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Chemistry Learning Media Innovation: Interactive Website Development for Buffer Solution Material

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ABSTRACT

Purpose of the study: To determine the feasibility of website-based buffer solution learning media as a learning resource for class XI students at State Senior High School 13 Semarang.

Methodology: This study used the Research and Development method, with the Thiagarajan model, which includes defining, designing, and developing. The feasibility of the learning media was based on the assessment results of media experts, material experts, high school chemistry educators, and student responses to the website-based learning media.

Main Findings: The assessment results from material experts were 66.67%, categorized as good. The assessment results from media experts were 86.1%, categorized as very good. The assessment results from high school chemistry educators were 79.1%, categorized as good. The results from the student response questionnaire were 76.67%, categorized as good. Based on these results, it can be concluded that website-based learning media is suitable for use as a learning resource for students.

Novelty/Originality of this study: This study presents the development of a website-based chemistry learning medium specifically designed for the topic of buffer solutions, integrating interactive features and self-paced learning components. Unlike previous studies, this study emphasizes accessibility and conceptual understanding through a digital platform. This research advances existing knowledge by providing an innovative and validated learning resource that supports flexible learning and enhances student engagement and understanding in chemistry education.

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1. INTRODUCTION

Chemistry education plays a crucial role in equipping students with scientific thinking skills and a deep understanding of concepts [1], [2]. However, many students still struggle to grasp abstract concepts in chemistry. One topic often considered difficult is buffer solutions, as they involve the concepts of equilibrium and mathematical calculations [3], [4]. This situation highlights the need for innovation in the learning process to facilitate comprehension. Therefore, developing effective learning media is crucial for improving the quality of chemistry learning [5], [6].

Developments in information technology have provided significant opportunities in education, particularly in the development of digital-based learning media [7], [8]. Website-based learning media is an alternative that can be easily accessed by students anytime and anywhere [9], [10]. Websites allow for interactive presentation of material through a combination of text, images, animations, and evaluations [11], [12]. This makes learning more engaging and less monotonous. This is expected to increase student motivation and engagement in learning chemistry.

Buffer solutions are a crucial topic in chemistry with widespread applications in everyday life and industry. This concept is closely related to the ability of a solution to maintain its pH when an acid or base is added. Despite their importance, many students have misconceptions regarding the mechanism of action of buffer solutions [13], [14]. This is due to the limitations of conventional learning media [15], [16]. Therefore, media capable of explaining concepts visually and interactively is needed.

The use of interactive learning media has been proven to improve conceptual understanding and student learning outcomes [17], [18]. Well-designed media can help students connect abstract concepts with more concrete visual representations [19], [20]. Furthermore, interactive media also allows students to learn independently at their own pace [11], [21]. However, many media still haven't fully utilized the potential of digital technology. This indicates an opportunity to develop more innovative learning media.

The development of website-based learning media offers several advantages over conventional media [22], [23]. Websites can be designed with interactive features such as simulations, quizzes, and direct feedback that support the learning process. Furthermore, websites are easily updated so that material can be adapted to curriculum developments. Ease of access through various devices is an added value in supporting flexible learning [24], [25]. Therefore, website-based media is a relevant solution in modern chemistry learning [23], [26].

Several previous studies have developed digital learning media for chemistry learning, but they still suffer from limitations in interactivity and material focus [27], [28]. Most media have not specifically examined buffer solutions in depth. Furthermore, the integration of concepts, practice questions, and evaluation within a single platform is still suboptimal. This indicates a research gap that needs to be filled. Therefore, the development of integrated website-based learning media is crucial.

This research is novel in the development of website-based chemistry learning media specifically designed for buffer solutions, integrating interactive features, concept visualizations, and self-assessment within a single, structured platform. Unlike previous research, this media not only presents the material but also facilitates independent learning and deeper conceptual understanding [29], [30]. The urgency of this research is based on students' still-poor understanding of the concept of buffer solutions and the limitations of learning media used in schools. Furthermore, the demands of learning in the digital era necessitate innovative media that are easily accessible and engaging for students. Therefore, this research is crucial to address the need for more effective, interactive, and technologically relevant chemistry learning.

Based on this description, this study aims to determine the feasibility of website-based buffer solution learning media as a learning resource for students. The developed media is expected to help students understand concepts more effectively. Furthermore, this media is also designed to increase student engagement and independence in learning. This research also aims to test the media's feasibility through expert validation and user feedback. Therefore, the results are expected to contribute to innovation in chemistry learning.

2. RESEARCH METHOD

2.1. Development Model

This study applies a research and development method aimed at producing a product and testing its effectiveness. The development model used refers to a four-stage model consisting of definition, design, development, and dissemination [31], [32]. However, in its implementation, the model was simplified into three stages: definition, design, and development. Due to time constraints, the dissemination stage was not carried out. Each stage in this model is designed to produce a structured and systematic learning system. The results of this study are website-based learning media focused on buffer solution material for eleventh-grade students.

2.2. Development Procedures

The development procedure for website-based learning media in this study refers to the development stages, consisting of definition, design, and development. The definition stage, the primary objective is to establish and formulate the basic requirements for developing the learning media [33], [34]. This stage begins with an initial analysis to identify problems encountered in the student learning process, including aspects of knowledge, skills, and attitudes. Furthermore, a gap analysis is conducted between expected and actual conditions, as well as student learning needs. Next, an analysis of student characteristics is conducted through questionnaires and interviews to obtain information on learning outcomes, material perceived as difficult, learning methods used, available facilities, and responses to the learning media. The next stage is task analysis, which aims to assess student skills through a review of the tasks given in the learning process, including content structure, procedures, information processing, and learning objectives that refer to the curriculum. Furthermore, a concept analysis is conducted to identify key concepts in the buffer solution material aligned with core competencies and basic competencies [35]. Based on this overall analysis, learning objectives are formulated, which serve as the basis for determining achievement indicators and the direction of media development to ensure they remain aligned with the applicable curriculum. In the design stage, activities focused on developing a prototype of the learning media. This stage began with selecting media tailored to the learning objectives, student characteristics, and any material deemed difficult. Next, a format was selected, encompassing the design of the learning content, the approach used, and relevant learning resources. The format was designed to be engaging, easy to use, and effectively support the understanding of chemistry concepts. Subsequently, an initial product design was developed, in the form of a website-based learning media prototype, adapted from the analysis results from the previous stage. This initial design was then consulted with the supervisor to obtain input as a basis for improvements before the product was further developed.

The development stage is the realization of the developed design into a product ready for testing. At this stage, the learning media, still in its conceptual stage, is developed into a product that can be used in learning. Validation was then conducted to assess the product's feasibility, which included media validation by experts in the field of learning media and material validation by experts in the field of chemistry. This validation process aims to identify the product's strengths and weaknesses so that improvements can be made. Following the validation stage, the product was piloted on a small group of nine students with varying ability levels. Students were asked to use website-based learning media and then provide feedback via a questionnaire regarding the media's design and usability. The results of this trial were used as a basis for revisions to improve the quality of the developed product.

2.3. Research Subjects

The subjects in this website-based learning media development research consisted of validators and students. The validators were a group of experts, including a chemistry subject matter expert on buffer solutions, a website-based media expert, and a chemistry educator [36]. Furthermore, this study involved nine eleventh-grade students in the natural science program from a high school as product trial subjects. The experts in this study consisted of two types: subject matter experts and media experts. The subject matter experts were chemistry lecturers with at least a master's degree and experience teaching chemistry, specifically buffer solutions. Meanwhile, the media experts were lecturers competent in developing computer-based learning media with a minimum master's degree. The involvement of these experts aimed to assess the feasibility of the product in terms of the material and design of the media developed.

In addition to the experts, chemistry educators were also involved as validators in this study. These educators were chemistry teachers who taught at the school where the research was conducted. Their role in this study was to assess the suitability of the learning media for classroom learning needs and student characteristics. The target students in this study were eleventh-grade science students selected based on initial observations. The class selected was one with a relatively better understanding of chemistry than other classes. From this class, nine students were selected and divided into three groups based on their ability level: high, medium, and low. This division aimed to obtain a more comprehensive picture of the effectiveness of the developed learning media for various levels of student ability.

2.4. Data Collection Techniques

This research requires valid data sources and appropriate data collection techniques to ensure the data meets established standards. Therefore, the researcher employed several data collection techniques tailored to the research needs. The first technique used was observation. Observation is the direct observation of the research object, utilizing all senses to obtain accurate information. In its implementation, the researcher used an observation sheet to record learning conditions and student activity during the chemistry learning process. Observations were conducted directly at the research location, involving chemistry educators and nine students as research subjects [37]. The second technique was interviews. Interviews were used to gather in-depth information regarding the educators' learning media development process. Through interviews, the researcher was able to obtain more detailed data regarding educators' needs and experiences in using learning media. The interviews in this study were conducted with chemistry educators teaching eleventh grade at the school where the research was conducted.

The third technique was a questionnaire. A questionnaire is a data collection method that involves providing respondents with a series of written questions to answer. The use of questionnaires aims to collect data efficiently, especially given the large number of respondents. In this study, a questionnaire was used to determine students' needs for website-based learning media, particularly for buffer solutions, and to obtain expert and student assessments of the developed media. The final technique was documentation. Documentation was used to collect data in the form of notes or documents relevant to the research. The data collected through this technique consisted of written information that supported the research. In this study, the documentation data used included students' grades before the learning improvement activities were implemented. This technique assisted researchers in obtaining objective and accountable supporting data.

2.5. Data Analysis Techniques

Data analysis techniques are the steps taken to process and interpret data after the entire data collection process is complete. This process begins with reviewing all data obtained from various sources, such as observations, interviews, questionnaires, and documentation. Each piece of data collected is systematically analyzed to provide a clear picture of the research findings. Therefore, data analysis is a crucial part of determining research conclusions.

The analytical method used in this development research is tailored to the research objective, which is to assess the feasibility of website-based learning media in supporting the achievement of expected competencies. The analysis focuses on the results of validation instrument assessments provided by several validators. These validators include material experts, media experts, and students as users of the learning media.

The validation test conducted by media experts, material experts, and students aims to determine the feasibility of the developed product. This assessment covers aspects of content, media presentation, and ease of use. The results of the validation test are then analyzed to determine whether the website-based learning media on buffer solutions meets the feasibility criteria as a learning resource. The assessment results are then calculated using a specific formula to obtain a quantitative feasibility score. The results of the validation test can be calculated using the following formula:

$$Presentation = \frac{\sum(\text{answer } x \; weight \; of \; each \; choice)}{n \; x \; highest \; weight} \ldots (1)$$

Table 1. Conversion of Achievement Levels

Percentage	Category	Information
81.25% ≤ x ≤ 100%	Excellent	Very good to use
62.50% ≤ x ≤ 81.25%	Good	Can be used with minor revisions
43.75% ≤ x ≤ 62.50	Fair	Can be used with major revisions
25% ≤ x ≤ 43.75	Poor	Must not be used

3. RESULTS AND DISCUSSION

This website-based chemistry learning media was developed with the aim of increasing student interest in learning and helping them understand the concept of buffer solutions more effectively. Based on the discussion of the development and manufacturing process, it can be concluded that this media has the potential to be an innovative and relevant alternative for chemistry learning. In the next stage, the developed media underwent validation testing by experts consisting of material experts and learning media experts. This validation aimed to assess the product's feasibility and identify its strengths and weaknesses. The results of the first stage of validation showed that the achievement level for the material aspect was 45.5%, while for the media aspect it was 53.8%. These values indicate that the media is still in the sufficient category and requires significant revision. The low validation results in the first stage were due to several shortcomings, both in the material and media aspects.

In the material aspect, misconceptions and a lack of examples of applications in everyday life were still found. Meanwhile, in the media aspect, several weaknesses existed, such as the use of an inappropriate domain, suboptimal display layout, lack of animation, and the lack of feedback features in the quizzes. Therefore, comprehensive improvements were made based on input from the validators. After the revisions, the learning media was re-validated to assess the results of the improvements. The results of the second validation phase showed a significant increase of 66.67% in the material aspect and 86.1% in the media aspect. This improvement indicates that the quality of the media has improved considerably, with the material aspect being in the good category and the media aspect being in the very good category. Therefore, this website-based learning media was declared suitable for use. In addition to validation by experts, the learning media was also validated by chemistry educators in high schools. The validation results from the educators showed a score of 79.1%, which is in the good category. This result indicates that the developed learning media is appropriate for classroom learning needs and can be used without further revision.

Limited user testing was conducted in small groups to obtain input and suggestions from potential users of the learning media. This phase involved eleventh-grade science students and chemistry educators. Nine students representing various ability levels were selected: three students with low ability, three students with medium ability, and three students with high ability. This selection was intended to ensure that the sample used represented the characteristics of the target population for the media being developed.

A limited user test was conducted by asking students to provide feedback on the website-based chemistry learning media that had been developed. This activity aimed to determine the level of suitability and meaningfulness of the media as a learning tool. Furthermore, this feedback test was also expected to provide an overview of the media's quality before its use on a wider scale. At this stage, students were given a questionnaire containing several questions related to various aspects of the learning media. Aspects assessed included the suitability of the material, design appearance, clarity of writing, level of motivation generated, and the usefulness of the media's use. The data obtained from this questionnaire were then analyzed to determine students' responses to the developed media. The results of this limited user test serve as the basis for further improvements and development of the learning media. With student input, it is hoped that the resulting media will be more optimal and meet user needs. Furthermore, the improved media can be tested on a wider scale to obtain more comprehensive results.

Table 2. Results of Student Response Questionnaire in Small Classes

Indicators	Average Percentage
Content Quality	75.0%
Enjoyment	68.85%
Evaluation	65.60%
Motivation	76.70%
Grammar	81.0%
Appearance	80.0%
Average	75.67%

Based on the questionnaire data from the small class, it was found that the student response indicator score for the website-based chemistry learning media for buffer solutions was 75.67%. Therefore, it can be concluded that the learning media is suitable for use. The research and development conducted by this researcher did not include operational field trials, but rather limited field testing.

Based on the results of the problem analysis, supporting media is needed as an alternative solution for the learning process. This media is a website-based chemistry learning media designed to be easy to understand, engaging, innovative, and creative. This media development is expected to increase student interest and motivation in learning chemistry, particularly buffer solutions. Therefore, the researcher took the initiative to develop a website-based learning media as a more effective learning tool.

The results of expert testing on the initial design of the learning media revealed various input and suggestions from the validators. This input served as the basis for improvements and refinements to the developed product. The revision process was carried out to improve the quality of the media, both in terms of content and presentation. These improvements were then analyzed to determine the improvement in validation results. The description of the increase in validation results from experts is presented in graphic form in the research results section.

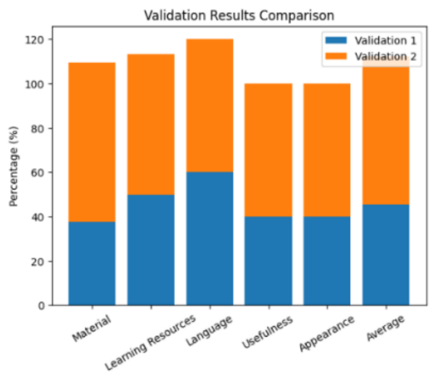

Figure 1. Content Assessment Graph

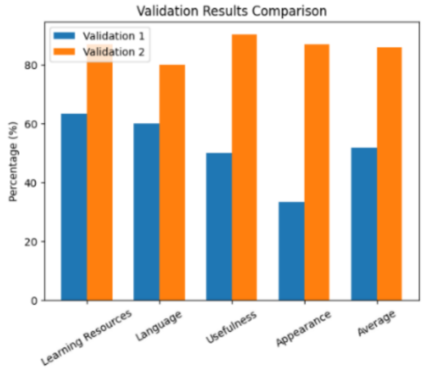

Figure 2. Media Content Assessment Graph

Based on the graphs displayed, changes in the assessment results before and after the validation process can be seen. The validation results from the material experts in the first assessment showed an average score of 45.50%, as depicted in the white graph. After revisions, the results of the second validation increased to 66.67%, as shown in the black graph. Meanwhile, the validation results from the media experts in the first assessment showed an average score of 51.65%, which increased to 85.85% in the second assessment after revisions. Based on the assessments from the material experts, it can be concluded that the quality of the learning media was initially in the "fair" category, with a rating of "suitable for use with revisions." After revisions, the quality of the material improved and entered the "good" category. This indicates that the revisions successfully addressed deficiencies in the material, making it more aligned with learning objectives.

The assessment results from the media experts indicate that the learning media was already in the "good" category at the initial stage. After revisions, the quality of the media significantly improved, reaching the "very good" category. This indicates that the media's appearance, design, and features met the expected criteria after the improvements. Furthermore, the website-based learning media was validated by chemistry educators to determine its suitability before use in the learning process. Validation by educators is crucial because educators understand the actual learning conditions in schools. The validation results from educators showed a score of 79.1%, which is considered good, so the learning media did not require further revision.

After being declared suitable, the learning media was then piloted with students as users. The pilot test was conducted on a small group of nine eleventh-grade science students. The students were divided into three groups based on their ability levels: high, medium, and low. This small group pilot test aimed to obtain student responses to the website-based learning media. Assessment was conducted through the distribution of questionnaires containing various aspects of the media's assessment. Through this activity, researchers were able to identify variations in student responses and assess the level of acceptance of the media as a learning tool. A graph containing student responses to this website-based learning media is shown in Figure 3.

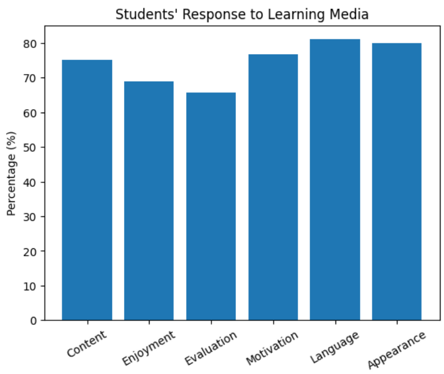

Figure 3. Graph of Student Responses to Website-Based Learning Media.

The results of the student responses obtained show a percentage that falls into the good and very good categories. Based on these assessment results, the average student responses indicate that this learning media is suitable for use in learning.

The development of website-based learning media for buffer solutions in this study demonstrates that integrating digital technology into chemistry learning has significant potential in bridging students' difficulties with abstract concepts. Conceptually, buffer solutions require simultaneous understanding at the macroscopic, submicroscopic, and symbolic levels [38]. Therefore, the presence of website-based media capable of integrating these various representations is highly relevant. Interactive media allows students not only to passively receive information but also to construct understanding through independent exploration, thus aligning with the constructivist approach to chemistry learning [2], [39].

Furthermore, the interactive features in the developed media, such as quizzes with immediate feedback and concept visualizations, play a crucial role in supporting self-regulated learning. In the context of chemistry education, independent learning skills are crucial given the complexity of the material, which often requires repetition and gradual deepening of concepts. Website-based media provides flexible access, allowing students to learn at their own pace, accommodating individual differences in ability [40]. This is a key advantage over conventional learning media, which tend to be one-way.

From a pedagogical content knowledge perspective, the development of this media also demonstrates an effort to align chemistry content with appropriate delivery strategies. Previously, buffer solution material tended to be presented in mathematical and theoretical formats, but this media allows for more contextual visualization [35]. This visualization helps students understand the working mechanisms of buffer solutions, particularly in maintaining pH, a common source of misconceptions. Thus, this media serves not only as an aid but also as a means to reconstruct students' conceptual understanding.

Furthermore, the development of this media also reflects the importance of technology-based learning design that emphasizes not only aesthetic aspects but also cognitive aspects. Principles of multimedia learning theory, such as the integration of text and visuals, and the structured presentation of information, are crucial factors in increasing the media's effectiveness [41]. Media designed with students' cognitive load in mind can help reduce cognitive overload, thus optimizing the learning process. Therefore, the quality of media design is a crucial factor in determining the success of its implementation in chemistry learning.

However, this media development still has limitations in measuring the direct impact on improving students' conceptual understanding. This research focuses more on feasibility and user response, thus not being able to provide an empirical picture of the media's effectiveness in improving learning outcomes. Therefore, further research is needed to examine the effect of this media on students' conceptual understanding, critical thinking skills, and the reduction of misconceptions regarding buffer solutions.

Overall, the results of this development contribute to the field of chemistry education, particularly in the innovation of digital-based learning media. Systematically designed website-based media based on student needs can be an alternative solution to address the challenges of chemistry learning in the digital age. The practical implication of this research is that educators need to begin integrating technology more optimally into their learning, not merely as a supplement, but as an integral part of a learning strategy oriented toward conceptual understanding.

This research has a positive impact on the development of chemistry learning, particularly in the use of website-based media as a means to improve the quality of learning in buffer solutions. The developed media has the potential to support more interactive, flexible, and student-centered learning, thereby helping to reduce difficulties in understanding abstract concepts through visual presentation and interactive features. Furthermore, this media also contributes to encouraging students' independent learning and increasing their motivation and engagement in the chemistry learning process. Practically, the results of this research can serve as a reference for educators in integrating digital technology into learning, as well as a basis for developing other innovative learning media relevant to 21st-century needs.

However, this research has several limitations that require consideration. This study only conducted a small group trial, thus not being able to broadly describe the media's effectiveness in real classroom learning contexts. The limited number of subjects also hinders the generalizability of the research results. Furthermore, this study did not directly measure improvements in students' conceptual understanding or reductions in misconceptions following the use of the media. Another limitation lies in the lack of operational field trials and long-term evaluation of the media's use. Therefore, further research is needed with a more comprehensive experimental design to empirically test the effectiveness of the media and expand the scope of its implementation in chemistry learning.

4. CONCLUSION

Based on the results of data analysis and discussion, several conclusions can be drawn as follows. First, this research and development used a four-stage development model modified into three stages, namely definition, design, and development. This research resulted in a website-based chemistry learning media on the material of buffer solutions. The developed media has several main components arranged in the form of a menu, namely the homepage, curriculum, apperception, teaching materials, important information sections, reflections, bibliography, and a question column as a means of interaction. Second, the developed website-based chemistry learning media proved to be suitable for use in the learning process. This is indicated by the validation results from media experts who obtained a score of 86.1% with a very good category, and the validation results from material experts of 66.67% with a good category. In addition, the validation results from high school educators showed a score of

79.1% which is included in the good category. Furthermore, the results of student responses to the learning media showed an achievement level of 76.67% with a good category. These results indicate that the developed website-based learning media can be well received by students and is suitable for use as a learning resource in chemistry learning. Future research is recommended to test the effectiveness of this website-based learning media through an experimental design involving a larger and more diverse sample, so that improvements in conceptual understanding and reductions in student misconceptions can be more comprehensively measured.

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AUTHOR CONTRIBUTIONS

Conceptualization, F.F. and M.S.; Methodology, F.F.; Software, F.F.; Validation, F.F. and M.S.; Formal Analysis, F.F.; Investigation, F.F.; Resources, M.S.; Data Curation, F.F.; Writing – Original Draft Preparation, F.F.; Writing – Review & Editing, F.F. and M.S.; Visualization, F.F.; Supervision, M.S.; Project Administration, F.F.; Funding Acquisition, M.S.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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