DEVELOMPMENT OF E-MODULES ON CHEMICAL MATERIALS AROUND US USING A SYSTEMS THINKING APPROACH IN THE CONTEXT OF THE SEBATIK ISLANDS

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Abstract. *As an island region on the outer edge of Indonesia, learning processes on Sebatik Island require learning materials that improve students' system thinking skills, which contain the abilities to identify parts of systems and their interactions, identify cause and effect, organise their relationships among parts of systems, and hold ownership for their environment. According to those significant abilities for Sebatik's students, this study aims to develop a systems thinking-based e-module on environmental chemistry that aligns with the contextual characteristics of Sebatik Island. With the availability of learning media in the form of system thinking-based e-modules on environmental chemistry, it is hoped that students' understanding of contextual chemistry in accordance with the nature of Sebatik Island will improve. This study applies the Research and Development (R&D) method by adopting the development stages in the ADDIE model, focusing on the development and validation of a newly developed e-module. However, this research focuses on the development stage, taking into account the conditions of the region and the time frame of the research. 10th-grade MIPA students from SMA/MA participated in providing feedback on the e-module through student response sheets,this module has been validated by subject matter and media experts and evaluated by teachers to assess its suitability and effectiveness. The validation results show that the subject matter aspect achieved a score of 98.6% (very good), the media aspect 86.7% (very good), and the teacher's assessment 93.33% (very good). Student responses were also positive, with a percentage of 97.3% (very good). Based on these results, the system thinking-based e-module developed is suitable for use as an alternative learning medium, capable of facilitating holistic conceptual understanding, and relevant to the context of students' daily lives.*

Keywords: *E-module, Chemistry around us, Systems thinking, Learning media*

INTRODUCTION

The outer Sebatik Island plays a strategic contribution in shaping a generation that excels academically while also possessing social sensitivity, responsibility and environmentally responsible. As an area located on the outer edge of Indonesia, the quality of education on Sebatik Island often faces challenges, both in terms of infrastructure and limited human resources for educators [1]. This condition requires innovative efforts in the learning process so that students continue to receive an optimal learning experience. One of the efforts that can be made is through the digitalization of education [2]. The digitization of education is a strategic effort to integrate technology to support the effectiveness of the learning process, while maintaining the substance and essential meaning of the teaching material delivery [3]. In the context of learning activities, effectively designed learning media acts as an intermediary that facilitates the connection between the material being studied and the students, facilitates understanding, and

increases learning motivation [4]. Although learning media have been widely developed, their use in the field is still not optimal. Based on research [5], the use of technology-based learning media still faces obstacles, especially due to the lack of technological mastery among educators. As a result, innovation in material delivery and learning interaction is limited.

The transformation of the education system in Indonesia has become increasingly apparent after the COVID-19 pandemic, which accelerated changes in the curriculum and learning methods [6]. The curriculum serves as a learning guideline that includes objectives, content, and methods that continue to adapt [7]. One of the latest implementations is the independent curriculum, which emphasizes character, skills, and project-based learning [8]. However, the implementation of the current curriculum and the use of digital learning media such as e-modules are not yet evenly distributed in border areas, including the Sebatik Islands [9]. This condition shows that the development and application of innovative and effective e-modules still face various obstacles, causing an educational innovation gap in these island regions [10].

Regarding the development of technology in the digitalization era, e-modules have become one of the effective solutions in supporting the implementation of the independent curriculum [11]. E-modules are teaching materials designed using information and communication technology that include text, images, simulations, and audio and video elements [12]. The attractive appearance and interactive features such as hyperlinks in e-modules encourage student independence and active participation [13]. E-modules have advantages over printed modules, such as the presentation of material in the form of writing, graphics, animations, and videos that can create a more multi-sensory learning atmosphere [14]. Ayu Wina Hastari et al., (2019) reported that e-modules can increase student interest and motivation. However, conditions on Sebatik Island show that the use of learning technology is still limited because it has not been optimally implemented. Thus, the development of e-modules is necessary to strengthen and facilitate the continuity of learning activities.

Chemistry is a discipline rich in theoretical concepts [16]. Difficulties in learning chemistry often arise because students are unable to contextualise chemical concepts into everyday phenomena, which include the composition of substances and chemical processes in the environment [17]. Referring to findings obtained through interviews with chemistry teachers at MA As'Adiyah Sebatik Timur, most students were found to struggle with the topic of chemistry in our surroundings. Nearly 50% of students experienced learning difficulties, and their average score was 60.53, below the minimum passing standard of 70. This condition indicates a low level of understanding of chemistry concepts. This difficulty is caused by the density of the sub-material and the high interconnection between concepts, which often confuses students. In addition, learning that only uses printed books is ineffective due to limitations in presenting material visually and contextually [18]. This condition results in a lack of student understanding of chemical concepts around us [19]. To support this, the developed e-module will integrate a system thinking approach to help students understand the holistic relationship between chemical concepts and environmental issues.

Systems thinking is a promising approach, as well as the ability to identify the relationship between various components in a system to solve environmental problems through chemistry learning [20]. This approach is very relevant for schools in island regions that have their own challenges and potential. Sebatik Island, as Indonesia's outermost island, is a concrete example of a complex system. Its territory borders directly with other countries, has limited access to education and technology, but is rich in natural resources that can be used as a learning context [21]. The principle of system thinking places the environment as an interconnected part of several subsystems. Another characteristic of the system thinking approach is conducting investigations and assessments of problems in a systemic manner, where problem assessment and solution functions are considered as a learning system with the system as a lens through which to view problems. Thus, systems thinking is a simple form of a systems approach that has many advantages and is not complicated [22]. System thinking places chemistry content as the basis for understanding the environment or complex systems. Therefore, research on the

development of e-modules with a system thinking approach is important to attract students' interest in learning, create interesting and relevant learning, and improve learning outcomes and a deeper understanding of concepts.

In line with this, several previous studies have also developed e-modules based on innovative approaches in chemistry learning, such as the study conducted by Rindiani (2022), which developed e-modules based on green chemistry in electrochemistry material. The results showed that the e-modules received positive responses from students and teachers, making it applicable in the context of the electrochemical practicum learning process, especially in the material on electrolysis cells. In this study, there are similarities in the development of e-modules, namely the ADDIE R&D model, and differences from previous studies, namely e-modules developed based on system thinking on chemistry materials around us.

Previous studies on the development of e-modules have been conducted by Ayu Permata Sari & Suryelita (2023), which presented real-life problems that could help students use their existing conceptual understanding to find solutions. The findings of this study indicate the e-module developed demonstrates a very high level of practicality. In the author's research, there is a difference from previous studies in that the e-module developed presents problems in the surrounding environment in the Sebatik Islands.

Taking into account the issues outlined above, this study aims to design and develop a module based on systems thinking approach to chemistry in the local environment of the Sebatik Islands. The process of developing e-modules based on systems thinking approach is expected to enhance students' understand the concepts of chemistry materials around us holistically, helping students see how chemical concepts are interrelated and interact with the wider environmental system. Thus, the researcher focuses on designing systems thinking-based e-module that is appropriate for the context of the Sebatik Islands. In addition, it is hoped that this e-module can be used as an alternative for teachers and students in the learning process of chemistry materials around us that are linked to the surrounding context so that learning is more relevant and useful.

METHOD

This study adopts a research and development (R&D) method through the application of the ADDIE model, which consists of five main phases: analysis, design, development, implementation, and evaluation [25]. The ADDIE model has structured, systematic, effective, and efficient steps, making it the right choice [26]. This research is focused only on the development stage. This research focused on the development stage, producing systems thinking-based e-module on environmental chemistry. Validation data were collected through questionnaires and expert reviews, involving chemistry teachers and 10th grade MIPA students from senior high schools/MA in Sebatik Island as respondents to assess the module's content, media, and overall suitability for learning.

Analysis

The analysis stage in the development of this e-module includes curriculum analysis, material analysis, student analysis and learning environment analysis. Curriculum and material analysis were conducted through interviews with chemistry teachers at senior high schools/MA in Sebatik Island to evaluate the availability, relevance and alignment of the e-module with the Merdeka Curriculum. Student and learning environment analysis were carried out to ensure that the e-module meets students' needs and is sustaible for local learning context.

Design

The design stage includes data collection criteria, product design, layout design, technology selection, e-module specifications, and assessment instrument development. At this stage, an e-module prototype is produced, designed by applying systems thinking principles in the presentation of material. The context of the Sebatik archipelago is integrated through examples of chemical phenomena in the surrounding environment, so that students are able to understand chemistry concepts in the context of real-world applications. Thus, the e-module design not only emphasizes chemistry content, but also the interconnection between concepts and the island environment system. It is also

equipped with visualizations, illustrations, and contextual examples to create a more relevant and meaningful learning experience.

Development

The development stage was carried out by producing an improved product based on input from experts, assessors, and student responses. The experts in this study consisted of a subject matter expert, a media expert, three assessors (high school/vocational school chemistry teachers from MA As'Adiyah East Sebatik), and fifteen tenth-grade students as respondents to the developed product. This study only reached the stage of developing an electronic module, because the e-module developed was contextual and specifically designed for a particular region. Considering the limitations of access, distance, and research time, the implementation stage and evaluation of the effectiveness of the e-module in classroom learning could not be carried out in this study. Therefore, further research is needed to assess the effectiveness of e-modules in increasing student motivation in the targeted region..

Data Collection Techniques and Instruments

The data collection strategy in this study was conducted through interviews and questionnaires. Validation of the e-module was carried out by material and media experts to assess the feasibility and accuracy of the content and media. In addition, teachers used assessment sheets to evaluate the overall quality and effectiveness of the e-module for learning purposes. Student response sheets were also administered to gather students' feedback on usability, conceptual understanding, and the relevance of the e-module to their local context.

Data Analysis

Data analysis was conducted by transforming the results of assessments by subject matter experts, media experts, and reviewers from qualitative data into quantitative data based on a Likert scale with answer options of Very Good, Good, Fair, Poor, and Very Poor with values (scores of 5 to 1). Next, the overall score and the average for each assessment aspect were calculated. The average score is calculated using the following formula (1):

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

Explanation:

$\bar{X}$ = average score

$\sum x$ = total score

n = number of assessors

The calculated percentage of idealism is then interpreted into quality categories. These subjective quality categories are based on the ideal assessment criteria presented in table:

Table 1. Ideal Assessment Criteria

Score Range	Category
$\overline{x_i} + 1{,}8\ Sbi < X$	Very Good
$\overline{x_i} + 0{,}60\ Sbi < X \leq \overline{x_i} + 1{,}8\ Sbi$	Good
$\overline{x_i} - 0{,}60\ Sbi < X \leq \overline{x_i} + 0{,}60\ Sbi$	Fair
$\overline{x_i} - 1{,}80\ Sbi < X \leq \overline{x_i} - 0{,}60\ Sbi$	Poor
$X \leq \overline{x_i} - 1{,}8\ Sbi$	Very Poor

Explanation :

X = actual score

Sbi = standard deviation of ideal score

= $\frac{1}{6}$ × (maximum ideal score - minimum ideal score)

$\overline{x_i}$ = average number of ideal scores

= $\frac{1}{2}$ × (ideal maximum score + ideal minimum score)

Ideal maximum score = ∑ criteria items × highest score

Ideal minimum score = ∑ criteria items × lowest score

Using the Guttman scale, student responses were converted into scores and then processed into quantitative data as presented in the following table:

Table 2. Guttman Scale Scoring Rules

Description	Score
Yes	1
No	0

The next step is to process the quantitative data that has been converted into validation scores. This data is used to determine the idealism level of the product, both in terms of the overall components and each aspect. The idealism percentage (%) is calculated based on the following formula:

$$\% \text{ overall idealism} = \frac{\text{score achieved}}{\text{ideal highest score}} \times 100\% \quad (2)$$

RESULT AND DISCUSSION

This study aims to develop an interactive module based on a systems thinking approach to chemistry materials around us, designed to improve students' conceptual understanding. The subjects of this study were 10^{th}-grade MIPA SMA/MA students. The research design used was the ADDIE development model, but was limited to the development stage only. The following is a description of the stages in the ADDIE development model:

Analysis Stage

This stage involves analyzing requirements, curriculum, and module development as the basis for e-module design. The interview results show that students still lack independent learning materials, and the learning process still relies heavily on blackboards and printed books as the main media. In addition, a large number of students have difficulty understanding the chemical concepts found in their surroundings. Curriculum analysis ensures that the e-modules developed are in line with the learning outcomes of the Merdeka curriculum, while module analysis refers to the BSNP (2008) standards, thus requiring e-modules based on system thinking so that learning is more contextual and relevant to students' needs.

Table 3. Mapping of Independent Curriculum Competencies with Systems Thinking Elements

Learning Outcomes/Learning Objectives (Merdeka Curriculum Phase E)	Elements of Systems Thinking	Implementation in E-modules
Analyzing the relationship between substances, chemical reactions, and their application in everyday life	Understanding interconnections	Presenting the phenomenon of environmental pollution in the Sebatik Islands to demonstrate the relationship between chemical reactions and environmental systems
Identifying the cause-and-effect relationships of chemical changes that occur in the surrounding environment	Causal relationships	Providing infographics and case studies such as waste incineration, iron rust, and organic material decomposition

Design Stage

At this stage, researchers developed a conceptual framework for e-modules based on system thinking in accordance with theory and student needs. The e-module consists of an introduction, content (sub-material, perception, competency tests, integration of local chemical phenomena), and conclusion. The initial draft was created in Canva and then developed in Flipbook Corporate with animation features, video quizzes, and contextual content. As well as the creation of instruments.

Development Stage

This stage involves developing the design created in the previous stage into an e-module product. Before this e-module is used, it undergoes validity inspected by experts to ensure product quality, so that the resulting e-modules must be able to make a real contribution to achieving the learning objectives that have been set. The e-module features a user-friendly interface with clear navigation menus, colorful illustrations, and interactive exercises designed to facilitate students' understanding of environmental chemistry concepts and support systems thinking skills in the context of Sebatik Island.

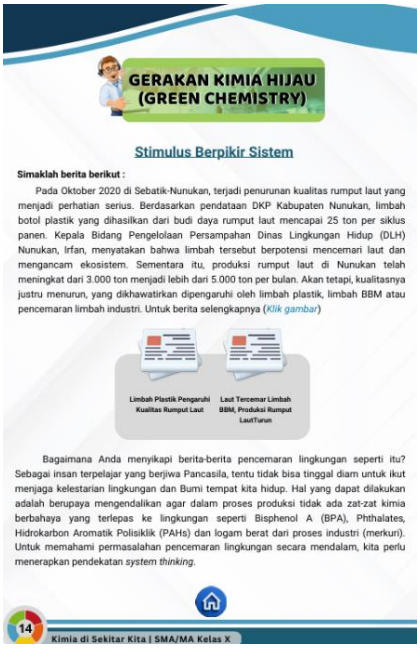

Figure 1. Stimulus System Thinking

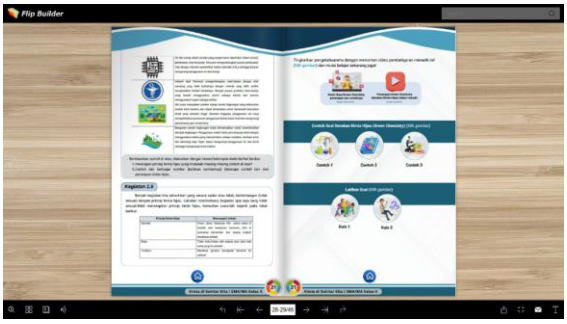

Figure 2. Main Interface of the E-module

E-module Validity by Material and Media Experts

Validity is assessed by subject matter experts and media experts as validators. The assessment instruments used cover aspects of content, language, e-module characteristics, presentation, graphics, and the system thinking approach. The following data presents the validation results provided by subject matter experts and media experts.

Table 4. Product Quality Assessment by Material and Media Experts

Product Quality Assessor	Assessment Aspects	Σ Score	Maximum Ideal Score	Ideal Percentage	Category
Subject Matter Expert	Contents	19	20	95%	Very Good
	Language	20	20	100%	Very Good
	Characteristics e-module	25	25	100%	Very Good
	System thinking approach	10	10	100%	Very Good
Media Expert	Presentation	14	15	93,3%	Very Good
	Graphics	12	15	80%	Good

Based on the validation results, this e-module achieved a score of 98.6%, which falls into the excellent category, and the assessment from media experts reached 86.7%, which was also in the excellent category. These findings indicate that the developed e-modules have met the criteria in terms of content, language, e-module characteristics, presentation, graphics, and integration of the system thinking approach. These results are consistent with findings from previous studies Rindiani (2022) which also shows a high level of validity in green chemistry-based e-modules. However, the aspect that significantly distinguishes this research is the application of a systems thinking approach, this has rarely been studied in the context of developing e-modules for chemistry learning. Thus, this study reinforces the evidence that innovations based on a system thinking approach can produce quality learning products.

Teacher Assessment and Student Response to E-modules

After testing for validity, the assessment instruments were submitted to high school chemistry teachers as reviewers, while student response questionnaires were used to

assess the suitability of the developed e-modules. The following are the assessment results from high school chemistry teachers and student responses.

Tabel 5. Product Quality Assessment by Chemistry Teachers and Student Responses

Product Quality Assessment/Student Response	Assessment Aspects	Σ Score	Maximum Ideal Score	Ideal Percentage	Category
Reviewer	Content	18,67	20	93,35%	Very Good
	Language	18	20	90%	Very Good
	Characteristics e-module	23,33	25	93,3%	Very Good
	Presentation	14,33	15	95,5%	Very Good
	Graphics	14	15	93,3%	Very Good
	System thinking approach	10	10	100%	Very Good
Student	Material	15	15	100%	Very Good
	Language	15	15	100%	Very Good
	Presentation	13	15	86,67%	Very Good
	User friendly	15	15	100%	Very Good
	System thinking approach	15	15	100%	Very Good

The results of the evaluation by high school chemistry teachers showed a percentage of 93.3% and student response reached 97.3%, both of which are classified as excellent. This data shows that the developed e-module has been proven to not only meet the feasibility criteria, but also has a high level of practicality in its application to the learning process. The high student response rate proves that presenting material in visual form, infographics, and integrating system thinking can facilitate the understanding of abstract chemistry concepts. Research by Ayu Wina Hastari et al. (2019) also states that e-modules can increase student motivation to learn. However, this study emphasizes students' ability to think systemically, that is, to see the interrelationships between concepts and their implications for the environment.

Based on the results obtained, the system thinking-based e-module is not only valid and practical, but also relevant to everyday life. Compared to previous studies, this study confirms a new contribution in the form of integrating system thinking as an approach to understanding chemistry concepts holistically and contextually. Therefore, this e-module has the potential to be used as an alternative learning medium in accordance with the implementation of the Merdeka Curriculum, especially in island regions that face learning resource limitations.

CONCLUSIONS AND RECOMMENDATIONS

The research produced an e-module based on system thinking on chemistry topics around us. The assessment from subject matter experts showed a percentage of 98.6% in the excellent category, while media experts gave a score of 86.7%, which was also in the excellent category. Reviewers gave a score of 93.3% in the excellent category. In addition, the response from high school/MA students reached 97.3% in the excellent category. Thus, This systems thinking-based e-module is worth utilizing as

an alternative learning medium that supports comprehensive understanding of chemistry concepts while increasing student motivation to learn. In addition, this research has significant importance for the Sebatik Islands region as a border area that faces limited access to learning resources. Furthermore, the development of the e-module is tailored to the social and environmental characteristics of the islands, such as coastal community activities, environmental pollution issues, and implementation of chemical concepts in everyday life. Thus, the development of this e-module can be a solution in equalizing the quality of chemistry education that is contextual and relevant to the characteristics of the island environment. Recommendations for further research include conducting an effectiveness test of the e-module in direct classroom application to determine its impact on student learning outcomes. Furthermore, the research can be expanded to other chemistry materials and more diverse systems thinking-based projects to optimize the benefits of the e-module.

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