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Development of a Nanotechnology E-Module Based on Problem Based Learning Using the Heyzine Application for the Independent Curriculum

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Abstract: Chemistry learning is still considered a difficult learning process, because it focuses on collecting facts and concepts and does not implement an independent curriculum that emphasizes concept discovery. This study aims to produce a nanotechnology-based problem-solving e-module using the Heyzine application for Independent Curriculum, analyze the validity and practicality of the E-module and analyze the effectiveness of the E-module. The type of research used is Research and Development (R&D) with a 4-D development model. The 4-D development model consists of 4 stages of development, namely define, design, develop and disseminate. The validity test uses the Aiken's V formula. The results of the validity test for the content component and presentation component are 0.91 and 0.90 respectively with a valid category. The results of the module practicality test carried out by teachers and students are 0.97 and 0.90 respectively with a very practical category. The effectiveness test of the E-module was carried out using the N-Gain test and obtained a result of 0.77 with a high category. The results of the study indicate that a valid, practical and effective problem-based nanotechnology E-module has been obtained.

Keywords: E-module; Heyzine application; Merdeka curriculum; Nanotechnology; Problem-based learning

Introduction

The progress of a nation is greatly influenced by education. The benchmark that can be used to assess the quality of a nation is the quality of its education system. If a country's education system is lagging behind, then that country will also be lagging behind other countries (Sujarwo, 2015). Based on Law no. 20 of 2003 chapter II article 3, it is stipulated that:"The function of national education is to form a civilized, dignified nation, create students' character, improve their abilities so that they can make the nation's life more intelligent."

Therefore, learning is needed that can serve all these purposes (quality and effective). The government designs signs that must be adhered to by all educational institutions as a minimum reference that determines the quality of the educational institution so that it can be equalized nationally. The curriculum is only a minimum standard that can be developed by educational institutions into something better without abandoning the essence of the curriculum. The curriculum as a minimum standard is needed as a basis for educational institutions at a higher level to continue the education of students. Education is carried out based on the curriculum. Educational goals can be achieved if learning opportunities are provided meaningfully in accordance with the curriculum (Nurfadhilah et al., 2024).

According to Bahri (2018), the curriculum is likened to a means of transportation that students can use to go to their respective destinations. So the more sophisticated and multifunctional this tool is, the easier

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it is for students to achieve their goals. This tool must also be suitable for the terrain to be covered. If this means of transportation is not suitable for the terrain to be traveled and is also unable to make the passengers, namely students, comfortable, then it will not be able to carry passengers to their destination. Students will experience failure in achieving their educational goals.

The curriculum is made according to the needs of the times so that the curriculum will only be maximum applicable in its time. The curriculum must always change and be updated according to current conditions and estimates of human progress in the future (Asri, 2017). Advancing the character and abilities of students is the main goal of the Independent Curriculum. The learning chosen in this curriculum is project-based learning, so that students' skills can develop. The expected character of students is a character based on the five principles of Pancasila. The material taught is only material that is considered essential so that the curriculum load is not too dense and there is plenty of time for students to develop themselves and improve their literacy and numeracy skills (Nurhafizah et al., 2022).

The learning planning prepared by the teacher greatly influences the success of learning. Likewise with the way teachers implement previously prepared learning plans. All learning plans must be written by the teacher in a neat and structured document so that it is easy to understand and implement. This document is also called a learning implementation plan (RPP) (Mawardi et al., 2022). This learning plan includes general information, core competencies, and appendices. Learning will also be greatly helped if the teacher prepares teaching materials called modules. Teaching modules are created by following several stages that must be understood, namely: 1). Learning outcomes (CP), 2). Learning objectives (TP), 3). Learning objective flow (ATP) (Numertayasa et al., 2022).

The Independent Curriculum wants teachers to implement the curriculum in their own way according to the needs of their respective students to catch up with students during the pandemic, using a variety of learning methods and models. The learning plan made by the teacher also contains teaching modules that will be discussed in the lesson. The teaching module is a development of the RPP in the 2013 Curriculum. The teaching module is in accordance with the CP developed. To start learning that is meaningful and appropriate for students, teachers must carry out two tests, namely cognitive diagnostic tests and non-cognitive diagnostic tests which function to determine the basic abilities and character of students. This test can also be used to determine students' responses to ongoing learning, whether it is enjoyable and meaningful or not. Teachers must create their own diagnostic tests because these tests are suited to the needs of each student.

Chemistry is part of natural science that can be found in everyday life and the world around us. Chemistry learning is still considered a difficult learning, because it focuses on collecting facts and concepts, and does not implement the Independent Curriculum which emphasizes the process of discovering concepts, so that students' mastery is only on that, but they do not have the ability to find concepts. The most suitable learning method in learning chemistry is the experimental method. However, in Nanotechnology material, the experimental method is difficult to carry out at the high school level, due to the limited tools and materials owned by the high school laboratory. So the solution that can be taken is to create a teaching module that can answer the needs in learning as a replacement for experiments that cannot be carried out. This teaching module must serve the needs in discussing chemistry, especially nanotechnology material from a macroscopic and microscopic perspective. Therefore, researchers developed an e-module that can provide the information needed by students about nanotechnology both macroscopically and microscopically.

Seeing the current trend, students are very familiar with the smartphones they have. This should be utilized by teachers in providing interesting teaching modules for students. Teachers can use applications that can make teaching materials accessible through the gadgets owned by students. The choice of application that teachers can use is "heyzine". Heyzine is a web application that can be used on smartphones. The output of heyzine is a flipbook in HTML format. This product can be used digitally online or in print. E-modules can be included in heyzine if the e-module product has been perfectly completed (Benitha et al., 2022). E-module products that use this heyzine can include videos, images, graphics, sounds, and links, so that the e-module can be attractive. By using heyzine, the e-module that is created can be added with videos, images, graphics, sounds, and links, so that the e-module that is created can look more attractive to students. When students read this heyzine-based e-module, because it is in the form of a flipbook, they get the sensation of physically opening a book page by page (Bernessa et al., 2024).

Method

This research uses the development of a four-dimensional model (Four-D model) by Thiagarajan et al. (1974) which consists of four main phases: define, design, develop, and disseminate.

Define

The aim of this stage is to determine and define the learning requirements, starting with an analysis of the objectives and limitations of the material being developed. This stage includes five main steps: Beginning-end analysis: Identifying learning problems in class X and conducting discussions with the chemistry teacher, Student analysis: Identifying the characteristics of students who will be used as samples, Task analysis: Analysis of learning outcomes in accordance with the Independent Curriculum, Concept analysis: Identifying learning outcomes for class X Phase E based on the Independent Curriculum that requires modules and Formulation of learning objectives: Determine the specifications of chemistry learning objectives in Phase E.

Design

The aim of this stage is to create a learning device prototype. This phase consists of four steps: Benchmark test preparation: Connect the definition and design phases by creating tests based on learning objectives, Media selection: Choosing the right media to convey material, Format selection: Develop learning tools as a guide for students and Educational module: Developing a Problem Based Learning-based module on nanotechnology material.

Develop

The aim of this stage is to create revised learning tools based on expert opinions. Validation test: Determines the level of valdity of the module created by validation from three lecturers and two chemistry teachers. The assessment given by the validator to each statement is analyzed using the Aiken's V formula shown in Equation 1.

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

Information:
r = value given by the validator
c = highest validity score
lo = lowest validity value
s = r- Io
n = number of expert validators

Practicality test: Testing the practicality of teaching materials through questionnaires to chemistry teachers and students. The data generated from the practicality test is analyzed using the formula as shown in Equation 2.

$$NP = \frac{R}{SM} \times 100\% \quad (2)$$

Where
NP : Practicality Value
R : Score
SM : Maximum Score

Effectiveness test: Using a Quasi Experimental Design research design with the "Nonequivalent Control Group Design" type. Analysis of learning outcomes tests was carried out using pretest and posttest, using the N-Gain test to determine the effectiveness of the e-modul test as shown in Equation 3 (Hake, 1999).

$$\text{N- Gain} = \frac{\text{posttest score} - \text{pretest score}}{100 - \text{pretest score}} \quad (3)$$

The results of the average N-Gain calculation can be seen in Table 1.

Table 1. N-Gain Criterion (Hake, 1998)

Limitation	Criterion
$g \geq 0.70$	Tall
$0.70 > g > 0.30$	Currently
$g \leq 0.30$	Low

The final stage is deployment. This stage is the stage of using devices that have been developed on a wider scale, for example in other classes, in other schools, or by other teachers.

This next analysis includes: Normality test: Determines whether the data is normally distributed, Homogeneity test: Determines whether the two groups of data have homogeneous variance, Paired Sample t-test: Compares the difference between two means from two paired samples and Normalized Gain (N-Gain): Measures the effectiveness of using e-modules by calculating the difference between pretest and posttest scores.

Disseminate

At this stage, the tools developed are used on a large scale to test the effectiveness of their use. However, in this study, limited distribution was carried out.

Result and Discussion

This research aims to determine the validity, practicality and effectiveness of the product being developed, namely a chemical e-module on nanotechnology materials. This research uses a 4-D model (four D models).

Define

The following is a description of the results obtained from each stage:

a) Initial final analysis

Based on the initial and final analysis by distributing questionnaires to 4 chemistry teachers in Payakumbuh City, several problems were found in the implementation of chemistry learning, especially in nanotechnology materials, namely: Nanotechnology materials are microscopic so they cannot be seen directly by students. There is no availability of adequate learning materials for nanotechnology material. Practicums for nanotechnology materials cannot be carried out because there are not enough tools and materials available at school.

The learning resources used by teachers are only textbooks provided by the government, which only provide material in the form of text and images, without detailed explanations about nanotechnology. The teaching materials provided are less attractive to students because they only consist of text and images, which do not really explain nanotechnology.

After analyzing the teaching materials for teachers in schools regarding nanotechnology, it turned out that the teaching materials used were textbooks from the Ministry of Education and Culture (natural science books, teachers' guides) and Phase E chemistry books published by Erlangga. These books only contain reading material accompanied by pictures that cannot explain nanotechnology microscopically. This causes less interest in reading books available in school libraries. Therefore, researchers developed an e-module about nanotechnology which is equipped with microscopic learning in the form of videos that can explain nano-sized particles.

This e-module can be accessed on each student's smartphone, because it uses the Heyzine application which supports use on smartphones. The Heyzine application allows students to access e-modules whenever and wherever they like. Students can repeat the lesson as often as they want until they feel sufficient and understand the nanotechnology material. In this e-module, students can also measure their own ability to master the material discussed, because there are pretest and posttest services. This allows students to find out their ability to master the initial material before learning by doing a pretest and their ability to master the material after learning by doing a posttest. If students feel they are still not satisfied with their achievements, they can repeat it again without a time limit.

b) Learner analysis

According to Piaget, the cognitive development of adolescents between the ages of 15-17 years is at the formal operation stage, which is the last stage of cognitive development. At this stage, teenagers have the ability to think abstractly, reason logically, and draw conclusions from existing information (Sulhan, 2024). It will be easier for someone to understand something if they start from something in the environment or something concrete. At the formal operational stage of development, a person has the ability to think abstractly and purely symbolically.

Through learning activities that use e-modules, it is hoped that students will be able to connect facts in the environment (macroscopic) with the theories discussed in the e-module (microscopic) and be able to find their own concepts so that the concepts obtained will stay in their long-term memory longer. To support your own concepts or knowledge, it is necessary to design e-modules that can be used repeatedly. Based on the results of observations using a questionnaire of 30 students, several students' thoughts were found in learning chemistry on nanotechnology materials:

c) Task analysis

In the Independent Curriculum, there are two types of learning outcomes that students must master: general chemistry learning outcomes and specific learning outcomes for a material. This curriculum emphasizes the importance of critical, active and creative thinking in learning, and provides freedom for students to determine their learning style to achieve complete and meaningful learning. The Merdeka Curriculum gives teachers the freedom to choose appropriate learning methods, so that they can serve various student learning styles. One solution that teachers can use is e-modules, which provide text, images and videos to serve various learning preferences, both those who like reading and those who prefer audiovisual learning.

d) Concept analysis

Concept analysis was carried out to identify learning outcomes and learning objectives in the even semester of Phase E. From the results of the identification, concepts were determined that could or could not be tested. If the concept cannot be tested due to limited tools and materials, then modules that replace experimental activities in the laboratory can be used.

e) Analysis of learning objectives

Subject objectives are analyzed to determine learning objectives that are in accordance with learning outcomes in Phase E.

Design

a) Selection of teaching materials

The appropriate media is selected in accordance with the material concept, student characteristics, and opportunities for developing teaching materials and disseminating the media. In this research, an e-module about nanotechnology was chosen which has text accompanied by images and videos that provide

microscopic explanations. This e-module will be used in the even semester of Class X Phase E of SMA.

b) Format Selection

The format of the e-module that will be created is determined based on the systematic presentation that follows the rules of spelling and scientific writing. The e-module is presented using the Heyzine application, which allows presenting material in the form of literacy, images, videos, as well as online pretests and posttests simultaneously. The Heyzine application was chosen because it is easy to use and is liked by students.

Research that supports the use of the Heyzine application: Sari et al. (2025), shows that the Heyzine application is very suitable for creating e-modules because it is free, can be filled with written, video or audio material, so it is able to provide differentiation in learning and can be accessed digitally on various devices. Ashari et al. (2024), shows that the student response was very good (98.69%) to the use of the Heyzine Flipbook-based E-Module at SMKN 2 Buduran Sidoarjo.

Khomaria et al. (2022), shows that creating online modules using the learning cycle model in OTKP classes gets good student response results.

Cover

The cover page is the initial display of the Phase E problem based learning nanotechnology chemistry e-module that has been created. The cover page provides information regarding the title, name of the author and supervisor.

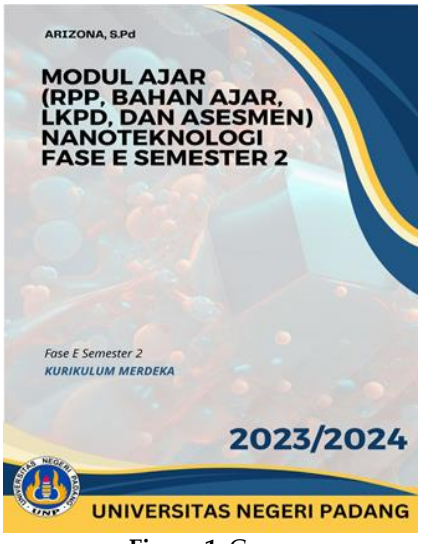

Figure 1. Cover

Pretest

Pretest is a collection of questions prepared to gain knowledge the beginning of every student about nanotechnology. In this e-module a pretest is created in google form format. The format of the questions given is multiple choice.

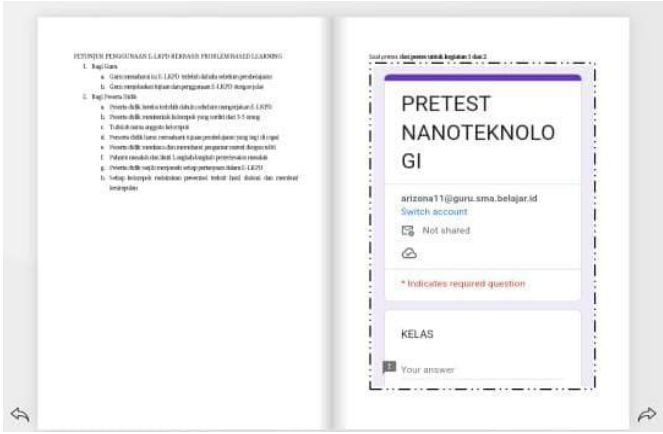

Figure 2. Pretest

Nanotechnology Materials

Nanotech nology discussion material is presented in the form of reading material equipped with colorful pictures with the aim of attracting more students' attention and increasing students' understanding.

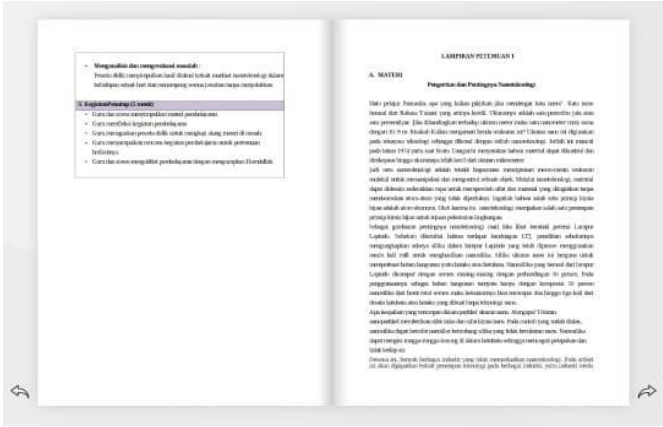

Figure 3. Nanotechnology materials

Learning Videos

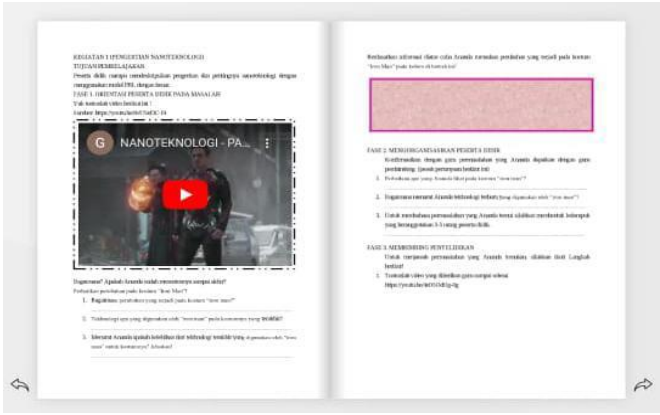

Figure 4. Learning videos

The learning videos provided are videos that provide discussion in sub-microscopic form. This video is contained in the LKPD alongside explanatory material and questions that must be completed by students.

Student worksheet

Student worksheets (LKPD) are part of the designed e-module. In this LKPD, material is placed in the form of reading texts, explanatory videos and practice questions.

Figure 5. Student worksheet

Posttest

Students' absorption of what has been shown and done on the e-module. From the post-test it will be seen whether there has been an increase in learning outcomes or not, or it might not even affect anything.

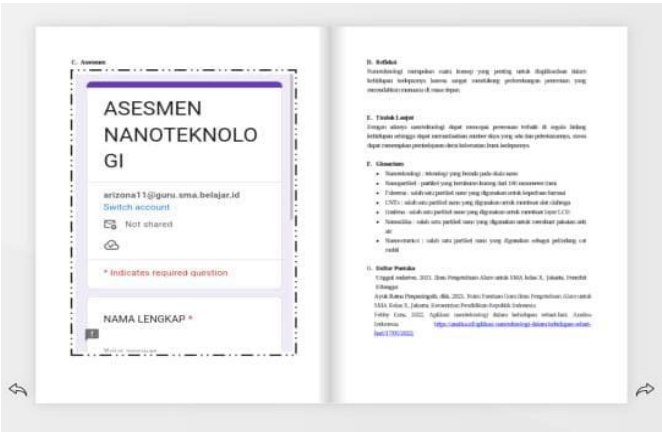

Figure 6. Posttest

Develop

Validity test

Validation of E-Modules to see the validity of a product being developed. Validation of learning E-modules that have been carried out by expert lecturers to determine the validity of E-modules is measured based on the aspects assessed (Yustinaningrum, 2017). The construct validity test consists of content components and presentation components. Based on the results of data analysis, an average value of 0.88 was obtained with a valid category for the content component of 0.91 and the presentation component obtained an average value of 0.90 with a valid category. So it can be concluded that the developed e-module is valid in terms of content and presentation. Apriliyana et al. (2012) explained that a product is said to be valid if the product being developed is adequate and all components produced are consistently interrelated. A superior product cannot be produced by one person alone, but is produced through collaboration between many parties. Therefore, collaboration between several people or units is very important to produce a superior product or is said to be valid (Irman et al., 2020). In line with the opinion of Asri et al. (2022), construct validity is the validity to what extent the impact of measurement results is able to reflect the theoretical constructs underlying the development of an instrument or product (Asri, 2017).

Practicality Test

Practicality is related to the usability of e-modules that will be used in chemistry learning. Practicality considerations can be seen from aspects such as ease of use, time efficiency and benefits (Sukardi, 2011). In the practicality test with teachers, a value of 0.926 was obtained with a very practical category. While the practicality test conducted with students obtained a value of 0.895 also with a high valid category. Based on the practicality value obtained, it can be said that the nanotechnology e-module based on problem based learning using heyzine for phase E can help teachers in delivering lessons sub-microscopically and teachers act as facilitators, helping teachers in guiding participants to understand the lesson material independently, arousing students' interest in learning and making it easier for students to find their own concepts in the learning process.

Table 2. Results of Module Practicality Data Analysis by Teachers and Students

Aspect	Teacher	Aspect	learners	Practicality category
Convenience	0.94	Etention	0.89	Very Practical
Time efficiency	0.87	Cognitive	0.89	Very Practical
Benefit	0.97	Compensatory	0.90	Very Practical
Average value	0.97		0.90	Very Practical

The results of the module practicality data analysis can be seen in Table 2. Based on these data, it can be stated that the nanotechnology e-module meets practical requirements and can be used.

Effectiveness Test

This stage aims to determine the level of effectiveness of the E-module developed by comparing the results of the pretest and posttest from students. The research data was obtained after conducting research at SMA Negeri 5 Payakumbuh in class XI. 1 as a sample class. Pretest questions were given to students before learning began to determine students' initial abilities. Then given treatment using E-module in learning then given posttest questions using the same questions. Then analyzed using the N-Gain test. The results of the N-Gain analysis can be seen in Table 3.

Table 3. Sample Class N-Gain Analysis Results

Class	N-Gain	Category
Control	0.56	Currently
Experiment	0.77	Tall

Based on the data from the N Gain processing results, it can be stated that the learning outcomes between the experimental class and the control class are significantly different, so it can be stated that the nanotechnology e-module that was tested is effective for nanotechnology learning. Media is more effective than learning without using media (Arip et al., 2021). In line with Arif, According to Hamalik in Dewanti et al. (Dewanti et al., 2018) the use of media can help the learning process become more effective and accelerate the process of students' understanding of the learning material they are studying. The acceleration of the process that occurs is because students feel happy and motivated in learning, because their learning style needs are met during the learning process using e-modules.

Conclusion

This research is development research that produces nanotechnology e-modules for Phase E SMA/MA. From the research results, it was concluded that the e-module produced was valid, practical and effective and could be used as teaching material for studying nanotechnology in Phase E in accordance with the Merdeka curriculum.

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Author Contributions

Creating research instruments, guiding the research process, and writing articles, A and validation the module, SA.

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Conflict of interest

The authors declare no conflict of interest.

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