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Development of E-module based on Multiple Representation to Improve the Competence of Chemical Literacy and Learning Independence of Students on the Material Reaction Rate

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Abstract: In The learning process, learning media, students, educators, environment conditions and everything related to education have a reciprocal relationship that is mutually dependent on each other and mutually utilizes each other with the aim of forming character in students who think cognitively and independently. The aim of this research is to determine the level of validity and practice of e-modules based on multiple representations to increase chemical literacy in odd semester class XI high school chemistry material in accordance with the independent learning curriculum. This type of research is R&D (Presearch & Development). Where this research produces products and tests the effectiveness of the products produced. Data collection techniques were carried out through interviews, validity sheets, teacher practitioner questionnaires and student response tests. The research results found that the E-module product based on multiple representations of reaction rate subject matter was very valid in terms of material validation, media validation and practitioners by teachers in the field of chemistry studies. So, it can be used in the learning process. Thus, the product developed can help teachers convey reaction rate material in an independent curriculum.

Keywords: Chemical Literacy; E-Module; Independence; Multiple Representation

Introduction

The curriculum is the "spirit" of education which must be evaluated innovatively, dynamically and periodically in accordance with developments in time and science and technology (Marisa, 2021). So curriculum changes are very necessary. This is because the very rapid development of science and technology no longer allows the world of education to stick with the current curriculum for long (Suryaman, 2020).

Education in Indonesia in 2022 will implement an independent learning curriculum as a follow-up to the abolition of the National Examination (UN) since 2021 and replaced with a Minimum Competency Assessment system and a characteristics survey (Rokhim et al., 2021). The AKM assessment is designed to measure student achievement from cognitive learning outcomes, namely literacy and numeracy. Literacy and numeracy skills can help students learn other fields of science by forming ways of thinking and training students to digest information in written form or numbers (Fauziah et al., 2021).

Based on the results of the PISA assessment in 2018, Indonesia was ranked 71st out of 79 countries (Hewi et al., 2020). This shows that the majority of students' scientific literacy achievements, including chemical literacy, in Indonesia are still not optimal. PISA measures three areas of literacy, namely: reading literacy (language), mathematics literacy and science literacy.

Chemistry is central in science lessons. Studying chemistry requires mastery of three levels, namely: the macroscopic level which can be seen, touched and smelled; the submicroscopic level relating to atoms, molecules, ions, and structures; and symbolic levels such as formulas, equations, symbols and graphs (Hurrahman et al., 2022). The scientific literacy

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assessment aims to determine students' ability to respond to scientific issues using scientific ideas (Aditomo & Faridz, 2019).

In the process of learning learning media, students, educators, the environment/conditions and everything related to education have a reciprocal relationship that is mutually dependent and mutually utilizes each other with the aim of forming students' cognitive thinking characteristics (Indriyani, 2019). There are many media that educators can use. However, in the 21st century, educators are starting to apply technology in learning, such as multimedia.

Multimedia is the presentation of material using words and images. In the learning process, presenting material in the form of multimedia products provides opportunities for students to process information. This means that multimedia products provide an interactive channel for students to understand material in various aspects such as text, images, video, audio and animation (Hasan, 2021).

A module is a unit of planned learning activities designed to help students complete certain goals by organizing learning material that is tailored to the individual's own personality so that they can maximize their intellectual abilities (Umaira et al., 2019). The module is designed specifically and clearly based on each student's speed of understanding, thereby encouraging students to learn according to their abilities (Sidiq & Najuah, 2020). In the era of the 21st century learning revolution, many modules have been developed in the form of electronic modules or e-modules. E-module is a digital teaching material product which is independently designed to be studied by students and can be used via computer, laptop, tablet or even smartphone access (Laili et al., 2019).

PISA (The Program for International Assessment) is a program to measure the potential achievement of 15 year old children in the areas of science, reading literacy and mathematics abilities. The assessment is carried out once every three years with a focus on a country's education. Based on the PISA assessment in 2018, Indonesia experienced a decrease in points in the field of science by 7 points, with a total of 396 points from the 403 points obtained in 2015 which caused Indonesia to rank 71st out of 79 countries (Hewi et al., 2020). This shows that the majority of students' scientific literacy achievements, including chemical literacy, in Indonesia are still not optimal

Learning independence can be defined as a reflection of creative attitudes, freedom of action and responsibility which is characterized by learning initiative and the desire to gain new experiences (Asmarani & Ibrahim, 2021; Barabasch & Keller, 2020; Mota & Scott, 2014). Teachers need to measure student learning independence to find out the extent of learning independence that students have, or whether there is an influence of learning carried out by teachers on student learning independence. To measure student learning independence, media and instruments are needed that refer to indicators of learning independence (Ariyanti, 2019).

Multiple representation as the practice of representing the same concept through various forms, including descriptive (verbal, graphic, table), experimental, mathematical, figurative (pictorial, analogy and metaphor), kinesthetic, visual and/or representation models. operational actional mode (Nisa et al., 2015). The representation of chemistry is divided into three different levels of representation, namely macroscopic, sub-microscopic and symbolic (Ramdhani et al., 2020). Multiple representations are expected to be able to provide implications for the process of teaching reaction rate material, where the teacher knows the process of conveying the concept of reaction rate in terms of which representation comes first and which requires emphasis, so that students can easily connect the concept of reaction rate at three levels of representation (Safitri et al., 2019).

In fact, it was found that chemical literacy competency and several indicators of independence were not met from students' attitudes, such as lack of student learning initiative; students are unable to monitor, organize and control their learning; students are unable to set goals and targets; and the habit of analyzing learning needs. This is proven by the fact that the learning process is still teacher-centered based on students filling out pre-research questionnaires.

Method

Based on the problems and objectives that have been stated, this type of research is R & D (Research and development). This research produces products and tests the effectiveness of the products produced. Researchers carry out e-module products. R&D research with the aim of developing a product in the form of an electronic module (E-module) of reaction rates based on multiple representations to increase students' chemical literacy competence and learning independence. This type of research is limited ADDIE development research (Rusdi, 2018), which only achieves feasibility, practicality and small-scale responses from students. The steps taken in this research are:

Analyze

The first is needs analysis. Needs analysis is an important thing to do to ensure that a product will be developed in accordance with user needs. Product

development can be carried out in aspects of curriculum needs. At this stage the author carried out an analysis by observing and interviewing chemistry teachers at SMAN 1 Kampar Timur, SMAN 2 Kampar Timur. These observations and interviews aim to find out about the process of learning activities at school, the characteristics of students and the learning resources used in learning. The second is the analysis of the characteristics of learners. Analysis of student characteristics includes interests, talents, limitations and individual strengths (Abdi et al., 2011). In the independent curriculum, students are grouped based on interests and grouped according to the higher education department plan. The third is the analysis of prerequisite skills and initial skills. The learning environment has been specifically designed to enable students to learn with a higher level of participation and independence. Analysis of the learning environment can include learning culture in schools, learning culture in the classroom, educational interactions with students and student interactions with students, potential involvement of students in the learning process, availability of learning resources, availability of information technology facilities and other supports (Mawarsih et al., 2013).

Design

Consists of determining the resources needed, compiling materials, compiling e-modules, and designing learning content in e-modules.

Development

This stage consists of preparing the initial product. The product developed is an e-module based on multiple representation. Initial product development consisted of teaching modules using assessment instruments that had been developed for research. The instruments developed were validation questionnaires, teacher and student response questionnaires and chemical literacy competency assessment instruments.

Then, at this stage, the initial product will be validated by experts and practitioners. The multiple representation-based e-module product that was developed was analyzed and validated by the supervisor, then revised. After going through a revision process by the supervising lecturer, the multiple representation-based e-module was submitted to expert validators consisting of 3 media expert lecturers and 3 material expert lecturers. The e-module developed was also analyzed for practicality by practitioners, namely 3 chemistry teachers, to get input from a practical perspective

The scoring on the questionnaire sheet refers to the Likert scale adapted from Sugiyono (2010), which consists of not good (1), fair (2), good (3) and very good (4). The purpose of this validation is to measure whether the product being developed is feasible and in accordance with the capabilities being measured. Then the e-module product is revised according to the validators' suggestions.

Table 1. Validity percentage category

Validity criteria (%)	Validity level	Information
85-100	Very good	Can be used without repair
70-84	Good	Can be used with minor revisions
50-69	Enough	Needs major revision
0-49	Not good	Not suitable for use

Implementation of this development research will begin in July 2022 – August 2023 at FKIP, Riau University. The data collection techniques used were interviews, questionnaires, non-test techniques, and documentation.

Results and Discussion

Needs Analysis

Needs analysis is carried out to ensure that the product used meets user needs. The development of e-modules for learning is carried out from aspects of curriculum needs at the educational unit level. Analysis of curriculum needs is related to analysis of indicators of learning achievement and learning objectives. At the time of this research, high school level schools used the Merdeka Belajar curriculum. What is done at this stage is to examine the factors needed for e-module development, the resources required, determine potential delivery systems, and prepare a processing plan for e-module development.

Analysis of Student Characteristics

Analysis of student characteristics includes individual interests, talents, limitations and strengths (Rusdi, 2018). In this research conducted at SMAN 1 Kampar Timur class XI, students were divided based on students' interests and grouped into one elective subject in the class. At this stage, the results show that there is still a lack of students' literacy competence, a lack of understanding of students' learning using textbooks, and a lack of students' interest in learning chemistry.

Initial Analysis of Prerequisite Abilities and Initial Abilities

The learning product developed in the form of an e-module based on multiple representations requires prerequisite abilities and initial abilities that students must have. At this stage, as a result of interviews and observations, students have the prerequisite skills and ability to use e-modules. Students have studied

stoichiometry and the concept of moles which are needed to study reaction rate material. Students also have Android and have used Android in learning. The results of the questionnaire distribution showed that 90% of students had Android and 88% used Android to study.

Learning Environment Analysis

Analysis of the learning environment can include learning culture at school, learning culture in the classroom, interaction between students and educators, and interaction between students and other students, the potential for student involvement in learning, availability of learning resources, availability of facilities and infrastructure (Rusdi, 2018). Based on the results of interviews and school observations at SMAN 1 Kampar Timur, it is known that SMAN 1 Kampar Timur is located after the market and the average occupation of the parents is farmers and traders. has implemented a literacy movement which is supported by providing time for literacy every day at the start of class, providing a reading corner, literacy stage and other facilities. Most of the learning process is carried out in the classroom so that chemistry learning is less enthusiastic because currently learning resources such as independent curriculum books are still limited so they are used in turns while the availability of technological infrastructure is adequate.

Design Stage

At this stage, designing the expected learning media is carried out with appropriate testing. At the design stage, researchers verify the material that will be included in the e-module, CP, TAPI, IKTP, as well as determine the content of reaction rate material, collect images, videos, animations that will support multiple representations of reaction rate material, rate law, collision theory and factors. -factors that influence the rate of a reaction. Then the researchers made a flow diagram from the reaction rate material based on multiple representations.

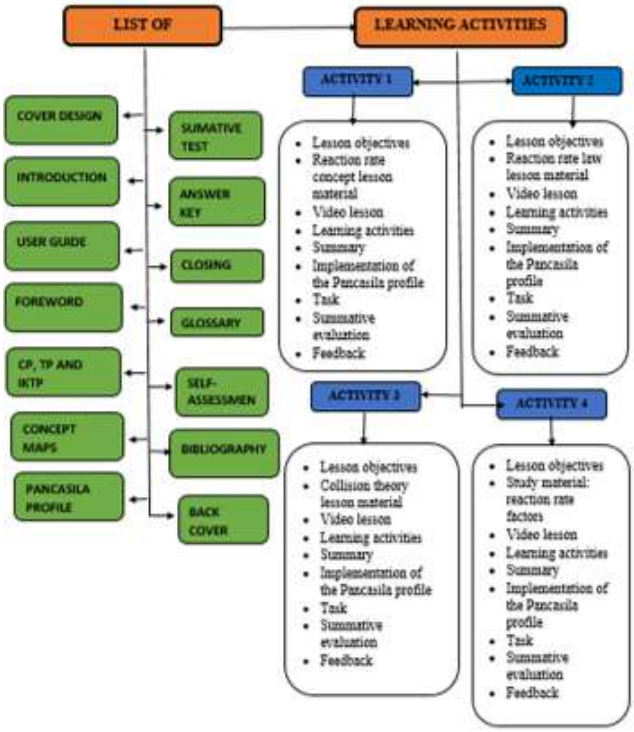

Figure 1. Reaction rate e-module flow diagram

Next, the researcher compiled the e-module material into the inkspace application to create pages. The material structure that has been determined is then arranged into e-module components based on a flow diagram. Material descriptions and test questions were developed based on chemical literacy competency indicators based on multiple representations and learning independence.

Development Stage

The development stage includes: Combining design material content with multiple levels of representation. The aim of this procedure is to produce e-modules based on multiple representations that are in accordance with the independent curriculum and are able to provide chemical literacy competencies and increase students' learning independence.

Expert Validation, e-modules that have been completed are made into products and then validated by experts consisting of a team of material experts and media experts. The validation test aims to determine the validity of the resulting media.e-module validation is needed to get suggestions and improvements so that the e-module is suitable for use (Ginting et al., 2022).

Expert Validation

E-Module Validation by Material Experts

Validation of the e-module was carried out by 3 validators whose aim was to see the suitability of the design, the suitability of the material, the suitability of

the presentation and the suitability of the language. Validation of the e-module was carried out repeatedly and assessed twice on the validation sheet by the validator team. The questionnaire sheet indicators were quoted from Apriani et al. (2021) which were adapted to the research.

Table 2. Recapitulation of validation results I and II on aspects of learning design suitability

Assessment Items	Feasibility Value (%)	
	I	II
Material is presented in accordance with learning outcomes and learning objectives	83	100
The material is in accordance with the indicators of achievement of learning objectives	100	100

The design aspect gets a percentage of 100%. This shows that the material presented is in accordance with the learning outcomes and learning objectives. A teaching material can provide a good understanding of learning for students (Aisyah et al., 2020).

Table 3. Recapitulation of validation results I and II on the feasibility aspect of the material content

Assessment Items	Feasibility Value (%)	
	I	II
There are independent curriculum learning outcomes	92	100
The material presented in the module is based on multiple representation	75	100
The (macroscopic) images contained in the module correspond to the reaction rate material	67	92
Images of examples of compounds (microscopically) in the module in accordance with the concept of reaction rate	75	92
Chemical symbols and chemical formulas are given according to the actual reaction rate material	83	100
The material presented is complete	83	92
The material is presented sequentially	92	100
The material presented is easy to understand	75	100
Examples of questions are presented according to the reaction rate material	75	100
The practice questions are in accordance with the Learning Goal Achievement Indicators and chemical literacy	75	92
The material is presented sequentially	75	92
The material presented is easy to understand	83	83

The material aspect received a percentage of 95% with a very valid category. This shows that the material provided is consistent, the pictures are clear, the videos are appropriate, the example questions and practice questions can train students' chemical literacy. If the material provided is appropriate, it can prevent students' conceptual errors (Dewi et al., 2021).

Table 4. Recapitulation of validation results I and II in the aspect of material presentation

Assessment Items	Feasibility Value (%)	
	I	II
The systematics of module preparation is complete and systematic	92	92
The summary is presented coherently and completely	83	100
The material presented in the module covers all three levels of representation (macroscopic, microscopic and symbolic)	83	100
Consistent use of chemical symbols/icons	83	92
Instructions for using the application-assisted multiple representation-based module are clear and easy to understand.	92	100

Aspects of material presentation obtained a percentage of 97% which is included in the very valid category. This data shows that the presentation of material in the e-module includes three levels of representation and is equipped with animations, pictures, symbols and example questions that are clear and easy to understand.

Table 5. Recapitulation of validation results I and II on the language aspect

Assessment Items	Feasibility Value (%)	
	I	II
Straightforward	75	96.6
Communicative	83	100
Developmental appropriateness	83	100
Language suitability	83	100
Conformity icon symbol	83	100

Based on table 5, the average language percentage calculated is 99% with a very valid category. In this way, it can be concluded that the language used in the e-module meets the aspects of being straightforward, communicative, in accordance with good language rules and easy to understand for high school level students.

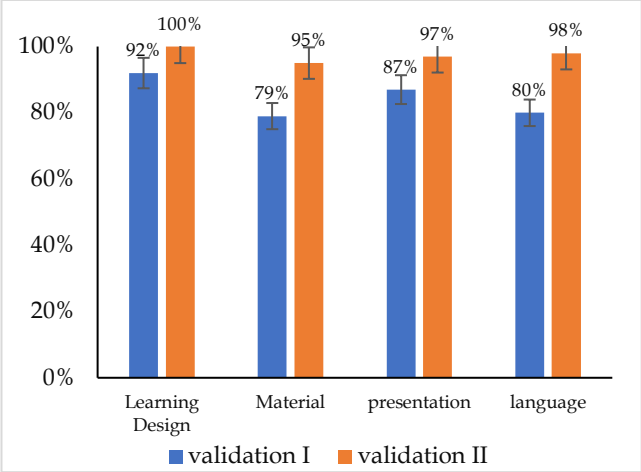

Figure 2. Recapitulation of material expert e-module validation

Based on the graph in Figure 2, an increase can be seen between the average of validation I to validation II. This increase can occur due to improvements/revisions carried out in accordance with the validator's suggestions.

E-Module Validation by Media Experts

This validation aims to see the suitability of the media design, software and language suitability. In the software aspect, the percentage was 100% with a very valid category. In this way, it can be concluded that it can be used well, the buttons function well, and various links are easy to access.In accordance with Elvarita's research which states that E-modules are teaching materials that are considered innovative, the modules are equipped with appropriate teaching material components, there are also pictures, video links, practice questions and summative tests to attract students' interest (Elvarita et al., 2020).

Table 6. Recapitulation of validation aspects of design appearance

Assessment Items	Feasibility Value (%)	
	I	II
The size of the module used is in accordance with the standard (A4)	100	100
The layout and systematics of the cover are correct	83	92
The layout of each part in the proportional module	92	92
Attractive module display	92	100
The letters used are attractive and easy to read	83	100
The presentation of the image on the cover is appropriate and attractive	92	92
The selection and layout of images within the module is precise	100	100
The selection and layout of videos in the module is precise	100	100
Instructions for using the module using the application are clear and easy to understand	83	100
The e-module contains all the initial components of the module (cover, foreword, table of contents, guide, concept map	100	100
The e-module contains all components of the e-module content (learning outcomes, material descriptions, activities, assignments, worksheets and summative tests)	100	100
The e-module contains all the final components of the e-module (summary, feedback, glossary and bibliography)	100	100

The design appearance aspect obtained a percentage of 98% which is included in the very valid category. These results show that the size and appearance of the e-module using the Android application is appropriate and attractive. The attractive appearance of the e-module can attract students' interest in learning (Mumpuni & Nurbaeti, 2019).

Figure 3 is a recapitulation of the results of validation I and validation II by media experts consisting of 3 aspects, namely aspects of design appearance, software suitability and language suitability. The graph shows an increase between the average values in validation I and validation II. This increase occurred because these two aspects had been corrected or revised in accordance with suggestions from the validator.

Practicing Chemistry Teacher

The practitioner test was carried out on 3 educators at two schools, namely at SMAN 1 Kampar Timur and at SMAN 2 Kampar Timur. The practitioner test on educators from SMAN 2 Kampar Timur was carried out on August 8 2023. Meanwhile, 2 educators at SMAN 1 Kampar Timur were carried out on August 21 2023.

Table 7. Recapitulation of validation aspects of software feasibility

Assessment Items	Feasibility Value (%)	
	I	II
The module application is easy to operate on an Android smartphone	100	100
The buttons on the reaction rate application function properly	92	100
Various other application sources are well connected in the e-module	100	100
The multiple representation visualization is presented well	100	100
The quality of the videos presented in the emodule	100	100
Practicality of using e-modules.	100	100

Table 8. Recapitulation of validation of linguistic aspects

Assessment Items	Feasibility Value (%)	
	I	II
Straightforward	97.3	100
Communicative	92	100
Developmental appropriateness	100	100
Language suitability	92	100
Conformity icon symbol	92	100

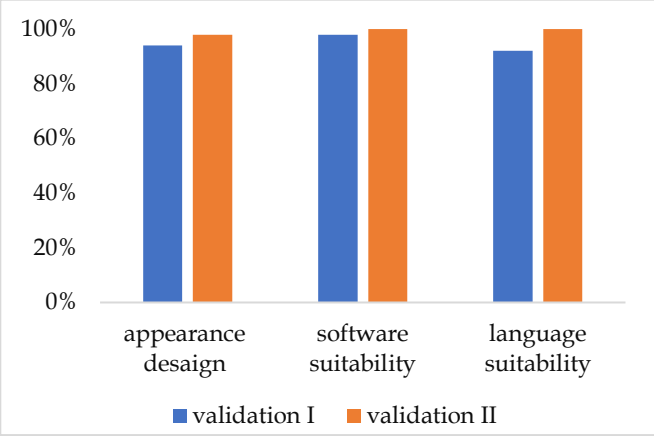

Figure 3. Recapitulation of e-module validation by media experts

Table 9. Results of data analysis of educator response questionnaires

Respondent	Score	Practicality Category
Practitioner I (SMAN 2 East Kampar)	87	Very good
Practitioner II (SMAN 1 Kampar Timur)	97	Very good
Practitioner III (SMAN 1 Kampar Timur	90	Very good
TOTAL	91.33	Very good

Educators are given time to read and assess the e-module both in terms of material and quality of the e-module as well as practicality in operating the e-module in the learning process. Then educators were given a response questionnaire aimed at obtaining further information about the practicality of e-modules. The educator response questionnaire consists of 25 statement items which are assessed using a 1-4 Likert scale. Data from the teacher response questionnaire assessment were analyzed using percentage descriptive statistics, the results of which can be seen in table 9.

Based on table 9, it is known that educators gave a high practitioner response with an average score of 91.33% in the very good category, meaning that the modules were developed in accordance with the independent curriculum for high school level F phase, very easy to operate, the presentation of the material was sequential and systematic.Previous research also obtained results that stated that learning using technology can help teachers convey learning material (Yuliono et al., 2018), provide visualization and assist in the learning process(Kusdiyanti et al., 2020).

Implementation

At the implementation stage, one-on-one tests and teacher response tests were carried out on 10 students from SMAN 1 East Kampar and 10 students from SMAN 2 East Kampar.There were three students in class (Wahyuni & Hardeli, 2019).The response test is carried out with the aim of knowing the response to the use of e-modules by students according to the aspects that have been measured. The conditions for selecting respondents were students who had studied reaction rate material (Rusdi, 2018), therefore students were selected in class XII.

Evaluation

In the evaluation, students' and teachers' responses to the e-module will be measured. Evaluation is what connects design and users directly. The implementation stage contains elements of formative evaluation in the form of small-scale tests (student responses) (Rusdi, 2018).

The one-on-one test phase was carried out on 4 and 7 August 2023 at SMAN 1 Kampar Timur. The first step is that the researcher provides an e-module soft file that has been uploaded to the participant's Android cellphone. The subject matter in the e-module is understanding reaction rates, the law of reaction rates, collision theory and factors that influence reaction rates. This activity lasted for two days, where on the first day participants studied the content of activities 1 and 2, while on the second day they studied the content of activities 3 and 4 in the e-module as a whole with the

guidance of researchers assisted by chemistry teachers. Then participants work on questions on learning e-modules I, II, III and IV. The time required for learning is 4x45 minutes. After working on the questions on the e-module, participants wrote down comments and suggestions given during the use of the e-module on a sheet provided by the researcher. The average results of student responses to multiple representation-based e-modules can be seen in table 10.

Table 10. Results of recapitulation of average student responses

Question	score	Percentage (%)
The systematics of module preparation is complete and systematic	77	96
The summary is presented coherently and completely	71	89
The material presented in the module covers all three levels of representation (macroscopic, microscopic and symbolic)	71	89
Consistent use of chemical symbols/icons	71	89
Instructions for using the application-assisted multiple representation-based module are clear and easy to understand	74	93
The material in the e-module is easy to understand	71	84
The reaction rate module application is easy to operate on an Android smartphone	72	90
The buttons on the reaction rate application function properly	70	88
Various other application sources are well connected in the e-module	69	86
Multiple representation visualization is presented well	69	86
The quality of the videos presented in the e-module	74	92
The material presented in the multiple representation-based e-module can help me understand the material on reaction rates	72	90
The multi-representation-based e-module helped me visualize the reaction rate process	72	90
The multi-representation based e-module made me interested in studying reaction rates	74	92

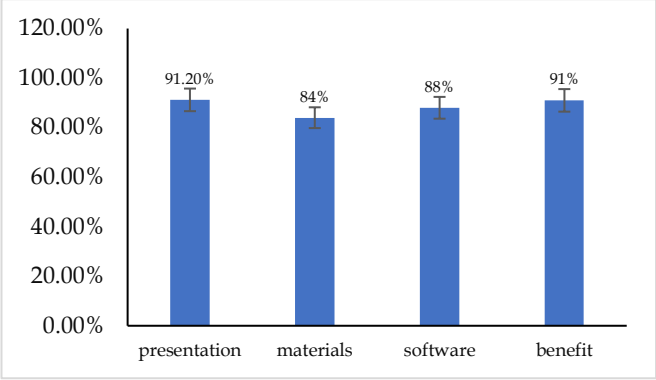

Figure 4. The results of quantitative data analysis of student response

Based on figure 4, the overall average of the four assessment aspects was calculated and a result of 89% was obtained in the very good category. Thus, it can be concluded that the e-module based on multiple representations of reaction rate material received a positive response from students. The assessment results show that the product has a dancing appearance, the material is easy to understand, can help visualize reaction rates and make students interested in learning it. Because of the multiple-based e-module, the representation of the material presented is more interesting. Apart from that, with the e-module, teachers can monitor students' learning independence at home because the exercises are connected using a goggle form and immediate feedback is provided.

Conclusion

This research produces a product in the form of an E-Module on reaction rate material based on multiple representations using the ADDIE model which is limited to small-scale student responses. Based on the results of the research conducted, it can be concluded that the e-module on reaction rate material based on multiple representations is classified as very valid in terms of validation of the material, media and practitioners by teachers in the field of chemistry studies. So, it can be used in the learning process. Thus, the product developed can help teachers convey reaction rate material in the independent curriculum.

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Author Contributions
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The authors declare no conflict of interest

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