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Development of Discovery Learning-Based E-Module with Video Demonstration to Improve Students' Conceptual Understanding on Reaction Rate and Chemical Equilibrium

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Abstract

Learning chemistry concepts such as reaction rate and chemical equilibrium often pose challenges for students due to their abstract nature and limited opportunities for laboratory practice. This research aims to determine the validity, practicality, and effectiveness of the discovery learning-based e-module with a video demonstration on high school students' reaction rate and chemical equilibrium subjects. The type of research carried out was education design research (EDR) with the Plomp development model. This research involved six chemistry lecturers of the Faculty of Mathematics and Natural Sciences and Faculty of Engineering Universitas Negeri Padang. Teachers and students at the high school level from several schools were also involved in this research. Questionnaires, observations, interviews, and post-test and pre-test scores were used to retrieve data. Based on the results, it was known that the two e-modules were in the valid category with values of 0.866 and 0.892. Furthermore, both e-modules have practicality values of 0.85 and 0.84 from teachers, respectively, and 0.96 and 0.87 from students, putting them in the practical category. The effectiveness values of the two e-modules were 0.59 and 0.67, so they were categorized as quite effective. The effectiveness of the developed e-module was evaluated based on the improvement of students' conceptual understanding in the cognitive domain.

Keywords: reaction rate, chemical equilibrium, e-module, video demonstration.

Pengembangan E-Modul Berbasis Discovery Learning dengan Video Demonstrasi untuk Meningkatkan Pemahaman Konseptual Siswa pada Materi Laju Reaksi dan Kesetimbangan Kimia

Abstrak

Mempelajari konsep-konsep kimia seperti laju reaksi dan kesetimbangan kimia seringkali menjadi tantangan bagi siswa karena sifatnya yang abstrak dan keterbatasan kesempatan untuk praktik laboratorium. Penelitian ini bertujuan untuk menentukan validitas, kelayakan, dan efektivitas modul e-learning berbasis pembelajaran penemuan dengan demonstrasi video pada mata pelajaran laju reaksi dan kesetimbangan kimia bagi siswa sekolah menengah atas. Jenis penelitian yang dilakukan adalah penelitian desain

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pendidikan (EDR) dengan model pengembangan Plomp. Penelitian ini melibatkan enam dosen kimia dari Fakultas Matematika dan Ilmu Pengetahuan Alam serta Fakultas Teknik Universitas Negeri Padang. Guru dan siswa tingkat SMA dari beberapa sekolah juga terlibat dalam penelitian ini. Data dikumpulkan melalui kuesioner, observasi, wawancara, serta skor post-test dan pre-test. Berdasarkan hasil penelitian, diketahui bahwa kedua e-module termasuk dalam kategori valid dengan nilai 0.866 dan 0.892. Selain itu, kedua e-modul memiliki nilai kepraktisan sebesar 0,85 dan 0,84 dari guru, serta 0,96 dan 0,87 dari siswa, sehingga masuk dalam kategori praktis. Nilai efektivitas kedua e-modul adalah 0,59 dan 0,67, sehingga dikategorikan sebagai cukup efektif. Efektivitas e-modul yang dikembangkan dievaluasi berdasarkan peningkatan pemahaman konseptual siswa dalam domain kognitif.

Kata kunci: laju reaksi, kesetimbangan kimia, e-modul, demonstrasi video.

INTRODUCTION

Technology integration in education supports the development of interactive learning media such as e-modules that promote independent and conceptual learning (Budiman, 2017; Ellizar et al., 2019). Based on the 2013 revised 2017 curriculum, learning emphasizes a scientific approach where students discover concepts through active participation (Ministry of Education, 2013).

Reaction rate and chemical equilibrium are two chemistry subjects that require a thorough understanding. Students must be guided through learning, but they must also construct their concepts (Pashler et al., 2008; Roghdah et al., 2021; Yerimadesi et al., 2017). The learning model is one of the methods used to achieve this goal (Abidin, 2014). The discovery learning model is one of the learning models that comply with the scientific approach required by the Indonesian curriculum (Ministry of Education, 2014; Rhosalia, 2017). On this basis, learners must find their way to understanding through a problem-solving approach technique (Supardi, 2013).

Besides the learning methods used, another factor that causes students to struggle with this subject is a lack of hands-on experience, such as laboratory practice or field observations. Furthermore, the lack of variety of questions in discussion activities is also a barrier, as the learning process generally takes place in a one-way fashion, often through teacher explanations (Indriani et al., 2017). Reaction rate and chemical equilibrium combines abstract ideas with concrete examples, so students must not only memorize the subject matter or perform calculations but also understand the concepts that are closely

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related to the subject, which can be obtained through practical/experiences (Darling-Hammond et al., 2020; Parwati et al., 2020).

SMA Negeri 7 Padang, SMA Negeri 1 Lubuk Alung, and SMA Negeri 2 Sawahlunto; some of the schools studied at this time had been previously studied (Permatasari et al., 2022). 67.7%, 75%, and 75% of students from each school, respectively, state that the reaction rate subject was challenging to comprehend. Furthermore, it was difficult to conduct practical training activities at the three schools due to limited facilities and infrastructure. Even worse, the three schools did not show any experimental activities during the Covid-19 pandemic. Thus, lessons were conducted solely through the delivery of theory by the teacher, following 65 percent, 60 percent, and 70 percent of students who believe that the media used in this process were uninteresting.

Additional observations by the authors revealed that there were no experimental activities at MAN 3 Payakumbuh and only 23.1% practical implementation at SMAN 14 Padang. Interviews with teachers indicated that limited facilities and infrastructure were the main contributing factors. Previously, the development of this e-module was motivated by the shift to online learning during the COVID-19 pandemic. However, in the current context where learning activities have returned to in-person settings, the use of digital-based learning media remains relevant. It supports students' independent learning, provides flexibility in accessing materials, and enhances conceptual understanding through visual demonstrations and interactive components. Based on the preliminary research analysis of the chemical equilibrium material questionnaire, 69.4% of students stated that the topic was difficult to understand, and 88.5% felt that the existing teaching materials were less appealing. Students continue to face challenges in learning due to limited school facilities, the complexity of the material, and time constraints during lessons. The problem is that not all students can easily digest the information presented (Wulandari et al., 2018).

Based on the findings described above, students experience difficulties in understanding chemical equilibrium concepts due to limited facilities, lack of engaging teaching materials, and the absence of laboratory activities. These issues lead to low conceptual understanding and reduced learning motivation. Therefore, a suitable solution to address these problems is to improve the learning media. Previous studies have developed chemistry modules based on multiple representations with expert validation,

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such as Rahmawati (2016), which showed that the modules were valid and effective in improving students' critical thinking skills (Rahmawati, 2016).

An e-module is a form of digital teaching material that allows students to learn independently and interactively without the need for printed materials (Solihudin JH, 2018). The e-module developed in this study contains descriptive explanations, visualizations through animations and motion videos, and is designed in an engaging format complete with images, content, and interactive features (Nirwana & Fitriyana, 2018; Suarsana & Mahayukti, 2013). To enhance the learning experience, the e-module is integrated with a laboratory activity demonstration video that serves as a substitute for experiments that cannot be carried out in schools. Moreover, it is designed using a Discovery Learning approach, guiding students to construct their own understanding rather than merely receiving information.

The e-module was developed using Microsoft Office, Google Forms, Flipbook PDF Professional, Canva, and Kinemaster applications. It was shared with teachers and students through an online link for easy access. Based on preliminary observations and questionnaire results, schools have sufficient digital facilities, and all students have mobile devices, ensuring accessibility of the e-module. Teachers and students also expressed high interest in using e-modules, with 100% indicating enthusiasm for chemistry learning through this medium.

Therefore, this study aims to develop a Discovery Learning-based e-module integrated with video demonstrations on the topics of reaction rate and chemical equilibrium to produce a valid, practical, and effective learning medium that improves students' conceptual understanding."

RESEARCH METHODS

The type of research conducted was education design research (EDR) (Akker et al., 2010). This research aimed to create a teaching material using an e-module with reaction rate and chemical equilibrium materials based on discovery learning, complete with a video demonstration. The video demonstration developed will help in the data collection stage in discovery learning. Distribution was done online via the link. The experiment (teaching activities with developed e-modules) was conducted at SMA Negeri 14 Padang with different classes for each e-module. Data collection activities for the reaction rate e-

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module were carried out at SMA Negeri 7 Padang, SMA Negeri 1 Lubuk Alung, SMAN 12 Padang and SMA Negeri 2 Sawahlunto. SMAN 7 Padang, SMAN 14 Padang and MAN 3 Payakumbuh, SMAN 12 Padang were for the chemical equilibrium e-module. SMAN is comparable to a senior public high school, whereas MAN is comparable to a senior Islamic public high school. The implementation year was 2021. Two classes from the second grade of each school were selected as the research sample. The research subjects were six lecturers from Universitas Negeri Padang (Padang State University), two chemistry teachers from each school above, and students from class XI for each e-module. Several instruments were used in this study, including validation sheets, practicality questionnaires, observation sheets, interview guides, and learning outcome tests. The validation sheets were used by experts to evaluate the content and construct validity of the developed e-module. The practicality questionnaires were distributed to teachers and students to assess usability aspects. Observation sheets and interview guides were used to gather qualitative feedback. The effectiveness of the e-module was measured through students' pre-test and post-test scores on the reaction rate and chemical equilibrium topics.

The research topic was the e-module learning media for reaction rate and chemical equilibrium materials for high school students. The Plomp model created the e-module (Plomp & Nieveen, 2013). In summary, this study followed the stages of the Plomp model, consisting of preliminary research, prototyping, and assessment. Various research instruments were employed, including validation sheets, practicality questionnaires, observation sheets, interview guides, and pre-test and post-test instruments. Data were collected through validation by experts, questionnaires distributed to teachers and students, classroom observations, interviews, and learning achievement tests. The data obtained were analyzed using both quantitative and qualitative approaches. Quantitative data from validity and practicality assessments were analyzed using Aiken's V formula to determine the level of agreement among experts and users, while effectiveness data were analyzed using the N-Gain formula to measure improvement in students' learning outcomes. Qualitative data from interviews and observations were analyzed descriptively to provide supporting insights into the practicality and usability of the developed e-module.

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RESULTS AND DISCUSSION

Identification results for reaction rate materials at SMA Negeri 7 Padang, SMA Negeri 1 Lubuk Alung, and SMA Negeri 2 Sawahlunto, and for chemical equilibrium at SMAN 7 Padang and MAN 3 Payakumbuh revealed significant problems. One of the difficulties encountered during the learning process was how to make learning more enjoyable. Furthermore, the lack of laboratory activities is a problem in chemistry learning. Moreover, students must be active participants in learning, especially in discovering concepts (Ministry of Education, 2017a).

The proposed solution is to develop electronic modules that can include images, videos of practical demonstrations and virtual laboratory activities, exercises, and material evaluations. Hands-on experiences, such as lab work, can help students develop into more active and critical thinkers and improve their ability to understand concepts. The discovery learning model can be used to implement this, which will develop students' critical thinking skills through their discovery of concepts. In accordance with Lestari & Sumardi's (2018) opinion, providing hands-on experience, even in a virtual format, is crucial because practicums have been shown to help students develop into more active and critical thinkers, as well as significantly improve their ability to understand scientific concepts. The proposed laboratory media development focuses on the creation of a comprehensive electronic module, designed to address accessibility limitations and improve learning outcomes through an interactive approach (Astuti et al., 2021).

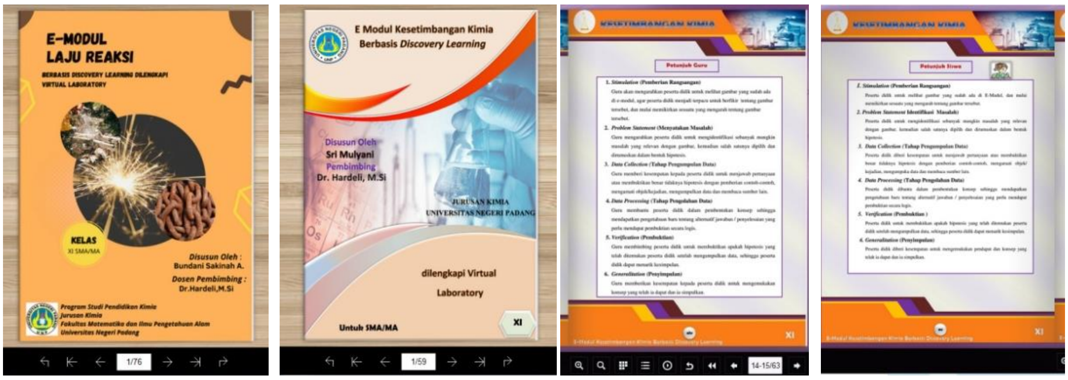

Figure 1. E-Module covers and instructions for using the E-Module

Figure 1 shows the cover display for the two developed e-modules. The module was created using the module writing guide for 2019 by the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia (Ministry of Education,

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2017b). At this stage, the design and fabrication of an e-module were carried out, mainly based on the material classification that has been performed on the reduction of basic competencies to Indicators of competency achievement. Following that, the e-module was enhanced with text, images, animation, and videos. The module's identity was contained in the e-module's cover, including the title, author's name, agency, e-module target, supporting images, and the author's supervisor. The title of the e-module informs users about the subject matter being discussed, and the goal is to provide information for users. The dominant colour on the e-module cover is orange, inspired by the distributed questionnaire. Colour choosing was intended to pique students' interest in learning (Amarin & Al-Saleh, 2020). Knowing how colour affects behaviour is very useful for designers and environmental psychologists when using a colour that evokes passion (Pett & Wilson, 1996). Studies found that warm colours like orange, red and yellow keep students from becoming bored (B. Chang et al., 2018). The image below Competencies to be achieved

The presentation of basic competencies, Indicators of competence achievement, and learning objectives is intended to inform teachers and students about the competencies that must be attained during the learning process. This component was previously determined during the curriculum analysis stage—one example in one part of the activity in the e-module is shown in the image below.

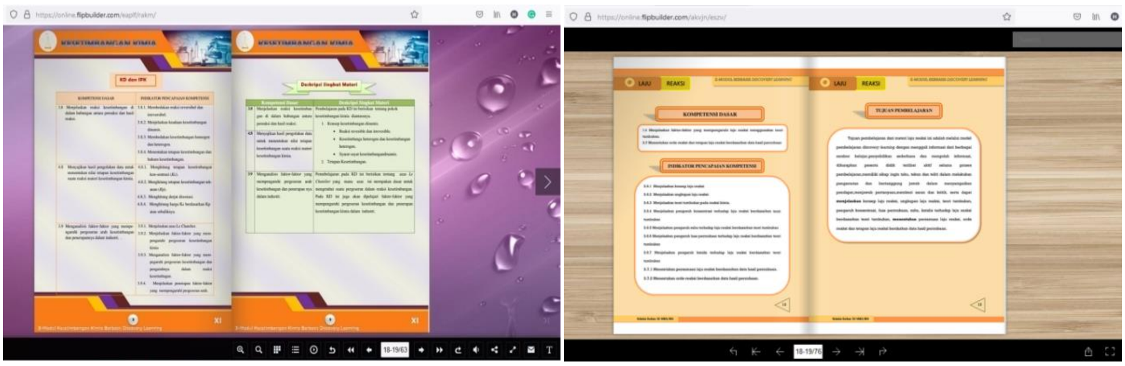

Figure 2. Basic competencies, indicators, and learning objectives

The activity sheet in the developed e-module uses the discovery learning model so that the learning stages use the stages in discovery learning, which are as follows: (a). Stimulation: At this point, students will be given a problem that they are likely to encounter in everyday life, and it is expected that they will wonder and discuss why this might happen. For example, in the e-reaction rate module, the problem selected is the

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difference between the change in rusting iron and the change that occurs when fireworks are lit. (b). Problem Statement: At this stage, students will be allowed to identify problems relevant to the subject matter as much as possible and then choose one which will be used as a hypothesis. (c). Data Collecting: The data collection stage is for students to explore and collect information. Lab work demonstration videos, virtual laboratory activities, explanation videos, animations, subject contents, and other items deemed necessary were provided to assist students in constructing knowledge and finding solutions to these problems. (d). Data Processing: This stage allows students to answer questions, provide simple explanations, and find concepts from the subject being studied, as well as providing reasons for their answers. (e). Verification: At this stage, students check carefully to prove whether the hypothesis is determined by the findings linked to the results of the processed data. (f). Generalization: Students will conclude previous processes that they can use as concepts.

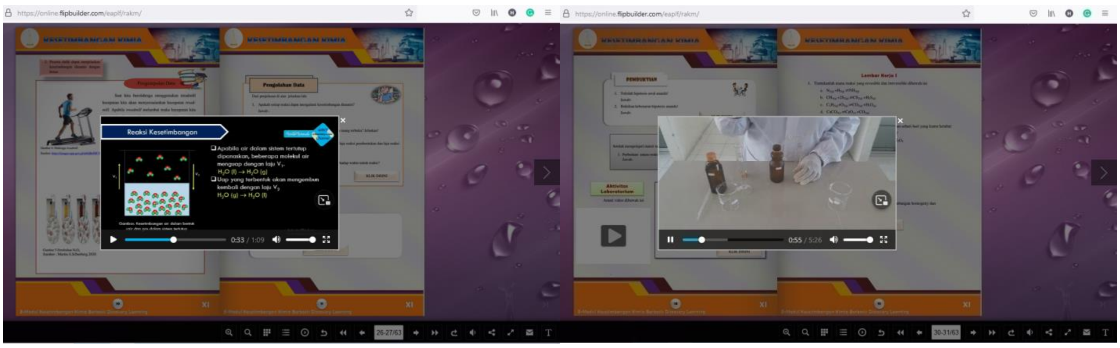

Figure 4. Examples of animation video and experiment demonstration video

Figure 4 show that there were several videos in the e-module: Videos of experimental laboratory activity demonstrations and animation videos. The author performs all laboratory activity demonstrations. Some correct and good animations were taken from the internet (sources are included), and the author created animations that are not found anywhere else.

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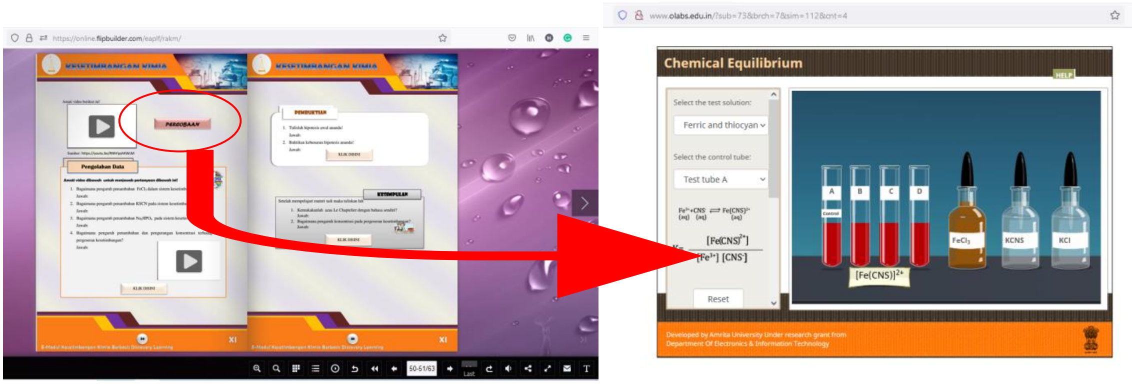

Figure 5. An example of a virtual laboratory link

A virtual laboratory was also presented in the e-module, in which students can conduct simple experiments. The virtual laboratory used is by OLABS virtual laboratory developed by Amrita Vishwa Vidyapeetham & CDAC Mumbai (Olabs Edu, 2014). The appropriate section of the module includes a link to the virtual laboratory, which students can access by clicking on the link. This module will integrate multimedia elements, including images, videos of practical demonstrations, virtual laboratory activities, exercises, and structured material evaluations (Wahyuni & Abdullah, 2020).

At this stage, the author reviews the instructional materials with one learner at a time. The author observes how the learner applies the instruction, takes notes on the learner's comments, and asks questions during and after the process. The goal of the one-on-one evaluation was to identify content clarity, direction clarity, completeness of instruction, difficulty level, quality, typographical/grammatical errors, and general motivational appeal. Three students with varying abilities (high, medium, and low) were subjected to a one-to-one evaluation test. Students' abilities were grouped by combining the value of learning outcomes obtained by students during learning (provided by teachers) and based on teacher recommendations. Students also participate in this evaluation test by filling out questionnaires. Based on the analysis of the student's responses, prototype 3^{rd} of the e-module produced was acceptable. It is in terms of the material's composition, practice questions, learning activity steps, design, and appearance of the e-module, which can assist students in understanding material contained in the e-module. Suggestions and improvements obtained during the activity were also applied to improve the product.

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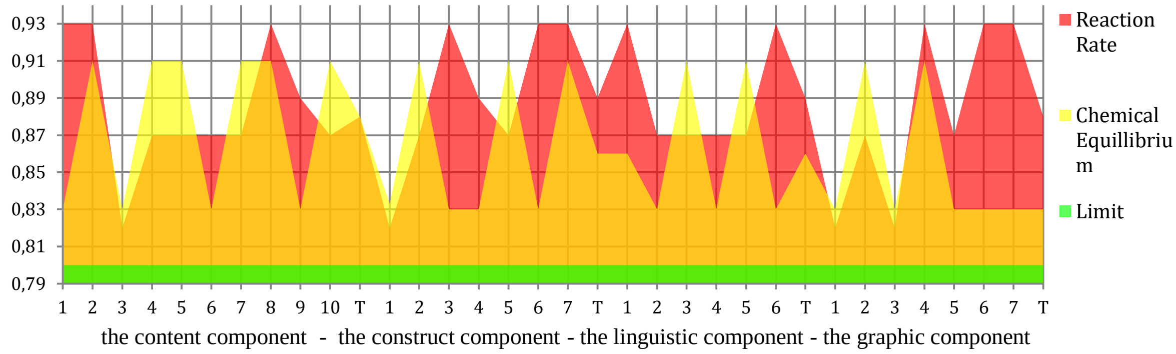

Figure 6. Comparison of the validity limit (green) with the validity of reaction rate (red) and chemical equilibrium (yellow) e-modules value in each point tested

Figure 6 show that three chemistry teachers and three lecturers (chemistry, education, and media experts) validated the resulting prototype II for each e-module. The content, the construct, the linguistic, and the graphic component comprise the validity test. These elements can be summarized in figure 4. The image shows that the value obtained in each of the criteria tested for both e-modules was higher than the validity limit (0.8). Based on the results, it is fair to conclude that both e-modules were valid. Table 2 shows the average value obtained for each criterion. The numbers represented on the graph will be explained in the discussion section. The T on the chart represents the total value obtained in each area. Based on the analysis results, the prototype III produced is valid and ready for the next stage. Teachers and students carry out the testing phase to obtain practical information on the use of the produced chemistry e-module. Practicality tests cover various topics such as ease of use, study time efficiency, and the benefits of using the module (Ministry of Education, 2008a).

Table 2. Average validity test results

No	Rated aspect	Reaction Rate		Chemical Equilibrium	
		V	Validity Category	*V*	Validity Category
1	Content components	0.88	valid	0.88	valid
2	Construct component	0.89	valid	0.86	valid
3	Linguistic component	0.89	valid	0.86	valid
4	Graphic component	0.88	valid	0.85	valid
	Average	0.885	valid	0.86	valid

Tabel 2 show that the practical results on the ease of use component of the reaction rate and chemical reaction e-modules have an average Aikens' V formula of 0.87 and 0.84 from the teacher's, while the students' scores are 0.97 and 0.87. It demonstrates that

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respondents believe the e-module presented is beneficial. The learning module's characteristics include using modules that are not accompanied by other media, making them simple. It provides information that the module's components can be used in clear learning instructions. The material displayed is simple, and the learning phase in the module can be appropriately implemented (Ministry of Education, 2008b). The Aikens' V average formula from the teacher's questionnaire yielded the same value, 0.83, for the test results on the time efficiency component of the reaction rate and chemical reaction e-modules. Meanwhile, the score of the student was 0.96 and 0.86. All values fall into the category of being practical. Based on this information, e-modules can supplement online learning during the pandemic. It is because e-modules can reduce learning time (Wahyuni & Yerimadesi, 2021).

A formative evaluation in a small group evaluation was carried out. The small group test was conducted on six students with varying abilities, including high, medium, and low. The questionnaire was then given to the participant. Table 3 displays the findings of a practicality assessment conducted by six students.

Table 3. Small-Group Practicality Test Results

No	Rated aspect	Reaction Rate		Chemical Equilibrium	
		V	Practicality Category	*V*	Practicality Category
1	Ease of Use	0.87	Practical	0.87	Practical
2	Time efficiency	0.87	Practical	0.9167	Practical
3	Benefit	0.86	Practical	0.89	Practical
	average	0.866	Practical	0.892	Practical

Based on the results obtained in the small group test, it was known that the two e-modules produced were in the practical category. Furthermore, based on the suggestions received, further improvements were made before the two e-modules were tested on a large scale.

At this point, the teacher and two classes (taught and non-taught classes) for each e-module conduct a field test to determine the level of the practicability of the e-module. The practicality test was carried out to gather information about the module's use by teachers and students. The practicality test included ease of use, time efficiency, and the e-module's benefits. According to the Plomp development model, this practicality test is divided into three stages: individual (one-to-one), small group, and large group (filed test) (Plomp & Nieveen, 2013; Tessmer, 1993).

Table 4. Field Practicality Test Result

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No	Rated aspect	Reaction Rate				Chemical Equilibrium			
		Teacher		Student		Teacher		Student	
		V	Cat.	*V*	Cat.	*V*	Cat.	*V*	Cat.
1	Ease of Use	0.87	Practical	0.97	Practical	0.84	Practical	0.87	Practical
2	Time efficiency	0.83	Practical	0.96	Practical	0.83	Practical	0.86	Practical
3	Benefit	0.87	Practical	0.96	Practical	0.86	Practical	0.88	Practical
	average	0.85	Practical	0.96	Practical	0.84	Practical	0.87	Practical

The practicality test results on the module benefit component have an Aikens' V average formula from the teacher's questionnaire of 0.87 and 0.86, with a very practical category. Meanwhile, the student's scores were 0.96 and 0.86. The module was created to focus on the layout and use of fonts and font sizes to make students feel at ease while learning. The teacher serves as a facilitator in the learning process, assisting students in discovering concepts (Yerimadesi et al., 2017).

The reaction rate e-module pre-test average was 78.2, and the post-test average after learning with the e-module was 82.5. Following the N Gain test, the N Gain value was 0.59. This category was rated as moderately effective or quite effective (Latief, 2016). The chemical equilibrium e-module pre-test average was 35.8, and the post-test average after learning with the e-module was 78.8. Following the N Gain test, the N Gain value was 0.67. This category was rated as moderately effective or quite effective (Latief, 2016). The research found that the two developed e-modules were quite effective. This study demonstrated that the developed discovery learning-based e-modules with video demonstrations are valid, practical, and moderately effective in enhancing students' understanding of reaction rate and chemical equilibrium concepts. The strength of this research lies in its integration of interactive video demonstrations that support independent learning and concept construction, even in schools with limited laboratory facilities. However, this study was limited to a small number of schools, and the effectiveness test was conducted within a relatively short period, so further studies with a larger population and longer implementation time are recommended. The results of this research are consistent with previous studies conducted by Suarsana & Mahayukti (2013), Yerimadesi et al. (2017), and Priantini (2021), which also found that e-modules based on discovery learning and supported by multimedia features can improve students' motivation and conceptual understanding. The effectiveness test was used to determine the success rate of a learning process. E-modules are considered effective if they positively impact student learning outcomes (Hariyani et al., 2021; Okta Priantini, 2021). E-modules that provide text that is easy to understand and images closer to the actual

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form of a component help students remember more easily (Bobek & Tversky, 2016).

CONCLUSION

This study aims to develop a discovery learning-based e-module with demonstration videos on reaction rates and chemical equilibrium to improve students' conceptual understanding. The development follows Plomp's model, which includes preliminary research, prototyping, and assessment stages. The initial results show the need for engaging learning media that can compensate for the limitations of school practicals. The developed e-module has been validated by experts with Aiken's V values of 0.885 and 0.86, indicating a valid category. In the practicality and effectiveness test stage, the e-module scored 0.85–0.96 (practical) and N-Gain of 0.59–0.67 (quite effective). This proves that the e-module can improve students' conceptual understanding and support independent learning. Thus, the discovery learning-based e-module with demonstration videos is declared valid, practical, and sufficiently effective as a digital chemistry learning medium in accordance with the 2013 Curriculum.

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