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Development of Interactive e-Modules Based on Socio-Scientific Issues Integrated Micro-Project to Train Students' Understanding of Concepts and Science Process Skills

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Abstract: This study aims to develop interactive e-modules based on socio-scientific issues integrated micro-projects to train students' understanding of concepts and science process skills on reaction rate material. This method of research is Research and Development (R&D) with a 4-D development model consisting of four stages namely define, design, develop, and disseminate. The data collected includes qualitative data, such as interview results and input regarding the e-module development, and quantitative data in the form of questionnaire scores. The quality of interactive e-modules is assessed based on expert assessments, chemistry teacher assessments, and student assessments. Data analysis techniques involved both qualitative and quantitative methods along with validity assessment criteria. The results of expert assessments of 95.88%, quality assessments by chemistry teachers of 89.1%, and student assessments of 88.2%, obtained high validity results so that it can be concluded that interactive e-modules is feasible to be used in schools on the reaction rate material. The implications of this study suggest that the integration of socio-scientific issues and micro-projects in e-modules can significantly support the improvement of students' understanding of scientific concepts and their science process skills fostering more meaningful and context-based learning experiences.

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Introduction

Chemistry education is often perceived as challenging due to its abstract concepts and the necessity for students to develop a deep understanding of both theoretical and practical aspects (Rahmawati et al., 2020). One of the most complex topics within this field is reaction rates, which involves understanding collision theory, reaction mechanisms, and the various factors that influence the speed of chemical reactions (Aulia et al., 2018; Dakabesi & Luoise, 2019). These concepts are not only abstract but also require students to simultaneously develop their science process skills, such as hypothesizing, experimenting, and analyzing data (Hamidi et al., 2024; Wijayanti et al., 2021).

Traditional teaching methods have often fallen short of effectively conveying these intricate concepts and skills (Maulana et al., 2023; Wiyarsi et al., 2023). As a result, there is a growing need for innovative educational approaches that can bridge this gap. One promising solution is the integration of Micro-Project-Based Learning (Micro-PjBL) and Socio-Scientific Issues (SSI) into interactive e-modules (Çalık & Wiyarsi, 2021; Cha et al., 2021). Micro-PjBL involves students in small-scale projects that promote critical thinking and problem-solving skills (Tian et al., 2023). These projects are designed to be manageable within a limited timeframe, making them ideal for classroom settings. On the other hand, SSI

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introduces real-world issues into the curriculum, making learning more relevant and engaging for students (Purwanto et al., 2022; Suparman et al., 2022). By connecting scientific concepts to societal issues, SSI helps students see the practical applications of their learning and fosters a deeper understanding of the material (López-Fernández et al., 2022). The combination of Micro-PjBL and SSI in interactive e-modules is expected to address several educational challenges. Firstly, it can enhance students' conceptual understanding by providing them with hands-on, practical experiences that reinforce theoretical knowledge (Tian et al., 2023). Secondly, it can improve students' science process skills by engaging them in authentic scientific investigations (He et al., 2023; Kriswantoro et al., 2021). Lastly, it can increase student motivation and interest in chemistry by making the learning process more relevant and connected to real-world issues (Rahayu et al., 2022).

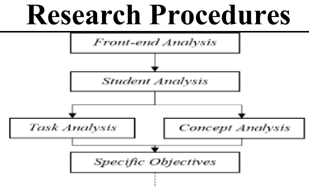
Previous studies have shown the effectiveness of project-based learning and SSI in improving student outcomes in various subjects. For instance, research on the development of interactive e-modules for colloidal concepts using PjBL has demonstrated significant improvements in students' conceptual understanding and engagement (Alya & Dwiningsih, 2024). Similarly, the use of SSI in science education has been found to enhance students' critical thinking and decision-making skills (López-Fernández et al., 2022). Another study on the development of PjBL-based e-modules for reaction rate material showed that these modules are feasible and effective in improving students' critical thinking skills (Herlita et al., 2023). However, there is limited research on the combined use of Micro-PjBL and SSI in interactive e-modules designed for teaching reaction rates.

This study aims to fill this gap by developing interactive e-modules that incorporate Micro-PjBL and SSI for teaching reaction rates. The novelty of this research lies in its integration of interactive features such as digital simulations, experimental videos, and animations of chemical concepts, designed specifically to enhance student engagement. The systematic modular structure provides flexibility for both teachers and students, enabling gradual and accessible learning of the material. Furthermore, the incorporation of Socio-Scientific Issues (SSI) offers a unique approach by connecting chemical concepts to real-world issues, fostering a deeper understanding of their practical implications. This innovative combination makes the e-modules a groundbreaking educational tool that bridges theoretical learning and practical applications, setting them apart from traditional chemistry teaching resources. The characteristics and quality of these e-modules will be assessed based on their ability to improve students' understanding of reaction rate concepts and their science process skills. By providing a comprehensive evaluation of these innovative educational tools, this study seeks to contribute to the ongoing efforts to improve chemistry education and make it more engaging for students.

Research Method

This research employs the Research and Development (R&D) method with the 4-D model (Thiagarajan et al., 1974). R&D is a process of developing and validating educational products in the form of learning objectives, methods, curriculum, evaluation, hardware, software, and methods or procedures (Sukmadinata., 2008). The steps as shown in Table 1.

Table 1. Stages of RnD of 4-D Model

No.	Stage	Research Procedures
1.	Define	

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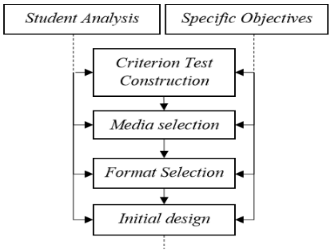
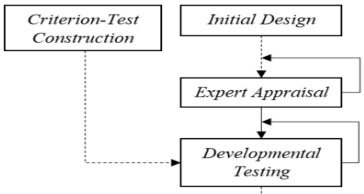
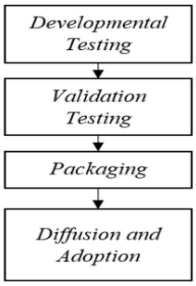
2.	Design	
3.	Develop	
4.	Disseminate	

The types of data obtained are qualitative data in the form of interview results and input regarding the development of interactive e-modules while quantitative data is in the form of questionnaire scores. The quality of interactive e-modules is assessed based on expert assessments, chemistry teacher assessments, and student assessments. The developmental research was conducted at SMA Muhammadiyah 2 Yogyakarta with teachers and students in class XI as the research subjects.

This method is used to produce products and test the effectiveness of the product (Fitri et al., 2023) while quantitative data is obtained using a questionnaire score containing five categories, namely very good, good, sufficient, lacking, and very lacking (Mardiah et al., 2018). The data obtained is then converted by giving a score to each category for each item (Izzati, 2017). To obtain the percentage of eligibility, the formula used is:

$$P = (n \div N) \times 100\%$$

Where P is the percentage of validation test results, n is the total expert assessment score and N is the maximum score that should be obtained (Sriwahyuni et al., 2019). The results of the calculation of the validity percentage that has been obtained can then be converted into an assessment statement (Nengsih et al., 2023). The criteria used refer to the eligibility criteria with the criteria very feasible, feasible, quite feasible, less feasible, and very less feasible (Yuliana et al., 2023). The validity results whose percentages have been known can be interpreted as follows:

Table 2. Validity Score Interpretation Criteria

No.	Percentage (%)	Criteria
1.	0-20	Very Less
2.	21-40	Not Enough
3.	41-60	Enough
4.	61-80	Good
5.	81-100	Very Good

Results and Discussion

Definition Stage

The define stage aims to establish and define the requirements for developing an interactive e-module. Needs analysis is carried out to understand several important aspects, starting with identifying problems faced by students in understanding the reaction rate material. Research shows that students face difficulties in understanding the concept of reaction rate and related science process skills. This problem was identified through literature studies and field observations which revealed that current learning media are inadequate. As one solution, interactive e-modules are designed to overcome this problem with more structured and interactive materials. This interactive e-module is adapted to the Independent Curriculum at SMA Muhammadiyah 2 Yogyakarta, according to BSKAP Decree No. 032 of 2024, and covers important concepts such as reaction rate, factors that affect reaction rate, reaction rate equation, and reaction orders in order to meet the expected learning outcomes.

According to Piaget's learning theory, students aged 15-18 years are at the formal operational stage, where they can think abstractly, idealistically, and logically. This interactive e-module supports hypothetical thinking by involving activities such as formulating hypotheses related to real-world problems. This interactive e-module also integrates socio-scientific aspects (SSI) by linking science to controversial and complex social problems. The SSIs involved include science-based issues such as acid rain, dust explosions in factories, frozen food, and the impact of carbide use on fruit. News articles about these issues will be used as stimuli and students will be invited to design simple experimental procedures as part of problem solving. In addition, students are also accustomed to operating personal computers and are accustomed to learning to use personal computers either independently or in class. At school, students are also supported by wi-fi access facilities, LCD and projectors, and multimedia rooms. So the researcher assumes that students in grade XI will be able to improve their abilities through electronic learning media such as interactive e-modules.

As part of this approach, the application of communication technology in learning also plays an important role in supporting innovation (Jafnihirda et al., 2022). Interactive e-modules are designed with characteristics such as self-instruction, self-contained, stand-alone, adaptive, and user-friendly (Salsabila & Nurjayadi, 2019; Wimbi et al., 2021). So that they allow students to learn independently. Through this media, teaching materials can be delivered more effectively so that it can increase student involvement and understanding.

Design Stage

In the design stage, the main objective is to design a storyboard that provides a clear picture of the structure and content of the interactive e-module based on SSI-integrated micro-PjBL. This storyboard includes learning elements, activities, and materials to be presented. In addition, this stage includes the design of validation instruments to measure the quality of the e-module from the perspective of media experts, material experts, and evaluation experts. Concept understanding test instruments and KPS are also designed to assess the effectiveness of the interactive e-module. Therefore, the elements needed in the e-module are 3D illustration images, explanations in the form of audio, 3D illustration videos and learning videos. The e-module to be created is designed in outline in a storyboard where the systematics of the interactive e-module are: cover page, identity page, foreword, table of contents, learning objectives, instructions for use, concept maps, reaction rate materials, project-based student worksheets, learning videos, virtual laboratories, comprehension tests, glossaries, and bibliographies. The storyboard is shown in Table 3 below.

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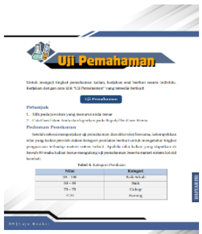
Table 3. Initial Draft of Interactive e-Module

No.	Description	Pictures	No.	Description	Pictures
1.	Cover Page		5.	Learning Videos	
2.	Instructions for Use		6.	Test of understanding	
3.	Reaction Rate Material Display		7.	Learning Video	
4.	Project-based Student Worksheets		8.	Virtual Laboratory	

Develop Stage

Theoretical Validation by Expert Lecturers

The e-module development framework that has been prepared can be realized at this development stage. In addition, revision and validation of the e-module also need to be done so that the e-module that has been developed is in line with the expected objectives. The development stage can be carried out in three stages, including product design development, expert validation, and revision.

The development of the product design is based on the previously prepared design. At this stage, a product in the form of an interactive e-module based on Micro-PjBL integrated with SSI reaction rate material was obtained to improve understanding of concepts and science process skills.

The interactive e-module product that has been designed requires validation from media experts, content experts, and learning design experts. The validation is carried out by lecturers (expert judgment). How good the quality measurement of a media is indicated by validity (Hendriani, 2021). One of the functions of expert validation is to determine the quality aspect of the e-module, namely validity, in addition to obtaining criticism and suggestions from validators that can be used to improve the e-module that has been developed based on the suitability of the material and e-module media. Validation of this interactive e-module is reviewed from the validity of the content and construct validity with the average results of media validation in Table 4 below.

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Table 4. Media Validation Results

No.	Validity	Percentage (%)	Criteria
1.	Content	90	Very Valid
2.	Construct	96	Very Valid

Table 4 shows that the interactive e-module developed obtained a percentage of results of 90% for content validation and a percentage of results of 96% for construct validation. Both validities are included in the very valid category so that the interactive e-module is worthy of use.

Content validity is a feasibility test of interactive e-modules developed by referring to indicators of conceptual understanding, science process skills, and reaction rate material. The following is a table of the results of the content validation feasibility test.

Table 5. Content Validation Results

No.	Validity	Percentage (%)	Criteria
1.	Content	90	Very Valid
2.	Conceptual	91	Very Valid
3.	Science Process	89	Very Valid

The material aspect includes the suitability of the content with the learning outcomes, namely explaining the factors that affect the reaction rate and explaining the collision theory to explain the influence of these factors on the reaction rate [2]. In the material aspect, a percentage of 90% was obtained which is included in the very valid category. Based on the material feasibility test, this interactive e-module is categorized according to the material taught and can be used to train students' understanding of concepts and science process skills in the reaction rate material [3].

The conceptual understanding aspect of the interactive e-module achieved a validity score of 91%, placing it in the very valid category. The module is designed to systematically guide students through the process of grasping reaction rate concepts by engaging them in problem-solving and real-life scenarios [14]. This approach allows students to link theoretical knowledge with practical applications, thereby reinforcing their understanding of fundamental concepts like reaction rate factors, collision theory, and rate equations.

The science process skills aspect was evaluated at 89% indicating very valid. The e-module incorporates inquiry-based tasks that promote the development of science process skills such as observation, experimentation, data analysis, and drawing conclusions [26]. These tasks align with the principles of Micro-PjBL, which encourages active learning and hands-on experimentation, allowing students to practice and refine their scientific investigation techniques within the context of the reaction rate material [7]. This focus on process skills not only improves practical competence but also enhances critical thinking and problem-solving abilities [9], [27].

Construct validity consists of two aspects, namely the presentation aspect and the language aspect [28]. The following is a table of the results of the content validation feasibility test.

Table 6. Construct Validation Results

No.	Validity	Percentage (%)	Criteria
1.	Presentation	97	Very Valid
2.	Language	95	Very Valid

The presentation aspect of the e-module, which includes the harmony of text and object colors with the background, consistent use of colors, accurate font type and size selection, and the appropriate use of images, animations, and videos, contributes to a visually appealing and comfortable learning experience [29]. Harmonious colors and the right font choices enhance the module's attractiveness, while well-selected multimedia elements support students' understanding of the material. Rated at 97% for its validity, the e-module's format is clear and well-organized, with illustrations that effectively incorporate macroscopic and symbolic representations to deepen comprehension, making the module user-friendly and pedagogically effective for the reaction rate material.

The language aspect scored 95%, which also falls in the very valid category. The e-module uses clear, concise, and age-appropriate language that avoids ambiguity, ensuring that students can easily follow and understand the content. This is in line with proper Indonesian language conventions (PUEBI) and effective communication principles, which support learners in comprehending the scientific concepts discussed. The appropriateness of the language and terms used will affect the students' understanding of the material. If there is inappropriate language and terms, the reader will have difficulty understanding the meaning of the writing [30]. The interactive e-module product of reaction rate sub-material to improve understanding of concepts and science process skills has been validated and then revised based on criticism and suggestions given by the validator so that the e-module can be used in the teaching and learning process.

Interactive e-Module Quality Test Results

Alternatives to overcome the mismatch between PjBL and the reality of classroom teaching by utilizing the micro-PjBL learning model. Micro-PjBL has the same core principles and mechanisms as PjBL but has a shorter learning cycle (Aksela & Haatainen, 2019; Cook et al., 2018). Micro-PjBL is suitable for application to reaction rate material so that it can direct students in developing conceptual knowledge and applying concepts to interpret phenomena in everyday life and solve problems in real life (Chen & Yang, 2019). The results of the quality test of the learning product, namely the interactive e-module based on micro-PjBL integrated with SSI, were assessed by five Chemistry teachers from SMA Muhammadiyah Yogyakarta.

Table 7. Quality Assessment Results by Chemistry Teachers

No.	Aspect	Average	Maximum Score	Ideal Percentage	Category
1.	Material or content	26	30	86,67%	Very Good
2.	Appearance	22,4	25	89,6%	Very Good
3.	Language	22,2	25	88,8%	Very Good
4.	Product characteristics	27,4	30	91,33%	Very Good

Based on Table 7, the quality of the interactive e-module is considered good, with the highest percentage of ideality in the product characteristic indicator. The interactive e-module developed has included micro-PjBL stages and is integrated with SSI. In addition, the five characteristics of the e-module are well met so that it is expected that this e-module can be used by students and teachers anywhere and anytime.

Test Student Readability

The interactive e-modules assessed by chemistry teachers from various schools in Yogyakarta were then tested for readability by students on the interactive e-modules. Readability includes material, appearance, and ease of use. The results of the product readability can be seen in Table 8 below.

Table 8. Product Readability Results by Students

No.	Aspect	Average	Maximum Score	Ideal Percentage	Category
1.	Content or Material	22	25	88%	Very Good
2.	Appearance	22,4	25	89,6%	Very Good

3.	Ease of use	17,4	20	87%	Very Good

Based on Table 4, the interactive e-module readability test by students measured from the aspects of material, appearance, and ease of use, showed very good results with an average of 88.2% so it falls into the very good category.

Based on the results obtained, the developed interactive e-module can be used in the learning process. According to the research results, micro-PjBL is effective in improving conceptual understanding and important learning skills (Tian et al., 2023). In addition, 68% of students consider SSI-integrated learning to help them understand how science can be applied in the real world (Çalık & Wiyarsi, 2021; Wiyarsi et al., 2023). Research shows that interactive e-modules can deepen students' understanding of chemistry materials (Rahmatsyah & Dwiningsih, 2021). These interactive e-modules are designed to connect chemistry concepts with relevant scientific and social issues, allowing students to understand the application of chemistry materials in real-world contexts. The results of the research reveal that PjBL-based modules can improve students' life skills (Ilyas et al., 2019). PjBL can stimulate students to develop process skills and understanding through real-world experiences and meaningful knowledge (Rusmansyah et al., 2023; Syukri et al., 2021; Wijayanti et al., 2021). Micro-PjBL can encourage students to engage in challenging small projects, which focus on solving problems related to reaction rates. The integration of SSI in this module provides an opportunity for students to explore social and scientific issues related to the reaction rate material, thereby increasing their awareness of the importance of the concept in everyday contexts. In addition, the features in this interactive e-module support students' science process skills, such as formulating hypotheses, observations, and others (Alya & Dwiningsih, 2024; Lumbantobing et al., 2022; Marjanah et al., 2021; Safaruddin et al., 2020). This interactive e-module facilitates students in applying the concept of reaction rate practically through project-based activities that are relevant to social scientific issues that enrich their learning experience.

This finding supports the results of research which shows that the integration of SSI in chemistry learning can improve students' science process skills by providing a broader and more applicable context (Ke et al., 2020; Purwanto et al., 2022). This interactive e-module successfully improves the understanding of the concept of reaction rate through an approach that is relevant and interesting for students, as well as equipping them with the skills needed to overcome scientific and social challenges. Thus, the interactive e-module based on micro-PjBL integrated with SSI on the reaction rate material can be considered an effective tool in improving students' understanding of concepts and science process skills in chemistry learning.

Disseminate Stage

The dissemination stage aims to disseminate the results of the development of interactive e-modules based on Micro-Project Based Learning (Micro-PjBL) integrated with Socio-Scientific Issues (SSI) on the material of reaction rates. This development product is declared ready for dissemination after going through expert validation and implementation in target groups that show consistent results and positive responses. At this stage, limited implementation is carried out in the real learning environment to measure the achievement of objectives, such as students' understanding of concepts and improving science process skills. The results of the implementation are used to correct deficiencies before being distributed more widely. Furthermore, the product is packaged in a digital format, such as an e-book or flipbook, which can be accessed boldly, and is provided in print to support users with limited access to technology. Dissemination is carried out through limited distribution to chemistry teachers at schools where the research was conducted, where teachers and students provide feedback on the developed e-modules. In addition, the results of this development are also published in indexed scientific journals to introduce the product to the education community and other researchers, so that it can be a reference for further research.

The conceptual implications of this study lie in the integration of Micro-PjBL and SSI as a learning approach which enriches educational theories by demonstrating how project-based learning combined with real-world socio-scientific issues can foster students' critical thinking and scientific literacy. Practically, the developed e-module serves as an innovative tool for chemistry learning, addressing the challenges of traditional learning methods by providing an engaging, context-based medium. It equips educators with an accessible resource and promotes effective learning even in areas with limited technological infrastructure. This dissemination stage is expected to expand the adoption of e-modules as an innovative learning medium, improve the quality of chemistry learning, and support the creation of learning that is relevant to local and global needs.

Conclusion

Based on the results of the research and discussion, it can be concluded that this interactive e-module which integrates socio-scientific issues and micro-projects is feasible and effective for use in schools on reaction rate material. The e-module accessible via PC, Android, and iOS devices promotes flexible and engaging learning with interactive animated videos and an online self-evaluation feature. Expert assessment score of 95.88%, chemistry teacher assessment score of 89.1%, and student assessment score of 88.2% indicates high validity, confirming that the e-module significantly supports students' understanding of scientific concepts and science process skills fostering meaningful and context-based learning experiences.

Recommendation

Based on the results of the study, it is recommended that teachers use the developed product as a reference for learning media in chemistry subjects as well as a reference in SSI-integrated micro-projects. The following is a link to the developed interactive e-module https://online.flipbuilder.com/zulws/iwfd/. Furthermore, research can explore the effectiveness of this product in the classroom learning process and is expected to develop interactive e-modules based on SSI-integrated micro-projects in other topics such as equilibrium and thermodynamics while integrating advanced technologies as additions such as augmented reality (AR) to make learning more interesting and interactive.

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