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Research Article

Improving Students' Critical Thinking Skills Through the Development of E-Learning-Based Chemistry Textbooks

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Abstract
This study was conducted with the aim of developing an effective and feasible e-learning-based chemistry textbook intended to enhance students' critical thinking abilities. The development process adhered to the ADDIE model, providing a systematic framework for the design of educational materials. Participants in the study consisted of first-semester chemistry education students at the Faculty of Tarbiyah and Teacher Training, UIN Mataram. Data were collected using both test and non-test instruments. Non-test instruments were employed to evaluate the feasibility of the e-learning-based chemistry textbook, whereas test instruments were used to measure students' critical thinking skills. The study was carried out in two primary stages: validation of the product and trials involving chemistry education students at UIN Mataram. For the trials, a quasi-experimental design with a pre-test/post-test control group was implemented. The results of the study led to the following conclusions: (1) The developed e-learning chemistry textbook attained validity scores ranging from 0.857 to 0.905, classifying it as very high, with a reliability coefficient of 0.865. These results indicate that the textbook is valid and reliable for use in Basic Chemistry courses at the tertiary level. (2) Analysis using an independent samples t-test revealed a significance value of 0.018, below the alpha threshold of 0.05, confirming that the e-learning chemistry textbook is effective in improving students' critical thinking skills. Overall, the findings demonstrate that the developed e-learning-based chemistry textbook is both valid and reliable, and it effectively enhances students' critical thinking abilities.

Keywords: Chemistry Textbooks, Critical Thinking Skills, E-Learning

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1. INTRODUCTION

In the 21st century, critical thinking skills are essential for success (Kotsis, 2025; Purnama, 2024). These skills involve the ability to analyze and evaluate ideas or problems presented to us. According to Wulandari et al. (2020), critical thinking can be understood as the process of dissecting concepts, distinguishing between them, selecting relevant information, and developing a more refined understanding. This skill set enables individuals to generate multiple alternative responses and creative ideas, fostering independent and natural thought. When confronted with a problem, critical thinkers consider various solutions rather than fixating on a single approach (Agustin et al., 2024; Suparman, 2014; Wahyudiati et al., 2020; Wahyudiati et al., 2023).

Initial observations at several universities in West Nusa Tenggara reveal a significant deficiency in students' critical thinking abilities. This underscores the urgency of this research, aimed at enhancing these vital soft skills. Strengthening critical thinking will better equip students to tackle real-life challenges and compete effectively in the workforce during the era of the Industrial Revolution 5.0.

To cultivate critical thinking skills, education must increasingly embrace e-learning, as the global trend in education is shifting toward this digital learning model (Aldian & Wahyudiati, 2024; Esteve et al., 2022; Sahwan et al., 2023; Sulhan et al., 2024; Wahyudiati, 2022; Krumsvik, 2012). Consequently, modern educational designs need to incorporate IT-based media and teaching materials through e-learning to keep

up with technological advancements (Castro et al., 2020; Verawati et al., 2022). E-learning has the unique capability to transform abstract concepts into more concrete and tangible forms, making learning more meaningful (Tapia, Hasson, & Alegría, 2018; Verawati et al., 2022; Wahyudiati, 2022). The benefits of implementing e-learning in education include increased engagement and flexibility (Aurora, 2019; Ihsan, 2019; Wahyudiati & Qurniati, 2022). Moreover, e-learning has proven to be an interactive and effective medium that enhances science process skills, interest, motivation, critical thinking skills, and scientific attitudes, all while being user-friendly (Sari et al., 2020; Verawati & Putu, 2020; Wahyudiati, 2023; Qurniati & Wahyudiati, 2023; Wahyudiati, 2024).

Given these findings and the current educational landscape, this study focuses on developing an e-learning-based chemistry textbook. The goal is to create a resource that is both feasible and effective in improving students' critical thinking skills.

2. METHODS

In the present study, a research and development (R&D) approach was employed to create e-learning-based chemistry textbooks. The development process followed the ADDIE model (Branch, 2009), which provided a structured framework for designing educational materials. The R&D approach was chosen because this study developed a product and tested the effectiveness of the product using a quasi-experimental design. The determination of experimental and control groups was determined randomly using a cluster random sampling technique. The participants in this study were first-semester Tadris Chemistry students at the Faculty of Tarbiyah and Teacher Training, UIN Mataram. The number of samples in this study totalled 18 people from the age range of 22-23 years, consisting of 12 women and 6 men. Data collection techniques included both test and non-test methods. Non-test techniques were utilized to gather information regarding the feasibility of the e-learning-based chemistry textbook, while test methods were employed to assess students' critical thinking skills.

Before the instrument was used, the validity and reliability of the instrument were tested, where the validity and reliability values obtained were greater than 0.75, so that the instrument was declared valid and feasible to be applied to research activities. The developed chemistry textbook was delivered as electronic media (non-print) using Flip PDF software, which allowed for the creation of flexible and practical e-learning resources. The textbook was designed to be visually appealing, varied, and communicative. Prior to testing, the e-learning-based chemistry textbooks and associated research instruments were validated by several experts, including content and media specialists. The testing process consisted of two phases: the product validation stage and the trial phase involving Tadris Chemistry students at UIN Mataram. A quasi-experimental design, specifically a pre-test/post-test control group design, was used for the trials (Campbell & Stanley, 1963). Data collection was carried out in the experimental class by applying the developed product (E-Learning chemistry teaching materials) on elemental material and its changes for 6 meetings. While in the control class in learning activities using chemistry teaching materials that are not based on e-learning were conducted for 6 meetings. The data analysis used was an independent sample t-test with the help of the SPSS application.

3. RESULTS AND DISCUSSION

The development of e-learning-based chemistry textbooks followed the stages outlined in the ADDIE model, aimed at creating a product and evaluating its feasibility and effectiveness. The process consisted of five key stages: (1) Analysis; (2) Design; (3) Development; (4) Implementation; and (5) Evaluation.

During the analysis stage, a comprehensive needs assessment was conducted through field studies and literature reviews. This analysis served as a foundation for understanding the necessity of developing e-learning chemistry textbooks and their relevance to real-world educational conditions. The goal was to ensure that the products developed would be beneficial in the educational landscape.

Several activities were undertaken during the literature review, including: (1) identifying the competencies that students must achieve in chemistry education at the higher education level; (2) analyzing the current implementation of chemistry teaching in universities; (3) evaluating contextual chemistry

materials; (4) identifying student characteristics; (5) examining the importance of fostering scientific attitudes and critical thinking skills, as well as visual-spatial intelligence among students; and (6) analyzing relevant research findings to support the theoretical framework of the study. These activities provided valuable insights that guided the development of effective e-learning materials tailored to meet students' needs and enhance their learning experiences in chemistry.

The next stage in the development process was the design phase. During this stage, the product's design was created to highlight its unique features, distinguishing it from other available resources. This systematic process involved setting clear goals, designing learning scenarios, creating learning tools, developing learning materials, and formulating assessment instruments to evaluate students' critical thinking skills. The researcher gathered references related to the textbook, selected an appropriate design, chose an attractive layout suited to student characteristics, and prepared materials for evaluation within the e-learning chemistry textbook.

In the development stage, the conceptual framework established during the design phase was transformed into a tangible product ready for implementation. The e-learning-based chemistry textbook was created as electronic media (non-print) using Flip PDF software, which enhanced its practicality and flexibility. The design aimed to be visually appealing, varied, and communicative. Flip PDF Corporate is an application that converts PDF documents into interactive digital publications, allowing for engaging learning content with several available features. Users can easily add features by dragging, dropping, or clicking. The software also supports the integration of audio, video, text, and Flash content, with various output formats including ZIP, HTML, FBR, EXE, Mac app, mobile versions, and the option to burn to CD. Research by Srihono and Fuad (2018) indicated that using Flip PDF Corporate can improve learning outcomes. The chemistry textbook is enriched with information presented in text, images, and videos, making it more engaging. It adheres to a structured textbook writing format, resulting in a well-organized e-learning chemistry resource. This product was then validated and reviewed by experts in educational technology and chemistry content. The final e-learning chemistry textbook is illustrated in Figure 1 and can be accessed at: https://modul.buanatechno.id/kampus/kimia/2/mobile/index.html. Examples of images and videos included in the e-learning-based chemistry textbook are shown in Figures 2 and 3.

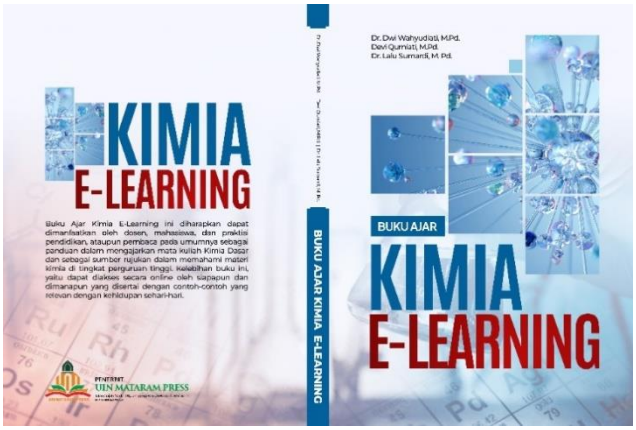

Figure 1. Cover of E-Learning-Based Chemistry Textbook

Figure 2. Crystal Structure

Figure 3. Video of Natural Material Extraction Methods

Figure 2 presents a GIF image of the crystal structure, which aids students in visualizing and comprehending the shape of crystals. Similarly, Figure 3 includes a video that illustrates the method of extracting natural materials, further enhancing students' understanding of resource extraction from nature.

Prior to validation, the e-learning-based chemistry textbooks underwent a comprehensive review by a team of proofreaders who specialized in educational media and chemistry content. The feedback from this team concentrated on three key areas: (1) ensuring alignment between teaching materials and learning indicators; (2) confirming that the scope of the material was appropriate in relation to the allocated instructional time; and (3) promoting the use of precise language to prevent ambiguity. Following the necessary revisions by the researcher, the next phase involved validating the developed e-learning-based chemistry textbook with a team of validators, which included content experts, linguists, and media specialists. The validity of the textbook was evaluated based on four criteria: presentation quality, rationality, linguistic clarity, and content feasibility. The textbook covers four primary subjects: separation of mixed components, changes in matter, periodic systems of elements, and chemical bonds. Data analysis indicated that the validity scores ranged from 0.857 to 0.905, which are classified as very high, with a reliability coefficient of 0.865. As a result, the developed e-learning-based chemistry textbook was recognized as valid and reliable for implementation in Basic Chemistry courses at the higher education level.

To assess the effectiveness of the e-learning-based chemistry textbooks, an evaluation of students' critical thinking skills was conducted during the implementation stage. The results of this effectiveness test reflect the quality of the developed product. Specifically, the effectiveness of the e-learning chemistry textbook was measured by analyzing how well it improved students' critical thinking abilities. In the present study, students' critical thinking skills were evaluated after they engaged with the e-learning chemistry textbook. The assessment was structured according to established indicators of critical thinking. These indicators included: (1) Providing a Simple Explanation—identifying the problem by focusing on relevant questions and elements; (2) Building Basic Skills—considering the credibility of sources, making observations, and reflecting on those observations; (3) Drawing Conclusions—formulating conclusions based on the encountered problems and the initial knowledge held; (4) Providing Further Explanations—identifying relationships between concepts in the problem and offering appropriate explanations; and (5) Organizing Strategies and Tactics—deciding on effective actions to solve problems, including accurate calculations.

Utilizing these critical thinking indicators enables students to enhance their understanding of various problems, evaluate specific conditions, and draw informed conclusions, thereby strengthening their overall knowledge (Wahyudiati, 2022). Furthermore, students are equipped to analyze problems logically and rationally, facilitating the discovery of viable solutions (Irwanto et al., 2018; Wahyudiati, 2022).

The data analysis confirmed that all assumptions required for the independent samples t-test were satisfied, thereby permitting the hypothesis testing to proceed. The test produced a significance value of 0.018, which was lower than the predetermined alpha level of 0.05. Consequently, the alternative hypothesis (Ha) was accepted, demonstrating a significant difference in the enhancement of students' critical thinking skills between those utilizing e-learning-based chemistry textbooks and those who did not. A summary of these results is presented in Table 1.

Table 1. Results of the Critical Thinking Skills Test of Students

		F	Sig	t	df	Sig (2-tailed)
NGain_persen	Equal Variances Assumed	903	.356	2.640	14	.018
	Equal Variances not Assumed			2.640	14.301	.019

The implementation of an e-learning-based chemistry textbook has been shown to significantly enhance students' critical thinking skills. Serving as an innovative instructional medium, this textbook enriches the chemistry learning experience through the integration of e-learning. Beyond simplifying the delivery of content, e-learning promotes the development of a wide range of student competencies. Rather than functioning as passive recipients of knowledge, students are encouraged to actively engage in observation, experimentation, and the demonstration of understanding. The presentation of chemistry content in diverse formats within e-learning textbooks makes the material more dynamic and appealing, thereby motivating students to take a more active role in the learning process. This finding is consistent with Dahiya's (2012) study, which emphasizes that e-learning enables students to learn at any time and in any place. Furthermore, prior research has indicated that e-learning facilitates effective comprehension of subject matter (Prastowo, 2014; Sugiarto, 2019) while also fostering a stimulating and engaging learning environment.

The effective integration of e-learning media can optimize educational outcomes, particularly by advancing students' critical thinking abilities. Through such innovations, students are empowered to sharpen their observational and analytical skills. The flexibility inherent in e-learning further allows unrestricted access to learning resources, independent of time and place. This adaptability reflects the advantages outlined by Rohmah (2016), namely: (1) minimizing study time and reducing educational costs; (2) facilitating meaningful interaction between learners and instructional materials; (3) enabling repeated access to resources and the exchange of information; and (4) extending knowledge acquisition beyond the confines of the classroom, with students actively engaging in the teaching and learning process through the use of computer technologies and networks.

After the implementation stage, an evaluation was carried out to examine the feasibility and effectiveness of the e-learning-based chemistry textbooks. Owing to their distinct advantages, these resources function as valuable alternative learning media that foster the development of students' critical thinking skills in chemistry education. The research findings highlight that the integration of e-learning-based chemistry textbooks can substantially enhance students' critical thinking abilities. This improvement is attributed to the contextual nature and high relevance of the materials to students' daily lives, which makes the learning process more effective and meaningful. Furthermore, these results align with previous studies demonstrating that e-learning approaches create more engaging, authentic, and relevant learning experiences, thereby increasing students' motivation, critical thinking skills, and cognitive performance (Verawati et al., 2022; Qurniati & Wahyudiati, 2023; Wahyudiati, 2023).

5. CONCLUSION

Based on the findings of this study, several conclusions were drawn: (1) The developed e-learning chemistry textbook obtained a validity score ranging from 0.857 to 0.905, which falls within the very high category, and a reliability coefficient of 0.865. These results indicate that the e-learning chemistry textbook is both valid and reliable for use in Basic Chemistry courses at the higher education level. (2) The results of the independent samples t-test revealed a significance value of 0.018, which is lower than the alpha threshold of 0.05. This demonstrates that the e-learning chemistry textbook is effective in enhancing students' critical thinking skills. The implications of this research suggest that educators and curriculum developers may use these findings as a reference in designing or implementing e-learning–based chemistry instructional materials to make chemistry learning more engaging and evidence-based. Furthermore, the application of e-learning–based textbooks holds potential not only in the natural sciences but also across various fields of study, including the social sciences.

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Research Ethics. This research has received ethical approval from the local university.

Data Availability Statement. All data can be obtained from the corresponding author.

Conflicts of Interest. The authors declare no conflict of interest.

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