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Development of Interactive Electronic Module for Charged Reaction Rate Science Technology Engineering and Mathematics (STEM)

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Abstract: Students' low critical thinking ability requires teachers to design the learning process creatively. One of the efforts teachers can make is integrating teaching materials with technology and learning models of *Science, Technology, Engineering, and Mathematics* (STEM). This study aims to develop an interactive electronic module containing STEM on the reaction rate material and determine the resulting module's quality. This research is development research (R&D) with a 4D development model (*Define, Design, Develop, and Disseminate*). The product is an interactive electronic module containing STEM in the form of HTML containing material, interactive quizzes, and STEM projects. The research instrument used was a quality assessment sheet for media experts, material experts, *reviewers* (high school chemistry teachers), and response sheets for class XI high school students. The results of the product quality assessment by media experts get a percentage of 96.7% in the very good category, material experts get 82.2% in the good category, and *reviewers* get 95.0% in the very good category. The students responded positively to the module with a percentage of 96.0%. Based on the assessment results and student responses, it can be concluded that the product developed is feasible to be used as an alternative media in the learning process on the reaction rate material to improve students' critical thinking skills.

Keywords: Interactive Module; STEM; Reaction Rate.

Introduction

The era of industrial revolution 4.0 was marked by supercomputers, artificial intelligence, cyber systems, and manufacturing collaborations (Karnegi & Iswahyudi, 2019). Along with technological developments, teachers must develop learning media to produce students who can answer the challenges of the 4.0 revolution and achieve *student center learning programs* (Fitriyah, 2019). The use of technology in the *student center learning process* can increase student interest in learning (Ibda, 2018). The presence of technology in the learning process has a positive impact in the form of better learning quality and increased student activity in finding learning materials so that students do not only depend on the material presented by the teacher (Cholik, 2017). Teachers must present learning media that collaborate teaching materials with technology so students can take advantage of available learning resources (Kuswanto, 2019). However, based on research conducted by Sulastri et al. (2021), many teachers are still technologically stuttering, so it is challenging to create technology-based learning media.

Integrating learning media with interactive multimedia technology can improve learning quality (Hastari et al., 2019). Interactive multimedia is needed to support student-centered learning (Situmorang et al., 2015). One of the interactive multimedia teaching materials is the electronic module (Pratama & Alamsyah, 2020). An electronic module is a learning media that uses a computer to display text, images, video, audio, animation, and graphics in the learning process (Winatha, 2018). The existence of animations and videos in the electronic module can create a vibrant

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learning atmosphere for students (Restiyowati & Sanjaya, 2012). In addition, animations and videos on electronic modules can make it easier for students with learning difficulties to only learn through text (Bire et al., 2014). Electronic modules have advantages, including: (1) the concept of material can be visualized in the form of animation, (2) presented in an attractive display, (3) material can be presented interactively and dynamically, and (4) can be accessed flexibly (Gevi & Andromeda, 2019). Herawati et al. (2020) state that the electronic module could increase students' interest in learning. However, the use of electronic modules in schools is still limited, and the existing modules are still in printed form, so it seems monotonous (Herawati & Muhtadi, 2018). Therefore, to support student activity in learning, it is necessary to develop an electronic module (Nafidah & Suratman, 2021). Electronic modules are suitable for visualizing abstract material to become more concrete (Munawaroh et al., 2019).

The material in chemistry is abstract and can be in logic so that the truth can be explained and proven by mathematical logic (Raharjo et al., 2017). Chemical material is abstract and contains much mathematical logic, one of which is reaction rate (Putri & Muhtadi, 2018). The reaction rate is a chemical material that understands the concept and its application (Putri & Mitarlis, 2015). Understanding the concepts contained in the reaction rate material relates to everyday life (Rachmawati et al., 2017). Adawiyah et al. (2019) stated that the reaction rate material studies microscopic things such as collision theory and the factors that affect the reaction rate, so teaching materials are needed to visualize the material. Visualizing these concepts requires teaching materials to make it easier for students to construct reaction rate materials (Pahriah & Hendrawani, 2018). In addition to concept visualization, teaching materials are also needed to integrate knowledge and skills to improve student's critical thinking skills (Astuti et al., 2018). Based on the research results, Hasanah et al. (2021) stated that students who only studied the reaction rate material by memorizing and counting had difficulty relating the reaction rate material to everyday life.

The development of interactive teaching materials can be used as an alternative to achieve critical thinking skills that are being promoted in the 21st century (Ananda & Dasna, 2019). One form of developing teaching materials that can train critical thinking skills is a module containing *Science Technology Engineering and Mathematics (STEM)* (Permanasari, 2016). The STEM module is a module that integrates knowledge, skills, science, technology, engineering, and mathematics to solve a problem related to learning in the context of everyday life (Setiawan et al., 2020). According to Tipani et al. (2019), STEM-based modules can STEM-charged modules make students trained to observe, identify problems, seek information, express ideas, design experiments, and generate ideas for solving a problem (Irmita, 2018). Thus, students will be encouraged to think critically and creatively (Syahirah et al., 2020). In addition, the loaded module Existing STEM At school, the number is still limited (Oktaviani et al., 2020).

Based on the explanation of the problem, the development of an interactive module on the reaction rate material with *Science Technology Engineering and Mathematics (STEM)* is needed. The development of an interactive module on STEM-charged reaction rate material is expected to help students improve their understanding of the concept of reaction rate and increase students' activeness and critical thinking skills. In addition, it is hoped that this interactive module can make it easier for teachers to explain the reaction rate material and students get a fun chemistry learning experience.

Method

The method used is development research (*R&D*) by adapting the 4-D model. According to Thiagarajan, the 4-D model includes defining, developing, and disseminating *stages*. The product developed is in the form of an interactive electronic module containing the reaction rate material *Science Technology Engineering and Mathematics* (STEM).

The *define stage* aims to determine the need and availability of STEM-loaded electronic modules in the learning process and collect various information related to the product to be developed. The *defined stage* includes needs and availability analysis through interviews with high school chemistry teachers. The *design stage* aims to design an interactive electronic module for STEM-charged reaction rate materials to be developed. This stage includes *software* selection, format selection, reference collection, module *layout* design, and instrument creation. The *development stage* aims to produce an interactive electronic module containing STEM.

The instruments used in the study were product quality assessment sheets and student response sheets. Analyzing data from the product quality assessment is done by changing the qualitative assessment to quantitative (score). Next, the validation score is calculated using the Equation 1.

$$\bar{X} = \frac{\sum x}{n} \quad (1)$$

Information:
$\bar{X}$ = Average score
X = Total score of each rater
n = number of raters

The score obtained is then calculated as the average score and then converted into a qualitative value according to the ideal assessment category (Sukardjo & Sari, 2008) as in Table 1.

Table 1. Ideal assessment criteria

Score Range	Category
Xi + 1.8 SBi < X	Very good
Xi + 0.6 SBi < X ≤ Xi + 1.8 SBi	Well
Xi – 0.6 SBi < X ≤ Xi + 0.6 SBi	Enough
Xi – 1.8 SBi < X ≤ Xi – 0.6 SBi	Not enough
X ≤ Xi – 1.80 SBi	Very less

Analyzing student responses by converting qualitative data into quantitative data in the form of scores using the *Guttman scale* (Bahrun et al., 2017). Student response data obtained next the ideal percentage is calculated using the Formula 2.

$$\text{Ideal percentage} = \frac{\text{score reached}}{\text{ideal max score}} \times 100\% \quad (2)$$

Result and Discussion

The media developed in the research is an interactive electronic module for the reaction rate material with *Science Technology Engineering and Mathematics* (STEM) content. *Software* used to create modules that are *Canva* and *Flip pdf corporate*. The two applications were chosen because of the compatibility between applications, which is good, and the features are quite complete and easy to use by beginners (Dayanti et al., 2021). Application *Canva* is used to create attractive designs and can be saved as a pdf (Puspita et al., 2021). Meanwhile, *Flip Pdf Corporate* is used to edit and convert pdf *files* into electronic modules in the form of *flips,* so it has a page view like a book (Susanti & Sholihah, 2021). The features provided in *Flip Pdf Corporate* include *links* that connect between module pages, images, videos, interactive quizzes, and various module formats for distribution (Seruni et al., 2019).

The developed electronic module is integrated with the *Science Technology Engineering and Mathematics* (STEM) learning model. STEM is a learning model that can help students think critically and creatively (Dywan & Airlanda, 2020). STEM integration in the developed module is poured into a STEM project. According to research by Davidi et al. (2021), STEM focuses on problem-solving and shows students how science, technology, engineering, and mathematics techniques are used in an integrated manner to develop products, processes, and systems that are beneficial to human life.

The research model used in this study adopts the 4-D model proposed by Thiagarajan (1974), which consists of *define, design, development, and disseminate stages*. However, this research was only carried out until the *development stage*.

The first stage is *defined,* which consists of availability analysis and needs analysis. Analysis of availability and needs was carried out by conducting interviews with chemistry teachers at SMA Budi Luhur, MA Ali Maksum Krapyak, MA Ibnu Sina, and MA Muhammadiyah 1 Yogyakarta. Interviews were conducted to determine the teaching materials and learning media used by teachers in the learning process. Based on the results of the interviews, information was obtained that the teaching materials used by the teacher in the learning process were in the form of textbooks and modules containing materials and questions. Books and modules are not integrated with the learning model that supports the *student center learning program*.

Meanwhile, based on the needs analysis results, it was found that the 2013 curriculum requires teachers to realize student-centered learning programs, prepare students to have critical thinking skills, and solve problems. However, this learning model cannot be implemented in the learning process because no teaching materials are designed to be student-centered. The chemistry teacher at Budi Luhur High School explained that the COVID-19 pandemic conditions, which required students to study from home, also made it difficult for teachers to deliver the existing printed modules, so electronic modules' availability was needed. Therefore, electronic modules are helpful for online learning.

At the *design stage,* The *software was* used to manufacture interactive electronic modules containing STEM in the form of *Canva and* Flip *pdf corporate.* Furthermore, the format selection is adjusted to the ease of use, namely the HTML format, where the module can be accessed using *a smartphone* or laptop without installing it. The reference or material used in the research is the reaction rate material, which consists of understanding the reaction rate, the factors that affect the reaction rate, and the reaction rate equation. The developed STEM-loaded interactive electronic module contains materials, interactive quizzes, and STEM projects and is equipped with simple activities before starting the core material. Making this practicum video begins with creating a *cover design* and module *layout using the Canva application*. The following is the process of doing STEM-loaded interactive electronic modules.

In the first stage, prepared the material for the reaction rate and other components needed in compiling the module. The second stage is the cover design process using *Canva,* which can be seen in Figure 1.

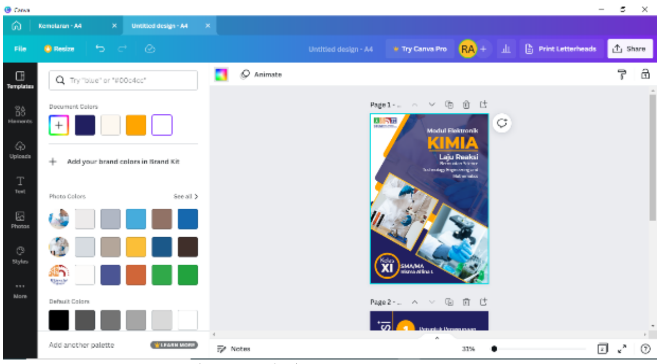

Figure 1. The Module Design Process In Canva

This stage is carried out by designing the module's entire content, including the illustration components that will be given a *linked pop-up* in the next stage. After the design process is complete, the results are saved in pdf format and converted into electronic form using the Flip pdf *corporate application*. The third stage is doing an interactive electronic module using *a corporate flip pdf* which can be seen in Figure 2.

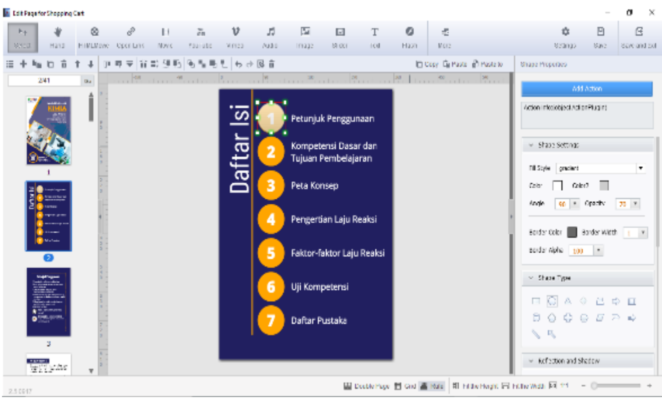

Figure 2. Interactive electronic module manufacturing process if

The fourth stage is making an interactive quiz using one of the menus available in *the corporate flip pdf*. Quizzes are available in the form of multiple-choice by displaying true and false information when students take the quiz. The process of making interactive quizzes can be seen in Figure 3.

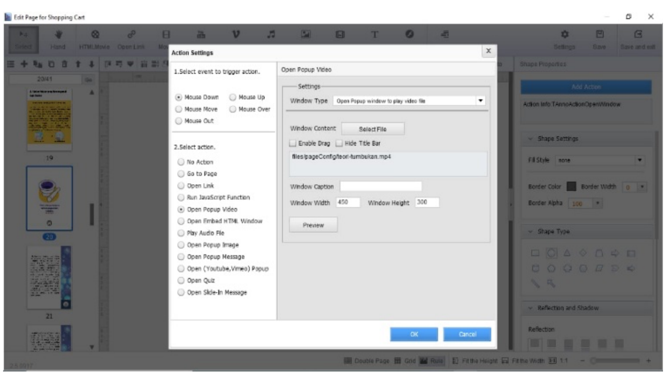

Figure 3. The process of creating interactive quizzes.

The fifth stage is inserting an illustration in the form of a video into the module using one of the menus available in *the corporate flip pdf.* The process of inserting illustrations can be seen in Figure 4.

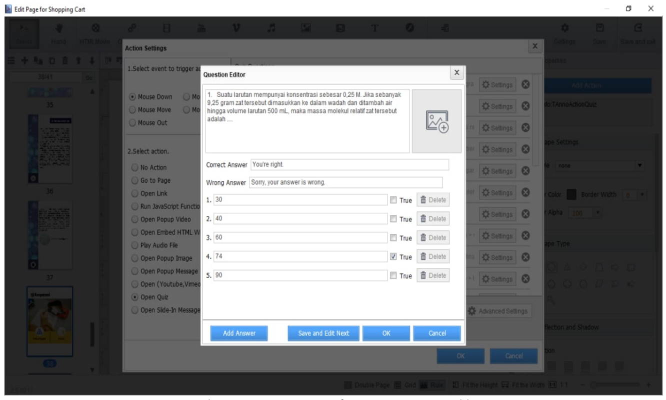

Figure 4. The process of inserting illustrations

The last stage is uploading the module *online* to get an HTML *link* to access the module via other devices. The final product is an electronic module in HTML format. The cover image of the interactive electronic module STEM charged reaction rate material can be seen in Figure 5.

Figure 5. The interactive electronic module cover

The components in the developed product consist of introduction, content, and closing. The introductory section contains a table of contents, instructions for use, essential competencies, learning objectives, and a concept map. The table of contents is presented as a sequence of essential parts of the module, such as instructions for use, concept maps, sub-materials, competency tests, and a bibliography. The numbers in the table of contents are linked to the page. Meanwhile, the user manual is intended to make it easier for readers to use the electronic module and understand the information on each *button* used in the module. The table of contents and instructions for using the electronic module can be seen in Figure 6.

Picture 6. Display of table of contents and instructions for use

The content section includes material on reaction rates and STEM projects. The reaction rate material in the module includes understanding reaction rates, reaction rate equations, and factors that affect reaction rates. The reaction rate material presented includes practical activities, interactive quizzes, and STEM projects. The display of the STEM project in the developed electronic module can be seen in Figure 7.

Figure 7. STEM project view

The STEM project is designed to follow the STEM learning syntax proposed by (Suryani et al., 2020). The first stage *observes* where students are motivated to observe a saponification reaction phenomenon in making bar soap related to the reaction rate factor. The view of the *observation* stage can be seen in Figure 8.

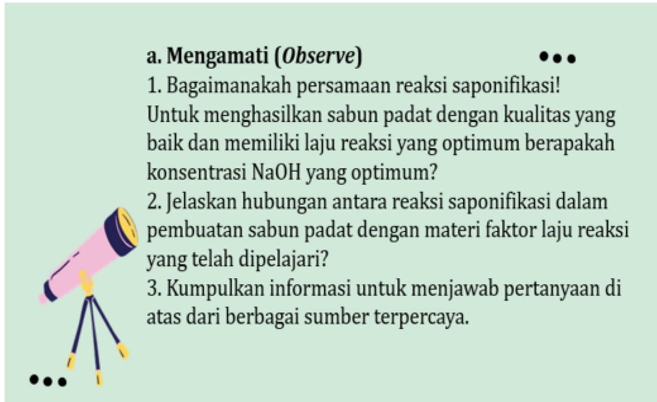

Figure 8. Stage *Observe*

The second stage, *New Idea*, is where students are asked to observe and look for additional information about the right ingredients to make good soap. Students are also asked to think of a new idea regarding additional ingredients to manufacture aromatic or antiseptic soap. This stage requires skills in analyzing and thinking creatively from students. The display of the New Idea stage can be seen in Figure 9.

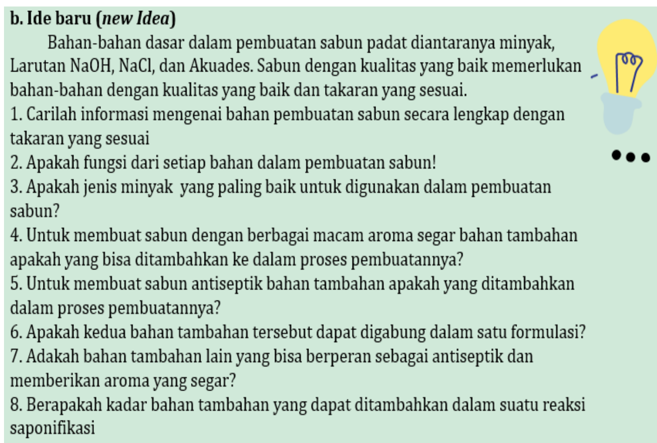

Figure 9. New Idea Stage

The third stage, *innovation,* contains instructions that ask students to describe the results of new ideas in the previous stage into a formulation. New soap according to the creativity of each student. The display of the innovation stage can be seen in Figure 10.

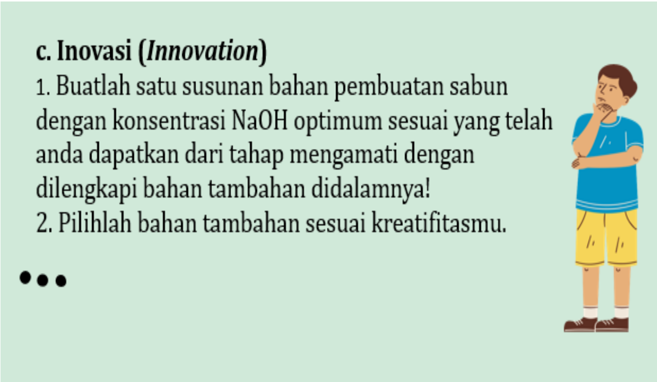

Figure 10. Innovation Stage

The fourth stage, namely *creativity* in the form of implementing all designs resulting from discussions about ideas and innovations that have been compiled into a product. Students were asked to realize the soap product according to the formulation that had been designed and make soap with several different concentrations of NaOH to observe the effect of NaOH concentration in the saponification reaction. The display of the creativity stage can be seen in Figure 11. The last stage, namely *society,* consists of questions assessing students' ideas for social life. The appearance of the society stage can be seen in Figure 12.

Furthermore, making a questionnaire instrument for assessing product quality and student responses. The questionnaire contains several aspects assessed by material experts, media experts, and *reviewers*. At the same time, the student response is only a statement that will be answered by the student with a yes or no answer.

The finished product is then validated and assessed at the development stage by media and material experts. Media experts validate and assess the module from the aspects of presentation, graphics, and module characteristics. The results of the module quality assessment according to media experts can be seen in Table 2.

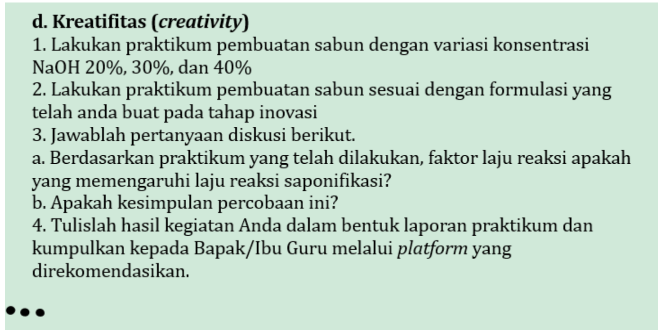

Figure 11. Creativity stage

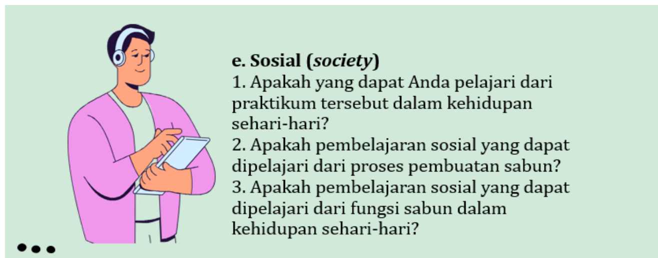

Figure 12. Stage of society

Table 2. Assessment of Module Quality by Media Experts

No.	Assessment Aspect	Score	Max Score. Ideal	Ideal Percentage (%)	Category
1	Presentation	20	20	100.0	Very good
2	Graphics a n	14	15	93.3	Very good
3	Module Characteristics	24	25	96.0	Very good
Total		58	60	9 6.7	Very good

Based on Table 2, it can be concluded that according to media experts, the quality of the module developed is in the Very Good category with an ideal percentage of 96.7%. Material experts play a role in validating and assessing modules from aspects of content, language, and *Science, Technology, Engineering, and Mathematics* (STEM). The results of the module quality assessment according to material experts can be seen in Table 3.

Table 3. Module Quality Assessment by Material Expert

No.	Assessment Aspect	Score	Max Score. Ideal	Ideal Percentage (%)	Category
1	Contents	16	20	80.0	Well
2	Language	1 7	20	85.0	Well
3	Science Technology Engineering and Mathematics (STEM)	4	5	80.0	Well
Total		37	45	82.2	Well

Based on Table 3, it can be concluded that according to the material expert, the quality of the module developed is in the **Good category** with an ideal percentage of 82.2%.

The module that was developed after being validated and revised according to suggestions from media experts and material experts was then assessed for quality by *reviewers* (high school chemistry teachers). The reviewer's role is to assess the aspects of content, language, presentation, graphics, module characteristics, and *Science, Technology, Engineering, and Mathematics* (STEM). The following are the results of the reviewers' module quality assessment, which can be seen in Table 4.

Table 4. Module Quality Assessment by *Reviewers*

No.	Assessment Aspect	Score	Max Score. Ideal	Ideal Percentage	Category
1	Contents	19.0	20	95.0	Very good
2	Language	19.3	20	96.3	Very good
3	Presentation	19.0	20	95.0	Very good
4	Graphics	14.3	15	95.0	Very good
5	Module characteristics	23.8	25	95.0	Very good
6	Science Technology Engineering and Mathematics (STEM)	4.8	5	95.0	Very good
Total		100	105	95.0	Very good

Based on Tab el 4, it can be concluded that according to *the reviewer*, the quality of the module developed is very good, with an ideal percentage of 95.0%.

The next stage is to conduct a limited trial of 10 students. Student response aims to assess the media regarding material presentation, interactive quizzes, *user-friendly*, critical thinking, and illustrations. The following is the student response data to the module, which can be seen in Table 5.

Table 5. Student Response

No.	Assessment Aspect	Indicator	Score	Max Score. Ideal	Ideal Percentage (%)
1	Material Presentation	2	1.8	2	90
2	Interactive Quiz	2	2.0	2	100
3	User Friendly	2	2.0	2	100
4	Critical thinking	2	1.8	2	90
5	Illustration	2	2.0	2	100
Total		10	9.6	10	96

Based on student responses results, the module's quality was very good, with an ideal percentage of 96%. The interactive electronic module of the reaction rate material with *Science Technology Engineering and Mathematics* (STEM) content developed has the characteristics of being easy to use, attractive, and STEM loaded so that it can improve critical thinking skills. The obstacle experienced by researchers in developing an interactive electronic module for STEM-charged reaction rate material is the difficulty of inserting interactive *essay questions* into the module. The interactive *essay questions were created using the* quiz.com web-based application attached to the *corporate flip pdf application*. However, the question cannot be executed, so the *essay question is* changed to a *pop-up image*. Another obstacle is writing chemical compound symbols in the interactive question feature. Number symbols cannot be written correctly because the equation menu is unavailable.

Conclusion

Based on the research, an interactive electronic module for the reaction rate material with *Science Technology Engineering and Mathematics* (STEM) content was developed to be easy to use, attractive, and STEM-loaded. The quality of the modules developed according to the assessment results by media experts was 9 6.67% in the very good category, material experts at 82.22% in the good category, and 95% *reviewers in the very good category.* Furthermore, based on the results of the student's responsibility to get a positive response with a percentage of 96% the interactive electronic module of the reaction rate material charged with *Science Technology Engineering and Mathematics* (STEM) can be used as an alternative medium for learning chemistry in high school class XI. The interactive electronic module of the reaction rate material containing *Science Technology Engineering and Mathematics* (STEM) helps improve students' critical thinking skills.

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