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Project-Based Interactive Colloidal E-Module in Chemistry Learning to Improve Student's Science Process Skills and Understanding Concepts

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Abstract

This research aims to create project-based interactive e-modules based on feasible colloidal material. Thiagarajan's 4D device development model (Four-D Model) is used in this research. This research was divided into three stages: defining, designing, and developing. This research investigates the feasibility of interactive e-modules in terms of 1) validity, which includes the quality of content and constructs; 2) practicality, which includes the results of student responses and is supported by data from observations of student activities, and 3) effectiveness, which is measured by student learning outcomes in aspects of conceptual understanding and scientific process skills. The research findings are as follows: 1) the interactive e-module is stated to be valid in terms of validation results of 86.42% with very valid criteria; 2) the practicality of the interactive e-module as seen from the student response questionnaire obtained a value of 96.87% with the very category practical and student activity observation sheets as supporting data obtained a value of 97.5% in the convenient category; and 3) The average N-Gain score on the conceptual understanding test obtained a value of 0.73 with high criteria, and on the science process skill test obtained a score of 0.82 with high criteria, and classical completeness on both tests was 86.67% respectively, indicating that interactive e-modules based on project-based learning on colloidal material are suitable for learning.
Keywords: Interactive E-module, Colloidal, Project Based Learning, Understanding Concept, Science Process Skills

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INTRODUCTION

Education is entering a new educational paradigm, namely the 21st-century learning concept, where it is necessary to carry out educational construction. ATC21S (Assessment and Teaching of 21st-Century Skills) divides 21st-century skills into four domains: thinking, working, working tools, and living in the world skills (Hasibuan et al., 2022). The way of thinking category includes problem-solving and decision-making, which are essential for students facing the 21st century (Sudarmin et al., 2020).

The pandemic resulted in reduced learning progress, so it became a factor in the decline in knowledge and skills due to learning being carried out at home for too long (learning loss) (Nursamsu & Rachmatsyah, 2021). According to the Organization for Economic Cooperation and Development's (OECD) 2019 Program for International Student Assessment (PISA), students' science skills in Indonesia are at a low level (OECD, 2019). The application of project-based learning is an option because it is considered to support learning recovery due to learning loss (Rachmawati et al., 2022). Project-based learning (PjBL) is a type of learning in which the teacher is a facilitator, guiding students through developing products, testing prototypes or plans, and reflecting on all experiences (Nagarajan & Overton, 2019). Through problem-solving activities in project activities, project-based learning can encourage students to develop process skills and understanding (Sonia et al., 2021).

The colloid system is a fundamental subject matter to be taught to students because it is very contextual for studying phenomena of natural material changes. The material in the colloid system chapter is mainly applied in everyday life, and students can carry out hands-on practice for making colloids so that learning is needed that is not only teacher-centered. Applying modules with a contextual approach can increase students' learning motivation toward chemistry because it is proven to help students find meaning in learning (Salsabila & Nurjayadi, 2019). Electronic modules are a collection of non-printed digital learning media that have been systematically designed and can be used independently, requiring students to solve problems in their own way (Ernica & Hardeli, 2019). The module's characteristics are a cover page, preface, table of contents, glossary, introduction, activities, evaluation, answer keys, scoring guidelines, bibliography, and attachments (Safaruddin et al., 2020). Modules are teaching materials arranged according to a contextual approach and are proven to create more exciting and practical learning.

The results of a pre-research questionnaire conducted at the senior high school of Muhammadiyah 4 Surabaya amounted to 94.1% of students stating that the colloidal system material was considered solid. 42% of students still lack science process skills and conceptual understanding of project-based colloidal learning materials. As a result, an e-module that can improve students' science process skills and conceptual understanding is required. According to studies (Ilyas et al., 2019), Project-based learning modules on colloid subjects are valid, effective, and practical in improving thinking, social, and academic skills. Meanwhile, according to research (Rahmatsyah & Dwiningsih, 2021), interactive e-modules on the elemental periodic system material can be used as learning media in carrying out learning activities.

Implementing project-based learning to improve science process skills and conceptual understanding necessitates the development of project-based teaching materials that allow students to apply concepts and principles through project work. Based on the abovementioned problems, the researcher wishes to create a chemistry learning e-module on colloidal material that is practical and the essence of learning.

METHODS

This research type has a one-group pre-test and post-test design (Sugiyono, 2013). The Thiagarajan 4D model (Define, Design, Develop, and Disseminate) was used in this development research, but only for the development stage. This model was chosen because it aimed to produce products through interactive e-modules. Apart from that, this model does not require a relatively long time because the research stages are relatively not too complex but remain systematic, making it easier to develop tools and instruments. In this research, product development took the form of interactive e-modules. The developed teaching material will be evaluated by media experts and material experts comprised of two chemistry lecturers and one chemistry teacher, hoping to be used in the chemistry learning process on colloidal system material.

Defining Stage

Competency analysis was performed at this stage, including Graduate Competency Standards, Core Competencies, and Basic Competencies by competency boundaries and related material in the developed media. This stage's goal was to define and establish learning conditions. This stage consists of five steps that must be completed: curriculum analysis, student analysis, task analysis, concept analysis, and the creation of learning objectives.

Design Stage

A draft of the interactive e-module components was created at this stage. This aimed to create a development format and elaborate on the material discussed in the teaching material. This stage was split into three sections: media selection, media format selection, and media creation.

The media selection stage was carried out by identifying learning tools relevant to students' material and characteristics. The development of learning media products was adapted to material considered difficult and adapted to the characteristics of students at the senior high school of Muhammadiyah 4 Surabaya.

It was intended to design or design learning content, approaches, and learning resources at this stage of selecting media format. The format chosen and used in the developing learning media has interesting criteria and facilitates and aids in learning chemistry. Both the content and the design used are tailored to the needs of the students and the curriculum.

Researchers made initial products (prototypes) or product designs at the stage of making media. The product to be developed is an interactive e-module adapted to the analysis results at the definition stage. The developed product will be given input by the supervisor, and then the improvement or revision stage will be carried out before production.

Development Stage

At this stage, experts reviewed and validated the device, including three chemistry lecturers and one chemistry teacher, and then made revisions. This stage aims to produce revised teaching materials based on expert input and suggestions; the results will be used for revision.

Product Assessment and Analysis Stage

The obtained data were analyzed using data analysis techniques and data analysis of feasibility results. The review data, in the form of suggestions and input from reviewers comprised of lecturers and media experts, was used to improve the e-module that has been developed. A qualitative descriptive analysis method will be used for the review analysis. Using media validation instruments, media experts and material experts will assess data on the media's election results, namely two chemistry lecturers and one high school chemistry teacher.

Furthermore, data from expert assessment results were descriptively and quantitatively analyzed. The following formula was used to analyze the research data:

$$P(\%) = (\sum \text{score obtained})/(\text{criterion score}) \times 100\%$$

The highest score, the number of respondents, and the number of questions were combined to create the criterion score. The percentage obtained was interpreted based on the validity of each criterion. If you get a score between (1) 0 to 20 percent, it is considered flawed criteria; (2) 21 to 40 percent included deficient criteria; (3) 41 to 60 percent included sufficient criteria; (4) 61 to 80 percent included valid criteria; and (5) 81 to 100 percent included very valid criteria.

The application is considered appropriate with the following content eligibility criteria, which is determined by the percentage of the criteria mentioned above: (1) the eligibility of the material content; (2) the accuracy of the material in the e-module; (3) updating questions and materials on e-modules; and (4) the suitability of the application with the dimensions of the skills being trained (concept understanding). Characteristics of the e-module, skills in the characteristics of the e-module, presentation and graphic components, and linguistic components form the construct feasibility criteria. The developed interactive e-module has very valid criteria if the percentage of research findings is 81%. Students who had evaluated the usefulness of the e-module filled out a response questionnaire to help determine how practical the e-module was. The percentage of student response data from the questionnaire was examined based on the Guttman scale. The Guttman Scale measurement is done to get a definite "yes" or "no" answer. Score "1" indicates "yes", while "2" indicates "no" (Sugiyono, 2016).

The results of the student response questionnaire were then quantitatively and descriptively analyzed as a percentage of the data from the Guttman Scale using the following formula:

Total score = (Sum of results: Score criteria) x 100%

The percentages obtained are then interpreted in terms of five response criteria. If you get a score between (1) 0 to 20 percent includes not practical criteria; (2) 21 to 40 percent includes less practical criteria; (3) 41 to 60 percent includes practical enough criteria; (4) 61 to 80 percent includes practical criteria; and (5) 81 to 100 percent includes efficient criteria.

If the percentage of research findings is less than 81%, e-module developed criteria are beneficial. The pretest-posttest-test sheet is used to determine e-module effectiveness. The initial test sheet, or pretest, can be used to determine students' initial abilities, and the final test sheet, or posttest, can be used to determine students' understanding abilities. The test sheet includes a skills domain description and multiple-choice questions from the knowledge domain. The following calculations were used in the descriptive and quantitative analysis of student-test results ata using N-gain scores.

$$(g) = \frac{[\%(Sf)\ -\ \%[Si]}{[100\%\ -\ \%(Si)]}$$

Information:
(g) : increase in learning outcomes
(Si) : mean pretest value
(Sf) : mean prosttest value

The score calculation (g) results are interpreted in the range of values according to the category.

Table 1. N-Gain Score Interpretation Criteria

Value Range	Criteria
G ≥ 0,7	High
0,3 ≤ G ≥ 0,7	Medium
G < 0,7	Low

Based on these criteria, the e-module is declared effective if an increase in the N-gain score is obtained ≥ 0.7, which is included in the high category.

RESULTS & DISCUSSION

Results

This chapter will describe the research findings on developing project-based interactive e-modules on colloidal materials using Thiagarajan's 4D device development model (Four-D Model). This research is divided into three stages: the defining stage, the design stage, and the development stage (Ibrahim, 2014). These stages will be described in detail below.

Defining Stage

a. Front End Analysis

Based on the results of interviews conducted by researchers, there were several problems faced by students, namely (1) learning Chemistry, especially colloidal system material, had not been linked to concrete learning in real life and its implementation had not been in the form of project-based learning; (2) there is no project-based interactive e-module on colloid material that has been developed; and (3) teachers have not paid attention to aspects of science process skills and conceptual understanding of colloidal system material so that students' abilities tend to be low.

b. Analysis of Student Characteristics

The research was conducted in class XI-IPA 1 with 30 students, so according to Piaget's theory, students of this age are in the formal operational stage. According to Piaget's learning theory, child development is divided into several stages, namely sensorimotor (0-2 years), pre-operational (2-7 years), concrete operations (7-11 years), and formal operations (11 years to adulthood). The research subjects were students of class XI SMA with an age range of 15-18 years, so according to Piaget's theory, students of this age were at the formal operational stage. Children can deal with hypothetical situations at this stage, and their thought processes are no longer dependent on immediate and tangible things. Children can think abstractly, idealistically, and logically.

The developed e-module supports a hypothetical way of thinking, as in activity two, students are asked to formulate hypotheses that arise from the problems they face. The topics of these problems include Haagen Dazs ice cream being withdrawn because of the content of ethylene oxide, markers containing xylene, dangerous chemicals, the effects of using counterfeit shampoo, and the dangers of DEET in mosquito repellents. Students are also invited to think about solving problems by designing simple experimental procedures.

c. Task Analysis

Material analysis is the stage of analyzing the Semester Implementation Plan and content standards the curriculum sets. Material analysis is done by detailing the content of learning materials. Content structure analysis is used to develop e-modules on colloidal system material, especially on understanding the colloid system, types of colloids, colloid properties, colloid stability, colloid making, colloid purification, and colloid use in everyday life.

d. Concept analysis

Concept analysis is needed to identify the main concepts to be taught. The material used in this research is colloid system material. The colloid system material has several sub-discussions, namely the types of colloid systems, the uses of colloids in life based on their properties, the manufacture of food or other products in the form of colloids, or involving the colloid principle. Colloid system material is contained in essential competencies 3.14, namely classifying various types of colloid systems and explaining the uses of colloids in life based on their properties, and 4.14, namely making food or other products in the form of colloids or involving the colloid principle. The concept used is solving problems and working in groups using project learning, and then the final result is in the form of a product presented in front of the class. With the help of interactive e-modules, students can more easily monitor and work on project assignments independently and determine whether the results obtained are correct.

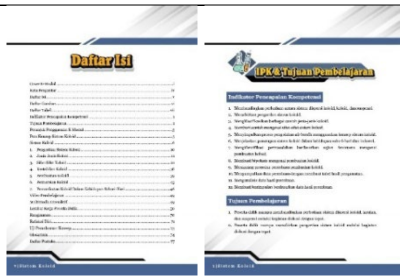
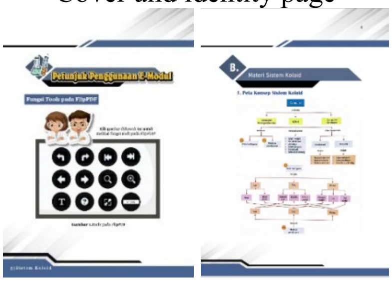
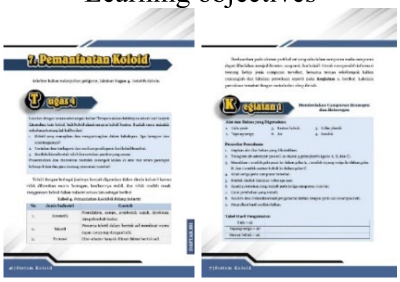
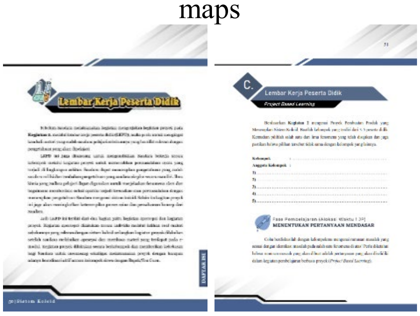
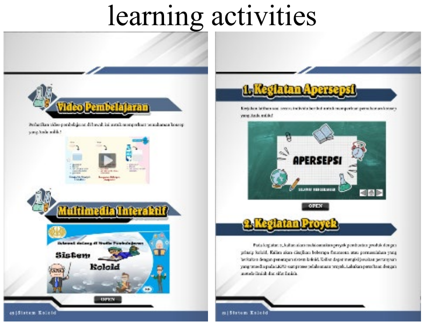
e. The Purpose of The e-module

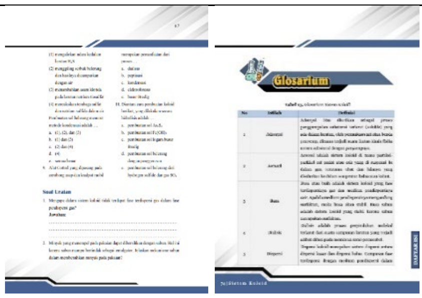
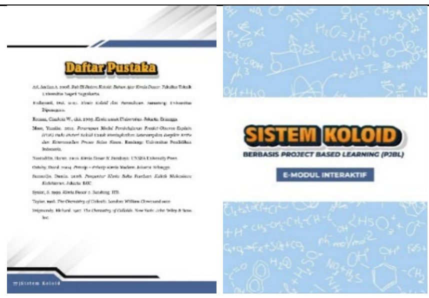
Instructional objectives are analyzed to determine indicators of learning achievement based on concept analysis and curriculum analysis. Writing learning objectives determines what studies will be displayed in the module, the problem grid, and how much the learning objectives have been achieved. The purpose of developing interactive e-modules on colloid material is to make it easier for students to understand the concept of colloidal systems and improve students' science process skills in solving project assignments in interactive e-modules.

Design Stage

A draft of the interactive e-module components is created during the media design stage. This aims to develop the format and elaboration of the material to be discussed in teaching materials. Table 2 shows the first draft or storyboard.

Table 2. Initial Draft of Interactive E-Module

Number.	Pictures and Descriptions	Number.	Pictures and Descriptions
1.	 Cover and identity page	2.	 Learning objectives
3.	 Instructions for use and concept maps	4.	 Materials, assignments, and learning activities
3.	 Project-based student worksheets	4.	 Interactive learning videos and multimedia

Number.	Pictures and Descriptions	Number.	Pictures and Descriptions
5.	 Understanding test and glossary	6.	 Bibliography and back cover page

Development Stage

In the Thiagarajan model, the development stage includes product design realization activities as well as validation or assessing the feasibility of the product design. The conceptual framework is realized into a product ready to be implemented in a limited trial of 30 students during development. The following describes the development phase that was carried out.

A chemistry lecturer carried out the research to get input from the lecturer to improve the project-based learning-based interactive e-module being developed. The research was carried out in draft 1 to get suggestions and input from the chemistry lecturer at the Faculty of Mathematics and Natural Sciences of Unesa and to produce draft 2. As a result, the media was ready for validation by three validators: two lecturers and one chemistry teacher. Table 3 summarizes the findings of the e-module review.

Table 3. Results of Review and Revision

Number.	Before Revision (Draft 1)	After Revision (Draft 2)
1.	The components on the cover page do not contain the Unesa logo, author's name, and supervisor.	I am adding the Unesa logo, author's, and supervisor's names on the cover page.
2.	The learning objectives listed in the e-module are not by the problem grid. 1. Students can predict colloid phenomena in everyday life. 2. Students can distinguish the types of colloids. 3. Students can analyze how to make colloids. 4. Students can analyze the use of colloidal properties in everyday life. 5. Students can analyze how to make colloids. 6. Students can analyze the definition of colloid. 7. Students can explain the role of colloids in cleaning oil with soap. 8. Students can explain the separation of amino acids using	Justification of learning objectives. 1. Students can compare differences in colloidal dispersion systems, solutions, and suspensions through appropriate discussion activities. 2. Students can interpret the meaning of the colloid system through appropriate discussion activities. 3. Students can classify various examples of colloid types after carrying out observation activities correctly. 4. Students can give examples regarding the properties of the colloidal system after carrying out observation activities in the literature study activities correctly. 5. Students can conclude the process of treating clean water using the

Number.	Before Revision (Draft 1)	After Revision (Draft 2)
	electrophoresis.	colloid system concept through appropriate discussion activities. 6. Students can explain the application of the colloid system in everyday life and industry after conducting appropriate literature study and discussion activities. 7. Students can formulate a problem by correctly presenting the phenomenon of making colloids. 8. Students can propose hypotheses correctly after formulating the appropriate problem. 9. Students can determine tools and materials, variables, and experimental procedures by correctly making colloids. 10. Students can make tables of observations based on experimental results correctly. 11. Students can analyze the process of making colloids through the experimental results obtained. 12. Students can make reasonable conclusions after analyzing data in groups. 13. Students can correctly communicate each group's experimental results through class discussion activities.
3.	There is no explanation regarding the tools in Flip PDF or instructions for using interactive e-modules.	We are adding tools to flip pdf and instructions for using interactive e-modules.
4.	There are no learning videos in interactive e-modules.	Adding learning videos to interactive e-modules such as experimental videos and material explanations.
5.	There is no interactive multimedia in the e-module.	Adding interactive multimedia to e-modules.
6.	Selection of problems presented in interactive e-modules. 1. Markers contain xylene, a dangerous chemical 2. Environmental damage due to tofu waste 3. Soy milk preservatives and durability 4. “Dry shampoo gel” is a natural shampoo made from lerak fruit extract. It is dangerous to eat	The problems presented in the interactive e-module. 1. Haagen Dazs ice cream was recalled due to its ethylene oxide content 2. Markers contain xylene, a dangerous chemical 3. Effects of using fake shampoo 4. Danger of DEET content in mosquito repellents

Number.	Before Revision (Draft 1)	After Revision (Draft 2)
	moldy bread	
7.	There are no guidelines for the implementation of project activities.	Additional guidelines for implementing project activities when learning uses interactive e-modules.
8.	The construct design on the concept map is not straightforward.	Revision of the concept map according to input from the lecturer.
9.	The Science Process Skills component on the worksheet is not yet visible.	Adding Science Process Skills components to student worksheets.
10.	The practice questions are not yet interactive.	Revise the practice questions to make them interactive.

The term validation is used to describe the validity of an e-module. Three validators performed the validation: two chemistry lecturers at the Faculty of Mathematics and Natural Sciences Unesa and one chemistry teacher at Muhammadiyah 4 Surabaya Senior High School. The validator validated Draft 2 (revision result). Content and construct validity (appearance, language, and presentation) are among the aspects evaluated.

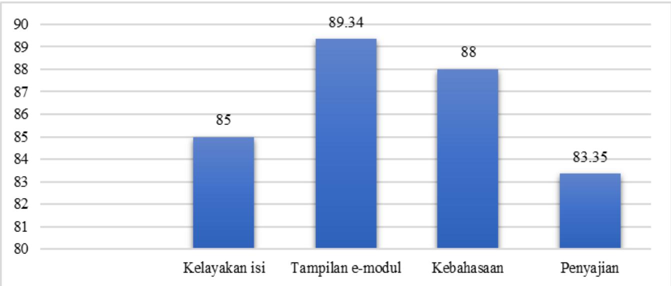


Figure 1. Validation Results Diagram

The e-module trial was carried out at the senior high school of Muhammadiyah 4 Surabaya with 30 students who had received colloidal system material as subjects. The students tested were 30 students with heterogeneous academic abilities: 10 upper groups, 10 middle groups, and ten lower groups. Students are divided into five groups of six students each. The try-out was conducted on students with diverse academic abilities, so the data obtained represented all students in the field with varying abilities. The flow of the e-module trial is presented in Figure 2.

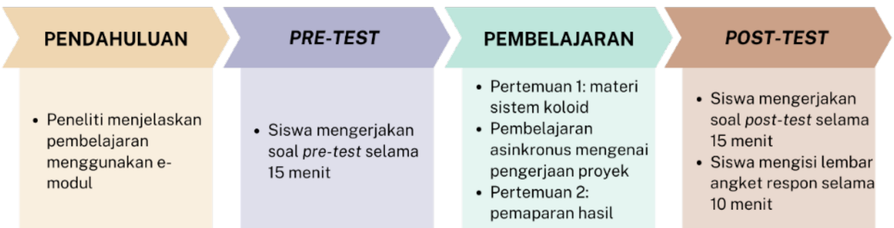


Figure 2. The Flow of Interactive E-module Trial

Limited trials assessed the usefulness and effectiveness of the developed interactive electronic modules. The practicality test is an essential stage because it is used to collect data on the practicality of the e-module being developed. The instrument used was a student response questionnaire, and student activity was observed to support the response questionnaire data. Student responses are student responses after using interactive e-modules. Figure 3 shows a comparison of student response results for each component.

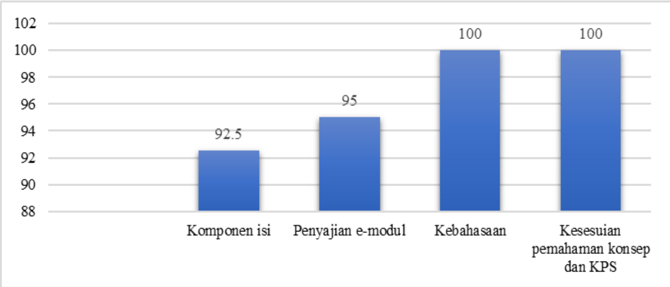


Figure 3. Student Response Diagram

The overall percentage of student responses received was 96.87%, which means that interactive e-modules are feasible to use in practical learning. From the user side, does a reality show that teachers and students can apply what is developed (Plomp & Nieven, 2010)?

This research measured the learning outcomes of understanding concepts using pre-test and post-test questions on concept understanding tests and science process skills tests. Before calculating the N-gain value, the data on the students' pre-test and post-test values are checked for normality. Average distributed data is defined as data that conforms to the shape of the normal distribution and is centered on the mean and median values (Ghasemi & Zahediasl, 2012). The normality test was carried out using SPSS version 26.0, and the Kolmogorov-Smirnov test showed that the data obtained was generally distributed if the significance value was more significant than 0.05. After completing the data normality test, the results are shown in Table 4 and Table 5.

Table 4. Normality Test on Concept Understanding Test

		Pre-Test	Post-Test
N		30	30
Normal Parameters[a,b]	Mean	47,0000	86.0000
	Std. Deviation	16,43168	9.41386
Most Extreme Differences	Absolute	0,132	0,138
	Positive	0,132	0,138
	Negative	-0,119	-0,131
Test Statistic		0,132	0,138
Asymp. Sig. (2-tailed)		0,196	0,150

a. Test distribution is normal.
b. Calculated from data.

Table 5. Normality Test on the Science Process Skills Test

		Pre-Test	Post-Test
N		30	30
Normal Parameters[a,b]	Mean	38,3330	88,4713
	Std. Deviation	15,64426	9,20031
Most Extreme Differences	Absolute	0,155	0,136
	Positive	0,155	0,106
	Negative	-0,098	-0,136

Test Statistic	0,155	0,136
Asymp. Sig. (2-tailed)	0,065	0,165

a. Test distribution is normal.
b. Calculated from data.

The significance value on the concept understanding aspect test obtained during the pre-test was 0.196, and the post-test significance value was 0.150. The significance value on the science process skills test obtained during the pre-test was 0.065, while the post-test significance value was 0.165. The significance value meets the minimum threshold for data considered normally distributed. In terms of effectiveness, the interactive e-module being developed is said to be feasible if the N-Gain value is at least 0.3 or is in the medium and high categories (De Cock, 2012). Students are said to be complete if their grades meet the Minimum Completeness Criteria (KKM), which is 75 (Agustina et al., 2021). The overall N-gain test was carried out using SPSS version 26.0. The data obtained by the N-gain on the concept understanding test was 0.7302. The science process skills test was 0.82, indicating that the N-gain score was 0.7 in the category high, meaning that the developed e-module is effectively used to improve students' conceptual understanding and science process skills. The results of the N-gain test are described in Table 6 and Table 7.

Table 6. N-Gain Test Results of Concept Understanding Test

			Statistic	Std. Error
N-Gain Score	Mean		0,7302	0,02920
	95% Confidence Interval for Mean	Lower Bound	0,6705	
		Upper Bound	0,7899	
	5% Trimmed Mean		0,7280	
	Median		0,6667	
	Variance		0,026	
	Std. Deviation		0,15993	
	Minimum		0,50	
	Maximum		1,00	
	Range		0,50	
	Interquartile Range		0,26	
	Skewness		0,513	0,427
	Kurtosis		-0,810	0,833

Each Concept Understanding component included in this research had its students' process skills analyzed. The results of the Concept Understanding test obtained in the limited trial will be described in the graphs in Figure 4.

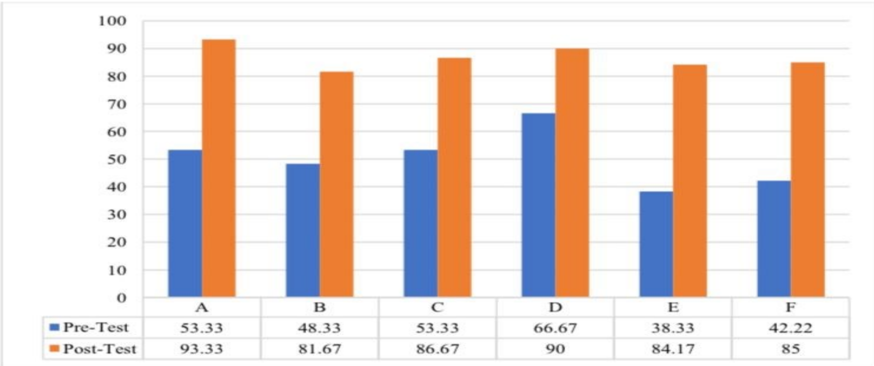


Figure 4. Pre-Test and Post-Test Values for Each Concept Understanding

Information:
A= Interpret
B= Giving Examples
C = Classifying
D= Drawing Inference
E = Comparing
F= Explaining

Table 7. N-Gain Test Results for the Science Process Skills Test

			Statistic	Std. Error
N-Gain Score	Mean		0,8189	.02579
	95% Confidence Interval for Mean	Lower Bound	0,7661	
		Upper Bound	0,8716	
	5% Trimmed Mean		0,8290	
	Median		0,8333	
	Variance		0,020	
	Std. Deviation		0,14126	
	Minimum		0,42	
	Maximum		1,00	
	Range		0,58	
	Interquartile Range		0,13	
	Skewness		-1,007	0,427
	Kurtosis		1,208	0,833

Each Science Process Skills component included in this research had its students' process skills analyzed. The results of the Science Process Skills test obtained in the limited trial will be described in the graphs in Figure 5.

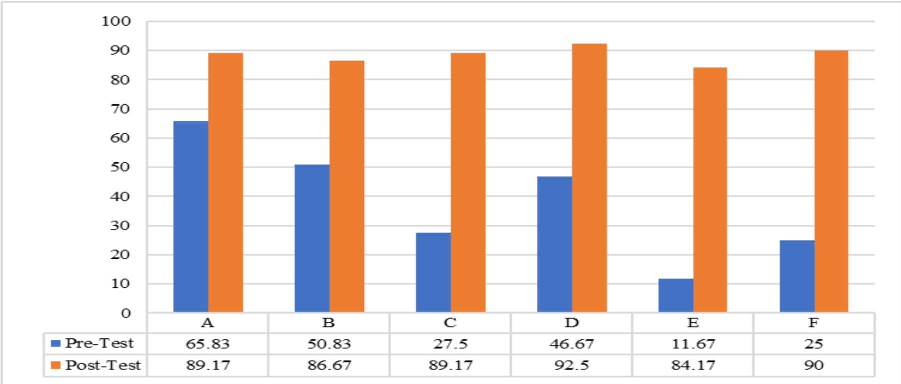


Figure 5. Pre-Test and Post-Test Values for Each Science Process Skills

Information:
A = Identifying Problems
B = Formulating a Hypothesis
C = Planning Experiments
D= Classifying Data
E = Interpreting Data
F = Making Conclusions

Based on the graphs in Figures 4 and 5, the results of students' concept understanding and science process skills tests show improved learning using interactive e-modules.

Discussion

Validity of Interactive e-module

Validation is used to describe the validity of the e-module. Three validators, two chemistry lecturers, and one chemistry teacher did the validation. The validator validated draft 2 (the result of revision). The aspects assessed include content and construct validity (appearance, language, and presentation).

Interactive e-module validation consists of four criteria namely: 1) content feasibility provides an assessment of the components in the e-module, including material suitability, content suitability with project-based learning syntax, and content suitability with concepts and skills understanding components process science; 2) the display of the e-module provides an assessment of the layout, design components such as color, font type, background, and others; 3) linguistics provides an assessment of the language used in the e-module including language structure, use of terms, symbols, icons, and conformity with PUEBI; and 4) the presentation provides an assessment of the presentation of e-modules, supports the presentation of material, presentation of learning, and presentation of illustrations and pictures. The results of the validation table show that the average content eligibility value is 85%, the e-module display is 89.34%, the language is 88%, and the presentation is 83.35%. Each criterion in the validation results is classified as very valid because it has a percentage value of more than 80% (Riduwan, 2013). The overall average percentage of e-module validation results is 86.42%, which shows very valid criteria. The validation results stated that the interactive e-module was valid and could be tested with minor revisions.

Figure 1 depicts the percentage of validation results more significant than 80%, indicating that they meet the valid criteria. The overall average percentage of e-module validation results is 86.42%, indicating that the criteria are very valid. The interactive e-module was declared valid and could be tested with minor changes according to the validation results.

The revision stage is carried out if the interactive e-module being developed contains aspects that the validator declares invalid, requiring revisions based on input from the validators to produce interactive e-modules that are declared valid. In this research, the aspects assessed were very valid criteria, so no revision was needed. The results of this revision will then be tested on 30 students. E-modules that have been reviewed and validated need to be evaluated. Evaluation is done through limited trials. The evaluation aims to determine whether the developed teaching materials are suitable or if things still need improvement (Rusmansyah et al., 2023).

Practicality of Interactive E-module

The practicality test is essential because it is used to obtain practicality data for the developed e-module. The instruments used were student response questionnaires and student activity observation to support the response questionnaire data. Student responses are student responses after using interactive e-modules. This response questionnaire is related to 1) knowing the clarity of the material and its relation to the components of understanding concepts and science process skills, 2) knowing the students' interest in the e-module, and 3) knowing the clarity of the language used in the e-module.

Student responses to the e-module content components averaged 92.5% with efficient criteria. The e-module, in terms of presentation, received a student response of 95% with efficient criteria. The e-module, when viewed on language and suitability with the components of understanding concepts and science process skills, gets a response of 100% with efficient criteria. The percentage of student responses as a whole received a response of 96.87%, so it can be concluded that interactive e-modules are declared suitable for use in learning in terms of practical aspects. According to Nieveen, regarding users, the reality shows that teachers and students can apply what is developed.

The results of observing student activities as a whole get a success percentage of 97.5% in the convenient category, so it can be concluded that interactive e-modules are declared suitable for use in learning in terms of practical aspects.

Effectiveness of Interactive E-module

The effectiveness of the media is one of the eligibility requirements of the media to be used in the learning process. The effectiveness of the interactive e-module developed is viewed from two data, namely data on learning outcomes in the aspect of understanding concepts and data on learning outcomes in the aspect of science process skills. These data were obtained from a limited trial conducted at SMA Muhammadiyah 4 Surabaya, which will be described and discussed below.

The learning outcomes that you want to know and improve in this research are the cognitive learning outcomes of students because they are included in the core competencies in Indonesia's curriculum. The syllabus's cognitive domain (knowledge) is in core competency 3. One of the cognitive domains that refer to Bloom's taxonomy is understanding, which is the ability to grasp the meaning of the material, which can be in the form of words or numbers, and explain cause and effect. Concept learning is a person's ability to develop abstract ideas that allow him to classify or categorize an object. The concept is tiered; it can be seen from the example of the concept of objective function developed from the concept of relations and so on (Sonia et al., 2021).

Understanding the concept can be interpreted as a person's thinking process to process the received teaching materials so that they become meaningful. Conceptual understanding is understanding concepts, operations, and relationships (Sonia et al., 2021). Indicators of understanding the concept are an essential aspect of learning.

Indicators of understanding the concept are interpreting, giving examples, classifying, drawing inferences, comparing, and explaining (Rusmansyah et al., 2023).

The learning outcomes of the conceptual understanding aspects in this research were measured using the pre-test and post-test—n-Gain value calculation. The significance value (α) obtained during the pre-test was 0.196, while the significance value (α) obtained during the post-test was 0.150. The interactive e-module developed can be said to be feasible in terms of effectiveness if the minimum N-Gain value is 0.3 or is in the medium and high categories (De Cock, 2012). The N-Gain results of the concept understanding test showed that 14 students in this research were in the high category while 16 were in the medium category. Students 2, 10, 12, 19, and 27 obtained the highest N-Gain scores, which reached 1.00. The overall N-gain test was carried out using SPSS version 26.0, which shows that the data obtained by N-Gain with a score of 0.7302 means that the N-gain score ≥ 0.7 is in the high category, so it can be said that the e-module being developed is effectively used to improve students' conceptual understanding.

Analysis of learning outcomes aspects of science process skills will be described as follows. Science Process Skills are essential for students because with these skills, students are expected to gain new knowledge or develop the knowledge they have (Agustina et al., 2021). The science process skills approach is a vehicle for students to find and develop the facts, concepts, and principles that will be developed to support the development of process abilities in students. The Science Process Skills trained on students in this research included identifying problems, formulating hypotheses, planning experiments, classifying, interpreting data, and drawing conclusions (Fitriya & Mitarlis, 2020).

Learning outcomes in the science process skills aspect of this research were measured using pre-test and post-test questions—n-Gain value calculation. The significance value (α) obtained during the pre-test was 0.065, while the significance value (α) obtained during the post-test was 0.165. The interactive e-module developed can be said to be feasible in terms of effectiveness if the N-Gain value is at least 0.3 or is in the medium and high categories (De Cock, 2012). The results of the N-Gain test of science process skills showed that 25 students in this research were in the high category, while five were in the medium category. The highest N-Gain scores were obtained by students 2, 16, 17, 20 and 30, reaching 1.00. The N-gain test as a whole was carried out using SPSS version 26.0, which shows that the data obtained by N-Gain with a score of 0.82 means that the developed e-module can be used effectively to improve students' science process skills.

Details of the scores for each science process skills component that students have achieved will be described as follows: (1) the percentage of students who identified problems increased from 65.83% to 89.17%. Students are given a phenomenon in everyday life to practice problem-identification skills. One of the science process skills components, namely identifying problems, can be trained through guided inquiry-based e-modules (Yanti, 2020); (2) the percentage of students who can formulate hypotheses has increased from 50.83% to 86.67%. One of the science process skills, namely formulating hypotheses, can be measured by making temporary answers or compiling sentences in the form of temporary statements based on experimental questions or conclusions to be made (Sudarmin et al., 2020). One of the science process skills components, namely formulating hypotheses, can be trained through chemo-entrepreneurship-based colloid e-modules (Harding et al., 2022); (3) the percentage of students who were able to plan experiments increased the average value during the pre-test by 27.5% while during the post-test by 89.17%. One of the science process skills components, namely planning experiments, can be trained through student worksheets on acid-base material (Fitriya & Mitarlis, 2020); (4) the percentage of students who were able to classify data increased from 46.67% to 92.5%. Data classification skills can be measured by identifying the general characteristics of a chemical reaction, identifying the general characteristics of a chemical reaction that has ended or is nearing the end, and writing down observations in the observation table. In the learning that has been done, students are asked to solve problems regarding colloidal systems using project activities in groups. Students are asked to determine and record the time when experimenting, and students are asked to enter the data from the experiment in an observation table (Sudarmin et al., 2020); (5) The percentage of students who can interpret data has increased the average value of students from 11.67% to 84.17%. The science process skills of analyzing data can be measured using scientific knowledge and understanding to explain and interpret observations, measurements, or data examples. Students are asked to analyze the data written on the results of observations in learning. Where the observation data is obtained based on experiments carried out during learning (Yanti, 2020); (6) the percentage of students who could draw conclusions increased the average value from 25% to 90%. One of the science process skills, namely, concluding, can be measured by stating whether hypotheses can be accepted or rejected with appropriate reasons and considering whether the evidence collected is sufficient to support the conclusion (Sudarmin et al., 2020). So, the results of students' science process skills tests show an improvement before they learn using interactive e-modules. This demonstrates the impact of incorporating interactive e-modules into learning to help students develop Science Process Skills.

The findings of this research are also supported by constructivist theory. According to constructivist learning theory, students must personally find and apply complex information and check the information they have obtained (Nur et al., 2008). Project-based learning modules on colloids to improve life skills have proven valid, effective, and practical in improving thinking, social, and academic skills, showing a percentage increase at each meeting (Ilyas, 2019). Project-based learning tools are valid for improving students' science process skills (Fatmawati, 2022). interactive e-modules in chemistry material can be used as a learning medium for learning activities (Rahmatsyah & Dwiningsih, 2021). In this case, interactive e-modules can act as media that provide experiences for students to learn in a fun way, allowing students to build their knowledge independently.

CONCLUSION

The findings indicate that the interactive e-module based on the learning project on the developed colloidal material is suitable for use in the learning process. The feasibility of interactive e-modules can be assessed using three criteria: validity, practicability, and effectiveness. With very valid criteria, the interactive e-module validation results were 86.42%. In the convenient category, the results of practicality based on the number of student responses obtained a value of 96.87%. The N-Gain value demonstrates the effective results. The results of the pre-test and post-test conceptual understanding test obtained an average N-Gain value of 0.73 with high features, and the science process skills test results obtained an average N-Gain value of 0.82 with high features.

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