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Development of science, technology, engineering, and mathematics (STEM) based chemistry e-module learning materials on the topic of reaction rate of learning

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Abstract

Teaching materials are important components in learning, so they need more attention. This study aimed to determine the validity and response of the target audience to a STEM-based chemistry e-module on reaction rate. The research used the ADDIE development model, which consists of five stages: Analyze, Design, Develop, Implement, and Evaluate. However, this research was limited to the implementation stage through trials with a small group. The research instruments used were interview guidelines, student needs questionnaire sheets, validation sheets, and teacher and student response questionnaire sheets. The subjects of this study were 3 expert lecturers, 2 expert chemistry teachers, and 30 students of class XII IPA at SMA Negeri 2 Sentajo Raya. The results showed that the STEM-based chemistry e-module on reaction rate material was feasible to use with a validity value of 89.6% (very feasible criteria). Based on the responses of the target audience, it can also be concluded that the e-module is feasible to use with a teacher response percentage of 92% and students 88%. This means that e-modules are feasible to use as teaching materials on reaction rate materials at SMAN 2 Sentajo Raya.
Keywords: Teaching Material; Reaction Rate; STEM.

INTRODUCTION

One of the supporting factors to support an adequate learning process is teaching materials. Teaching materials are a collection of learning materials given to students to be mastered and used by students as learning resources (Agustina, 2018). By using teaching materials, teachers and students will find it easier and more helpful to carry out the learning process in class.

In the digital age, printed teaching materials are being replaced by more practical teaching materials that can be carried anywhere. Technological advancements have made humans more creative, aiming to make everyday life easier. In the field of education, the role of this technology is also very much needed so that the teaching and learning process is expected to be more maximized. If technology is used properly, it can expand, strengthen, and improve the quality of education (Budhwar, 2018). One of the roles of technology in education is e-books, which are digital versions of traditional books. E-modules are a specific type of e-book. E-modules are printed modules that have been converted into a digital format (Sugihartini & Jayanta, 2017). E-modules are more practical for students to use because they can be accessed on their smartphones or mobile phones, which are more widely carried by people today than printed books. This supports the function of the module itself, which is designed for self-directed learning that can be used anywhere and anytime.

Based on interviews with chemistry teachers at SMA Negeri 2 Sentajo Raya, students have only been using textbooks and worksheets as teaching materials in chemistry classes, which has not been very effective in stimulating their interest in the subject. Teachers have also expressed that many students struggle with chemistry due to the perception that it is a difficult subject. One particular topic that students find challenging is reaction rate, with some even scoring below the minimum passing grade (KKM) of 70. To address these issues and enhance the learning process, it is crucial to implement innovative teaching approaches that align with student characteristics and the subject matter (Oktariani, O; Febliza, 2019). Therefore, an approach is needed that can help students build a strong conceptual understanding. One of them is through the STEM approach. Based on the research, The implementation of STEM-based learning can enhance students' critical thinking skills compared to conventional learning (Khoiriyah et al., 2018). Similar to which shows that the STEM approach is able to improve students' understanding of concepts, critical thinking skills, and collaboration skills (Sandi, 2021). Another research conducted shows that the use of STEM in learning activities applied in teaching materials, in this case e-modules, is able to improve students' reasoning skills, improve critical thinking abilities, and increase understanding of the basic concepts of material (Lestari, 2021).

Previous research has shown that the STEM (Science, Technology, Engineering, and Mathematics) based modules on the topics of colligative properties and chemical equilibrium that were developed are worthy of further development and have received positive feedback (Arisya et al., 2021). This research has produced a chemistry learning module that has been validated by subject matter experts, media experts, and high school chemistry teachers, with a high validity category and a very good student response category.

In light of the aforementioned background, the researcher deems it necessary to conduct a study aimed at developing and validating STEM-based (Science, Technology, Engineering, and Mathematics) Chemistry E-Module Teaching Materials. The novelty of this research lies in the creation of an electronic module that can be easily accessed and utilized anytime, anywhere, and is equipped with stages that aid in fostering 21st-century skills among students.

METHODS

This research is classified as Research and Development (R&D) research. In accordance with its objectives, the research aimed to develop STEM-based chemistry e-module teaching materials specifically focused on reaction rate. The development process employed the ADDIE model, which stands for Analysis, Design, Development or Production, Implementation or Delivery, and Evaluation.

The research was conducted in several stages. The first stage involved a needs analysis to identify teaching requirements in high schools for supporting the chemistry learning process. This analysis incorporated input from teachers and students, as well as document analysis, including the curriculum, learning tools, and relevant research articles. The second stage focused on product development, where a draft of the e-module was created. This was followed by a validation stage where subject matter and media experts evaluated the developed e-module. Finally, the implementation or limited trial phase was conducted at SMA Negeri 2 Sentajo Raya, Kuansing Regency.

The participants in this research included chemistry teachers who provided responses during the needs analysis stage and user feedback on the e-module under development. Thirty students from the 11th grade Science stream at SMAN 2 Sentajo Raya participated in the needs analysis, while 30 students from the 12th grade Science stream provided user feedback on the e-module. Additionally, three subject matter experts who are lecturers served as validators to assess the feasibility of the e-module.

The research instruments used were an interview guide, a student needs questionnaire, a validation sheet, and a teacher and student response questionnaire. Data processing and analysis for the needs analysis interviews involved standardizing the interview data into a single written transcript. Conclusions were then drawn from the results of the needs analysis interviews. The student needs questionnaire utilized a Guttman scale. "Yes" answers were assigned a value of 1, and "no" answers were assigned a value of 0 for the questionnaire's alternative answers. This assessment was conducted as a checklist using the Guttman scale (1).

$$P = \frac{f}{n} \times 100\% \quad (1)$$

note:

P = percentage

f = frequency

P = 100

n = answers

Categories for interpreting the results of the needs analysis percentage are obtained from modifications to the research results (Munggaran, 2012). These categories are presented in Table 1.

Table 1. Needs analysis percentage category

Percentage	Category
0– 1,9%	Not needed
2% – 25,9%	A small number need it
26% – 49,9%	Less than half need
50%	Half need
50,1% – 75,9%	More than half need it
76% – 99,9%	Most need it
100%	Everyone needs it

The data obtained from the validation of the e-module by experts is a score on a Likert scale of 5 (5,4,3,2,1) with the descriptions of very good, good, fair, poor, very poor. The formula used to calculate data from experts is as follows (2):

$$P = \frac{F}{N} \times 100\% \quad (2)$$

Note:
P = percentage number of questionnaire data
F = total score obtained
N = maximum number of scores

Next, the percentage (%) of eligibility obtained is then interpreted into categories based on table 2:

Table 2. Eligibility criteria

Scoring	Criteria
$81 \leq P \leq 100\%$	Highly Suitable
$61 \leq P < 81\ \%$	Suitable
$41 \leq P < 61\ \%$	Moderately Suitable
$21 \leq P < 41\ \%$	Unsuitable
$0 \leq P < 21\ \%$	Highly Unsuitable

(Arikunto, 2012)

The data obtained from e-module user responses are scores on a Likert scale of 5 (5,4,3,2,1) with the information strongly agree, agree, moderately disagree, disagree, strongly disagree. The formula used to calculate data from experts is as follows (3):

$$P = \frac{F}{N} \times 100\ \% \quad (3)$$

note:
P = Percentage figure of questionnaire data
F = Total score obtained
N = Maximum number of scores

Then, the results of these percentages can be grouped into score inter-percentage criteria according to the Likert scale so that conclusions can be obtained about the responses of teachers and students. The criteria for score interpretation according to the Likert scale are as table 3:

Table 3. User response interpresentation criteria

Scoring	Interpresentation Criteria
$81 \leq P \leq 100\%$	Highly Practical (attractive/good/suitable)
$61 \leq P < 80$ %	Practical (attractive/good/suitable)
$41 \leq P < 60$ %	Appopriate (Practical/attractive/good/suitable)
$21 \leq P < 40$ %	Not practical (Practical/attractive/good/suitable)
$0 \leq P < 21$ %	Highly not practical (Practical/attractive/good/suitable)

(Parmin, 2012)

RESULT AND DISCUSSION

Analyze

Based on the results of interviews with chemistry teachers, the results of reducing interview transcripts concluded that: During the chemistry learning process in class, students tend to have difficulty understanding the chemistry material presented by the teacher. Students consider chemistry material to be difficult material. The teacher said that one of the materials that students considered difficult was reaction rate. In the chemistry learning process, students only use textbooks and worksheets. Students have never used electronic modules during the chemistry learning process. In chemistry learning, teachers have applied innovative learning models but not all models have been implemented.

Based on a student needs questionnaire distributed to 30 class 93.3% of students had difficulty understanding the reaction rate material through the teaching materials and methods applied by the teacher; 100% of students use textbooks and worksheets in chemistry learning; 93.3% of students are interested in reading chemistry books in electronic form (Digital); 96.6% of students need alternative teaching materials that can be used to study reaction rate material more easily and interestingly; In chemistry learning, only 16.6% of students have used the module.

Based on the results of the needs analysis, almost all students think that the reaction rate material is difficult material. Reaction rate is a chemical science that requires the study of macroscopic, microscopic and symbolic aspects. The concept of reaction rate taught without involving the microscopic aspects will create difficulties/obstacles to constructing a meaningful concept of reaction rate (Nur'ain et al., 2015; Sumargo & Yuanita, 2014).

During the learning process, the teaching materials used by students are in the form of textbooks and worksheets, almost all students have difficulty understanding the reaction rate material through the teaching materials and methods applied by the teacher. In teaching chemistry, teachers have not been able to find a suitable model for learning reaction rates. Innovative learning is learning that is designed in a different way from the learning that teachers usually do (conventional). Innovative learning is more oriented towards student-centered learning. The learning process is planned, structured and conditioned according to student needs (Uno & Muhammad, 2011).

STEM learning is a form of innovative learning that can be used to develop various skills needed by students to face the challenges of the 4.0 era. STEM can help students develop thinking skills, gain comprehensive knowledge and face various problems in everyday life. In the STEM approach, students are directly involved in the process of discovering the concepts being studied (Miyarso, 2021).
From the results of the needs analysis, it was also found that 96.6% of students needed alternative teaching materials that could be used to study reaction rate material more easily and interestingly. From the results of the needs analysis, almost all students are interested in reading chemistry books in digital form, and only 16.6% of students studying chemistry have ever used modules in learning. From the explanation of the needs analysis, it can be concluded that teaching materials are needed that can help make understanding difficult material easier, one of which is using e-modules. To overcome this problem, the solution that can be done is to develop a STEM-based chemistry E-module teaching material that can help students understand reaction rate material.
E-modules can help make learning more interesting because they can add pictures or videos. E-modules can also help students understand lesson material because there are consistent study instructions and understanding of concepts. Students can repeat or study the material according to their needs, because the modules can be studied independently at home without the help of other people (Fauziah et al., 2023; Yudha & Rahmi, 2023).

After carrying out needs analysis activities, the next stage is to carry out an analysis of the material that will be included in teaching materials in accordance with the 2013 curriculum. The teaching materials will contain material on reaction rates which will be studied by class XI students in the odd semester. Based on the curriculum analysis and content standards, it can be concluded that the basic concepts of reaction rate material that must be included in the module are:
CHAPTER I Concept of Reaction Rate and Collision Theory

a. Molarity
b. Understanding Reaction Rate
c. Understanding Collision Theory

CHAPTER II Factors that Affecting Reaction Rate

a. Concentration
b. Temperature
c. Surface area
d. Catalyst

CHAPTER III Reaction Rate Equations

a. Reaction Rate Equation
b. Meaning of Reaction Order

Design

After carrying out the stages of analyzing student needs, the author decided to create a teaching material to support students in the chemistry learning process, especially regarding reaction rate material. The stages carried out are as follows:

a. Collecting references to be used as content material for products that will be developed in the form of STEM-based teaching materials on reaction rate material.
b. Designing E-modules according to E-module components. Where the E-module component consists of:
   1) The cover contains the title and image related to the material.
   2) Foreword, table of contents, list of images, and list of tables which can make it easier to use the e-module.
   3) Study instructions which include teacher instructions and student instructions.
   4) Competencies achieved in the form of KI, KD, indicators of competency achievement, and learning objectives as well as a concept map in the material.
   5) Contents / Description of the reaction rate material
   6) Activity sheets/student activities to support learning activities
   7) Evaluation sheet containing questions that have been studied to measure students' ability to understand the reaction rate material.

The components of the learning module are as follows; 1) There are learning objectives; 2) Teaching Materials; 3) Exercises presented to apply the skills and competencies being studied; 4) The existence of feedback which is an indicator shows the quality of the training carried out by students (Ibrahim, 2010).

Select supporting applications to produce the developed teaching materials.
In developing STEM-based chemistry e-module teaching materials, the Canva and Heyzine applications were selected. Canva is a graphic design website that makes it easy for users to create creative designs online. Canva allows users to easily customize the e-modules they create and create attractive designs without hiring a designer. In the learning concept, this can help increase the effectiveness and variety of teaching and learning, which can be enjoyable for students and teachers (Irkhamni et al., 2021).
Heyzine is a free flipbook-based digital book-making application that includes text, images or both with access via electronic devices such as computers and cellphones (Humairah, 2022). According to (Khomaria & Puspasari 2022), *heyzine flipbooks* is an application that can convert PDFs into books, magazines and brochures digitally by adding videos, images, audio, animations, links and other interesting things. Based on the description presented, the conclusion regarding *heyzine flipbooks* is a tool that can be used to create flipbooks by providing a more interesting PDF reading experience and pages that can be opened like a book.

Development
In the next stage, namely the product development stage, at this stage the overall STEM-based chemistry E-module is developed based on the E-module design that has been created. Furthermore, at this stage a validation process is also carried out on the E-module to find out whether the product being developed is suitable for use by students as teaching material.

The results of the validation of STEM (Science, Technology, Engineering and Mathematics) based chemistry E-module teaching materials on reaction rates can be seen from several aspects which are described as Table 4.

Table 4. Material validation results

No	Aspects	V1	V 2	V3	Mean
1	Content Eligibility	85%	85%	95%	88,3%
2	Presentation	87%	87%	95%	89,6%

*V1 : Validator 1
*V2 : Validator 2
*V3 : Validator 3

From the validation results, it was found that the feasibility of the E-module content obtained a percentage of 83.3% with a very feasible category. Meanwhile, the presentation aspect obtained 89.6% with a very decent category. This corresponds to the percentage criteria (Arikunto, 2012) where the percentage of 81-100% includes very feasible criteria.

The first aspect assessed by material experts is the suitability aspect of the content. This aspect received validation with the criteria "very feasible". These results are in line with research (Nugraha & Syafi, 2020) In terms of the appropriateness of the content, the content is also assessed as very good, by looking at the relevance of the teaching content to the competencies and needs of students.

The second aspect is the appropriateness of presentation. This aspect received validation with the criteria "very feasible". The research results are in line with (Lestari et al., 2018) revealed that learning material must be coherent, consistent and balanced between chapters in the material. Furthermore (Pawestri & Zulfiati, 2020) revealed that learning material must be appropriate to the level of students' abilities in order to make it easier for students to understand the material.

Table 5. Media validation results

Aspects	V 1	V 2	V 3	Mean
E-modul interface	83,3%	90%	83,3%	85,5%
E-modul design	83,3%	93,3%	83,3%	86%

*V1 : Validator 1
*V2 : Validator 2
*V3 : Validator 3

In the media validation results (Table 5), the e-module content design aspect obtained the highest percentage, namely 86% with very feasible criteria. In the display aspect, the E-module obtained a percentage of 85.5% with very feasible criteria. This is in accordance with (Arikunto, 2012) if the percentage is higher, namely 81-100%, then the criteria are very feasible.

Table 6. Language validation results

No	Aspects	V1	V 2	V3	Mean
1	Readability	86,6%	93,3%	100%	93,3%
2	Use of terms and symbols	95%	95%	100%	96,6%

*V1 : Validator 1

*V2 : Validator 2

*V3 : Validator 3

In language validation (Table 6), it was found that the aspect of using terms and symbols obtained the highest percentage of 96.6%, and with very appropriate criteria. Meanwhile, the readability aspect also received high validation of 93.3% with very adequate criteria. The higher the percentage value obtained, the E-module being developed is suitable for use.

In aacordance with research from (Nugraha & Syafi 2020), which also scores very well for readability. This high readability value shows that the module developed is easy for users to use, where the text contained in the e-module can be read clearly, the language used is easy to understand, and the e-module was developed in communicative language so it will not cause boredom when using language which seems stiff and formal. Every instruction and presentation of information contained in the e-module is useful (Sugianto et al., 2018).

The validation results described above show that the STEM-based chemistry e-module teaching material on reaction rates is suitable for use in the next stage, namely user response testing.

Table 7. Overall validation results of e-module

No	Validator	Material Validation	Media Validation	Language Validation
1	Validator 1	81,4%	83,3%	91,4%
2	Validator 2	86,4%	92,2%	94,2%
3	Validator 3	95%	82,2%	100%
	Total	262,8%	257,7%	285,6
	Mean	87,6%	86%	95,2%
	Grand total average		89,6%	

From the validation results, it was found that language validation had the highest percentage value of 95.2% with a very feasible category. Meanwhile, material and language validation has a percentage of 87.6% and 86% which are still in the very feasible category. This 81-100% criterion is included in the very feasible category. Based on Table 7, it can be seen that the overall validation results of the STEM (Science, Technology, Engineering and Mathematics) based chemistry e-module teaching materials on reaction rate material obtained 89.6% in the "very feasible" category. The higher the percentage value obtained, the E-module developed is suitable for use in chemistry learning, especially in reaction rate material. Based on the results above, it can be concluded that the E-module has been declared valid by experts so that it is feasible and can be tested in the field.

Implementation

The implementation stage is the product trial stage that has been validated by material and media experts. In this stage, the first thing to do is ask for feedback or assessment responses from teachers in the field of chemistry regarding the electronic module that has been created, then the next stage is to try it out on students to find out the student's response after using the electronic module.

Teacher Response to the E-Module

The results of the assessment by the chemistry teacher can be seen in Table 8.

Table 8. Teacher Response Test Results for E-modules

Aspects	Percentage	Criteria
Content Eligibility	90%	Highly Suitable
Electronic Module Presentation	93,3%	Very good
Language Suitability	100%	Highly suitable
Use of Electronic Modules	100%	Highly Practical
STEM	80%	Highly suitable
Graphic Eligibility	90%	Highly Suitable
Total Score	92%	Highly Suitable

Based on the table above, it can be seen that the overall percentage of teacher response test results obtained a score of 92% with the criteria "Highly Suitable". The results of the teacher's responses for several aspects are 90% appropriateness of content, 93.3% appropriateness of presentation, 100% appropriateness of language, use of E-modules 100%, STEM 80%, and appropriateness of graphics 90% with the criteria for these six aspects, namely “Highly Suitable.” In accordance with (Parmin, 2012) the higher the percentage obtained, the E-Module being developed is suitable for use and testing on students.

Based on the results of the teacher's response to the e-module being developed, it can be concluded that the STEM-based E-module is declared feasible and can be tested on students in chemistry learning, especially reaction rate material.

Practical teaching materials are teaching materials that are easy to use and in the form of the teaching materials themselves. Teaching materials themselves can be in print and electronic or digital form. Digital teaching materials are one thing that can make teaching materials more practical in terms of ease of use. Likewise, the practicality of digital teaching materials is very good. Digital teaching materials can be in the form of electronic modules (e-modules), which are not only digital, but these e-modules can also be accessed on the Internet (Usman et al., 2020).

The results of student participants' responses to the e-module developed can be seen in Table 9.

Table 9. Results of student responses to e-modules

No	Scoring Aspects	Percentage	Criteria
1	Ease of Understanding the Material	92,2%	Very good
2	Learning Independence	84,6%	Very good
3	Learning Activeness	82,0%	Very good
4	Interest to learn	86,0%	Very good
5	Electronic Module Presentation	91,0%	Very good
6	Use of Electronic Modules	88,3%	Very Practical
	Total Score	88,0%	Highly Suitable

Based on the table above, it can be seen that the overall percentage of student responses to the E-module obtained a score of 88% with the criteria "very feasible". The results of student responses for several aspects, namely the aspect of ease in understanding the material 92.2%, learning independence 84.6%, active learning 82%, interest in learning 86%, presentation of electronic modules 91% and use of electronic modules 88.3% with The criteria for these six aspects are "very feasible". The higher the percentage obtained, the E-module developed is very suitable for use by students in learning chemistry, especially in reaction rate material.

E-modules can increase students' understanding, motivation and interest in learning, because the presentation can be modified in each lesson, developed as interesting and effective as possible according to students' needs and their learning environment (Kastolani, 2018).

By implementing STEM education, students can develop scientific thinking processes regarding problems. Students will be trained to think logically, creatively and disciplined (Ernawati & Sujatmika, 2021; R. Kelley et al., 2019). One approach to learning that helps in various areas of life cannot be separated from developing human abilities in the field of natural sciences. Apart from that, it is also necessary to develop learning activities that can include science, technology, engineering and mathematics, which is often abbreviated as STEM. Implementing STEM education can develop students' scientific thinking about problems. Students are trained to think logically, creatively and disciplined (Flynn et al., 2019).

STEM modules can help students create innovations based on the cases given and the benefits of the innovations created. Modules influence learning motivation, as previous research revealed that sigil-based e-module learning media influences student learning motivation in graphic design subjects (Putri & Purmadi, 2020; Syahirah et al., 2020). Learning through a STEM approach can increase understanding of chemical concepts because students are more active in their learning (Pujiati, 2020). This shows that learning through a STEM approach can help students better understand the concept of reaction rate to meet student needs. Apart from that, from the children's experience after they learn directly with the STEM approach, it turns out that it can increase their motivation to learn. Learning using a STEM approach can build positive experiences for children and can lead to a better mindset in learning (He et al., 2021; Park et al., 2018). Therefore, by providing STEM learning that focuses on problem solving with the Engineering Design Process can increase the possibility of developing a strong foundation for further learning in the future.

Based on the validation of the e-module with material, media and language experts, the research results obtained were 89.6% with very feasible criteria. The percentage of product validity can be seen from the material aspect of 87.6% material, 86% media and 95.2% language with very appropriate criteria. This means that according to experts the product is suitable for use in terms of material, media and language aspects. For user responses, the e-module can be used well with a score of (92% of teachers and 88% of students). The STEM-based chemical E-module product in the resulting reaction rate material compares favorably with previous researchers in terms of the language aspect. This E-module obtained the highest score, namely 95.2%, which meets the criteria of being highly suitable on research on the Development of STEM-Based Chemistry E-module Teaching Materials. In this Reaction Rate Material, it is directly proportional to other researchers because it has high product feasibility and very good response. In this way, the process of creating this module can be continued to the next stage so that it can be used and useful in the chemistry learning process.

The development of this STEM E-module has advantages compared to other researchers because in every learning activity there are examples or phenomena presented in real everyday life and in the E-module projects are presented that students must work on which focus on solving problems using the Engineering Design Process. The Engineering Design Process (EDP) approach is used because the learning process is closely related to everyday life, namely by focusing the learning process on solving problems in real life, so that students can understand the material studied based on their learning experiences.

This research stage needs to be continued if the e-module being developed is to be used on a large scale. This is because product testing is still being carried out on a small scale and needs improvements according to user input. Apart from that, it is necessary to carry out a product implementation stage to prove whether this e-module product can help improve student understanding and overcome problems in learning chemistry.

CONCLUSION

Based on the research that has been carried out, the STEM (Science, Technology, Engineering and Mathematics) based chemistry e-module teaching materials on reaction rates are suitable for use according to the validation results, namely 89.6% with very feasible criteria. The percentage of product validity can be seen from the material aspect of 87.6% material, 86% media and 95.2% language with very appropriate criteria. This means that according to experts the product is suitable for use in terms of material, media and language aspects. Based on the results of responses from potential users of STEM (Science, Technology, Engineering and Mathematics) based chemistry e-module teaching materials on the reaction rate material that has been developed, it is stated that it is very feasible. This is in accordance with the assessments of teachers and students, where teachers and students are 92% and 88% respectively. This means that based on the results of responses from prospective users, the E-module is suitable for students to use as teaching material for chemistry learning, especially in reaction rate material at SMAN 2 Sentajo Raya. To be able to see the effectiveness of e-modules in improving student understanding, further research is needed.

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