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Development of Website Based Learning Media with Problem Based Learning Model to Improve Student Learning Outcomes on Chemical Equilibrium Material at High School Level

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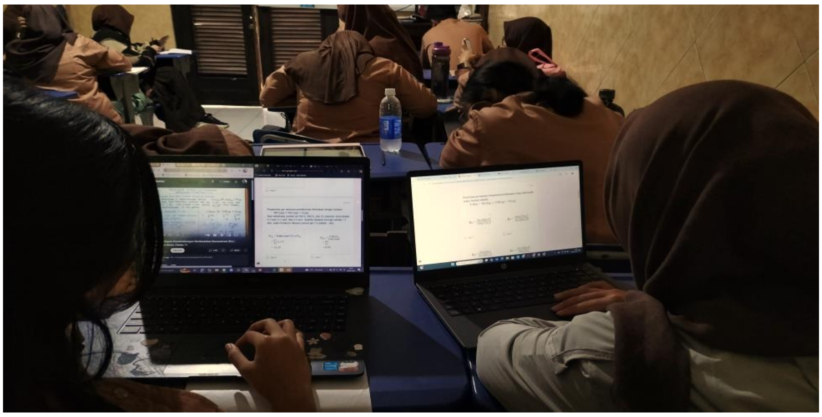
This study aimed to develop and produce a website-based learning media integrated with the Problem-Based Learning (PBL) model on chemical equilibrium topics, to examine the product's validity, feasibility, and practicality, as well as to evaluate its effectiveness on students learning outcomes. The research employed a Research and Development (R&D) approach using the ADDIE development model integrated with the PBL model and supported by Google Sites. The study involved 34 eleventh-grade students and applied a pre-experimental research method with a one-group pretest–posttest design. The results indicated that the website-based learning media demonstrated a very high level of validity. The feasibility test showed that the product met the feasible criteria, while the practicality test indicated that the media was categorized as very practical. The implementation of the learning media had a positive impact on students' learning outcomes, as evidenced by an N-gain score of 0.564, classified as a moderate improvement, and an effect size of 1.05, classified as a very large improvement. These findings demonstrate that website-based learning media integrated with the Problem-Based Learning model is effective as an instructional innovation in chemistry education to enhance the quality of both the learning process and students' learning outcomes, and it has the potential to serve as a reference for the development of digital learning media in other chemistry topics.

Graphical abstract



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1. Introduction

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Students' learning outcomes in chemical equilibrium topics remain low due to the difficulty of understanding abstract chemical concepts [1]. Learning outcomes represent the final results or levels of achievement in the learning process, as they serve as a foundation for measuring students' competencies and evaluating the effectiveness of teachers' instructional practices [2]. Previous research from Danggus [3] reported that chemical equilibrium yielded the lowest average test scores compared to other chemistry topics. This topic is characterized by abstract concepts and mathematical formulations that are often challenging for students to comprehend [4]. Another contributing factor to these learning difficulties is the limited implementation of technology-based interactive learning, even though innovative learning media have been shown to contribute significantly to improving educational quality [5]. Therefore, the adoption of innovative learning media is considered a viable solution to support and enhance students' learning outcomes in the instructional process.

Learning media are tools designed to deliver instructional content in a way that stimulates students' thinking, emotions, and attention, thereby creating meaningful learning experiences [6]. Website-based learning media developed using Google Sites serve as an alternative form of interactive instructional media that can be adopted by educators due to their flexible accessibility, which supports independent learning and enhances students' conceptual understanding [7]. In chemistry education, the effectiveness of learning media is strengthened by the presentation of concepts through multiple forms of representation, such as visual and symbolic representations, as emphasized in the theory of multiple representations to facilitate the understanding of abstract concepts [8]. However, the effectiveness of learning media ultimately depends on their integration with appropriate instructional models, as such integration is essential to ensure that students' learning experiences become more dynamic and optimally structured [9, 10].

The instructional model that supports this learning process is Problem-Based Learning (PBL), as it is grounded in constructivist theory, in which students actively construct their own knowledge through the learning process [11]. Problem-Based Learning is a meaningful instructional model that promotes active learning by enabling learners to develop knowledge derived from experience and has been shown to deepen scientific understanding [12]. Research conducted by Jansson et al. [13] revealed that the Problem-Based Learning model can optimize students' learning outcomes in chemistry and effectively support student engagement during the learning process. Similarly, a study by Nuswowati et al. [14] reported comparable findings, demonstrating that the Problem-Based Learning model is capable of enhancing students' cognitive abilities in chemistry. This improvement is reflected in the percentage of students who achieved mastery based on the average cognitive learning outcome scores. Therefore, the implementation of the PBL model is expected to contribute to improved student learning outcomes.

Previous studies have addressed the development of learning media and the improvement of students' learning outcomes through the implementation of instructional models. For instance, Danin [15] reported that website-based chemistry learning media were effective due to their accessibility, interactivity, and flexibility. Meanwhile, the Problem-Based Learning (PBL) model has been proven to enhance students' learning outcomes in chemistry, as it provides learners with challenges to solve real-life problems and encourages them to connect these problems with instructional content [13]. However, studies integrating Google Sites with the PBL model specifically on chemical equilibrium topics remain limited. Therefore, this study offers novelty by developing and implementing Google Sites–based learning media integrated with the PBL model and by examining its validity, practicality, feasibility, and effectiveness in improving students' learning outcomes.

Based on the previous explanation, an appropriate solution to the identified problems is required, namely the development of website-based learning media to support instructional activities in an eleventh-grade chemistry class at a public senior high school in Malang, focusing on chemical equilibrium topics. This study is important because it contributes to the development of digital learning resources that are relevant to the conditions and needs of both students and teachers. This research aims to:

- To develop website-based learning media integrated with the Problem-Based Learning model for chemical equilibrium topics;
- To analyze the validity, feasibility, and practicality of the developed learning media;
- To evaluate the effectiveness of the learning media in improving students' learning outcomes.

2. Material and Methods

2.1 Participants

The subjects of this study included one lecturer from Universitas Negeri Malang, a chemistry teacher, and one class of eleventh-grade students (class XI-D) from the 2024/2025 academic year at a public senior high school in Malang. The selection of student participants employed a purposive sampling technique. The sample was chosen based on the alignment of chemical equilibrium content with the currently implemented curriculum, as well as the readiness of both students and teachers to use website-based learning media. This study complied with ethical principles in educational research. Informed consent was obtained from students as research participants, and official permission was granted by the school as the host institution. All student data were kept confidential and used solely for academic purposes.

2.2 Research Design

This study employed a Research and Development (R&D) method using the ADDIE development model, which consists of five stages: analyze, design, develop, implement, and evaluate [16]. In addition, a pre-experimental research method with a one-group pretest–posttest design was applied to examine the effectiveness of the learning media on students' learning outcomes [17].

A. Analyze Stage

This stage is divided into two parts: needs analysis and front-end analysis. The needs analysis focuses on identifying the current conditions, the desired conditions, and the type of problems that form the basis of the needs. Front-end analysis involves determining how to bridge the gap between the current and desired states through result-oriented solutions [16]. Various actions undertaken during this stage include conducting a needs analysis by administering a needs questionnaire, followed by providing solutions to the identified problems.

B. Design Stage

The design stage is a systematic process aimed at planning a multimedia-based learning solution in detail, documented in a comprehensive technical and instructional design plan [16]. Various actions undertaken in this stage include the preparation of learning materials, storyboards, and flowcharts.

C. Develop Stage

The development stage is the process of constructing the physical product of the planned learning solution [16]. Various actions carried out during this stage include realising the product through Google Sites and subsequently publishing it.

D. Implement Stage

The implementation stage is the process of applying the developed learning media in a real learning situation [16]. Various actions undertaken during this stage were carried out through a one-group pretest-posttest design, which involved administering a pretest, delivering the treatment, and concluding with a posttest. This activity involved Year 11 students at a state senior high school in Malang.

E. Evaluate Stage

The evaluation stage is a systematic process used to assess the quality, effectiveness, and impact of the developed learning media [16]. Various actions undertaken during this stage include conducting validation, feasibility testing, followed by revisions, as well as carrying out practicality testing and evaluating the effectiveness of the learning media.

2.3 Instruments

The research instruments used in this study included validation sheets, response questionnaires, learning outcome tests, and interview guidelines. Validation sheets were employed to assess the validity of the learning media, instructional content, teaching modules, student worksheets (LKPD), and learning outcome tests based on content, presentation, and language aspects. Response questionnaires were used to collect data on the practicality of the learning media from both students and teachers using a Likert scale. Learning outcome tests in the form of pretests and posttests were administered to measure improvements in students' learning outcomes after the implementation of the learning media and were validated prior to use. In addition, interviews were conducted with an eleventh-grade chemistry teacher at a public senior high school in Malang to obtain data related to the needs and implementation of the learning media.

2.4 Data Analysis

The data analysis techniques employed in this study included questionnaire analysis, test analysis, and analysis of the effectiveness of the learning media. Questionnaire data were analyzed using both qualitative and quantitative approaches. Qualitative data were obtained from critiques, comments, and suggestions provided by validators and respondents, while quantitative data were derived from Likert-scale questionnaire scores that were converted into numerical values. The formula used is as follows:

$$\text{Score (\%)} = \frac{\Sigma x}{\Sigma xi} \times 100\%$$

Information:

Score(%)= Percentage of validity/feasibility/practicality

Σx = Total score

Σxi = Maximum score

The percentages obtained from the validation tests of the learning media, instructional content, teaching modules, and student worksheets (LKPD) were interpreted into validity categories. Furthermore, the scores from the student readability test and the practicality of the learning media, derived from teacher and student response questionnaires, were also interpreted according to the criteria presented in Table 1.

Table 1. Interpretation of the Validity, Feasibility, and Practicality of Learning Media [18]

Percentage (%)	Criteria
100 - 86	Very valid / Very feasible / Very practical
85 - 76	Valid / Feasible / Practical
75 - 56	Moderately valid / Moderately feasible / Moderately practical
59 - 55	Less valid / Less feasible / Less practical
≤ 54	Invalid / Not feasible / Not practical

The analysis of the test instruments was conducted through a content validity test using Aiken's V index, which was assessed by validators through a Likert-scale questionnaire with a scoring range from one to five. According to Aiken [19], this test is based on the following formula:

$$V = \frac{\Sigma s}{n(c-1)}$$

Information:

s = x-1 (validator given value minus minimum scale value)

n = number of validators

c = number of scale categories

With the interpretation of Aiken's V values as shown in Table 2 below:

Table 2. Interpretation of Aiken's V values [20].

Value Aiken's V	Criteria
0,76 < V ≤ 1,00	Very good
0,59 < V ≤ 0,76	Good
0,41 < V ≤ 0,59	Pretty good
0.24 < V ≤ 0,41	Not good
V ≤ 0,24	Very bad

The analysis of the media's effectiveness was conducted using normality tests, hypothesis testing, N-Gain tests, and effect size tests. The normality and hypothesis tests were analysed using SPSS version 26. Subsequently, the N-Gain test was used to measure the improvement in learning scores from the pretest to the posttest. The formula used in this test is as follows:

$$\text{N-gain} = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum score} - \text{Pretest Score}}$$

With interpretation based on criteria as in table 3.

Table 3. Interpretation of N-gain [21]

Score Range	Criteria
g > 0,70	High
0,30 ≤ g < 0,70	Currently
g < 0,30	Low

Subsequently, the effect size test was conducted to measure the improvement in students' learning outcomes after the implementation of the learning media in the instructional process. This study employed Cohen's d effect size calculation [22], where a larger effect size value indicates a greater impact of the website-based learning media on students' learning outcomes. The formula used in this analysis is as follows:

3.1 Validity of the Learning Media

The quality assessment results of the website-based learning media are presented through a summary of its validity, feasibility, and practicality. The evaluation encompassed the validation of the learning media, instructional content, teaching modules, and student worksheets (LKPD), as well as feasibility and practicality tests based on student and teacher responses. Overall, the learning media achieved high percentage scores across all assessment aspects, indicating that its design, content, and implementation are well aligned with the requirements for supporting the chemistry learning process. A summary of the assessment results is presented in Figure 1.

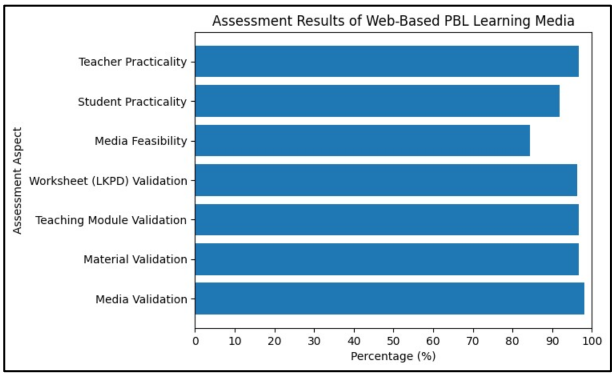

Fig. 1. Recapitulation of the Validity, Feasibility, and Practicality of Website-Based Learning Media.

3.2 Effectiveness of the Learning Media on Learning Outcomes

The effectiveness of the learning media on students' learning outcomes was analyzed by comparing pretest and posttest scores, as well as by calculating N-gain and effect size values. The results of the effectiveness analysis are presented in Table 5.

Table 5. Analysis of the Effectiveness of Learning Media on Students' Learning Outcomes

Indicator	Score	Meaning
N-gain	0.564	Moderate Improvement
Effect Size	1.05	Very Significant Impact

These results indicate that the website-based learning media not only meets the quality criteria for development but also has a tangible impact on improving students' learning outcomes.

$$d = \frac{M_{posttest} - M_{pretest}}{\sqrt{\frac{(SD_{Pretest}^2 + SD_{Posttest}^2)}{2}}}$$

With interpretation based on criteria as in table 4.

Table 4. Interpretation Effect Size [22]

Rentang Skor	Kriteria
d > 0,8	Very large
0,5 < d ≤ 0,8	Big
0,2 < d ≤ 0,5	Currently
0 < d < 0,2	Small

3. Results and Discussion

3.3 Analyze Stage

The analysis stage began with a preliminary study involving initial observations through interviews and questionnaires. Interviews were conducted with a chemistry teacher at a public senior high school in Malang, and a needs analysis was administered to eleventh-grade students in class XI-D. The analysis revealed that students experienced difficulties in mastering chemistry topics because the teacher's instruction was limited to the macroscopic and symbolic levels of representation. In studying chemical equilibrium, understanding all three levels of chemical representation is essential due to the abstract nature of the subject [23]. Students' perceptions of the chemical equilibrium topic indicated that 37.1% found it abstract, 28.6% considered it calculation-heavy, 25.7% viewed it as requiring extensive memorization, and only 8.6% found it enjoyable. This is correlated with the monotony of traditional instructional methods, such as discussions, laboratory practices, lectures, and Q&A sessions. To enable students to grasp abstract concepts and create an active learning environment, teachers can leverage learning media integrated with an appropriate instructional model [24].

The chemistry teacher also reported that students often misunderstand equilibrium shifts due to weak conceptual understanding. In addition, there is a need for innovative learning media, as 60% of students considered the current media to be ordinary, despite 100% acknowledging the importance of learning media in chemistry instruction. Innovative media can optimize the learning process for chemical equilibrium topics, enhancing both students' comprehension and learning outcomes [25]. Therefore, an appropriate step is to select and implement suitable innovative learning media for the instructional process.

The evaluation conducted at this stage involved assessing the alignment between the identified student needs and the actual conditions in the classroom. The analysis results were then compared with the teacher's interview responses to ensure that the learning problems had been accurately identified. This evaluation indicated that the analysis outcomes were appropriate and could serve as a foundation for the development of the learning media.

3.4 Design Stage

The design stage began with the development of a material hierarchy for the learning media, focusing on the chemical equilibrium topic. Next, an appropriate instructional model was selected, tailored to the students' characteristics and the subject matter. The Problem-Based Learning (PBL) model was integrated into the learning media development because it can enhance student engagement during instructional activities. Student-centered PBL promotes active learning by encouraging students to study independently and build confidence in their own abilities [13]. The subsequent steps involved designing the teaching module, followed by the preparation of a test blueprint and instruments to assess students' learning outcomes. This study employed objective tests in the form of multiple-choice questions to measure learning improvement, while Likert scales were used for product evaluation guidelines. The content of the learning media was then structured by creating a storyboard, followed by the development of a flowchart to illustrate the design and navigation of the website's content menus.

The evaluation at this stage involved assessing the alignment of the instructional materials with the learning objectives. This was carried out by comparing the designed learning syntax with the implemented instructional model and by examining the suitability of the assessment instruments in relation to the learning objectives. The results indicated that the design met the expected criteria and was ready for further development.

3.5 Develop Stage

A. Product of the Developed Learning Media

The product resulting from the development of this learning media is a website named Setia. Setia is a web-based learning medium that delivers chemistry lessons on the topic of chemical equilibrium, integrated with the Problem-Based Learning (PBL) model. The website consists of several menus, including: (1) homepage, (2) user guide, (3) learning outcomes, (4) learning activities, (5) virtual lab, (6) glossary, and (7) references. The Setia website offers a variety of engaging and comprehensive features such as worksheets (LKPD), teaching materials, instructional videos, a virtual lab, and game-based practice questions. In addition, the website is easily accessible via multiple devices, including smartphones, tablets, and laptops/computers, making it flexible for use in various student learning contexts.

The first menu, namely Home, is shown in Figure 2. The Home page is designed as the main page, providing quick access to various primary menus. This page contains several pieces of information, including the website name, main menus, a brief description of the website, the developer's profile, and the address where the media was developed.

Fig. 2. Home page view.

The second menu, namely Website User Guide, as shown in Figure 3, contains instructions for users to make optimal use of all the menus. This guide explains the function of each menu available on the website. Users can understand any desired menu without having to read through each of the other menus individually.

The next menu section is the Learning Outcomes, as shown in Figure 4. This menu consists of: (1) learning outcomes, (2) initial competencies, (3) the Pancasila Student Profile, (4) learning objectives, (5) the learning objectives flow, and (6) meaningful understanding. The learning outcomes, learning objectives, and learning objectives flow are structured in accordance with the Merdeka Curriculum. The initial competencies section outlines the prior knowledge required before students study the topic of chemical equilibrium, while the Pancasila Student Profile serves to instil character values based on the principles of Pancasila. In addition, this menu also includes meaningful understanding, which links the concept of chemical equilibrium to real-world phenomena.

Fig. 3. View of the guide page.

Fig. 4. View of the learning achievement page.

The fourth menu is the Learning Activities, as shown in Figure 5. This menu contains a concept map, pre-test, learning activities, practice questions, and a post-test. The pre-test and post-test are used to measure the effectiveness of the learning media. The learning activities consist of four sessions, arranged according to the number of subtopics in this material. Each session of the learning activities is organized following the five stages of the Problem-Based Learning (PBL) model. In addition, the learning activities include student worksheets (LKPD), teaching materials, instructional videos, and practice questions, all of which facilitate students in their learning process.

Fig. 5. View of the learning activity page.

The fifth menu is the virtual lab, as shown in Figure 6. The experiments that can be carried out involve factors affecting the shift in equilibrium, such as concentration, temperature, pressure, and volume. The purpose of the virtual lab is to enhance learning independence, improve conceptual understanding, and reduce costs. The sixth menu is the glossary, which serves to facilitate the understanding of terms contained in the material. The final menu is the bibliography, which contains references used in the design of the learning materials.

Fig 6. Virtual lab page view.

The advantage of this website is that it can enhance students' engagement as it applies the Problem-Based Learning (PBL) model. This learning model guides students to seek solutions to problems through discussion and practical activities. The website can also be utilised by students for independent learning without having to wait for the teacher's explanation, as it already contains relevant learning resources that can be accessed at any time. The drawback of this medium is that it requires internet access and is susceptible to distractions from other applications during use.

The evaluation carried out at this stage is to ensure that the media product developed is in accordance with the design specifications illustrated in the flowchart. The evaluation was conducted by comparing the page display flow, material arrangement, and content structure on the website with the pre-designed plan. Each section was examined to ensure the proper sequence of material delivery and consistency of display format. The evaluation results indicate that the medium aligns with the design, although minor adjustments were made to clarify the presentation of information.

3.6 Implement Stage

The implementation stage was carried out to examine the effectiveness of using the website on students' learning outcomes. The assessment of learning outcomes was conducted using a one-group pretest–posttest design. A single group of students was administered a pretest, followed by learning activities utilizing the website over four sessions totaling ten instructional hours (45 minutes each). Afterward, a posttest was administered to determine the extent of improvement in students' learning outcomes, thereby obtaining the learning outcome data.

The average pretest score was 73.59, while the posttest score was 89.04. Although the students' pretest score reached an average of 73.59, this score had not yet reached the maximum category, as it did not fully reflect the achievement of all learning objectives. This indicates the need for improvement in the learning process, one of which can be achieved through the development and utilization of instructional media, particularly for subjects that tend to be abstract, such as chemical equilibrium [26]. The increase in the posttest score, which reached an average of 89.04, demonstrates a significant improvement in students' understanding after using the instructional media. This finding suggests that the developed media was effective in helping achieve learning objectives and enhancing learning outcomes. Website-based instructional media is expected to assist students in achieving the learning objectives and facilitate teachers in delivering the material [27]. The students' learning outcomes are presented in Figure 7.

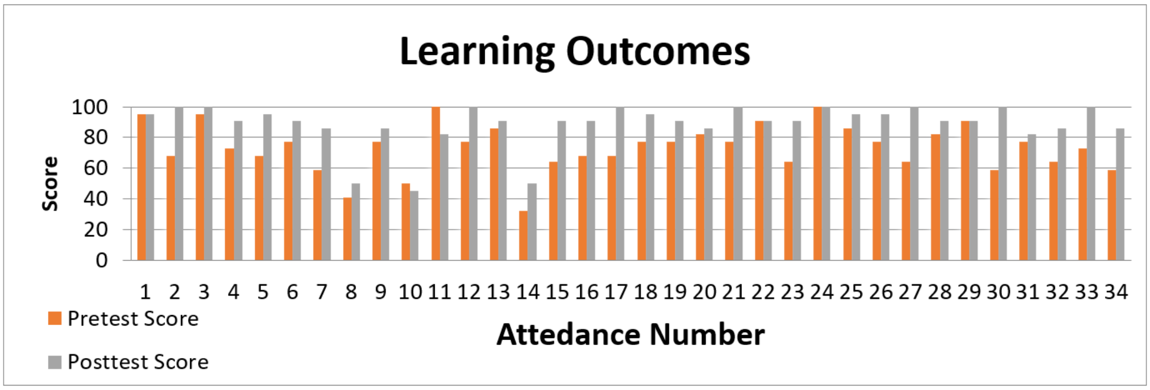

Fig. 7. Student learning outcomes.

The evaluation conducted at this stage focused on assessing the use of the media in the learning process, with particular emphasis on observing the implementation of classroom activities. The observation was carried out to determine whether the media could assist students in understanding the material and following the learning flow in accordance with the PBL syntax. The evaluation results indicated that students engaged in learning activities in alignment with the syntax presented in the instructional media.

3.7 Evaluate Stage

A. Formative Evaluation

Formative evaluation was conducted prior to implementation through validation and feasibility tests to ensure that the learning media were valid and suitable for use. This evaluation aimed to guarantee that the learning process could be conducted effectively and efficiently by utilizing appropriate and accurate materials or media, thereby achieving the intended learning objectives. A summary of the interpretation results for the validity of the media, instructional content, teaching modules, student worksheets (LKPD), and learning outcome tests, as presented in Figure 1, shows that all components met the "very valid" criteria.

This indicates that the developed instructional materials are aligned with the curriculum, learning objectives, and students' characteristics. The high validity of the media and content demonstrates that the material is presented systematically, accurately, and clearly, enabling students to build conceptual understanding independently through the website-based platform. In the context of Problem-Based Learning (PBL), this condition is essential, as students require clear and reliable learning resources as a foundation for analyzing and solving the given problems [28].

The validity of the teaching modules, student worksheets (LKPD), and learning outcome tests indicates that the learning activities and assessments were designed in alignment with the PBL syntax and competency indicators. This finding suggests that students are not merely recipients of information but are guided to think critically, engage in discussions, and apply concepts in contextual problem-solving situations. The integration of highly valid instructional components with website-based media allows the learning process to be more interactive, flexible, and student-centered. Therefore, the combination of PBL and website-based learning can enhance learning outcomes by providing students with meaningful, structured, and consistent learning experiences across objectives, processes, and assessments [29].

Furthermore, the feasibility test results of the learning media, as presented in Figure 1, show that the media meet the criteria for suitability in instruction. This feasibility indicates that the web-based media align the content, material presentation, and learning flow with students' characteristics and the PBL syntax. The interpretation of this finding is that the media can function as a pedagogically supportive learning environment, facilitating problem exploration, group discussions, and concept reinforcement. With a structure and presentation consistent with the PBL stages, the media enable the learning process to proceed systematically and purposefully, without distorting the concepts or students' reasoning processes [15].

The validity and feasibility of the media were further reinforced by qualitative comments and suggestions from validators and users, particularly regarding the need to strengthen concept representations through the addition of instructional videos and the integration of multiple representations. These suggestions indicate that the media are evaluated not only based on their appearance but also on their capacity to facilitate comprehensive conceptual understanding. The inclusion of interactive games supports enjoyable, play-based learning and can enhance students' motivation, which in turn positively influences their understanding of the material [30]. Moreover, the use of multiple representations provides a stimulus for students to develop their imagination, aiding in the comprehension of abstract concepts [31].

Furthermore, the validators' comments regarding the learning syntax and evaluation instruments emphasized the importance of consistency between planning, implementation, and assessment in PBL. Suggestions to specify the stage for collecting students' work highlight the role of the LKPD as a systematic guide that assists students in understanding concepts and solving problems according to learning indicators [31, 32]. Additionally, feedback concerning language clarity, alignment of indicators, and the homogeneity of answer options indicates that the evaluation instruments were designed to measure learning achievement accurately. Homogeneous options are necessary to ensure that all choices are presented within an equivalent context and are easily understood by students [34]. Therefore, it can be concluded that website-based learning media facilitate students' learning by reducing tension in the learning environment while enhancing the quality of the instructional process, making it more effective, interactive, and engaging [35].

Referring to the comments and suggestions provided by the validators, Table 6 presents the revisions made in accordance with their recommendations prior to the implementation with students.

B. Summative Evaluation

The summative evaluation was conducted after implementation by assessing the practicality of the learning media through response questionnaires administered to both teachers and students, followed by an evaluation of the effectiveness of the website in enhancing students' learning outcomes. The summary of student and teacher responses, presented in Figure 1, met the "very practical" criteria, indicating that PBL-based website learning can be consistently applied in instructional activities. The positive responses from students and teachers reflect that the integration of PBL with website-based media effectively supports the implementation of the learning syntax, facilitates problem exploration, and provides easier access to learning resources. This finding demonstrates that the level of acceptance of both the instructional model and the learning media contributes significantly to supporting effective learning.

The acceptance of the instructional model and learning media was demonstrated not only perceptually but also supported by the analysis of students' learning outcomes. The collected data were then analyzed using several statistical tests, including the normality test and hypothesis testing with IBM SPSS Statistics 26, followed by the N-gain test and effect size analysis using Microsoft Excel. The results of the normality test indicated that the data were not normally distributed; therefore, a non-parametric statistical analysis, specifically the Wilcoxon test, was conducted. The results showed a significance value of 0.00, indicating a significant difference in the improvement of students' learning outcomes when website-based instructional media was used in the learning process.

Subsequently, an N-gain analysis was conducted to measure the improvement in learning outcome scores from the pretest to the posttest. The result obtained was 0.564, which falls within the "moderate" category. This result is higher than that reported in a similar study by Iswanda [36], which achieved an N-gain score of 0.28, but slightly lower than the finding of Dewi [37], which reported an N-gain score of 0.87. An improvement within the moderate category indicates that some students demonstrated a considerable enhancement in understanding, while others progressed more slowly. Factors contributing to these differences in learning outcomes among students include health conditions, learning awareness and interest, as well as the surrounding environmental conditions [38].

Table 6. Improvement of Learning Media.

<table>
<tr><th>Repair Results</th><th>Information</th></tr>
<tr><td>Fase 2: Mengorganisasi Siswa untuk Belajar (10 menit)
• Siswa dibagi ke dalam kelompok kecil (2-3 orang)
• Setiap kelompok menerima Lembar Kerja Peserta Didik (LKPD) yang berisi pertanyaan dan tugas terkait masalah yang disajikan.
• Siswa menyusun rencana pembagian pengerjaan tugas.
Fase 3: Penyelidikan dan Analisis (35 menit)
• Siswa melakukan riset dengan mengeksplorasi materi yang tersedia di dalam website
• Siswa mencatat poin-poin penting yang berkaitan dengan konsep kesetimbangan kimia
• Siswa berdiskusi dalam kelompok mengenai informasi yang didapatkan
• Guru berkeliling untuk memantau dan memberikan bimbingan.
Fase 4: Mengembangkan dan Menyajikan Hasil Karya (25 menit)
• Setiap kelompok memaparkan karya mereka dalam bentuk penyelesaian LKPD untuk menjelaskan hasil analisis terhadap masalah yang diberikan.
• Diskusi terbuka diadakan setelah presentasi untuk memberikan umpan balik dan klarifikasi.
Fase 5: Menganalisis dan Mengevaluasi Proses Pemecahan Masalah (25 menit)
• Siswa bersama guru menganalisis dan mengevaluasi proses pemecahan masalah yang telah dilakukan.
• Siswa menuliskan hasil evaluasi pada LKPD.
• Siswa mengerjakan latihan soal di website untuk memperdalam pemahaman</td><td>In the learning syntax, collecting work results is still very common and time allocation is estimated again.</td></tr>
<tr><td>Apa yang dimaksud dengan kesetimbangan kimia.... * 1 poin
○ Kondisi di mana reaksi berhenti setelah reaktan dan produk terbentuk dalam jumlah yang sama
○ Kondisi di mana jumlah reaktan selalu lebih banyak daripada produk dalam sistem reaksi
○ Kondisi di mana reaksi hanya berlangsung dalam satu arah tanpa adanya reaksi balik
○ Kondisi di mana reaktan habis bereaksi dan hanya menyisakan produk
○ Kondisi di mana laju reaksi maju sama dengan laju reaksi mundur</td><td>The answer options presented must be clear and homogeneous.</td></tr>
<tr><td>Contoh Soal:
Pada suhu 298 K, reaksi berikut mempunyai K_c sebesar 7,0 x 10^{25} $mol^{-1}L$.
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ K_c = … (1)
Tentukan K_c dari reaksi-reaksi berikut ini
a. $4SO_2(g) + 2O_2(g) \rightleftharpoons 4SO_3(g)$ K_c’ = … (2)
b. $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ K_c”= … (3)
c. $SO_3(g) \rightleftharpoons SO_2(g) + ½ O_2(g)$ K_c’”= … (4)
Jawab:</td><td>Revise incorrect punctuation.</td></tr>
<tr><td></td><td>It is better if the media is supplemented with videos that explain the material so that it can facilitate students with a visual learning style.</td></tr>
<tr><td></td><td>Link the game to the study material, not stand alone.</td></tr>
</table>

In addition, an effect size analysis was conducted to measure the effectiveness of students’ learning outcomes after implementing the instructional media in the learning process. The result obtained was 1.05, which falls within the “very large” category. This finding is higher than that reported in a similar study by Hatip [39], which achieved an effect size score of 0.81, but slightly lower than the result Huda et. al [40], which obtained an effect size score of 1.1. The very large effect size serves as strong evidence that the implementation of technology-based instructional media, supported by the application of the Problem-Based Learning (PBL) model, has a significant positive impact on students’ learning outcomes.

Internally, based on the pretest scores obtained, the analysis was carried out by dividing the class into two groups: the upper group (students with high levels of understanding) and the lower group (students with low levels of understanding). This grouping is presented in Table 7.

Based on Table 7, the N-gain calculation results indicate that both the lower and upper groups experienced a moderate level of improvement; however, the lower group achieved a higher score of 0.606, compared to 0.526 for the upper group. Furthermore, the effect size analysis revealed a very large improvement in students’ learning outcomes when using the website-based learning approach. Both the lower and upper groups demonstrated a very large effect size, with the lower group achieving a higher value of 1.50 compared to 1.09 for the upper group. Prior to the learning process, 100% of students in the upper group had achieved the minimum mastery criteria (KKM), whereas only 5.9% of students in the lower group met the KKM. After the implementation of the website-based instructional media, 82.4% of students in the lower group achieved the KKM. These findings indicate that the media is effective in improving students’ learning outcomes.

Table 7. Comparison of Values

	Upper Group	Lower Group
N-Gain	0.526	0.606
Effect Size	1.09	1.50
Before Learning	100% reach the Minimum Passing Grade	5.9% reach the Minimum Passing Grade
After Learning	100% reach the Minimum Passing Grade	82.4% reach the Minimum Passing Grade

The improvement in learning outcomes occurred because the implementation of PBL-based website learning aligns with the principles of constructivist theory, where knowledge is actively constructed by students through direct engagement in problem-solving [11]. The website-based media function as a learning environment that provides various resources, representations, and activities, enabling students to construct conceptual understanding both independently and collaboratively. Through structured discussion, exploration, and reflection processes inherent in PBL, students do not merely receive information but connect new concepts with their prior knowledge, leading to deeper understanding and resulting in improved learning outcomes [41].

The researcher recommends several measures to further maximize the improvement of learning outcomes, such as incorporating additional steps like administering diagnostic tests to identify students' misconceptions [42]. Based on the N-gain and effect size analyses, it can be concluded that this website-based instructional media is more effective for students in the lower group. For students in the upper group, it is suggested to integrate a combination of Higher Order Thinking Skills (HOTS) questions into the instructional media. Assessments using HOTS questions can enhance students' learning motivation by connecting lesson content with real-world contexts, thereby making learning more meaningful. Moreover, such assessments foster creative and critical thinking skills beyond mere recall or restatement, thus contributing to improved learning outcomes and enhancing students' competitiveness at both national and international levels [43].

3.8 Research Limitations

This study has several limitations that should be considered. First, the research was conducted in a single school, which limits the generalizability of the findings. Second, the sample size was relatively small and involved only one class, so the diversity of student characteristics was not broadly represented. Third, data on practicality and feasibility were obtained through perception-based questionnaires, which may be subject to respondent bias. Therefore, future studies are recommended to involve larger samples, employ more robust experimental designs, and utilize a wider range of effectiveness measurements.

4. Conclusions

This study contributes to the development of website-based learning media integrated with the PBL model for chemical equilibrium topics, supporting student-centered learning. The integration of PBL with website media promotes active student engagement in problem-solving and meaningful concept construction, supported by the demonstrated effectiveness of the media in enhancing learning outcomes. Pedagogically, this media serves not only as a tool for content delivery but also as a facilitator of systematic, interactive, and contextual learning, with potential for broader application in teaching abstract chemistry topics. Future research is recommended to compare the effectiveness of PBL-based website learning with other instructional models and to examine its implementation across different topics and educational levels.

Author Contributions

Aisyah Permatasari developed the research concept, developed the research design, conducted data collection and analysis, and interpreted the results. Aisyah Permatasari also acted as a reviewer of the original draft. Sumari also served as the research supervisor and reviewed and edited the final draft.

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