

Development of Chemistry e-Book Based on STEM Approach (Science, Technology, Engineering, and Mathematics)

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Abstract. The ADDIE model was utilized in the examination of the suitability of STEM-based chemistry e-books for eleventh-grade high school students. This research and development (R&D) study encompassed the analysis, design, and development phases. The validation process involved subject matter experts, consisting of three chemistry lecturers and three teachers, along with a media expert specializing in educational technology. The validation results from material experts for chemistry e-books employing STEM approaches indicated feasibility, with an average score of 3.64, corresponding to a percentage of 91.00%. Similarly, media expert validation affirmed high feasibility, recording an average score of 4.62, equivalent to a percentage of 92.40%. These outcomes support the conclusion that the STEM-based chemistry e-book is a viable learning resource.

Keywords: e-book, chemistry, STEM approach..

1 Introduction

In the era of 21st century education, technological skills are an important key that must be possessed by students. Therefore, teachers must have more creativity in how to teach in class. One way that teachers can do is to develop textbooks. Teaching materials are learning media that have an important role in the classroom and are one of the important components of the education system [1]. In the absence of sufficient learning materials, students may face challenges in understanding the content presented by their teachers. An effective remedy would be for educators to integrate textbooks as a teaching resource, facilitating a more seamless and comfortable learning experience for students [2]. Most high school students exhibit low levels of critical thinking abilities. These findings suggest that interventions aimed at improving their critical thinking skills are crucial at this level, and teachers play a vital role in this process [3]. Fajrina, Simorangkir, dan Nurfajriani (2018) [4] emphasizes the

importance of teachers being able to stimulate and provide encouragement and reinforcement to dynamically foster the potential, activities, and motivation of students. This approach makes the teaching and learning process more engaging, leading to better academic achievements to meet the challenges of modern education. Numerous research studies have examined several alternative solutions to address the issue of students' poor critical thinking skills. One such solution involves implementing various learning designs that focus on enhancing critical thinking skills, such as STEM education. STEM education is an effective strategy that meets the quality standards of 21st-century learning objectives [5,6]. STEM relies on the accomplishments in science and mathematics and should be suitable when integrated with technology and engineering [7].

Currently, there are many learning resources in the form of books that were originally printed (text book), now developed into electronic versions (e-books). According to Fuad (2016) [5], E-books are a form of digital literature that deviates from the conventional paper or physical media books. These digital books are a product of recent advances in information technology, particularly in the realms of internet and computer technology. One effective approach to fostering independent learning for students, whether it be at school or from their homes, is to utilize e-books as a teaching resource [8] it is expected that the e-book will facilitate students' proficiency in using media, information, and communication technology (ICT) to meet the demands of the 21st century. Moreover, it is anticipated that the e-book will augment students' critical thinking and self-directed learning capabilities. Employing e-books in teaching can assist educators in conveying learning materials, enabling students to comprehend the subject matter autonomously. [9].

According to Mulyani (2019) [5], one of the most effective methods of integrating STEM is through the use of e-Books. E-Books can support students in problem-solving, improve their memory retention, and enhance their higher-order thinking skills, including the ability to analyze, evaluate, and create. An e-Book is an electronic learning material that contains information, such as text, animations, videos, or images. They are convenient to use due to their small size, durability, and the ability to display multimedia illustrations, such as animations. According to Martha et al. (2018) [5], the use of mobile learning-based e-books can enhance students' comprehension of abstract concepts by providing a visual representation. When utilizing e-books taught through STEM (Science, Technology, Engineering, and Mathematics) methodology, learning outcomes can significantly improve. STEM education fosters the development of students' abilities to apply knowledge to design solutions for environmental issues and cultivates scientific literacy [10].

Chemistry e-books based on STEM approaches afford active learning opportunities for students. The use of these resources within a single semester proves to be highly practical, as it eliminates the need for students to search for e-books that cover additional materials, thereby optimizing time management. Furthermore, the utilization of chemistry e-books based on the STEM approach ensures that student activities are centered on the learners themselves, thus resulting in enhanced understanding and retention of the material.

Given the issues outlined earlier, researchers aim to investigate development of chemistry e-books based on STEM (Science, Technology, Engineering, and Mathematics) approaches. This study intends to provide supplementary technology-based resources to assess students'

critical thinking abilities and learning autonomy. Ultimately, the research findings may serve as a reference for developing chemistry e-books based on STEM approaches.

2 Method

The study used a research and development approach as its research model. The ADDIE development model was chosen for this research due to its systematic approach that acknowledges and values each preceding stage. This model is expected to provide a valuable product [11]. For the purpose of this project, the development strategy is restricted to the development phase, with the objective of producing an chemistry e-books based on the STEM approach and will be verified by experts. Non-test instruments, such as questionnaires, were utilized to collect data and determine the e-book's feasibility value or validity. The e-book has undergone validation by content and media validators. This research involved six expert validators in their fields, consisting of three chemistry education program lecturers and three chemistry teachers. Apart from that, there is also a media expert who is a lecturer in the educational technology program at Medan State University.

The initial research phase involves an examination that encompasses curriculum analysis, the identification of educational objectives, the execution of a learning analysis, and an assessment of the context. The subsequent stage focuses on product design, specifically the creation of chemistry e-books using STEM-based methodologies. Following this, the comprehensive product development phase is undertaken. Once the product is created, a validation process is conducted for the developed learning product. The criteria for the validity of a product by material experts are presented in Table 1. The criteria for the validity of a product by media experts are presented in Table 2.

Table 1. Validity criteria by material experts.

Score	Criteria	Information
1,00 – 1,75	Invalid	Invalid need total revision
1,76 – 2,50	Less Valid	Valid in use but with moderate revision improvements
2,51 – 3,25	Valid	Valid needs minor revision
3,26 – 4,00	Very Valid	Valid no revision required

Table 2. Validity criteria by media experts.

Score	Criteria	Information
1,00 – 2,49	Invalid	Cannot be used
2,50 – 3,32	Less Valid	Needs major revision
3,33 – 4,16	Valid	Valid for use but with revision improvements
4,17 – 5,00	Very Valid	Valid no revision required

3. Research Results and Discussions

Analysis

The initial stage of developing a chemistry e-Book based on a STEM approach is the needs analysis stage. Needs analysis is an initial analysis carried out to collect the necessary information as consideration in the development of chemistry e-Books based on STEM approaches. This analysis was obtained from observation and interview activities. The observation activities carried out are analyzing the curriculum (including learning outcomes, flow of learning objectives, and materials) used in schools, analysis of textbooks that are being used in schools, and analysis of the needs of chemistry e-Books based on STEM approaches through the distribution of questionnaires. In the interview activity, namely interviewing 1 chemistry teacher and 2 students. Chemistry teacher interviews are conducted to analyze the learning process in the classroom starting from the approach, methods, learning models used and analyze the thinking skills of students. Learners are interviewed to evaluate their learning independence. According to the findings of the investigation, it was discovered that both educators and students need textbooks that are simple to manage, can be accessed at any time and from any location, and specifically take the shape of chemistry e-books that are based on a STEM methodology. These textbooks are particularly significant in the learning process since they have the potential to develop students' critical thinking abilities as well as their ability to study independently.

Design

Researchers developed a chemistry e-book aimed at odd semester classes using a STEM approach. This e-Book was created using the Canva application and adjusted to align with learning outcomes and objectives. Chemistry e-Books cover a wide range of chemistry material, including web links or references, chemistry-related information, interactive practice questions, educational videos, summaries, opportunities for self-reflection, a glossary, and a periodic table of elements. This e-book includes several sections, as specified in **Table 3**, that help explain the outline of the book.

Table 3. The outline of the contents of a chemistry e-book based on a STEM approach.

Part	Component
Beginning	Cover
	Front Cover
	Foreword
	Characteristics of the Chemistry e-Book
	Explanation of the contents of the Chemistry e-Book
	Instructions for use of the Chemistry e-Book
	Table of Contents
	Learning Outcomes and Learning Objectives
	Pancasila Student Profile
	Core
Chapter 1. Chemical Calculations (Stoichiometry)	
Chapter 2. Chemical Bonding	
Chapter 3. Thermochemistry	
Chapter 4. Chemical Kinetics	
End	Integrated Question Practice
	Glossary
	Bibliography

Periodic Table of Elements
Author Profile

During this phase, researchers also prepare assessment items to be administered at the conclusion of the session following the development of chemistry e-Books using STEM approaches. In this instance, the researcher devised a set of written test questions in the form of reasoned multiple-choice questions, totaling 20 questions. A subject matter expert, specifically a chemistry lecturer, then validated these questions.

Development

The procedure includes formulating a framework for the chemistry e-book and subsequently refining it based on feedback received from validators. This chemistry e-book, based on a STEM approach, successfully underwent validation by subject matter experts. The validation encompassed aspects such as content validity, language validity, presentation validity, and graphic validity. The outcomes of the validation process conducted by material experts are documented in **Table 4**.

Table 4. Validation results by material experts.

Assessed Aspects	Average	Percentage (%)	Criteria
Content Validity	3.53	88.25	Valid no revision required
Language Validity	3.68	92.00	Valid no revision required
Presentation Validity	3.63	90.75	Valid no revision required
Graphic Validity	3.70	92.50	Valid no revision required
Average	3.64	91.00	Valid no revision required

Based on validation results assessed by material experts, the chemistry e-Book developed using a STEM approach has obtained an average score of 3.64 or the equivalent of 91.00%. This shows that the e-Book is considered valid without the need for any revision and is ready to be used at the next research stage.

The validation process also involves evaluation by media experts who assess various aspects including guidelines and information, program performance, systematic organization, aesthetics, and design principles. The results of validation by media experts can be seen in **Table 5**.

Table 5. Validation results by media experts.

Assessed Aspects	Average	Percentage (%)	Criteria
Guides and information	4.67	93.40	Valid no revision required
Program Performance	4.60	92.00	Valid no revision required
Systemtics, Aesthetics, and Engineering Principles	4.60	92.00	Valid no revision required
Average	4.62	92.40	Valid no revision required

According on validation results assessed conducted by media expert, the chemistry e-Book developed using a STEM approach has obtained an average score of 4.62 or the equivalent to

92.40%. This confirms that this e-Book is considered valid and does not require any revision so it is suitable to be continued to the next research stage. The data obtained from the validation of material experts and media experts can be seen in **Figure 2**.

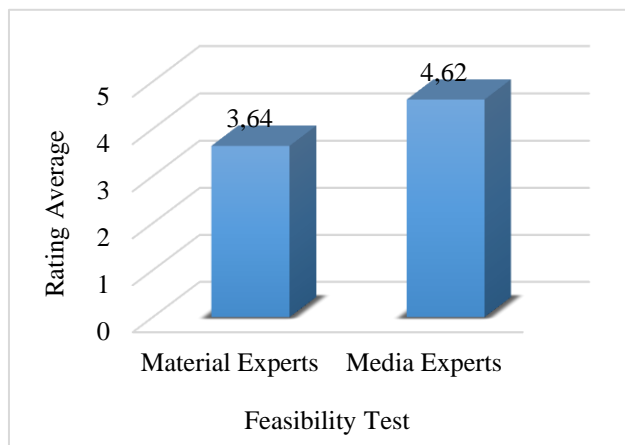


Fig. 1. Validation results of material experts and media experts.

A valid STEM-based chemistry e-Book on chemistry materials for grade XI high school odd semester can be seen in **Figure 2**.



Fig. 2. Valid STEM approach-based chemistry e-Book.

5. Conclusion

This research has successfully produced a chemistry e-book based on the STEM approach, aimed at addressing challenges or issues in chemistry learning in the classroom. The suitability of the e-book was evaluated through validation involving material experts and media experts. The findings indicate that the chemistry e-book based on the STEM approach that was developed is valid. Material experts affirmed its validity with a validity rate of 91.00%, while the validation results from media experts reached 92.40%. Therefore, the research results confirm that this STEM-based chemistry e-book is valid and does not require further revisions, allowing it to proceed to the implementation phase

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