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Development of a Chemistry E-module with a STEM-Integrated Project Based Learning Model on Chemical Equilibrium Material

Taufik Ali Ibrahim[1], Ani Sutiani[2]*

[1,2]*Chemistry Education Study Program, Universitas Negeri Medan*

Email: anisutiani@unimed.ac.id

Abstract: *The purpose of this study is to develop an e-module with an Integrated Project Based Learning (PjBL) Model for Science, Technology, Engineering, and Mathematics (STEM) on Chemical Equilibrium, and to measure the level of validity and student response to the e-module. This study uses the Research and Development (R&D) method with a 4D development model that includes the Define, Design, Develop, and Disseminate stages. The research subjects were 39 students of class XI A Plus of SMA Negeri 1 Kutacane in the 2024/2025 academic year. The instruments used included an interview questionnaire, a validation questionnaire from material and media experts, and a student response questionnaire. The validation results by material experts showed a validity level of 97.2%, while the validation results by media experts showed a validity level of 97.3%, both of which are in the very valid category. Meanwhile, the results of the level of practicality by teachers towards the e-module were 92% which was said to be very practical, and the results of the student response questionnaire towards the e-module showed an average value of 92%, which was included in the very practical category.*

Keywords: *e-module; project based learning; stem; chemical equilibrium; 4D development*

INTRODUCTION

Education is a crucial factor in improving the quality of a nation's human resources. However, in today's educational landscape, many students still struggle to understand the material taught in schools. One contributing factor is the use of uninteresting and monotonous media and teaching materials. Teaching materials are a crucial part of the learning process. They are highly beneficial in the learning process, providing students with opportunities for independence, reducing dependence on teachers, and facilitating the development of their own concepts (Putra, 2022).

Learning media is a tool used by educators to ensure effective learning. One use of media in learning as supplementary teaching materials is learning modules. Modules are supporting learning resources in teaching and learning activities. A module is defined as a single unit of teaching material that can be used for independent learning because it is delivered in a self-instructional format. By using modules, students can learn according to their ability level, and after class, students can determine their level of success (Mufida et al., 2022).

In today's digital age, education is no longer confined to classrooms and printed

textbooks, but can be accessed anywhere and at any time through online media. Technology is one factor that can help accelerate educational development. The development of information technology has had a significant impact on the world of education, particularly in the development of learning media that can facilitate more interactive and effective learning.

Learning models are an important component in learning. Learning models can provide useful information for students in their learning process(Anastasia & Sutiani, 2022). Based on research conducted by Suryadi (2019), electronic modules are an innovative medium that can increase student interest in learning. To improve learning outcomes, a learning process needs to be supported by appropriate learning tools. This is because face-to-face classroom time is very limited compared to the volume of material that must be completed.

In the learning process, e-modules are an innovative product of Information and Communication Technology (ICT)-based modules. They offer advantages over printed modules, including the inclusion of audio, video, images, animations, and quizzes that provide feedback to students.

This is because most modules are produced in printed format, which tends to be monotonous, which can impact student interest and enthusiasm for using them. E-modules make it easier for students to access learning materials anytime and anywhere via computers or smartphones. The use of e-modules for learning can be designed in an attractive and innovative way, applicable to current situations, and can be combined with technological developments(Cheva & Zainul, 2019).

Based on an interview with a chemistry teacher at SMA Negeri 1 Kutacane, the teaching materials used are still limited to textbooks and have not yet utilized modules as supplementary teaching materials, either printed or electronic, in the learning process. Consequently, students lack a thorough understanding of chemistry, particularly chemical equilibrium. Chemical equilibrium is considered difficult for students because the concept involves numerous mathematical calculations. Chemical equilibrium is a complex concept in chemistry because it calculates the reversible reactions between reactants and products.

This is considered one of the most difficult topics in chemistry learning because chemical equilibrium often confuses students, including the number of moles of reactants, the number of moles during the reaction, the time of decomposition, the time at which equilibrium is reached, and the remainder of the reaction (Situmorang, 2015).

Students' difficulties in understanding the Chemical Equilibrium material can be seen from the students' learning outcomes which are still below the Minimum Competency (KKM), there are still students who have not been trained to learn independently, and more than 50% of students' quiz results are still low.

The process of developing e-modules requires innovation based on models, approaches, or methods. One learning model relevant to the independence curriculum is the Project-Based Learning (PjBL) model. PjBL learning activities are student-centered, thus actively engaging students in information discovery (Darmawan, 2021). PjBL is a project-based learning model that engages students in project activities, from planning and designing to implementation and reporting results in the form of a product (Dewi, 2023).

The Project-Based Learning strategy is employed due to its enhanced effectiveness when paired with a learning resource like a module (Sari et al., 2019). Utilizing Project-Based Learning (PjBL) in learning modules has the potential to sharpen the cognitive abilities of students. A frequently underestimated benefit of Project-Based Learning (PjBL) involves the compilation of data and the subsequent use of this

information to address tangible, authentic issues.

This research endeavors to assess how well students grasp the subject matter by creating an electronic module that incorporates a Project Based Learning (PjBL) method, connecting Science, Technology, Engineering, and Mathematics (STEM) with the topic of Chemical Equilibrium. The purpose of creating the e-module was to make it easier for students to engage in real-world projects related to chemical equilibrium concepts, thereby fostering abilities in critical thinking and problem-solving. By integrating the STEM method, the learning of Science, Technology, Engineering, and Mathematics principles is made possible in a cohesive way, thus making the learning experience more engaging, relevant, and practical.

LITERATURE REVIEW

Development

Development refers to the approach employed to create or confirm the effectiveness of resources used for education. Developmental research involves a series of actions taken to either introduce a novel resource or enhance one already in place, with the goal of ensuring responsibility. The main idea of this research is to make a new resource by developing it. This sort of research uses a repeating process. The actions taken in research or the development process include looking at what research has already found about the resource that is going to be developed, creating the resource using what was discovered, doing tests in real situations that fit where the resource will be used, and changing the resource based on what the tests show (Punanji Setyosari, 2013) .

Developmental research aims to produce learning tools, for example, syllabi, teaching materials, media, practical modules, student worksheets, tools for measuring learning progress, tools for measuring learning outcomes, and so on. The background to conducting developmental research is the problem of inadequate learning tools. Developmental research is defined as a research activity that begins with research and then continues with development. Both activities are carried out to produce learning tools (Ainin, 2014).

R&D Development

Research and Development represents a methodical undertaking executed to conceive, construct, and assess novel offerings or refine current merchandise grounded in findings from investigations, assuring the resultant item is sound, functional, and yields desired outcomes when utilized. When specifically applied to education, R&D is commonly employed in the creation of educational resources, learning units, or instructional aids that facilitate and enhance the educational experience.

E-Module

An e-module, which stands for electronic module, is a digital rendition of a learning module. You can get to it through electronic devices such as smartphones, desktop computers, notebooks, and similar gadgets. An e-module serves as an educational resource or platform that includes content, methodologies, exercises, and assessments, all meticulously arranged and presented in an engaging way to meet specific educational goals. (Endah Tri Priyatni, Siti Chodijah Hamidah, 2017). This digital learning resource comes in a book-like layout and is shown on a screen. It is accessed through electronic storage methods like a hard drive, a floppy disk (Wijayanto & Zuhri, 2014).

Teachers can enhance their instructional resources with e-modules during learning sessions and employ them for conducting lessons using digital platforms. To facilitate students' self-directed study of content via electronic means, supplementary educational resources, including e-modules, are essential. E-modules have the potential to make it easier for teachers to present the topics they need to cover. E-modules play a crucial role in learning. Learning can take place effectively when using e-modules because they can assist students experiencing learning difficulties. E-Modules can help students to learn independently and can measure their

own level of understanding. In E-modules, there are final objectives in the learning activities that will be carried out so that students can know what they must master or understand to achieve the learning objectives that have been set.

Project-Based Learning Model

According to Damayanti Nababan et al. (2023), Project-based learning (PjBL) constitutes an instructional strategy wherein pupils assume the role of primary participants, highlighting the educational journey that culminates in a tangible outcome. This indicates that pupils possess the autonomy to shape their personal learning pursuits and cooperate collectively on educational endeavors until a deliverable is finalized. Consequently, student involvement significantly impacts the efficacy of this instructional method.

Employing the Project-Based Learning (PjBL) approach represents a novel and inventive educational strategy. Within this framework, instructorstransition into the role of a guide, aiding students in exploring theoretical concepts and fostering their engagement throughout the educational journey. Yahya Muhammad Mukhlis suggests that this educational paradigm enables teachers to have complete oversight of the instructional activities. The methodology of teaching integrates project-based tasks within the educational experience (in Trianto, 2014:42).

The characteristics of Project-Based Learning (PjBL) are developing students' thinking skills, enabling them to be creative and skilled, and encouraging them to work collaboratively (Indriyani & Wrahatno, 2019). This means that students play the primary role, while teachers act as facilitators and guides the learning process. Therefore, students must design appropriate frameworks and problem-solving strategies.

STEM approach

STEM is an acronym for science, technology, engineering, and mathematics and is a popular contemporary initiative in education (Fisher: 2015). STEM is a highly popular learning model worldwide that is effective in integrative thematics because it combines four core areas of education: science, technology, mathematics, and engineering. This method can foster a unified educational framework and engaged instruction since tackling challenges requires the concurrent utilization of all four components.

According to Sanders (2009), STEM signifies an educational strategy integrating at a minimum a couple of science disciplines included within STEM, or relationships occurring among science disciplines within STEM alongside a minimum of one different academic discipline. In line with the opinion of Kelley and Knowles (2016), According to someone, STEM represents a method of instruction where STEM topics from a minimum of two STEM areas are taught, utilizing STEM methods within real-world situations, with the objective of linking these subjects together to improve educational outcomes for students.

According to the Malaysian Ministry of Education (2016), the characteristics of STEM learning identified to guide teachers in implementing STEM learning in schools are as follows:

a. Increasing students' sensitivity to real-world problems.
b. Involving students in teamwork.
c. Engaging students in investigations.
d. Encouraging students to provide various answers or solutions with justification.
e. Involving students in applying design process skills.
f. Providing students with opportunities to improve their answers or products.

METHODS

This particularinvestigation makes use of a research and development (R&D) methodology. The methodology utilized in this study was Research and Development (R&D), a type of research focused on creating a product while also assessing

whether it is both possible and useful within an educational setting. The 4-D model, encompassing four distinct phases, serves as the framework for this study: Define, Design, Develop, and Disseminate, with a limited focus on the Develop stage, which tests the product's practicality and feasibility. The STEM-integrated Project-Based Learning (PjBL)-based chemistry e-module was validated by two chemistry lecturers from the Faculty of Mathematics and Natural Sciences (FMIPA) of Universitas Indonesia (UNMED) and one chemistry teacher from SMA Negeri 1 Kutacane to ensure the product met feasibility standards and could be used practically in the learning process.

The instruments used to collect data in this study were non-test instruments consisting of an interview sheet, an e-module validation sheet, a media expert validation sheet, and a student response sheet. Prior to use, the non-test instruments were analyzed for validity by a validator.

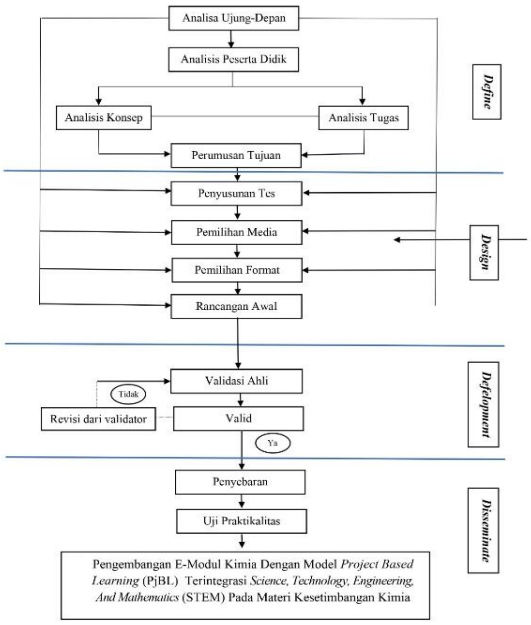

Figure 1. Research Flow

RESULT AND DISCUSSION

Define Stage

At this stage, researchers gather information on actual conditions in the field to identify students' needs and challenges. The results of this data collection are used as a basis for designing relevant e-modules that meet student needs before further development.

Design Stage

At this stage, the e-module design is prepared with reference to the media suitability standards set by BSNP. The design process begins with the preparation of a draft e-module as a basic framework, followed by media selection and determining an appropriate format for the e-module. This design stage aims to produce an initial draft e-module that is ready to be used as learning material for chemical equilibrium.

Dessiminate Stage

Teacher Practicality Test Results

After obtaining the results, the predetermined Practicality criteria were obtained. The following table shows the Practicality results analyzed by the teacher:

Table 1. Analysis of Teacher Practicality

No.	Assessment Aspect	Percentage (%)
1	Material	88%
2	Design and Content	86%
3	Learning Time Efficiency	96%
4	Benefits	90%
Average Assessment (%)		92%
Criteria for Interpreting Questionnaire Results		Very Practical

An e-module can be considered highly practical if it satisfies the required conditions, specifically being classified as "Very Practical. " This determination is based on the teacher's assessment of the e-module. According to the evaluation results and the score calculations provided by the teacher, the average percentage reached 92%. This outcome suggests that the e-module falls into the "Very Practical" category.

Student Response Analysis

After obtaining the results, the predetermined attractiveness criteria were obtained. The following table shows the results of the student responses:

Table 2. Analysis of Student Responses

No.	Assessment Aspect	Percentage Average
1	Material Presentation	88%
2	Media or Display	93%
3	Learning with E-modules	93%
4	Benefit Feasibility	94%
	Average	92%
	Questionnaire Results Interpretation Criteria	Very Practical

Validity Level of E-Modules with STEM Integrated Project Based Learning (PjBL) Model by Material and Media Experts

Subject Matter Expert

The e-module was evaluated by a material specialist, receiving an average score of 97.2%, which indicates it is highly usable. According to the assessment across five areas, the e-module fulfilled the requirements for being self-instructive, comprehensive, independent, adaptable, and simple to use, suggesting that it can be used effectively as a self-directed learning tool that is straightforward for students.

Media expert

Based on the experts' evaluations, the overall rating of the chemistry e-module improved a lot. At first, the e-module had an average score of 86.3%, but after making changes, the average went up to 97.3%, which is considered very practical. This big improvement shows that the e-module was greatly improved in many areas like content, how it's structured, its design, how well it works, and other technical parts. Overall, the e-module meets the standards for being a good digital teaching tool that is effective, engaging, and easy for students to use.

CONCLUSION

Validation results indicate that the STEM-integrated Project-Based Learning (PjBL) chemistry e-module on Chemical Equilibrium has a very high feasibility level, with an average percentage of 86.3% for the media aspect and 87.3% for the material aspect, which increased to 97.3% and 97.2% after revision, respectively, categorizing it as very valid. The e-module's practicality level reached 92%, categorizing it as very good. Furthermore, student responses showed an average score of 92% (very practical), indicating that the e-module facilitated conceptual understanding, increased learning motivation, and created an interactive and enjoyable learning environment.

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