysis of physics learning needs for teachers through interviews. The interview was held with teachers from senior high schools in Padang City. The main point of this interview is to acquire information about learning planning and implementation, the application of physics teaching materials, and the students' learning independence and their association with the teaching material and an independent curriculum.

In the planning and implementation of learning, five questions are asked of the teachers. According to the findings of the interviews, information was obtained that the schools were already using an independent curriculum. There is a difference between the independent curriculum and the previous curricula. The independent curriculum is known as the term access learning that has been given by the government, which is a guide to teachers in formulating the learning objectives and the course of learning goals. Two of the three samples conducted a learning access analysis together with the physical teacher at the school to obtain the learning objectives. There are three considerations of teachers in the formulation of the purpose of learning and the course of learning goals: the school, the students, and the potential of the region. Finally, from the results of the interviews, it is known that the teachers prepare modules that are tailored to the development and abilities of the students.

The second aspect is the application of physics teaching materials in learning. Based on the interviews, obtained information that teachers have already used the integrated science handbook published by the Ministry of Education, Culture, and Technology in 2021. However, the existing books have not described physics materials properly and have not been able to facilitate students to study independently. Because of that, teachers need other supporting teaching materials, like student worksheets, presentation media, learning videos, and sets of topics. Besides, it was also revealed that teachers still use the 2013 curriculum books that have the same teaching material as those in the independent curricula.

The last aspect is the student's learning independence and its connection to the teaching material. The teachers informed that the student's learning independence at this time had declined compared with when the conditions before the pandemic. Teachers felt this, especially when teaching first-grade students at senior high school. To ensure that the learning goes well, teachers must teach the material at the previous grade before teaching material that should. One of the effects of learning loss is a decrease in the student's ability to learn. Therefore, increased learning independence of the student needs to be done to deal with the learning loss impact further.

From the problems found, it is necessary to use physics teaching materials that not only contain material but can also be a facility to improve the independence of learning students. Therefore, the researchers researched to develop independent teaching material on physics materials that already use the independent curriculum.

B. Development Phase

1) Prototype design

Prototype design aims to design solutions to problems that have been identified in the previous stage. Refers to the findings of interviews with teachers and literature reviews, an e-module was designed using the Flip PDF professional application to turn the module into electronic teaching material that utilizes various multimedia (see Fig. 2–4).

The e-module is divided into three main parts: the first part consists of the cover, the introductory word, the instructions for use, the list of contents, and the glossary. The core part consists of learning access and learning material that supports the student's independence of learning. And the last part, the closing part, consists of the answer key, the library list, the table list, and the picture list.

Fig. 2. Design cover e-modul.

Fig. 3. The prototype design stage on the instructions section for teachers and students.

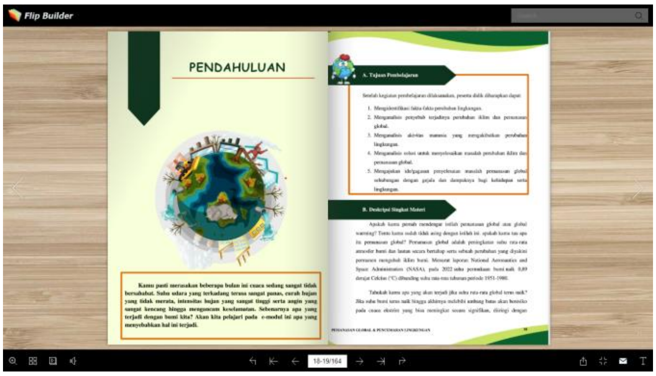

Fig. 4. Material content design of the e-module.

2) Formative evaluation

a) Self-evaluation

The stage of self-evaluation is carried out by the researchers to see the initial errors that appear from the initial development results. In addition, the completeness and compatibility of the formatted e-module is also assessed. Data collection is carried out through a self-evaluation lift consisting of aspects of learning effectiveness, learning interest/motivation, quality of content, technical quality, and application [33]. Table 7 shows the results of the self-evaluation lift.

From Table 7, it was found that of the five aspects at the self-evaluation stage tested, only one aspect gained an imperfect score, while the other aspects gained a perfect score. The learning effectiveness aspect gets a score of more than 90%. The revision at this stage results in a prototype II that goes to the next stage of expert review.

Table 7. Self-evaluation questionnaire results

	Assessed aspects	Score	%
Learning effectiveness	Learner performance	4	94.44%
	Clarity of writing/narration	3	
	Proper sequencing of content	4	
	Effectiveness of strategies	4	
	Realistic examples	4	
	Amount of practice	4	
	Quality of feedback	4	
	Quality of learner interactions	4	
	Coherence of graphics	3	
Learner interest/ motivation	Interest in content	4	100%
	Level of learner challenge	4	
	Willingness to learn more	4	
	User willingness to use	4	
Content quality	Content accuracy	4	100%
	Content completeness	4	
	Content superfluousness	4	
Technical quality	Visual quality	4	100%
	Aural quality	4	
	Effective use of media	4	
Implementability	Teacher ease of use	4	100%
	Learner ease of use	4	
	Fit to learning environment	4	
	Average		98.88%
	Category		Valid

b) Validity

Validation at the expert review stage is carried out by experts. The data collection instrument used is a validation lift. The aspects assessed on this aspect are the substance of the material, the design of learning, the appearance (visual communication), the use of software [34], and independent learning [42]. Tables 8–12 provide the data analysis results for each aspect of the validation instrument.

After analyzing data on validation instruments obtained in Table 8, the validation values on the material substance aspect for each statement are ⩾0.78. According to Aiken's V validity scale criteria [41], it can be seen that aspects of material substances acquire acceptable values. Table 9 shows that the value of each statement on the learning design aspect [43] is more than 0.80. Statements number 2, 3, 4, and 18 obtain a value of 1.00, which means that each validator gives the maximum score on the statement. Every statement on learning design aspects already has a valid category.

According to Table 10, the values of each statement on the aspect of display (visual communication) are in the range of 0.70 to 0.95. Statement number 6 has a value of less than 0.78. The e-module layout design needs to be revised. On this aspect, there is still a statement whose value is invalid. However, from the average values on this aspect, it is clear that the e-module developed has already been categorized as valid.

After conducting data analysis for the aspects of software utilization (visual communication) [34], we obtained a validity value of this aspect of 0.79 with a valid category. Table 11 contains three statements, each of which has been categorized as valid because the value of V received is ≥ 0.78.

Table 8. Result of validation instrument analysis on material substance aspects

No	Statement	r_1	r_2	r_3	r_4	r_5	r_6	∑s	V
1	E-modules are presented in accordance with: a. Theory of science b. Testable/tested c. Factuality (based on facts) d. Logical/rational	4	4	4	4	3	4	17	0.94
2	The material contained in the E-module has been presented by: a. Material supplies b. Exploration/development c. Collaboration with other materials/other lessons d. Descriptive/imaginative	3	4	3	4	3	3	14	0.78
3	E-module presented already; a. Actuality (see from the material point of view) b. Up to date (using examples of application/ application based on current real conditions) c. Innovative (bringing about new things)	4	4	4	4	3	3	16	0.89
4	The E-module presented uses standard and understandable grammar.	4	4	4	3	4	4	17	0.94
Validity of material substance aspects									0.89
Category									Valid

Note: r_1 to r_6 represents the score given from validator 1 to validator 6 for each statement.

Table 9. Result of validation instrument analysis on learning design aspect

No	Statement	r_1	r_2	r_3	r_4	r_5	r_6	∑s	V
1	The E-module presented has an interesting and relevant cover.	4	4	4	4	4	3	17	0.94
2	The E-module presented has a list of contents.	4	4	4	4	4	4	18	1.00
3	The E-module presented has a complete glossary.	4	4	4	4	4	4	18	1.00
4	The E-module presented lists learning access	4	4	4	4	4	4	18	1.00

5	The E-modules are presented by the learning access and show the benefits obtained for the learners.	4	4	3	3	4	4	16	0.89
6	The E-modules presented have motivation for the pupils.	4	3	4	3	4	3	15	0.83
7	The E-module presented has instructions for use by teachers and pupils as well.	3	4	4	4	4	4	17	0.94
8	The E-module presented has general instructions for use.	3	4	4	4	4	4	17	0.94
9	E-modules are presented by the learning objectives of each learning activity.	4	4	4	3	4	4	17	0.94
10	The E-modules presented have materials that match learning access and purpose.	4	3	4	3	4	4	16	0.89
11	The E-module presented contains a summary of the material description	4	4	4	3	4	4	17	0.94
12	The E-module presented has a task that reinforces the understanding of the students and matches the purpose.	3	4	4	4	3	4	16	0.89
13	The E-module presented has a worksheet consisting of work instructions that train the skills of the established learning objectives.	3	3	4	4	3	4	15	0.83
14	The E-modules presented have training that allows the student to master learning access through the expected learning objectives.	3	4	4	4	3	4	16	0.89
15	The E-module presented has an evaluation that can help the student to assess his or her abilities.	3	3	4	4	3	4	15	0.83
16	The E-module presented has the answer key.	4	4	4	4	3	4	17	0.94
17	The E-module presented contains a list of references.	3	4	4	4	4	4	17	0.94
18	The E-modules presented have an attachment containing a table list and a picture list.	4	4	4	4	4	4	18	1.00
Validity of learning design aspects									0.92
Category									Valid

Note: r_1 to r_6 represents the score given from validator 1 to validator 6 for each statement.

Table 10. Result of validation instrument analysis on display (visual communication) aspects

No	Statement	r_1	r_2	r_3	r_4	r_5	r_6	∑s	V
1	The E-module presented uses basic navigation and hyperlinks that work well.	3	4	4	3	4	3	15	0.83
2	The E-module is presented using readable, proportional, and good composition letters.	3	4	3	3	4	3	14	0.78
3	The E-modules are presented using images, sounds, and videos that match the material presented.	4	3	4	4	3	3	15	0.83
4	The E-module presented has a good color composition and an attractive appearance.	4	4	4	4	4	3	17	0.94
5	The E-module presented uses an animation that matches the context and does not slow down the slide display.	4	4	3	3	3	3	14	0.78
6	The E-module presented has a proportional and interesting design layout.	3	4	4	3	2	3	13	0.72
Validity of display (visual communication) aspect									0.81
Category									Valid

Note: r_1 to r_6 represents the score given from validator 1 to validator 6 for on each statement.

Table 11. Result of validation instrument analysis on software utilization aspect

No	Statement	r_1	r_2	r_3	r_4	r_5	r_6	∑s	V
1	The E-module presented provides feedback from the system to the student	4	3	4	3	3	3	14	0.78
2	E-modules are presented using supporting software other than the main software	4	3	4	4	3	3	15	0.83
3	Originality of the E-module.	3	4	4	3	3	3	14	0.78
Validity of software utilization aspect									0.79
Category									Valid

Note: r_1 to r_6 represents the score given from validator 1 to validator 6 for on each statement.

Table 12. Result of validation instrument analysis on independent learning aspects

No	Statement	r_1	r_2	r_3	r_4	r_5	r_6	∑s	V
1	The E-modules presented can improve the student's learning independence by the indicators of student independence, including: a. initiative and motivation b. learning needs c. Learning objectives/targets d. Relevant learning sources e. evaluation of learning processes and outcomes by the student.	4	4	3	4	3	4	16	0.89
Category									Valid

Note: r_1 to r_6 represents the score given from validator 1 to validator 6 for on each statement.

This e-module is structured in addition to as a learning resource to enhance the learning independence of the student. From Table 12, the validation value obtained on the learning independence aspects is higher than 0.78 and is already acceptable with a valid category.

c) Practicality

Practicality tests on Plomp development models are conducted through two stages, one-to-one and small groups. The one-to-one phase is carried out by conducting practicality tests on first-grade students at senior high schools in three different schools. Each school took three students with low, medium, and high abilities and a physics teacher to perform the practicality test of the e-module.

The instrument used in data capture uses a lift consisting of e-module content aspects, e-module display and media, ease of use, and independent learning aspects. Table 13 shows the results of the one-to-one practicality for teacher's responses. Based on the analysis of data in Table 13, the four aspects tested for practicality obtained a score of over 90%. Indeed, regarding the e-module, display, and media, they got the maximum score. The one-to-one practicality test to the teacher stated that the e-module developed was very practical.

Table 13. Results of one-to-one teacher practicality questionnaire

Evaluation	Percentage	Information
E-module content	96.30%	Very practical
E-module display and media	100%	Very practical
Ease of E-module	96.11%	Very practical
Students learning independence	98.61%	Very practical

According to Table 14, the value of the one-to-one stage practicality test to students got a practicality score of between 80% and 92%. Each aspect tested practicality is already in the category of very practical. From the one-to-one stage practicability test, both from the teachers' and students' responses, the result that the e-module developed is already very practical.

Table 14. Results of one-to-one students practicality questionnaire

Evaluation	Percentage	Information
E-module content	90.13%	Very practical
E-module display and media	91.67%	Very practical
Ease of E-module	80.57%	Very practical
Students learning independence	87.05%	Very practical

After analyzing the data of the practicality test at the small group stage in Table 15, it is known the practicality value of e-modules already exceeds 70%. This means that the e-modules developed are already practical. There are aspects already worth over 80%, such as e-module content and e-module displays and media that can already be very practical.

Table 15. Results of small group practicality questionnaire

Evaluation	Percentage	Information
E-module content	94.57%	Very practical
E-module display and media	83.37%	Very practical
Ease of E-module	77.14%	Practical
Students learning independence	79.17%	Practical

IV. Discussion

According to the results of the interviews and the library reviews that have been obtained, it can be seen that there is a match between the two. Independent curricula have been implemented in senior high schools in Padang City. The independent curriculum provides educational resources that can support lessons. Physics subjects for 1st-grade students at senior high schools use natural science teaching materials published in 2021 by the Ministry of Education, Culture, Research, and Technology. However, the physics material in this book has not been explained well. The findings agree with previous research, which found that teaching materials to help students understand the conceptual material and the impact of global warming are still lacking [44]. As a result, teachers have to find or compile teaching materials to supplement physics materials that are not in that book. The impact of the teaching material used in the study has not been tested for its eligibility. There is no guarantee that the teaching material prepared by the teacher is in line with the existing learning access.

Independent curricula require students to learn independently to overcome learning losses. Impacts caused by learning loss include reduced academic ability [3], learning gaps, long-term recovery, lack of student readiness in learning, increased social disparity, and student risk of failure in education [45]. Therefore, researchers are developing physics materials that can facilitate students to learn independently based on independent curricula.

The e-module is a type of teaching material that is suitable for addressing the problems of the availability of teaching materials as well as enhancing the independence of the learners [46]. The e-module is an interactive material that encourages critical thinking and gives feedback [47]. The e-module is structured by multimedia that facilitates the teacher's development of learning techniques and producing maximum results [48]. The characteristics of the e-module that supports self-learning are also perfectly compatible with the independent curriculum to overcome learning loss.

The results of the instrument validation of teaching materials evaluated by the experts there are five aspects: the substance of the material, learning design, display (visual communication), the use of software, and the autonomy of learning. From the results of the analysis, the validity values in each aspect are 0.89, 0.92, 0.81, 0.79 0.89. All the assessed aspects have already met the valid category; the data is acceptable. The validator's suggestions were used to update the e-module. The revisions made to the e-module were adjusted with a statement on each aspect that obtained a low value. The part of the e-module that needs to be noted is the layout design. This is because the validity value gained on the design statement is less than 0.78. That means this statement is not valid.

The practicality test was conducted in two stages. In the one-to-one stage, the teachers' and students' responses were obtained. These results, on a scale of 0%–100%, were 97.75% for the teachers' responses and 87.35% for students' responses. In small group stage practicality tests, the average result was 81.15%. Based on the practicality assessment category, the three results were in the very practical category. The results in Tables 13 and 14 show that the data obtained for each aspect is already in the very practical category. Only in Table 15 is the data obtained divided into two categories, which are very practical and practical. Aspects of e-module ease and the independent learning of the student in the practical category. This is because in the ease aspect of the e-module, the e-module can only be used when the student is connected to the internet, and the link accessed by the student cannot be opened when the student is offline. In the aspect of learning independence, the students still need help from the teacher in learning activities using the e-module.

From the entire data analysis, the e-module developed is already worthy of being used as it has passed validity and practicality tests with the category already accepted. However, this e-module still requires improvement, especially for the ease of the e-module aspect and the independent learning aspect of the student. It would be even better if this e-module was also tested for its effectiveness.

V. Conclusion

This research was conducted to develop e-modules suitable for independent learning on physics materials based on the independent curriculum. This research began with preliminary research to analyze the needs of teaching materials. Based on a preliminary research, it was found that e-modules for independent learning on physical materials based on an independent curriculum are very needed. e-module tested validity and practicality through 4 stages. According to the results of the stage of self-evaluation, the five aspects validated obtained an average percentage of validation e-module valued at 98.88% with valid category. From validation results of the expert review stage from five aspects obtained averages of each aspect were 0.89, 0.92, 0.81, 0.79, and 0.89, acceptability. Overall, the e-modules developed are valid. The practicality test was conducted in two stages, one-to-one and small group with a score of 97.75% for the teacher's response and 87.35% for the student's response. For the small group stage obtained total score of 81.15% with very practical category.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Najmi Asfiya developed research instruments, collected data, analyzed data, and wrote the paper. Pakhrur Razi, as the supervisor, validated the research instruments used and guided the writing of the paper. Hidayati and Silvi Yulia Sari provide research guidance, review and provide suggestions in product development. The final manuscript has been written with the participation of all authors.

References

[1] B. R. Aditya and Andrisyah, "Digital transformation in early childhood education: Teachers' self-regulated model for digital learning," *Int. J. Inf. Educ. Technol.*, vol. 13, no. 2, pp. 329–334, 2023. doi: 10.18178/ijiet.2023.13.2.1811

[2] R. A. Rizki and L. Fahkrunisa, "Evaluation of implementation of independent curriculum," *J. Curric. Pedagog. Stud.*, vol. 1, no. 4, pp. 32–41, 2022.

[3] R. Donnelly and H. A. Patrinos, "Learning loss during Covid-19: An early systematic review," *Prospects*, vol. 51, no. 4, pp. 601–609, 2022. doi: 10.1007/s11125-021-09582-6

[4] S. Agustin and P. Razi, "Validity of e-book based on problem-based learning with higher order thinking skills oriented for senior high school validity of e-book based on problem-based learning with higher order thinking skills oriented for senior high," *J. Phys. Conf. Ser.*, vol. 2582, no. 1, 012066, 2023. doi: 10.1088/1742-6596/2582/1/012066

[5] M. Hassan, "Online teaching challenges during COVID-19 pandemic," *Int. J. Inf. Educ. Technol.*, vol. 11, no. 1, pp. 41–46, 2020. doi: 10.18178/ijiet.2021.11.1.1487

[6] S. Bhaskaran and R. Marappan, "Design and analysis of an efficient machine learning based hybrid recommendation system with enhanced density-based spatial clustering for digital e-learning applications," *Complex Intell. Syst.*, vol. 9, no. 4, pp. 3517–3533, 2023. doi: 10.1007/s40747-021-00509-4

[7] R. Afkar and N. Yarrow, "Rewrite the future: How Indonesia's education system can overcome the losses from the COVID-19 pandemic and raise learning outcomes for all," 2021.

[8] D. E. Kusumaningrum, E. M. Budiarti, T. Triwiyanto, and R. Utari, "The effect of distance learning in an online learning framework on student learning independence during the COVID-19 pandemic," in *Proc. 2020 6th Int. Conf. Educ. Technol.*, 2020, pp. 182–185. doi: 10.1109/ICET51153.2020.9276564

[9] D. Irawati, H. Najili, S. Supiana, and Q. Y. Zaqiah, "Merdeka belajar curriculum innovation and its application in education units," *Edumaspul J. Pendidik.*, vol. 6, no. 2, pp. 2506–2514, 2022.

[10] R. R. Aliyyah, Rasmitadila, G. Gunadi, A. Sutisnawati, and S. Febriantina, "Perceptions of elementary school teachers towards the implementation of the independent curriculum during the COVID-19 pandemic," *J. Educ. e-Learning Res.*, vol. 10, no. 2, pp. 154–164. 2023. doi: 10.20448/jeelr.v10i2.4490

[11] A. Almarisi, "Kelebihan dan kekurangan kurikulum merdeka pada pembelajaran sejarah dalam perspektif historis," *MUKADIMAH J. Pendidikan, Sejarah, dan Ilmu-ilmu Sos.*, vol. 7, no. 1, pp. 111–117, 2023. doi: 10.30743/mkd.v7i1.6291

[12] A. Munte, "Philosophy of giorgio agamben-homo sacer's on the independent curriculum for learning in Indonesia: Critical reflection," *Int. Semin. Commem. 100th Annniversary Tamansiswa*, vol. 1, no. 1, pp. 464–468, 2022.

[13] A. Unda-López, G. Osejo-Taco, A. Vinueza-Cabezas, C. Paz, and P. Hidalgo-Andrade, "Procrastination during the COVID-19 pandemic: A scoping review," *Behav. Sci. (Basel).*, vol. 12, no. 2, pp. 150–155, 2022. doi: 10.3390/bs12020038

[14] A. E. Cahyono, "Membangun kemandirian belajar untuk mengatasi learning loss dalam pembelajaran berdiferensiasi," *Educ. J. J. Educ. Res. Dev.*, vol. 7, no. 2, pp. 167–174, 2023. doi: 10.31537/ej.v7i2.1257

[15] A. Isa, "The Relationship between learning independence and learning motivation with student academic achievement," *J. Educ. Method Learn. Strateg.*, vol. 1, no. 01, pp. 1–8, 2023. doi: 10.59653/jemls.v1i01.11

[16] I. Sujono, Z. Malaka, L. Istifhama, N. Nasiri, and S. Anah, "Efforts to strengthen islamic moderation of islamic religious universities in Indonesia," in *Proc. 6th Batusangkar Int. Conf.*, pp. 1–6, 2022. doi: 10.4108/eai.11-10-2021.2319459

[17] M. C. Escolar-Llamazares, "The socio-educational, psychological and family-related antecedents of entrepreneurial intentions among Spanish Youth," *Sustain.*, vol. 11, no. 5, pp. 1–21, 2019. doi: 10.3390/su11051252

[18] P. Y. A. Dewi and K. H. Primayana, "Effect of learning module with setting contextual teaching and learning to increase the understanding of concepts," *Int. J. Educ. Learn.*, vol. 1, no. 1, pp. 19–26, 2019. doi: 10.31763/ijele.v1i1.26

[19] Halimah, Subanji, and D. Septi Nur Afifah, "Student's cognitive conflict form problem solving on mathematics," *J. Phys. Conf. Ser.*, vol. 1339, no. 1, 2019. doi: 10.1088/1742-6596/1339/1/012127

[20] R. Sandra and P. Razi, "Development of physics module using moodle integrated lab rotation in senior high school," *Pillar Phys. Educ.*, vol. 15, no. 2, pp. 132–138, 2022. doi: 10.24036/12848171074

[21] D. Handayani, Elvinawati, Isnaeni, and M. Alperi, "Development of guided discovery based electronic module for chemical lessons in redox reaction materials," *Int. J. Interact. Mob. Technol.*, vol. 15, no. 7, pp. 94–106, 2021. doi: 10.3991/ijim.v15i07.21559

[22] D. M. Yusra, Y. D. Citra, and R. Rosnita, "Explicit instruction based e-module development on momentum and impulsive material," *Integr. Sci. Educ. J.*, vol. 4, no. 1, pp. 14–19, 2023. doi: 10.37251/isej.v4i1.295

[23] S. Yulando, S. Sutopo, and T. Franklin Chi, "Electronic module design and development: An interactive learning," *Am. J. Educ. Res.*, vol. 7, no. 10, pp. 694–698, 2019. doi: 10.12691/education-7-10-4

[24] H. Komikesari, M. Mutoharoh, P. S. Dewi, G. N. Utami, W. Anggraini, and E. F. Himmah, "Development of E-module using flip pdf professional on temperature and heat material," *J. Phys. Conf. Ser.*, vol. 1572, no. 1, 2020. doi: 10.1088/1742-6596/1572/1/012017

[25] I. Wahyuni, A. M. Noer, and R. Linda, "Development of electronic module using kvisoft flipbookmaker application on the chemical equilibirium," *in Proc. 2nd URICES*, pp. 1–12, 2018.

[26] H. Kristina, M. Vitasari, and A. N. Taufik, "Pengembangan E-modul berbasis literasi sains tema ayo siaga bencana untuk melatih kemandirian belajar siswa SMP," *PENDIPA J. Sci. Educ.*, vol. 6, no. 3, pp. 754–763, 2022. doi: 10.33369/pendipa.6.3.754-763

[27] A. Mufidah, S. Indana, and I. S. Z. Arifin, "E-module based on blended learning type flipped classroom on climate change materials to train

students' digital literacy ability," *Int. J. Curr. Educ. Res.*, vol. 2, no. 1, pp. 1–16, 2023. doi: 10.53621/ijocer.v2i1.204
[28] C. A. Dewi *et al.*, "Using android-based e-module to Improve Students' Digital Literacy on Chemical Bonding," *Int. J. Interact. Mob. Technol.*, vol. 16, no. 22, pp. 191–208, 2022. doi: 10.3991/ijim.v16i22.34151
[29] T. Plomp and N. Nieveen, *An Introduction to Educational Design Research*, Enschede: Netherlands Institute for Curriculum Development (SLO), 2010.
[30] A. Arianatasari and L. Hakim, "Penerapan desain model plomp pada pengembangan buku teks berbasis guided inquiry," *J. Pendidik. Akunt.*, vol. 6, no. 1, pp. 36–40, 2018.
[31] J. E. Wijaya and A. Vidianti, "Pengembangan bahan ajar modul elektronik interaktif pada mata kuliah inovasi pendidikan program studi teknologi pendidikan universitas baturaja," *J. Pendidik. Glas.*, vol. 3, no. 2, p. 142, 2019. doi: 10.32529/glasser.v3i2.334
[32] N. F. Saraswati and M. Djazari, "Implementasi metode pembelajaran small group discussion untuk meningkatkan aktivitas belajar pada kompetensi dasar jurnal penyesuaian siswa kelas X akuntansi SMK muhammadiyah kretek tahun ajaran 2017/2018," *J. Pendidik. Akunt. Indones.*, vol. 16, no. 2, 2018. doi: 10.21831/jpai.v16i2.22049
[33] M. Tessmer, *Planning and Conducting Formative Evaluations Improving the Quality of Education and Training*, Pertama. Britania Raya: Kogan Page, 1993.
[34] P. Razi, *Multimedia Interaktif: Buku Ajar*, Pertama, Padang: UNP Padang, 2013.
[35] B. Njie and S. Asimiran, "Case study as a choice in qualitative methodology," *IOSR J. Res. Method Educ.*, vol. 4, no. 3, pp. 35–40, 2014. doi: 10.9790/7388-04313540
[36] S. Yunus, N. Abbas, and I. Djakaria, "Pengembangan e-modul berbasis flip book berdasarkan model plomp materi segi empat," vol. 4, no. 2, pp. 139–147, 2023.
[37] F. Handayani and P. Razi, "Pengembangan handout fisika berbentuk komik terintegrasi nilai-nilai pendidikan karakter untuk meningkatkan keterampilan proses sains siswa kleas X SMA pada materi gerak," *J. Penelit. Pembelajaran Fis.*, vol. 8, no. 2, p. 213, 2022. doi: 10.24036/jppf.v8i2.118495
[38] N. Susanti, Y. Yennita, and A. Azhar, "Development of contextual based electronic global warming modules using flipbook applications as physics learning media in high schools," *J. Educ. Sci.*, vol. 4, no. 3, p. 541, 2020. doi: 10.31258/jes.4.3.p.541-559
[39] R. Linda, H. Herdini, I. S. S, and T. P. Putra, "Interactive e-module development through chemistry magazine on kvisoft flipbook maker application for chemistry learning in second semester at second grade senior high school," *J. Sci. Learn.*, vol. 2, no. 1, pp. 21, 2018. doi: 10.17509/jsl.v2i1.12933
[40] A. Alamanda, M. Mawardi, and O. Suryani, "Development of teaching material based on plomp development model to support indonesian merdeka curriculum on chemical bonding topic in Phase E," *J. Pijar Mipa*, vol. 18, no. 4, pp. 564–571, 2023. doi: 10.29303/jpm.v18i4.5288
[41] L. R. Aiken, "Three coefficients for analyzing the reliability and validity of ratings, educational and psychological measurument," *J. Artic. Reports - Res. Numer. Data*, vol. 45, no. 1, pp. 131–142, 1985.
[42] I. Ariyanti, "Uji Validitas dan Reliabilitas Instrumen Angket Kemandirian Belajar Matematik," *THETA J. Pendidik. Mat.*, vol. 1, no. 2, pp. 53–57, 2019.
[43] K. P. Kebudayaan, "Panduan praktis penyusunan e-modul," *Direktorat Pembinanan Sekolah Menengah Atas*, Jakarta, pp. 1–57, 2017.
[44] S. Camelia, M. Mawardi, and O. Suryani, "Pengembangan bahan ajar untuk menunjang pembelajaran kurikulum merdeka pada materi konsep dan dampak pemanasan global fase E SMA/MA," *J. Pendidik. Mipa*, vol. 13, no. 2, pp. 530–537, 2023. doi: 10.37630/jpm.v13i2.1091
[45] E. M. Aucejo, J. French, M. P. Ugalde Araya, and B. Zafar, "The impact of COVID-19 on student experiences and expectations: Evidence from a survey," *J. Public Econ.*, vol. 191, 104271, 2020. doi: 10.1016/j.jpubeco.2020.104271
[46] R. Sidiq and P. Suhendro, "Utilization of interactive e-modules in formation of students's independent characters in the era of pandemic," *Int. J. Educ. Res. Soc. Sci.*, vol. 2, no. 6, pp. 1651–1657, 2021.
[47] A. Kavadella *et al.*, "Recommendations for the development of e-modules for the continuing professional development of European dentists," *Eur. J. Dent. Educ.*, vol. 17, no. SUPPL. 1, pp. 45–54, 2013. doi: 10.1111/eje.12039
[48] M. Mulyadi, A. Atmazaki *et al*., "The development of interactive multimedia E-module on Indonesia language course," vol. 178, no. ICoIE 2018, pp. 291–295, 2019. doi: 10.2991/icoie-18.2019.65