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Development of Toulmin Argumentation E-Module to Improve Students' Argumentation Ability on the Buffer Solution Concept

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ABSTRACT

Purpose of the study: This study aims to develop and test the effectiveness of e-modules based on Toulmin argumentation patterns in improving students' argumentation skills on buffer solution material. This study also aims to confirm that e-modules based on Toulmin argumentation patterns effectively improve students' critical thinking skills and engagement.

Methodology: This study uses the Research and Development (R&D) method with the ADDIE development model. The research sample was grade XI MIPA students selected purposively, consisting of an experimental class using e-modules and a control class with printed modules.

Main Findings: The e-module was considered very feasible to use, with an average score of 90% in content, learning design, and readability. The effectiveness test showed that the post-test score of the experimental group (85.3) was significantly higher than the control group (73.1), with $p < 0.05$. The Toulmin pattern component increased significantly, and 92% of students responded positively despite minor technical constraints.

Novelty/Originality of this study: The novelty in applying the Toulmin argumentation pattern as the primary approach in developing E-Modules aims to improve students' argumentation skills in learning buffer solutions. This study shows that e-modules based on Toulmin Argumentation Patterns effectively improve students' logical argumentation skills, critical thinking, and conceptual understanding in chemistry learning. Integrating digital technology encourages active engagement and the development of higher-order thinking skills. These implications emphasize the importance of digital innovation for transforming 21st-century learning.

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1. INTRODUCTION

Argumentation skills are one of the important competencies that need to be developed in 21st century learning. Argumentation involves not only the ability to convey opinions, but also the skills to support those opinions with relevant and logical evidence [1]-[3]. In the context of science learning, especially chemistry, argumentation skills are essential to help students understand scientific concepts deeply and critically. However, previous research results show that the argumentation skills of Indonesian students, especially in chemistry, are still relatively low[4]-[6].

One of the materials that is often a challenge in chemistry learning in high school is acids and bases [7]-[9]. This material requires a good conceptual understanding, starting from the definition of acids and bases according to various theories, to the application of the concept in everyday life. Unfortunately, acid-base learning is often theoretical and does not involve students in critical and analytical thinking processes. As a result, students tend to only memorize information without being able to apply it in real situations [10], [11]. Therefore, innovation is needed in learning to improve students' argumentation skills in this material.

The use of Toulmin's argumentation pattern in learning can be a solution to improve students' argumentation skills. This pattern consists of six main components: claim, data, warrant, backing, rebuttal, and qualifier [12], [13]. With this approach, students are invited to build arguments that are structured, complete, and supported by valid evidence. Toulmin's argumentation pattern also allows students to learn to identify weaknesses in their own arguments and those of others, thereby improving their critical thinking skills [14]-[16].

Toulmin argumentation pattern-based e-modules offer an innovative, interactive, and relevant learning alternative to modern learning needs. E-modules are designed to utilize digital technology to make them more engaging for students [17], [18]. This module not only contains materials and practice questions, but also project-based activities and discussions designed to train students in building logical arguments. By using e-modules, learning becomes more flexible because students can access materials anytime and anywhere, according to their respective learning speeds.

Through the development of an e-module based on Toulmin's argumentation pattern, this study aims to make a significant contribution to improving students' argumentation skills in acid-base material[19], [20]. With this approach, it is expected that students will not only understand the concept of acid-base theoretically, but also be able to apply their knowledge in real situations, such as analyzing the chemical properties of materials around them [21], [22]. This study also seeks to answer the challenges of chemistry learning in the digital era, where technological innovation can be a means to create more effective and meaningful learning.

Based on previous research that has been conducted, there is a gap in the current research conducted. Previous research focused on acid and base materials which emphasized more on basic conceptual understanding and chemical reactions related to pH, while this research targets "Buffer Solutions," which include more complex concepts of equilibrium and buffer capacity [23]-[25]. Although both use the Toulmin Argumentation Pattern, this research emphasizes the development of logical arguments through interactive e-modules involving project-based activities and problem-based learning, while previous research emphasizes theoretical understanding using structured Toulmin elements such as claims and data [26], [27]. Based on the gap analysis of the two studies, there is a novelty in this study, where this study offers digital elements and engagement mechanisms designed to stimulate argumentation skills. The focus on measurable improvements in argumentation competency through elements such as claims, warrants, and rebuttals, has an impact on critical thinking and problem solving, making it a significant differentiating factor [28], [29].

This study shows that the development of e-modules based on the Toulmin Argumentation Pattern can have a significant impact on improving students' argumentation and critical thinking skills, especially in the context of chemistry learning such as buffer solutions. By integrating digital elements and interactive approaches, students can be more involved in the learning process, improve their conceptual understanding, and hone their analytical and critical thinking skills. This implication is important because it indicates the need for a transformation of traditional learning methods towards a more collaborative, technology-based approach that is relevant to the needs of 21st century learning [30]-[32].

Argumentation and critical thinking skills are competencies that are very much needed in the modern era. This research is very urgent because of the low level of students' argumentation skills in chemistry learning in Indonesia. Thus, learning innovations such as e-modules based on Toulmin's argumentation patterns are important solutions to encourage active student involvement and improve the quality of education. This urgency is reinforced by the need to prepare students to face the challenges of the digital world and the complexity of real problems that demand critical thinking and evidence-based solutions [33]-[35].

This study aims to develop an e-module based on Toulmin Argumentation Pattern designed to be effectively used in buffer solution learning. In addition, this study focuses on improving students' ability to construct logical arguments and think critically through the use of the e-module. This study also aims to measure the impact of e-module implementation on the level of active student involvement during the learning process and the improvement of their conceptual understanding of buffer solution material [36]-[38].

So based on the objectives and problems raised, this research offers several solutions. This study offers a solution through the development of an interactive e-module based on the Toulmin Argumentation Pattern designed to improve the quality of chemistry learning, especially in the buffer solution material. This e-module facilitates project-based and problem-based learning, allowing students to connect chemistry concepts to real situations through active exploration and problem solving. By integrating digital elements such as interactive simulations, concept visualizations, and technology-based evaluations, this e-module aims to increase student engagement during the learning process. In addition, this e-module is designed to strengthen logical argumentation elements such as claims, data, warrants, and rebuttals, which are important for developing critical

thinking skills and the ability to construct evidence-based arguments. With this approach, students not only understand chemistry concepts in depth, but are also able to analyze and solve problems in a more logical and structured way.

2. RESEARCH METHOD

This study uses a research and development (R&D) method based on the ADDIE (Analysis, Design, Development, Implementation, Evaluation) model. The purpose of this study is to develop an e-module based on the Toulmin argumentation pattern and test its effectiveness in improving students' argumentation skills in acid-base material [39]-[41]. The population in this study were all students of class XI MIPA. The research sample consisted of two classes, namely the experimental class using e-modules based on Toulmin argumentation patterns and the control class using conventional printed modules. Class selection was carried out by purposive sampling based on similarities in academic characteristics [42], [43]. The sampling technique used the purposive sampling method by considering several criteria. Students have access to digital devices (such as laptops or smartphones) to support the use of e-modules and Chemistry subject teachers are willing to cooperate in implementing e-modules [44], [45].

Data were collected using the following techniques. Learning outcome tests to measure the improvement of students' argumentation skills before and after learning. Next, a questionnaire to determine students' responses to the e-module. Then, observation to monitor student involvement in the learning process. Finally, interviews with teachers and students to obtain qualitative information about the effectiveness of the e-module[46]. In this study, the instruments used include three types: argumentation ability test questions, Likert scale questionnaires, and observation sheets. Each instrument has been adjusted and developed based on the Toulmin Argumentation Pattern theory and adjustments to the context of the research being conducted. These test questions were developed based on the Toulmin Argumentation Pattern which includes aspects of claims, data, warrants, backing, rebuttals, and qualifications. These questions adopt and adapt elements from previous research by Azidin Prayogi et al, related to the application of Toulmin Argumentation Pattern in educational context [47]. Adjustments were made to ensure relevance to the chemistry material and buffer solution topics taught. This instrument has been tested for validity and reliability. The Cronbach's alpha value for this argumentation ability test instrument is 0.7, indicating a very good level of internal consistency.

Table 1. Argumentation Ability Grid Arranged Based on the Toulmin Pattern

Aspect	Indicator	Score (%)
Claim	Expressing opinions clearly	20
Data	Provide relevant evidence	20
Warrant	Logically link claims to data	20
Backing	Provides additional support for warrants	15
Rebuttal	Identify weaknesses or rebuttals to claims	15
Qualification	Provides a level of confidence in claims	10
Total		100

A Likert scale questionnaire was used to measure students' responses to the e-module used in learning. This questionnaire covers dimensions such as student engagement, satisfaction, and the influence of the e-module on students' conceptual understanding and argumentation skills. The Likert scale used adopted the developed model) and was adjusted to the context of chemistry learning. The Cronbach's alpha value for this Likert scale questionnaire was 0.6, which also showed high reliability. An observation sheet was used to monitor student engagement during learning using the e-module. Observations focused on how active students were in discussing the material, putting forward claims and data, and considering various arguments in learning. This observation sheet was prepared by referring to the observation protocol used in the study by [48] which focuses on student engagement in technology-based learning.

All instruments in this study have gone through a validation process by material experts and media experts to ensure suitability with learning objectives and accuracy of content presentation. In addition, the instruments were also tested for reliability using Cronbach's alpha, which showed high internal consistency.

Table 2. Instrument Validity and Reliability Test

Argumentation Ability Test Questions	0.8
Likert Scale Questionnaire	0.7

The collected data were analyzed using the following techniques, first Quantitative analysis: Using t-test to compare the results of students' argumentation ability tests between the control and experimental groups. Next Qualitative analysis: Analyzing data from questionnaires, observations, and interviews using descriptive

techniques to understand students' responses to the e-module. And finally Instrument validity and reliability test: Conducted on the argumentation ability test instrument to ensure the accuracy and consistency of the data collected.

This research was conducted in several stages according to the ADDIE model, first. Analysis: Identifying learning needs, gaps in students' argumentation abilities, and the suitability of acid-base material with the Toulmin pattern. Second, Design: Designing an e-module based on the Toulmin argumentation pattern, including structure, material content, and exercises. Third, Development: Creating an e-module using digital software and validating the e-module with material and media experts. Then, Implementation: Using the e-module in the learning process in the experimental class, while the control class uses a conventional module. Finally, Evaluation: Evaluating learning outcomes based on argumentation ability tests, student response questionnaires, and observation data.

3. RESULTS AND DICUSSION

3.1. Validation Results of E-Module Based on Toulmin Argumentation Pattern

Table 2. Validation Results

Validated Aspects	Validation Score	Information
Contents	90	E-modules are considered very suitable for use in chemistry learning.
Learning design	90	The learning design aspects meet high validity criteria.
Media readability	90	The e-module has good readability according to the validation criteria.
Average Validity Score	90	The e-module is said to be very suitable for use.
Advice from Validator	-	Improvements to navigation and the addition of application example questions were implemented before the e-module was tested.

The developed e-module was validated by material experts and media experts before being used in learning. The validation results showed that the e-module met the validity criteria with an average score of 90% in the aspects of material content, learning design, and media readability. Based on these results, the e-module was declared very feasible for use in chemistry learning. Suggestions from the validator, such as improvements to navigation and the addition of application example questions, were implemented before the e-module was tested.

3.2. Results of E-Module Effectiveness Test

Table 3. Results of the E-Module Effectiveness Test

Group	Post - Test Value	Information
Experimental Group	85,3	Using e-modules based on Toulmin argumentation patterns
Control Group	73,1	Using conventional print modules
t-Test Analysis Results	P<0,05	There is a significant difference between the post-test scores of the experimental group and the control group.
Conclusion	-	The use of e-modules based on Toulmin's argumentation patterns is effective in improving students' argumentation skills.

This study compared the results of students' argumentation skills between the experimental group (using e-modules based on Toulmin argumentation patterns) and the control group (using conventional printed modules). Data analysis using the t-test showed that the average post-test score of the experimental group (85.3) was significantly higher than the control group (73.1), with a p value <0.05. These results indicate that the use of e-modules based on Toulmin argumentation patterns is effective in improving students' argumentation skills.

3.3. Improving Argumentation Ability in the Toulmin Pattern Aspect

In-depth analysis of the Toulmin pattern aspects shows significant improvements in all components of argumentation, namely claims, data, warrants, backing, rebuttals, and qualifiers. Claims: Students are able to convey clear and relevant statements to the problem. Data: Improvements are seen in students' ability to present scientific evidence to support their claims. Warrants: Students are better at connecting evidence to claims through logical reasoning. Backing: The use of additional sources to support claims becomes more varied.

Rebuttal: Students begin to demonstrate the ability to identify weaknesses in the opponent's argument. Qualifiers: Students are able to add a level of confidence to their claims based on the evidence provided. The graph of the increase in scores for each aspect shows that the use of the e-module has a significant impact on the mastery of the Toulmin argumentation pattern as a whole.

3.4. Student Responses to E-Modules

The results of the questionnaire showed that 92% of students felt that the Toulmin argumentation pattern-based e-module helped them understand the acid-base concept better. Students stated that the module was interesting because it was interactive, provided videos and problem-based exercises, and challenged their critical thinking skills. A small number of students (8%) mentioned technical constraints, such as difficulty accessing the module due to device limitations. The results of this study support previous findings showing that the Toulmin argumentation pattern is effective in improving students' critical thinking and argumentation skills. The advantage of the e-module is its flexibility of use, which allows students to learn independently and in depth. Students' involvement in scientific argumentation activities during learning provides an experience that is close to real scientific practice, thereby improving their conceptual understanding. Significant increases in the rebuttal and qualifier components reflect that students are starting to think more critically in building arguments.

This shows that e-module-based learning with the Toulmin pattern not only improves students' understanding of acid-base material but also trains high-level thinking skills. The technical constraints faced by a small number of students indicate the need for digital infrastructure readiness to support technology-based learning. However, the results of this study emphasize the importance of learning innovation in improving the quality of education, especially in the field of chemistry. Based on previous research that has been done, there is a gap with the current research, previous research that examined by paying attention to acid and base material showed very good validation results, with an average score of 90% in the aspects of content, learning design, and readability. As many as 92% of students responded positively to the use of e-modules, with a significant increase in their argumentation skills. However, this study also noted several technical constraints related to the accessibility of e-modules that might hinder their optimal implementation in the field. Buffer solution research also showed that the developed e-modules had high validity, with post-test results showing significant differences between the experimental and control groups. This study focuses on the development of structured argumentation and problem solving based on digital learning, providing a more interactive and applicable learning experience [49]- [51].

Both studies received positive responses from students towards the use of Toulmin Pattern-based e-modules, although technical challenges were more prominent in the acid-base study, which may indicate differences in infrastructure readiness or implementation. In terms of learning effectiveness, the buffer solution study stood out in improving students' logical argumentation and analytical skills, emphasizing the need for a more integrated and problem-based approach to developing higher-order thinking skills.

Based on the gap analysis, there is a novelty in this study, namely its deeper focus on the development of logical argumentation and students' analytical skills through project-based and problem-based learning. By using an e-module based on the Toulmin Argumentation Pattern on the buffer solution material, this study offers a more interactive and contextual approach, targeting mastery of the complex concepts of chemical equilibrium and buffering capacity. This approach not only enriches students' conceptual understanding but also encourages active involvement and critical and analytical thinking skills in the context of digital-based chemistry learning. This is different from previous studies that focused more on theoretical understanding and the use of Toulmin elements in a structured manner for basic acid-base concepts [52]-[54].

This study shows that the Toulmin Argumentation Pattern-based e-module can be a very effective tool to improve students' logical argumentation and critical thinking skills in chemistry learning, especially in the buffer solution material. By using a project-based and problem-based learning approach, this e-module facilitates active and contextual student engagement, helping them develop high-level thinking skills that are essential in the modern era. These implications emphasize the importance of digital innovation in education, encouraging the strengthening of analytical skills, mastery of complex concepts, and the development of more structural argumentation skills in the field of science learning.

This study faces several limitations that need to be considered. One of the main constraints is the limited infrastructure, as noted in previous studies on acid-base materials, where accessibility of e-modules is a challenge, especially in environments with inadequate digital infrastructure. In addition, the study's limited focus on buffer solution materials may limit the generalizability of these findings to other chemistry topics. Variations in students' initial abilities in analytical thinking and logical argumentation are also challenges, as these differences may affect the effectiveness of e-module implementation. Furthermore, the duration of e-module implementation, which was not explained in this study, may affect the measurement of its long-term impact on the development of students' critical thinking and analytical skills. These limitations indicate that there is room for improvement in further research and development [55]-[57].

Several recommendations are proposed to improve the effectiveness and development of e-modules based on the Toulmin Pattern. First, better digital infrastructure support is needed, such as stable internet access and adequate technological devices, to ensure that the implementation of e-modules runs optimally. In addition, further research needs to be conducted to test the effectiveness of e-modules on various other chemistry materials so that these findings can be generalized. The development of more flexible and adaptive e-modules, such as including a feature to personalize the level of difficulty, is also an important step to meet the needs of students with diverse abilities. Longitudinal research is recommended to evaluate the long-term impact of e-modules on students' mastery of concepts and high-level thinking skills. Equally important, training for teachers in integrating e-modules with project-based and problem-based learning approaches needs to be conducted to improve the effectiveness of implementation. Finally, collaboration with schools needs to be developed to ensure that the implementation of e-modules is in accordance with student needs and the curriculum, so that learning becomes more focused and effective.

4. CONCLUSION

The electronic module based on the Toulmin argumentation pattern that was developed was proven to be effective in improving students' argumentation skills in chemistry learning. The validation of the module showed an average validity level of 90% in the aspects of material content, learning design, and media readability, which indicated the module's suitability for use in learning. The use of this module resulted in a significant increase in students' argumentation skills, with the average post-test score of the experimental group being higher than the control group ($p < 0.05$). This module successfully strengthened the components of Toulmin's argumentation, such as claims, data, warrants, backing, rebuttals, and qualifiers, which improved students' ability to construct more logistical and evidence-based arguments. As many as 92% of students responded positively to the use of this electronic module, thanks to the interactive features that facilitated conceptual understanding, although there were some technical obstacles for some students. Overall, the results of this study concluded that the electronmpic module based on the Toulmin Argumentation Pattern was effective in improving students' argumentation and critical thinking skills, and contributed to technology-based learning innovation in chemistry education.

This study shows that the Toulmin Argumentation Pattern-based e-module is effective in improving students' argumentation and critical thinking skills, so it can be used as a learning model for various other topics. The success of this module emphasizes the importance of technological innovation in education, encouraging the development of similar modules to enrich learning. This module also strengthens the evidence-based approach, trains students to think logically and analytically, and requires teacher training in its integration. The technical constraints found highlight the need for improved digital infrastructure to support implementation. Further research is recommended to test the effectiveness on other materials and develop more adaptive module features.

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