Development of STEM-Based E-Modules on Colloid Material to Train Scientific Literacy Skills

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Abstract: *The causes of low literacy in Indonesia are influenced by several factors including teaching materials that are not under the development of students, teacher-centered learning, and low levels of reading ability. This research was conducted to determine the differences in teaching materials used in schools and STEM-based e-modules that were developed and to see the level of feasibility and practicality of STEM-based e-modules. This research used to research and development (R&D) methods by adopting the borg and gall model consisting of over seven stages namely, research and data collection, planning, development, product validation, product revision, field trial, and final product. based on the results of STEM-based e-module validation on colloidal material, the percentage of media and material experts was 89.6% and 90.6%. The practicality of the teacher obtained a percentage of 89%. Based on the validation results of media experts, material experts, and teacher practicality, it was found that STEM-based e-modules were declared feasible and practical to use in the learning process. Based on the results of an analysis of differences in teaching materials in schools and the developed e-modules, it was stated that they were different both in terms of the format and the learning model used.*

INTRODUCTION

The ever-developing technology has a major influence on the field of education. Technology can be used as a means of providing and obtaining information needed by teachers and students. In this technological era, educators are expected to be able to be more creative and innovative in developing media and teaching materials used in the learning process. Teaching materials that follow technological developments can support learning to achieve the desired competencies (Rahman et al., 2021).

The use of interactive teaching materials is needed in learning to develop soft skills owned by students. This is because interactive teaching materials can increase efficiency and motivation in learning and facilitate students to learn independently. Currently, many technology-integrated teaching materials have been developed to maximize the learning process, both group and independent learning (Muchtar et al., 2022).

One type of technology-integrated teaching material is an e-module. Dalimunthe & Simorangkir, n.d. (2022) explained that e-modules are teaching materials consisting of learning series packaged in electronic form. The advantages of e-modules compared to other non-electronic teaching materials are that e-modules can contain animations, images, videos, and so on. The use of e-modules is not only practical but also able to improve critical thinking learners.

Pangesti et al., (2017) explained that STEM is an integrated approach to science, technology, engineering, and math. STEM-based learning has characteristics including improving students' soft skills in solving a problem, training students' sensitivity in dealing with developing issues, an inquiry learning process that involves students, providing freedom

of opinion, and guiding students to apply STEM understanding at work. groups or independently(Jamilah & Silaban, n.d.).

Based on the results of the OECD study (Organisation for Economic Co-operation and Development) in PISA (Programme for International Student Assessment) conducted from 2000-2018, placing Indonesia is one of the countries with the lowest literacy rates. PISA its elf aims to evaluate the education system related to learning achievement which is followed by more than 79 participating countries (Narut & Supradi, 2019). In 2018, Indonesia was ranked 74th out of 79 participating countries with a student literacy score of 396. This score is very far from the expected score, this shows that the level of scientific literacy ability in Indonesia is still relatively low. The causes of low scientific literacy in Indonesia can be influenced by several factors including, the selection of teaching materials that have not fully touched the souls of students, the tendency of teachers to provide material concepts that are not related to everyday life, the lack of interest in reading students and teacher-centered learning which is oriented towards targeting mastery of the material without considering the ability of students to receive learning well (Fuadi et al., 2020).

Based on the results of interviews with chemistry teachers and students at SMA Negeri 07 Medan and SMA Negeri 15 Medan, stated that colloidal system material is material that contains theoretical concepts and tends to be memorized so that it makes students bored in learning. Learning resources that are often used by teachers in learning are printed books, PowerPoint, youtube, and the internet. In addition to learning resources, the learning methods used by chemistry teachers are PBL and PjBL learning methods such as debriefing in solving a problem, and sometimes doing simple practicums on certain sub-materials. The learning resources that are often used are not yet integrated so the chemistry learning process is only centered on the teacher and doing exercises, resulting in a lack of students' critical thinking level in implementing colloidal system material in everyday life.

In line with the research conducted, the results of the research conducted by Suryani et al., (2020) related to the development of STEM-based digital modules using the 3d flipbook application obtained very valid results with a feasibility score of 92.44% and practical 81.70% so that it can be utilized as an alternative teaching material that can be used in learning. Furthermore, the results of Susanti's research (2018) stated that the application of science, technology, engineering, and mathematics (STEM)-based chemistry learning media to improve student learning outcomes obtained an average overall validation value of experts starting from the assessment of material, media, and evaluation of 92.23%, this shows that STEM-based e-modules are very feasible to be used as an alternative source of teaching materials.

Another study regarding STEM-based E-modules by Nurhayati et al., (2021) stated that the development of STEM-based chemistry e-modules with an ethnoscience approach showed very good student responses. Of the five indicators given the assessment showed a positive response with an average practicality test result of 86.2%, meaning that this module is practically used in the learning process. The highest percentage data is shown in the presentation of the material at 92.3%, while in the learning category it shows the lowest percentage of responses, namely 83.3% when compared to other indicators, although it is still within practical criteria.

Based on the problems above, there is a need for innovation in teaching materials, namely in the form of chemical e-modules that are integrated with STEM as an alternative teaching material that supports and trains and increases scientific literacy. Besides that, by developing STEM-based e-modules it can support independent learning students. So that

researchers are interested in carrying out research with the title "development of STEM-based e-modules on colloidal material to train scientific literacy skills.

RESEARCH METHOD

This research was conducted at SMA Negeri 07 Medan and SMA Negeri 15 Medan. This type of research is descriptive quantitative research by applying the R&D method. The research design adopts the model Borg and Gall which consists of 7 stages, namely research and data collection, planning, development, product validation, product revision, field trials, and the final product. Model Borg and Gall is a research model that is oriented towards developing teaching material products that are suitable for use (Dhia Octariani, 2020). The purpose of research and development is to produce a product using testing and validation to produce a product that is feasible, practical, and useful for learning. The development stage model Borg & Gall can be seen in **Figure 1.**
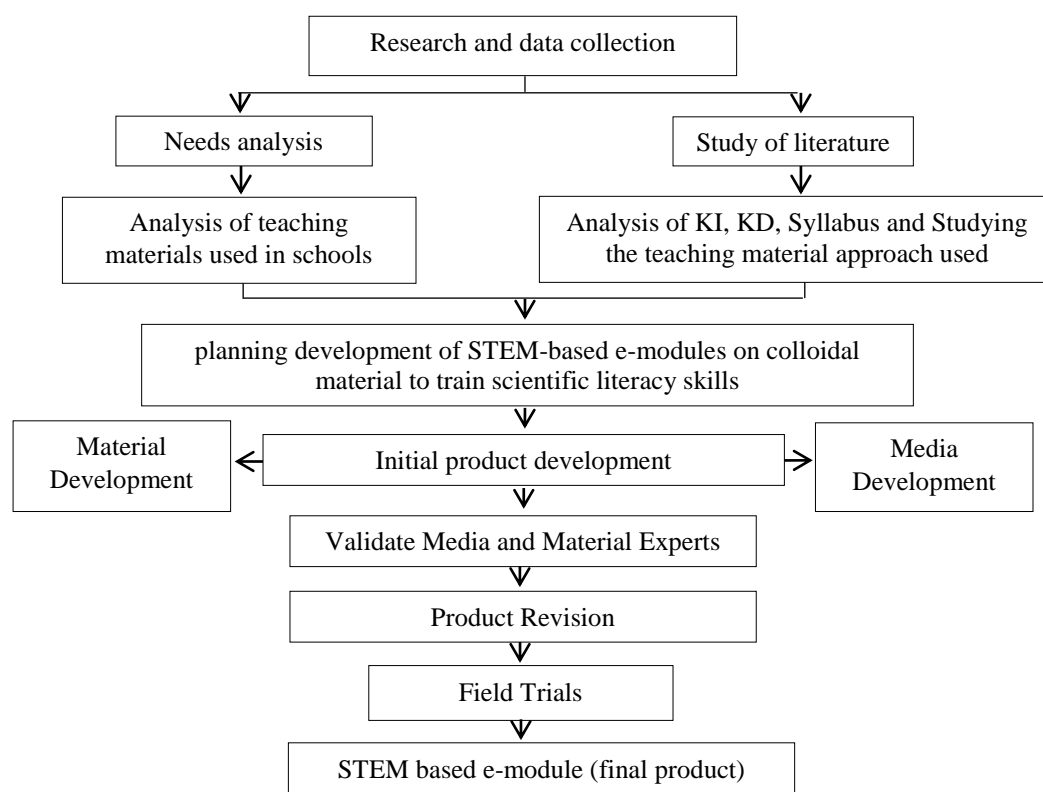
Figure 1 The research procedure of the borg and gall model

The data obtained during the research were tested qualitatively descriptively and quantitatively. Descriptive qualitative analysis is obtained from the accumulation of observational data, interviews, and input from expert validators to perfect the product being developed. Meanwhile, quantitative analysis was carried out by calculating the results of expert validation and the results of teacher response sheets to see the level of feasibility and practicality of the e-module being developed. The feasibility aspect of the teaching materials developed was adopted from the feasibility aspect according to BSNP (Ummah et al., 2018).

1.   *Expert Validation*

Before being used in the learning process, the developed module should be categorized as feasible. The feasibility categorization of e-modules can be done using a validation (feasibility) test (Irman & Waskito, 2020). The STEM-based e-module validity instrument used is a media expert validation sheet and a material expert validation sheet. Validation assessment using Likert scale criteria. The Likert scale is a measurement scale that has a score range of 4 or more questions that are combined in finding values to present the results of the product being developed (Setyawan & Atapukan, 2018). The validation questionnaire used has a score range of 1-5, each answer choice is given a score of: (5) (SS) Strongly Agree; (4) (S) Agree; (3) (KS) Disagree; (2) (TS) Disagree; and (1) (STS) Strongly Disagree(Andaresta & Rachmadiarti, 2021). Likert scala criteria can be seen in **Table 1**.

Table 1 Scale Answer Criteria Likert

Criteria	Score
Strongly Agree (SS)	5
Strongly Agree (S)	4
Disagree (KS)	3
Disagree (TS)	2
Strongly Disagree (STS)	1

After the assessment score is obtained, the next step is to calculate using the equation:

$$Xaverage = \frac{\sum x}{n}$$

Information:

$\overline{X}$ = average score

$\sum X$ = total score obtained

n   = number of validators

The total rating score obtained is then substituted into the equation:

$$P_k = \frac{TSe}{TSh} \times 100\%$$

Information:

P_k = validity percentage

Tse   = Empirical Total Score (Validation Result)

TSh   = maximum expected total score

Based on the percentage of results of the validation score obtained, it's then interpreted using the validity criteria. STEM-based e-modules can be declared valid if the score obtained is $\geq$ 61% (Tarbiyah et al., n.d.). The percentage of egilibility can be seen in the **Table 2.**

Table 2 Validity category percentage

Percentage (%)	category
0%-20%	Totally invalid
21%-40%	Invalid
41%-60%	Invalid
61%-80%	Valid
81%-100%	Very Valid

2. Teacher Response Sheet

The teacher's respondent sheet is used to measure the level of practicality of the STEM-based e-module being developed. Practicality is a measure to determine the response of respondents to the product being developed (Rejeki & Azis, 2022). Analysis of the teacher's response sheet and students applying the scale Likert, score range 1-4. Each answer choice was given a score, namely: (1) Strongly Disagree (STS), (2) Disagree (ST), (3) Agree (S), and (4) Strongly Agree (SS). The teacher's response score can be seen in the **Table 3.**

Table 3 Likert scale answer criteria

Criteria	Score
Strongly Agree (SS)	4
Agree (S)	3
Disagree (KS)	2
Strongly Disagree (STS)	1

To find out the percentage of teacher practicality responses, you can use the following equation:

$$Pp = \frac{TSe}{TSh} \times 100\%$$

Information:

P_p = Practical Percentage

TSe = Empirical Total Score (Response Questionnaire Result)

TSh = Maximum Expected Total Score

Based on the results of the practicality score percentage obtained, it is then interpreted using practicality criteria. STEM-based e-modules can be declared practical if the score obtained is $\geq$ 61% (Tarbiyah et al., n.d.). The practicality percentage can be seen in the **Table 4.**

Table 4 Practicality Category

percentage (%)	category
0%-25%	Tidak Praktis
26%-50%	Kurang Praktis
51%-75%	Praktis
76% - 100%	Sangat Praktiss

RESULT AND DISCUSSION

The research and development stage (R&D) was carried out by adopting the borg and gall model with 7 stages. The following is the process of research and development of STEM-based e-module products on colloidal materials:

1. Research and Data Collection

The research and data collection stages were carried out to review the needs and variations of teaching materials used in schools. The information obtained is used as a reference in developing STEM-based chemical e-modules on colloidal materials. At this stage, an assessment was also carried out on KI, KD, syllabus, and chemistry books which were used as reference materials in the development of colloidal system materials.

2. Planning

The planning stage is carried out to consider the design used in developing the e-module, with the development of this design it can build the knowledge and skills needed by students. Asmiyunda denotes the planning stage (design) carried out in preparing the initial design of the e-module, this stage includes preparing the initial draft, determining the media, and the e-module format (Asmiyunda et al., 2018).

The determination of teaching materials must be based on certain benchmarks so that the learning objectives can be achieved. Learning that is in accordance with student development can stimulate and involve students to be active, innovative, creative, and can create a fun learning environment so that quality learning can be achieved (Andari, 2019).

The determination of media is useful in identifying study media that are substantially used in colloidal material characters. Determining the media is useful in optimizing the use of the developed e-module. The media that support the creation of e-modules in this study are Microsoft word and heyzineflipbookhtml.

The choice of format in the development of e-modules is intended to design and design e-modules. The format used is a format that meets the criteria of being interesting to read and supports students in understanding colloidal material.

3. Product Development

At the development stage, the e-module is prepared according to the initial draft. After the preparation of the e-module is complete, the developed e-module is ready to be validated. A validity test is carried out to see the feasibility level of the developed e-module. The initial prototype of the STEM-based e-module consists of an opening page (cover), instructions for using the e-module, a contents page, STEM material, cover page.

In addition, there are KI, KD, indicators, concept maps, descriptions of e-modules, formative tests, glossaries, author biographies, and elements of the periodic system. Following Prototype early STEM-based e-modules:

Figure 2. Cover
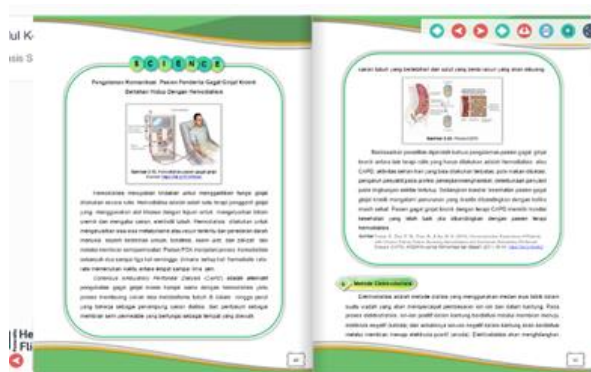
Figure 3. Contens page

Figure 4. Contens STEM

Figure 5 cover pag

4. Validity Test

After the development stage is carried out, then the validity test stage is carried out. A validity test was carried out to determine the eligibility level of the e-module being developed. The validity test is divided into 2 parts, namely media validity test and the material validity test.

1) Media Expert Validity Test

The media validity test was carried out to assess the validity of the e-module from the aspect of the media being developed (Herawati & Muhtadi, 2018). Imansari explained that data collection on the media validity test was obtained from the validator by distributing the developed e-module media assessment sheets (Imansari & Sunaryantiningsih, 2017). The criteria for evaluating this research are graphic feasibility, word and language feasibility, and e-module operational aspects based on the National Education Standards Agency (BSNP). The media validator consists of 3 media expert lecturers. Each media validator is given a code V1 (1st Validator), V2 (2nd Validator), and V3 (3rd Validator). The percentage of media validation results can be seen in **Table 5**:

Table 5 Results of Media Validity

Assessment Aspect	Average Percentage (%)			Average (%)	Eligibility Criteria
	V1	V2	V3		
Aspect of graphics	86	88	96	90,3	Worth using with revision
Aspect of words and language	83,3	83	95	87,2	Worth using with revision
Operational Aspect	91,4	85,7	97,1	91,4	Worth using with revision
Percentage interpretation				89,6	Very high
Eligibility criteria					Valid/worthy

In Table 5 the media validation as results can be seen in the results of the average percentage of each validator, namely, V1 = 87.0%, V2 = 85.8%, and V3 = 96.1%. The lowest percentage was obtained from the validator V2 at 85.8% and the highest percentage was obtained from V3 at 96.1%.

The percentage results from the assessment of each aspect are graphical aspects = 90.3%, word and language aspects = 87.2%, operational aspects = 91.4% and the average percentage of all aspects assessed is 89.6%. Judging from the average percentage of all

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Bulan, …. Tahun. Vol.., No….
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pp……

aspects obtained, it can be interpreted that the developed STEM-based e-module belongs to the "valid" category to use.

2) *Material Expert Validation*

Material validation is carried out to determine the validity of the developed e-module. Material expert assessment includes aspects of content feasibility, language feasibility, and presentation by the National Education Standards Agency (BSNP). The material expert validators consisted of 2 lecturers from Medan State University and 4 chemistry teachers. Each materials validator is given a coded V1 (1st Validator), V2 (2nd Validator), V3 (3rd Validator), V4 (4th Validator), V5 (5th Validator) and V6 (6th Validator).The percentage of material expert validation results can be seen in **Table 6**.

Table 6 Results of Material Validity

Assessment aspect	Average Percentage (%)						Average (%)	Validity Criteria
	V1	V2	V3	V4	V5	V6		
Content eligibility	92,4	88,6	81,0	94,3	89,5	93,3	89,8	Worth using with revisions
Language eligibility	91,4	90	82,8	94,3	91,4	94,3	90,7	Worth using with revisions
Presentation eligibility	94	96	82	92	90	94	91,3	Worth using with revisions
Percetage interpretation							90,6	Very high
Validity Criteria								Valid/feasible

In Table 6 the results of the material expert validation can be seen the results of the average percentage of each validator, namely V1 = 92.6%, V2 = 91.5%, V3 = 81.9%, V4 = 93.5 V5 = 90, 3% and V6 = 93.8%. The lowest percentage was obtained from the validator V3 of 81.9% and the highest percentage was obtained from V6 of 93.8%.

The results of the percentage of each aspect assessed are content eligibility aspects = 89.8%, language eligibility aspects = 90.7%, presentation eligibility aspects = 91.3% and the average percentage of all assessed aspects is 90.6% . Judging from the average percentage of all aspects obtained, it can be concluded that the STEM-based e-module in the colloidal material developed is classified as a valid category to use.

In line with Kiswanda's research shows that validated STEM-based e-modules can be used as a learning tool for students, both in group learning processes and in independent learning (Tarbiyah et al., n.d.).

5. Product Revision

This revision is based on input and suggestions provided by the media expert validator and material expert. This revision was made to improve the e-module product so that it is suitable for use. The following is before and after the revision:

a) Color change in sections background cover the colloidal system becomes lighter blue, the author's name is left aligned, the position change is "for SMA/MA class XI" on the lower left and the logo is enlarged.
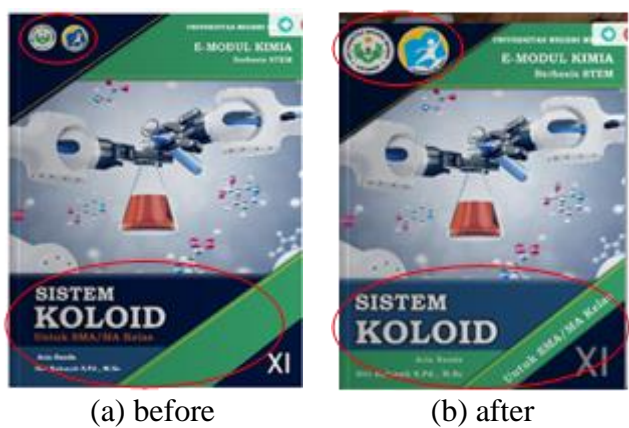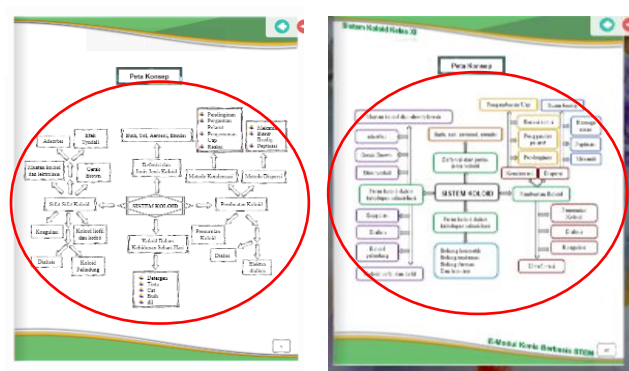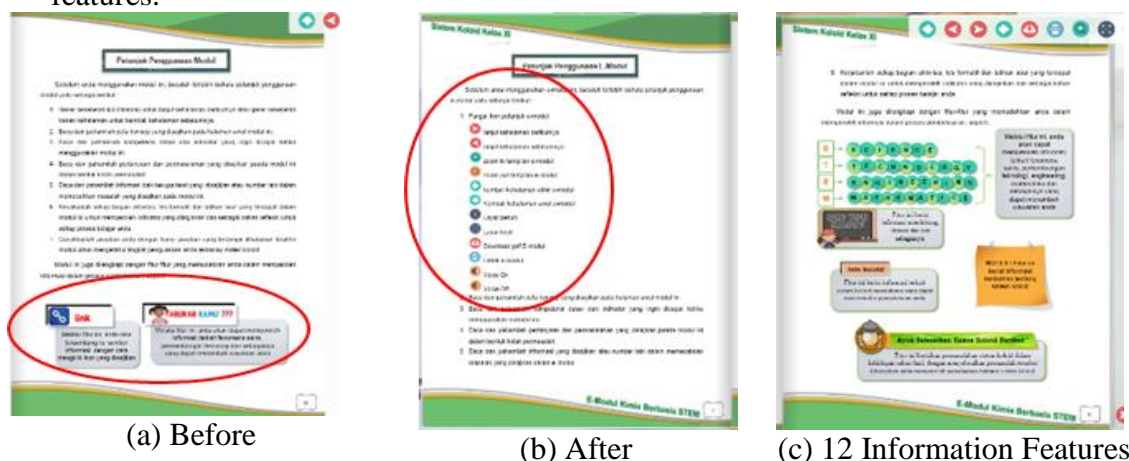
(a) before   (b) after

Figure 6. Cover

b) Clarify the concept map section by emphasizing the lines and adding color to the sub-material sections to make it easier to classify material based on the sub-material presented.

Figure 7 concept maps (a) before and (b) after
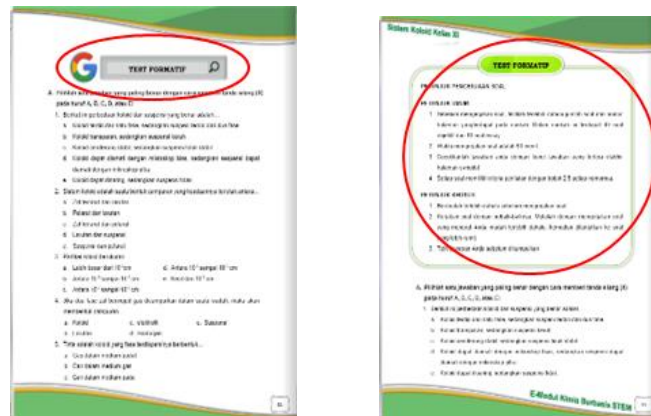
c) Added 12 e-module user manual features and added 12 e-module information features.

(a) Before   (b) After   (c) 12 Information Features

Figure 8. Instructions for Using the E-Module

d) The google icon was replaced and instructions for working on questions were added to the formative test section

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Bulan,…. Tahun. Vol.., No….
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pp……

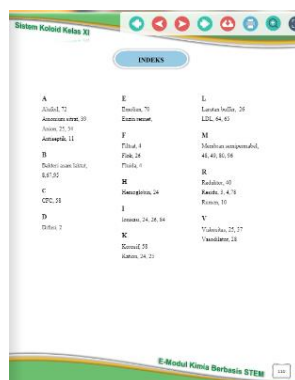(a) Before   (b) After

Figure 9. Formative Test

e) The periodic system attached to the e-module is the newest periodic system and contains element number 118

(a) Before   (b) After

Figure 10. Periodic System of Elements

f) Added e-module index after the glossary page

Figure 11. E-Module index

6. Field Trials

Field trials were carried out to see whether the products developed were practical and could be used in learning. This test is carried out by distributing response sheets to the

teacher. One of the stages of the practicality test is done by asking the teacher to fill out a practicality response sheet.

1) Chemistry Teacher Response Questionnaire

In the field test, a practicality test was carried out with 4 chemistry teacher respondents by providing a questionnaire responding to the practicality assessment of the developed e-module, each respondent was given a code G1 (1st teacher), G2 (2nd teacher), G3 (3rd teacher) and G4 (4th teacher). The practicality assessment is one of the educators' responses to the e-Modules the researchers developed, both in design and content, the benefits of e-Modules for teachers, and the time efficiency used. The table of results of the e-Module practicality response questionnaire assessment by chemistry teachers can be seen in **Table 7**.

Table 7 Practicality Test Results (Chemistry Teacher Response)

Assessment Aspect	Respondents				Average (%)	Category
	G1	G2	G3	G4		
Design and content	75%	89%	86%	100%	88%	Very Practical
Benefit	75%	94%	100%	94%	91%	Very Practical
Usae time efficiency	75%	92%	92%	92%	88%	Very Practical
Average (%)					89%	Very Practical

On Table 7 the results of the teacher's response questionnaire can be seen from the three aspects that assess the percentage of each aspect, namely the design and content aspects of 88%, the benefits aspect of 91%, and the presentation time efficiency aspect of 88%. The lowest percentage was obtained from the aspect of design and content and presentation time efficiency which had a percentage of 88% and the highest percentage was obtained from the benefit aspect of 91%. Based on the results of the average percentage of all aspects assessed, it was obtained at 89%, so it can be concluded that the STEM-based e-module in the developed colloidal material belongs to the "very practical" category. At this stage, it is done finishing the final product is based on data from teacher responses as well as student responses to the developed STEM-based e-modules. Based on the results of teacher and student responses, the STEM-based e-modules were stated to be very practical and there were no suggestions for improvements to the STEM e-modules being developed so these e-modules have been declared as final products which can then be disseminated to users.

7. The Final Product

At this stage, it is done finishing the final product is based on data from teacher responses as well as student responses to the developed STEM-based e-modules. Based on the results of teacher and student responses, the STEM-based e-modules were stated to be very practical and there were no suggestions for improvements to the STEM e-modules being developed, so these e-modules have been declared as final products which can then be disseminated to users.

8. Differences in School Teaching Materials and Developed Teaching Materials

Teaching materials are learning tools that are arranged based on a specific curriculum that aims to achieve the desired competence. For educators teaching materials can be used as a guide in directing learning activities (Nurdyansyah & Mutala'liah, 2015). There are many types of teaching materials used in the learning process, such as animated videos, printed books, PPT, and other technology-based teaching materials. From the several types of teaching materials that have been analyzed, it shows that there are differences in the teaching

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Bulan,…. Tahun. Vol.., No….
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pp……

materials used in schools and the teaching materials developed. The differences in teaching materials at school and the e-modules developed can be seen in the **Table 8**.

Table 8. Differences in School Teaching Materials and Developed Teaching Materials

Difference	Teaching Materials in Research Schools	Developed E-Module
Form	Printed Electronic Module	Electronic Module
Objective	Emphasizes The Presentation of Teaching Materials	Contains Objectives And Evaluation Activities
Function	Emphasis on the function of presenting the material	Could Replace Some Teaching Roles
Usage	Designed for fac- to-face needs	Designed of the purpose for a self-learning
Subject	Wider material coverage	Material coverage focuses on colloidal materials
Model	PBL and PjBL	STEM
Learning system	Tend to be informative on unidirectional	Tend to be communicative or two way

4. CONCLUSION

Based on the validation results of media and material experts, the average percentage of media experts were 89.6% and material experts was 90.6% with a valid category. Meanwhile, in the teacher practicality test, the average percentage of chemistry teachers was 89% in the very practical category. Based on the percentage of the results of the validity test and practicality test of STEM-based e-modules on colloidal material to train scientific literacy skills it was declared feasible and practical to use in learning.

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