

DEVELOPMENT OF AN INTERACTIVE FLIPBOOK TYPE E-BOOK TO IMPROVE STUDENTS' CRITICAL THINKING SKILLS ON ACID-BASE TOPICS

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Abstract

Critical thinking is an essential competency that should be developed in chemistry learning; however, conventional teaching methods are often considered insufficient to foster this skill effectively. One potential solution is the use of an interactive e-book as a learning material. The interactive e-book was designed by integrating Facione's critical thinking indicators, namely interpretation, inference, analysis, explanation, evaluation, and self-regulation, to facilitate students' independent learning and improve their understanding of acid-base concepts. This study aimed to develop an interactive flipbook-type e-book on acid-base topics and evaluate its validity, practicality, and effectiveness in improving students' critical thinking skills. The study employed the ADDIE development model. The product was validated by three validators consisting of a media expert, an acid-base subject matter expert, and a senior chemistry teacher. A limited field trial was conducted with 33 twelfth-grade students. The interactive e-book achieved a minimum validation mode score of 4 for both content and construct validity, indicating that it was valid for use in chemistry learning. The implementation of learning activities obtained an average score of 97.58%, while the practicality score reached 96.66%, indicating that the interactive e-book was implemented very well and was highly practical. The effectiveness of the interactive e-book was evaluated using the Shapiro–Wilk normality test followed by a paired-samples *t*-test. The analysis revealed a statistically significant improvement in students' critical thinking skills after using the interactive e-book ($p < 0.001$). These findings indicate that the developed interactive flipbook-type e-book is valid, practical, and effective in enhancing students' critical thinking skills in learning acid-base concepts.

Keywords: interactive e-book, critical thinking skills, acid-base, chemistry learning

INTRODUCTION

The rapid advancement of technology and communication in the twenty-first century has transformed the educational landscape and requires students to master essential twenty-first-century competencies. One of these competencies is critical thinking, which enables students to analyze arguments, draw logical conclusions, make judgments, and solve problems effectively [1]. According to [2], critical thinking consists of six core skills: interpretation, inference, analysis, explanation, evaluation, and self-regulation. In Indonesia, the Merdeka Curriculum emphasizes student-centered learning and encourages the integration of technology to support active, independent, and meaningful learning. Furthermore, the Chemistry Learning Outcomes for Phase F in BSKAP Decree No. 046/H/KR/2025

require students to develop scientific reasoning, critical thinking, collaboration, and innovation through deep learning approaches.

The rapid advancement of technology and communication in the twenty-first century has transformed the educational landscape and requires students to master essential twenty-first-century competencies. The educational sector has undergone significant transformation along with the advancement of globalization and information openness. This condition requires every individual to possess various competencies to adapt and contribute optimally. These competencies refer to the 4C framework formulated by the Partnership for 21st Century Skills (P21), which includes critical thinking, creativity, collaboration, and communication. Students' success in the learning process is strongly influenced by the mastery of

critical thinking skills as one of the essential twenty-first-century competencies. One of these competencies is critical thinking, which enables students to analyze arguments, draw logical conclusions, make judgments, and solve problems effectively [1]. According to [2], critical thinking consists of six core skills: interpretation, inference, analysis, explanation, evaluation, and self-regulation. In Indonesia, the Merdeka Curriculum emphasizes student-centered learning and encourages the integration of technology to support active, independent, and meaningful learning. Furthermore, the Chemistry Learning Outcomes for Phase F in BSKAP Decree No. 046/H/KR/2025 require students to develop scientific reasoning, critical thinking, collaboration, and innovation through deep learning approaches.

Interactive e-books are considered one of the digital learning resources that support the implementation of the Merdeka Curriculum. Their interactive features, such as animations, simulations, quizzes, and contextual problem-solving activities, enable students to actively construct knowledge while promoting higher-order thinking skills (HOTS). Consequently, interactive e-books not only facilitate students' understanding of chemistry concepts but also contribute to strengthening the Pancasila Student Profile by fostering independent learning, scientific reasoning, and critical thinking. Previous research by [3] demonstrated that e-books are valid and practical learning materials for supporting learning. However, most of these studies have focused on evaluating the feasibility of the media, while the development of e-books specifically designed to improve students' critical thinking skills in acid-base materials has received limited attention. Therefore, this study develops an interactive e-book that integrates Facione's six critical thinking indicators, namely interpretation, inference, analysis, explanation, evaluation, and self-regulation [2]. Thus, this study not only emphasizes the feasibility of the learning media but also facilitates the improvement of students' critical thinking skills in acid-base materials.

Based on interviews with a chemistry teacher at SMA Negeri 3 Sidoarjo, acid-base

learning is still supported mainly by printed worksheets (LKS and LKPD), which contain only brief explanations and lower-order cognitive questions (Bloom's taxonomy C1–C3). These learning materials do not explicitly facilitate the development of critical thinking skills despite the availability of adequate technological facilities, such as computers and internet access. A survey involving 30 twelfth-grade students revealed that 69.4% considered acid-base concepts to be the most difficult chemistry topic because of the large number of formulas, abstract theories, and limited learning resources. Furthermore, a preliminary study showed that students' critical thinking skills remained low across all indicators, with interpretation (52.07%), inference (55.86%), analysis (59.02%), explanation (76.20%), evaluation (41.84%), and self-regulation (41.84%).

Considering these findings, the development of an interactive flipbook-type e-book is necessary to address the limitations of conventional learning materials while supporting the demands of twenty-first-century education and the Merdeka Curriculum. This study differs from previous research by integrating contextual animations, simulations, and HOTS-based activities into acid-base learning with the explicit objective of improving students' critical thinking skills. Therefore, this study aims to develop an interactive flipbook-type e-book and evaluate its effectiveness in enhancing students' critical thinking skills on acid-base topics.

METHOD

This study employed a quantitative descriptive approach within the framework of Research and Development (R&D). This study employed the Research and Development (R&D) method, which aims to produce a product and to examine the effectiveness of the product. The objective of this study was to develop an interactive flipbook-type e-book on acid-base topics and to evaluate its validity, practicality, and effectiveness in improving students' critical thinking skills. The interactive flipbook-type e-book was developed using the ADDIE instructional design model adapted from [4], which consists of five stages:

Analysis, Design, Development, Implementation, and Evaluation, as presented in the following Figure 1.

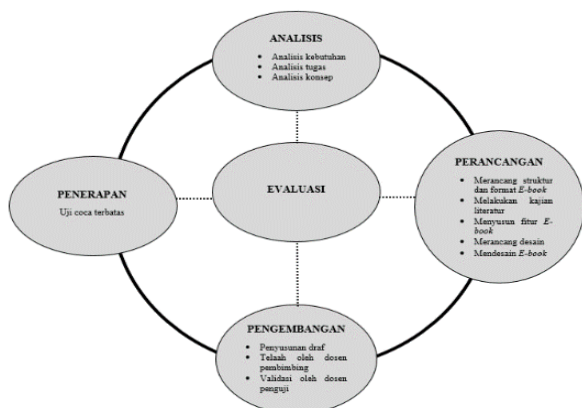


Figure 1. Development Design of an Interactive Flipbook-Type E-book on Acid–Base Topics to Improve Students’ Critical Thinking Skills

During the analysis stage, learning needs, curriculum, learning outcomes, acid-base concepts, and students’ critical thinking skills were analyzed through teacher questionnaires and literature review. The design stage involved determining the e-book structure, developing the learning content, interactive features, and critical thinking activities based on the learning objectives and Facione’s critical thinking indicators. In the development stage, the e-book was created using Microsoft Word, Canva, and Flip PDF Professional, followed by expert validation and product revision based on the validators’ feedback. The implementation stage consisted of a limited field trial involving 33 twelfth-grade students over four learning sessions, including the administration of the pre-test, learning activities using the interactive e-book, practical work, and the post-test. Finally, the evaluation stage was conducted formatively throughout the development process through expert validation, product revision, student responses, and limited field testing to determine the feasibility of the developed interactive e-book. The ADDIE model was selected because it provides a systematic and comprehensive framework for developing educational products, particularly digital learning materials.

The study was conducted at Universitas Negeri Surabaya and SMA Negeri 3 Sidoarjo in

November 2025. The proposal preparation, product development, expert review, and validation processes were carried out at Universitas Negeri Surabaya, whereas the product implementation and field testing were conducted at SMA Negeri 3 Sidoarjo. The product was validated by three validators consisting of a media expert, an acid-base subject matter expert from the Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya, and a senior chemistry teacher from SMA Negeri 3 Sidoarjo. The participants in the field trial were 33 twelfth-grade students of class XII F4 in the 2025/2026 academic year, selected using simple random sampling. The research design is illustrated in Figure 2.

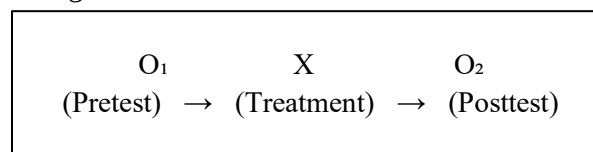


Figure 2. One Group Pretest–Posttest Design

The effectiveness of the developed interactive e-book was evaluated using a One Group Pretest–Posttest Design (Figure 1). Students completed a pretest to measure their critical thinking skills before the implementation of the interactive e-book (O₁) and a posttest after the learning activities (O₂). Data were collected through expert validation sheets, learning implementation observation sheets, student response questionnaires, and critical thinking tests. Product validity, learning implementation, and student responses were analyzed descriptively using the mode based on a five-point Likert scale in Table 1. The effectiveness of the interactive e-book was analyzed using pretest and posttest scores. The interactive e-book was considered feasible when the obtained mode was ≥ 4 .

Table 1. Likert Scale

Skor	Criteria
5	Very good
4	Good
3	Fair
2	Weak
1	Very weak

The effectiveness of the developed interactive e-book was evaluated by comparing students' pre-test and post-test scores. Prior to hypothesis testing, the data were examined for normality using the Shapiro–Wilk test. Since the data were normally distributed, a paired-samples t-test was performed using IBM SPSS to determine whether there was a statistically significant improvement in students' critical thinking skills after the implementation of the interactive flipbook-type e-book. Statistical significance was established at $p < 0.05$.

RESULTS AND DISCUSSION

Research on the development of an interactive e-book to improve students' critical thinking skills, with the final product being an interactive e-book that is valid, practical, and effective, and aimed at improving students' critical thinking skills, was conducted from November 3 to 10, 2025, involving 33 twelfth-grade students of class XII F4 at SMA Negeri 3 Sidoarjo. The final interactive e-book product consists of pages containing learning materials, instructions, and learning activities designed to develop students' cognitive aspects as well as to provide guidance for developing all aspects of learning through an interactive e-book based on critical thinking indicators. The interactive e-book was developed using the ADDIE development model. This study included the Analysis stage (needs, task, and concept analysis), Design (determining the e-book structure and format, developing the learning materials, organizing the features, and designing the e-book), Development (developing the interactive e-book and research instruments), Implementation, and Evaluation. Each stage was evaluated and revised before proceeding to the next stage.

The high percentage of students' activities during the learning process indicates that the developed interactive e-book is easy to use, attractive, and able to facilitate students to actively participate in the learning process. The available features, namely Chemistry Watch, Chemistry Understand, Chemistry Experiment, Chemistry Test Practice, and Chemistry Reflect, help students

understand the material, conduct experiments, develop critical thinking skills, and reflect on the learning activities that have been carried out. Therefore, based on the observation results of students' activities with an average percentage of 97.58%, the developed interactive e-book is categorized as very practical for use in acid-base learning as presented in the following Table 2.

Table 2. Observation Results of Students' Learning Activities

Students' Activities	P(%)
Average of Meeting 1	95.75
Average of Meeting II	95.61
Average of Meeting III	98.98
Average of Meeting IV	100
Overall Average	97.58

Practicality indicates that the developed learning materials are easy to use, easy to understand, and can be implemented in accordance with the learning. Furthermore, practicality is also demonstrated when the learning materials can be implemented well in the classroom, are student-oriented, and are able to support interaction during the learning process. The practicality score of 96.66% indicates that the critical thinking-based e-book on acid-base topics has a very high level of practicality. The e-book is easy to use, helps students understand the material, and has an attractive presentation that can increase students' learning motivation. Therefore, the developed e-book is suitable for use as a supporting teaching material in chemistry learning, especially on acid-base topics, as presented in the following Table 3.

Table 3. Results of the Students' Response

Assessment Aspect	P%
Average Ease Aspect	100
Average Practicality Aspect	95
Average Presentation Aspect	95
Overall Average of All Aspects	96,66

Based on the practicality score interpretation criteria, the average percentage of 96.66% falls within the range of 81–100%, indicating that the critical thinking-based e-book on acid-base topics is categorized as very practical. These results indicate that the e-book is easy for students to use, effectively supports the learning process, and has an attractive appearance and presentation that

facilitates students in understanding the learning material.

The effectiveness of learning materials can be measured through the assessment of students' learning outcomes. The effectiveness of the interactive e-book was evaluated based on the students' pretest and posttest results. These results were used to determine the feasibility of the developed interactive e-book in terms of its effectiveness. The purpose of administering the pretest and posttest was to determine the effect of the treatment on improving students' critical thinking skills. After obtaining the pretest and posttest results of students' critical thinking skills, as presented in the following Table 4.

Table 4. Pretest and Posttest Score of Students' Critical Thinking Skills

Critical Thinking Skills Indicators	Pretest (%)	Posttest (%)
Interpretation	53.95	91.96
Inference	56.26	84.85
Analysis	66.20	94.84
Explanation	76.51	83.73
Evaluation	42.42	85.66
Self-Regulation	63.63	96.81

Based on the research results, the use of the interactive e-book on acid-base topics was able to improve students' critical thinking skills. The improvement was reflected in the pre-test and post-test results as well as the achievement of the critical thinking indicators, including interpretation, analysis, inference, explanation, evaluation, and self-regulation. These results indicate that the interactive e-book not only functions as a teaching material for delivering learning content but also facilitates students in actively constructing their knowledge through the various learning activities provided.

The interactive e-book on acid-base topics was analyzed based on the results of the students' pre-test and post-test on critical thinking skills. Before hypothesis testing was conducted, the data met the normality assumption; therefore, the analysis was continued using the Paired Samples t-Test. Based on the analysis results, the mean pre-test score was 59.58, whereas the mean post-test score was 85.85. This indicates an increase in the

mean score of 26.27 points after the students participated in learning using the interactive e-book. This improvement indicates that the use of the interactive e-book was able to improve students' critical thinking skills on acid-base topics.

In addition to the increase in the mean score, the standard deviation of the post-test results was 7.336, which was lower than the pre-test standard deviation of 13.746. This indicates that the variation in students' scores after learning became smaller than before learning. In other words, the improvement in critical thinking skills occurred not only among some students but was also relatively evenly distributed across all students.

The effectiveness of the interactive e-book was also demonstrated by the results of the Paired Samples t-Test, which showed a Sig. (2-tailed) value of 0.000 ($p < 0.05$). This value indicates that there was a significant difference between the students' pre-test and post-test critical thinking skills. Therefore, the research hypothesis stating that the use of the interactive e-book can improve students' critical thinking skills on acid-base topics was accepted.

The improvement in students' critical thinking skills was inseparable from the characteristics of the developed interactive e-book. The e-book presents acid-base material systematically and is complemented by images, learning videos, illustrations, problem-based exercises, and activities designed to train Facione's critical thinking indicators, namely interpretation, analysis, inference, evaluation, explanation, and self-regulation. This presentation enables students not only to memorize acid-base concepts but also to analyze phenomena, relate concepts to everyday life, evaluate the information obtained, and draw conclusions based on scientific evidence.

The findings of this study are also consistent with Jean Piaget's constructivist theory, which states that students actively construct their knowledge through the processes of assimilation and accommodation. Assimilation is the process of integrating new information into existing cognitive structures, whereas accommodation is the process of adjusting or forming new cognitive structures

when the acquired information is inconsistent with prior knowledge. Through the use of the interactive e-book, students have the opportunity to connect their prior knowledge of acid-base concepts with new information presented through learning materials, illustrations, learning videos, and contextual phenomena. Furthermore, through activities such as observing, analyzing problems, answering critical thinking-based questions, and evaluating their findings, students adjust their understanding, resulting in the development of more comprehensive concepts. This process demonstrates the occurrence of assimilation and accommodation as proposed by Piaget, making learning more meaningful and contributing to the improvement of students' critical thinking skills.

The findings of this study are also supported by the Dual Coding Theory, which explains that information presented through a combination of verbal and visual representations is easier to understand and remember than information presented only in text form. The presentation of acid-base material in the form of text, illustrations, videos, and interactive activities in the e-book enables students to process information through two cognitive channels simultaneously, thereby improving conceptual understanding as well as critical thinking skills.

Based on the results of the statistical analysis and discussion, it can be concluded that the developed interactive e-book is effective in improving students' critical thinking skills on acid-base topics. Its effectiveness is evidenced by the increase in the mean score from 59.58 to 85.85 and the results of the Paired Samples t-Test, which showed a Sig. (2-tailed) value of 0.000 ($p < 0.05$). Therefore, the interactive e-book is feasible to be used as one of the teaching materials to support learning on acid-base topics while facilitating the development of students' critical thinking skills.

CONCLUSION

Based on the results of this study, it can be concluded that the interactive flipbook-type e-book developed for acid-base topics is valid, practical, and effective in improving twelfth-grade students' critical thinking skills. The e-book achieved a

minimum validation mode score of 4 from expert validators for both content and construct validity, indicating that it is suitable for use in chemistry learning. In addition, the e-book demonstrated a very high level of practicality, with an average practicality score of 96.66%, showing that it is easy to use, supports the learning process effectively, and facilitates students' understanding of acid-base concepts. Furthermore, the paired-samples t-test yielded a p-value of 0.000 ($p < 0.05$), indicating that students' posttest scores were significantly higher than their pretest scores. Therefore, the developed interactive flipbook-type e-book is effective in enhancing students' critical thinking skills on acid-base topics.

This study has several limitations. First, the study focused only on evaluating the quality of the interactive e-book in terms of its validity, practicality, and effectiveness. Second, the study was conducted only up to the initial implementation stage of the ADDIE model; therefore, no continuous evaluation was carried out to determine the long-term effectiveness of the e-book. Third, the developed interactive e-book only covers acid-base topics; therefore, the findings cannot yet be generalized to other chemistry topics. Future studies are recommended to develop interactive e-books for other chemistry topics, such as buffer solutions, salt hydrolysis, or chemical equilibrium, so that the benefits of the learning media can be applied to a broader range of subject matter. Future studies are also expected to conduct implementation with a larger sample size and involve several schools with different student characteristics, so that a broader understanding of the effectiveness of the e-book can be obtained and the research findings will have a higher level of generalizability.

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