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The Impact of Formative Feedback-Based Educational Websites on Students' Problem-Solving Abilities in Hydrostatic Pressure

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ABSTRACT In the context of physics education, it is imperative that educators prioritize the development of students' problem-solving abilities. Given the interdisciplinary nature of physics and its relevance to everyday life, students must possess robust problem-solving skills. However, conventional and uninspiring learning approaches have been shown to diminish students' interest and proficiency in problem-solving. In response to this challenge, a website based on formative feedback has been developed to enhance students' problem-solving abilities in hydrostatic pressure. This research employed the research and development method with the ADDIE model, involving two classes, to assess the developed media's validity, practicality, and effectiveness. The website has been tested and proven valid, practical, and effective. This is based on the testing of the website on students with pre-test and post-test, which resulted in significant outcomes ($p < 0.05$), indicating a clear distinction between the control and experimental classes. Additionally, the N-gain scores in the experimental class showed that the website effectively enhances students' problem-solving skills. In contrast, the N-gain scores in the control class showed ineffective results. Therefore, the media is suitable for implementation in schools.

Keywords: ADDIE, Formative feedback, Hydrostatic pressure, Problem-solving, Website

1. INTRODUCTION

The field of physics is often perceived as challenging and uninspiring by students (Ramadhani & Sulisworo, 2022). However, it is closely intertwined with the problems commonly encountered in everyday life (Sari et al., 2023). Furthermore, physics is perceived as an abstract subject less descriptive than other disciplines, with a greater focus on quantitative analysis due to the lack of meaningful connections to real-life experiences (Wangchuk et al., 2023). Further, the prevalence of complex formulas and challenging problems in physics contributes to its reputation as a complex subject (Nurfadilah et al., 2021). This phenomenon is also attributed to students not always paying attention to the material presented in class.

Static fluid is intimately connected to the realms of everyday life, such as the construction of dam walls, hydraulic jacks, and the sinking and floating of objects (Radjawane et al., 2022) and other abstract concepts (Prani et al., 2017). Several studies have indicated that students encounter difficulties in comprehending the underlying principles that underpin the solution of problems (Purnamasari et al., 2018) one such concept is that of hydrostatic pressure (Januarifin & Hidayat, 2017). Prior research indicates that students' problem-solving abilities remain relatively low, with an average score of 48.88 on a scale of 1-100 (Purwanto et al., 2017). Students encounter difficulties determining the depth of the fluid gun and making assumptions regarding the inverse proportionality of liquid pressure to depth and the influence of energy on pressure (Wahyuni et al., 2016). Additionally, students encounter difficulties in articulating the impact of fluid density in conjunction with the concept of hydrostatic pressure, which differs from the pressure experienced by an individual during swimming (Ringo et al., 2019). Among the various static fluid materials, students' lowest problem-solving ability has been reported in the hydrostatic pressure materials (Gunada & Roswiani, 2019). Therefore, it is imperative to reinforce this ability so that students can effectively comprehend the material.

In education, formative assessment is a valuable tool for enhancing students' problem-solving abilities. Popham (1995) asserts that assessment implementation is crucial for several reasons. It is a diagnostic tool for identifying

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students' strengths and weaknesses in the learning process. Secondly, it functions as a monitor of student development. Thirdly, it supports the determination of students' ability levels. Fourthly, it is employed to determine the effectiveness of the designed learning (Popham, 1995). The provision of feedback is intended to facilitate reflection and correction, as well as to direct students when they encounter deviations from the intended learning outcomes. This approach is designed to enhance the completeness of the learning experience (Ramadhani et al., 2021). One form of formative assessment is feedback, which can enhance student learning quality (Rahmawati & Nugroho, 2015). This includes providing a reflection and correction effort and offering direction to students when they deviate from the expected outcome (Ramadhani et al., 2021).

The rapid advancement of technology impacts student learning in and outside the classroom with interesting and fun methods (Jamun, 2018). The ease of access to information sources, coupled with the current generation Z, which is more modern and has an innovative, competitive character, has facilitated easy comprehension of technology, presenting a challenge for teachers (Munti & Syaifuddin, 2020). In such instances, educators may utilize a range of supplementary digital resources, including audio and video, to enhance the delivery of learning materials, mainly when practical experimentation is not feasible (Finnegan, 2017).

Learning media is crucial in attaining quality learning outcomes (Suyoso & Nurohman, 2014). The acquisition of science process skills, including problem-solving ability, can be facilitated through learning media. Similarly, assessment is an indispensable component of the learning process. Using learning media with formative feedback for students during the learning process is an effective learning strategy, particularly in physics, where students must develop a deep understanding of complex concepts (Azzahra et al., 2022). The material will be more comprehensible and engaging if learning media fosters greater student interest in the subject matter (Rahim et al., 2019). Student interest facilitates comprehension and problem-solving abilities (Septian et al., 2021).

Kahoot as a learning tool has been shown to yield results that are more appealing to students and elicit a more engaging response to the learning of physics (Wicaksono et al., 2022). Another research indicates that using the Google Sites website as a medium for physics learning enhances students' learning interest and capacity to learn independently (Ismawati et al., 2021). Using Google Classroom as a learning website facilitates flexible learning regarding time and place, student involvement, and ease of access to learning, thereby enhancing students' data and technology literacy (Nurfalah, 2019). Furthermore, students exhibit more interest in learning through the website, as it enhances their comprehension and engagement with physics, which was previously perceived as challenging and uninteresting (Azzahra et al., 2022). Previous studies have demonstrated the effectiveness of online learning media, such as websites, in fostering student interest in learning.

Over half of all searches and browsing activities are conducted on mobile devices (Global Stats, 2016). Accordingly, in this study, the researcher aims to leverage digital devices accessed through laptops and mobile devices (Vo & Sharp, 2019). Websites represent a medium that can support learning through digital devices and offer various advantages with standard browsers that reach almost all hardware (Vo & Sharp, 2019). Furthermore, website development can facilitate student problem-solving abilities concerning specific materials (Fajarianingtyas & Hidayat, 2023). This rationale justifies the development of a formative feedback-based website for learning to enhance students' problem-solving abilities.

In light of the preceding discussion, this study undertook research and development of a formative feedback-based hydrostatic pressure educational website with the objective of enhancing student problem-solving abilities. This research aims to develop, validate, test the practicality, and assess the effectiveness of educational websites based on formative feedback in improving student problem-solving abilities in hydrostatic pressure material. The utilization of formative feedback, which enables the control and training of students' problem-solving skills in hydrostatic pressure, represents a pivotal aspect of this research.

2. METHOD

This research, development, and product validation employed the Research and Development (R&D) method in conjunction with the ADDIE model, which was developed by Dick and Carey (Dick & Carey, 2001). The model is designed for research, development, and product validation. The research model comprises five stages, including analysis, design, development, implementation, and evaluation (Dick & Carey, 2001). This model is a classroom-oriented model identical to learning media. The development process was sequential and interactive, with the evaluation results of the previous stage informing the next stage (Hamzah, 2019). ADDIE has an evolving cycle that continues throughout planning and implementation. Each stage in ADDIE has a different purpose for developing instructional design (Peterson, 2003). The stages of the ADDIE model conducted in this study are described in Figure 1.

The analysis stage in ADDIE will be carried out by analyzing problems, needs, and solutions using literature studies, observations, and interviews conducted during teaching assistance at SMAN 1 Kepanjen, Indonesia. After that, the design stage will be conducted based on the analysis results, which will be carried out by creating

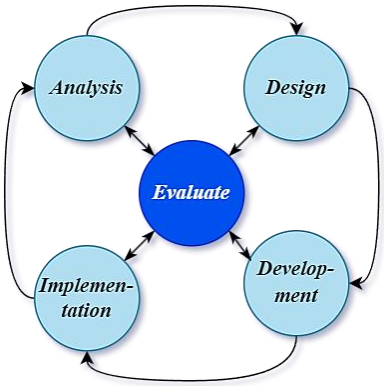

Figure 1 Stages in ADDIE development model (Hidayat & Nizar, 2021)

concept maps, storyboards, questions, formative feedback, and research instruments. The results will then be developed into an actual website and validated by experts in both media and materials as an evaluation at this stage. The validated website will be implemented on students using control and experimental classes with pre-test and post-tests and media practicality tests on teachers and students. In this research, evaluation was carried out at each stage so that any deficiencies could be corrected directly.

The research instruments employed in this study included interviews, questionnaires, a pre-test, and a post-test. The instruments were validated through questionnaires and discussions with media and material experts. Teachers completed the media practicality questionnaire, while students completed the practicality using the media readability response questionnaire. The data was obtained from the website assessment and qualitatively from the discussions conducted during the validation process. Consequently, the suggestions and input the validator provided were enhanced to ensure the website could be utilized effectively.

The feasibility of the product was evaluated using a Likert scale and equation presented in Equation 1.

$$V = \frac{\text{Total score}}{\text{Maximum total score}} \times 100\% \qquad (1)$$

Subsequently, the media validation results were assessed using the criteria presented in Table 1.

The practicality of the media was gauged based on the responses to the student and teacher questionnaires. The level of media practicality was analyzed based on the criteria presented in Table 2.

The effectiveness of increasing student problem-solving abilities due to media use was analyzed by administering a pre-test and post-test in control and experimental classes. The data were processed using N-gain Score analysis, and the equation for the N-gain Score equation is presented in Equation 2.

$$\text{N} - \text{Gain Score} = \frac{\text{Posttest} - \text{Pretest Score}}{\text{Ideal Score} - \text{Pretest Score}} \qquad (2)$$

The results of the N-gain Score can be categorized using the criteria presented in Table 3.

The categorization of N-gain score categories was based on the N-gain value or as a percentage of N-gain. Table 4 describes the division of N-gain effectiveness categories.

To assess the efficacy of the media, the developed media was implemented in a learning involving eleventh-grade students from State Senior High School 1 Kepanjen. The study involved administering a pre-test and post-test to students in a control class and an experimental class. Normality tests, homogeneity tests, independent t-tests, and N-gain scores analyzed the data. The results of these tests determined whether the media can be considered adequate, thus allowing the entire research and development process to be concluded in terms of its feasibility.

Table 1 Criteria for media validation results (Nurjannah et al., 2021)

Range of Percentage Value (%)	Validation Level
0-20	Very Invalid
21-40	Less Valid
41-60	Quite Valid
61-80	Valid
81-100	Very Valid

Table 2 Criteria for media practicality (Nurjannah et al., 2021)

Range of Percentage Value (%)	Practical Level
0-20	Very Impractical
21-40	Less Practical
41-60	Quite Practical
61-80	Practical
81-100	Very Practical

Table 3 Criteria for N-gain score (Lestari, 2019)

N-gain Score	Criteria
$\langle g \rangle > 0.7$	High
$0{,}3 \leq \langle g \rangle \leq 0.7$	Medium
$\langle g \rangle < 0.3$	Low

Table 4 Category of N-gain effectiveness (Juniayanti & Susila, 2022)

Percentage (%)	Interpretation
< 40	Ineffective
40 – 55	Less Effective
56 – 75	Effective Enough
> 76	Effective

Implementing research and development using the ADDIE model involved a series of activities at each stage. Additionally, evaluations were conducted at each stage to identify deficiencies and implement appropriate improvements. Based on the evaluation results, all stages were confirmed appropriate before progressing to the next stage.

3. RESULTS AND DISCUSSION

3.1 Analysis

The results of the problem analysis indicate that students struggle to solve problems sequentially to arrive at the correct final result. Additionally, some grade XI students do not fully understand the principles and concepts of hydrostatic pressure when faced with problems related to real-life situations. The availability of smartphones and laptops among students has also increased their interest in engaging digital media incorporating audio-visual elements. Based on the results of the analysis, supported by literature studies, digital media emerges as a viable solution. Therefore, a website that is easily accessible, flexible, and does not require much storage offers significant advantages and can be considered a suitable solution.

3.2 Design

The website is designed to be accessible online via computers, laptops, or smartphones. The concept of the hydrostatic pressure website is formulated to be specific, measurable, applicable, and realistic through the following steps.

Formulation of Map Concept

The concept map outlines the website's workflow and is created in detail from the initial opening to the problem-solving section to ensure no errors occur during development (Figure 2).

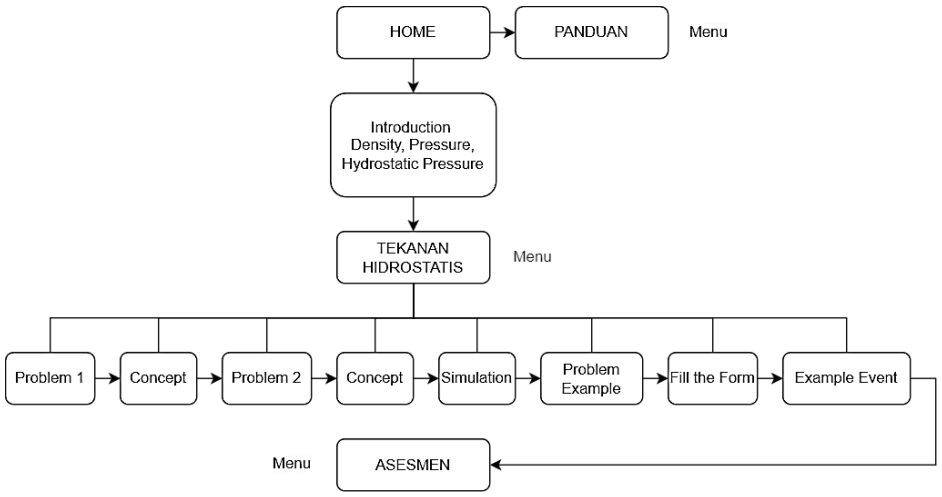

Figure 2 Map concept of website creation

Preparation of Storyboard

The creation of the storyboard serves as a design for the content to be developed, including the visuals that will appear on the website (Figure 3).

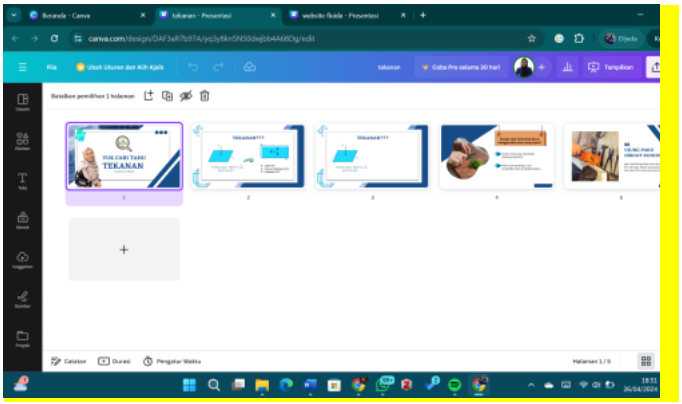

Figure 3 Storyboard

Formulation of Question Item and Formative Feedback on Hydrostatic Pressure

The questions are designed with careful consideration of their difficulty level and suitability for the website to ensure that users are not overwhelmed when attempting them. In addition to the questions, formative feedback is also created and tailored to match the questions.

Making of Instrument

The instruments used as measurement tools for the criteria to be assessed in the research consist of validation sheets, student and teacher response questionnaires, pre-test questions, and post-test questions.

The results obtained from testing with these instruments will be processed in data analysis.

3.3 Development

The product of this research is a hydrostatic pressure educational website (named "Yuk Cari Tahu") accompanied by formative feedback. The website has been

developed with various features, including audio and visual elements. Several images help to visualize the material being explained, along with a short video that explains the material in a design that facilitates ease of understanding. All elements on the website use casual language and are easily understood by teenagers or students. This ensures that students are not quickly bored with the standard language often found in textbooks.

In addition to images and videos, the website is linked to an online laboratory in the form of PHET, which is accessible for students to conduct rudimentary experiments based on the context of hydrostatic pressure. With guidance from the website, students can learn independently to conduct experiments using the virtual laboratory. Furthermore, this website is equipped with formative feedback-based problem exercises that can assist students in problem-solving based on the problems presented. The problem exercises have been adapted to the stages of problem-solving, according to Docktor. This is employed to facilitate coherent problem-solving, enabling students to reach appropriate conclusions regarding the results of their problem-solving efforts.

This website contains material on hydrostatic pressure and is equipped with examples of problem-solving, practice questions, and formative feedback. Its objective is to enhance students' problem-solving abilities on the material, beginning with understanding the concept and the correct methodology for problem-solving. The website's advantages include an attractive design and features. Various features of the website are presented below.

- The website's main page is designed to be visually appealing. It contains an introduction with language that is easy to understand and attracts attention, as shown in Figure 4.
- A brief video explanation of each sub-material facilitates a clear and straightforward understanding. Video explanations of hydrostatic pressure problem-solving examples are included in Figure 5.
- Written material is accompanied by illustrations of engaging and easy-to-understand images in detail, as shown in Figure 6.
- The PHET Virtual Laboratory provides students with an opportunity to apply the concept of hydrostatic pressure using the illustrative materials presented in Figure 7.
- The assessment tool offers formative feedback, which students can utilize for practice in problem-solving stages with immediate feedback, as demonstrated in Figure 8.

Before implementation in the learning process involving students, material and media validation was initially conducted on the developed website. The material validation criteria included an assessment of the material's alignment with the learning objectives, its suitability for problem-solving indicators, its presentation systematics,

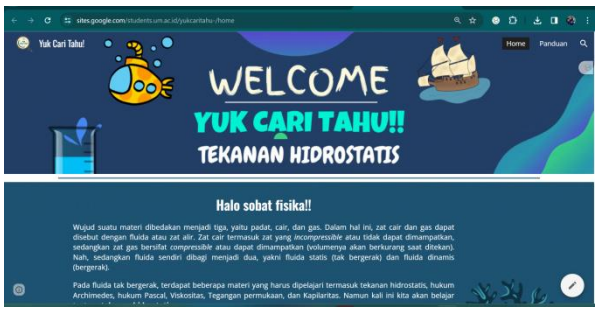

Figure 4 Main page of website

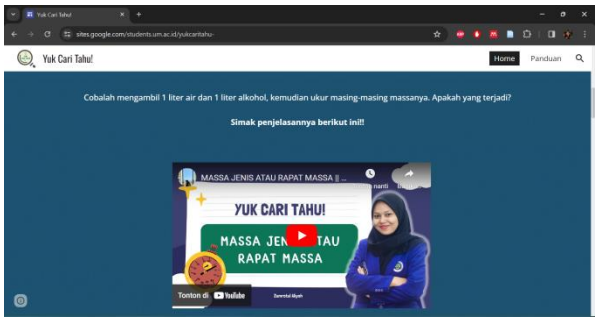

Figure 5 Videos on the website

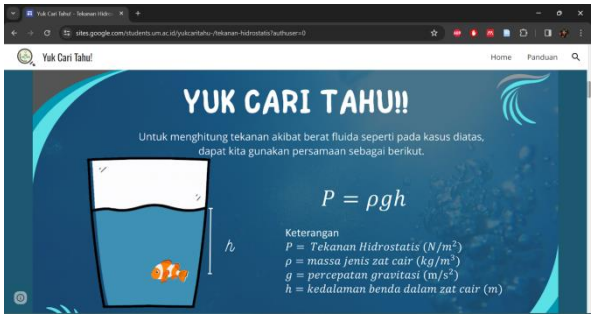

Figure 6 Illustrative material on the website

Figure 7 PHET virtual laboratory on the website

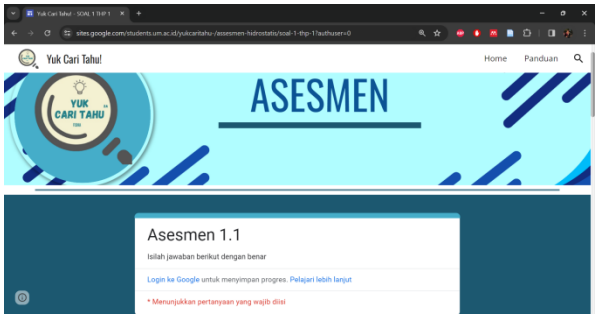

Figure 8 Assessment of the website

grammar, and concept suitability. Each aspect was evaluated using a Likert scale, while the concept's suitability was assessed using a Guttman scale (1 and 0). The Guttman scale was employed to obtain a definitive response from the validator. The results of the validation test conducted by the experts are presented in Table 5.

The results demonstrate that the material presented on the website meets the criteria for highly valid content. In addition, the aspect of concept suitability, which employs a Guttman scale, indicates that the concept is entirely appropriate. The suggestions and comments from the validators were submitted through joint discussions and subsequently improved by the researchers.

In addition to material validation, media validation was also carried out, which included assessment aspects pertaining to the appearance of websites (including images, language, fonts, and buttons) and videos (including grammar, images, and audio). The results of the media validation are presented in Table 6.

The validation results indicated that the media obtained an average score of 97.3% and was included in the highly valid category. Based on this validation, the hydrostatic pressure educational website is suitable for use, though there are minor revisions to some things in the media that need to be fixed. Therefore, students can use and implement the media to test its practicality and validity.

3.3 Implementation

This study involved teachers and students as respondents in the practicality test of the developed media. The results of the practicality test involving the teacher yielded a score of 90%, indicating that the media was deemed highly practical. In addition to the questionnaire, an interview was conducted with the teacher when the questionnaire was completed, resulting in suggestions and input to improve the volume of the back song, thereby ensuring that the material was effectively explained. Following the practicality test conducted by the teachers, a practicality test was administered to students using a media readability response questionnaire. The results of the practicality test indicated an average value of 90.04%, which fell within the very practical criteria. Based on the feedback provided by students, the media in the form of hydrostatic pressure educational websites are found to be engaging, straightforward, and not overly complex.

In addition to the questionnaire, interviews were conducted with students directly using the media. The results of the interviews indicated that physics learning must be made interesting. Many students stated that they are bored reading books and face difficulty understanding the material if they only use books. Furthermore, students quickly feel bored while learning and are happier if engaging media is used. Students also feel happy if they work on problems and get immediate feedback without waiting for the next meeting.

Table 5 Results of material validation

No.	Rated Aspect	Percentage (%)	Criteria
1.	Suitability of Material to Learning Objectives	80%	Valid
2.	Compliance with Problem-Solving Indicators	90%	Very Valid
3.	Systematic Appropriateness of Presentation	80%	Valid
4.	Grammar	100%	Very Valid
	Average	87.5%	Very Valid

Table 6 Results of media validation

No.	Rated Aspect	Percentage (%)	Criteria
1.	Website Appearance	95%	Very Valid
2.	Video	100%	Very Valid
	Average	97.3%	Very Valid

Table 7 Results of pre-test and post-test for control class

Indicator	Control	
	Pre	Post
Useful Description	3.80	4.30
Physics Approach	0.01	0.12
Specific Application of Physics	2.50	3.43
Mathematical Procedure	2.07	3.52
Logical Progression	0.42	0.70

Notwithstanding, some students have commented on the use of more diverse colors. This observation suggests that developers enhance the media's presentation engagingly and enjoyably. Based on the overall suggestions and comments, they offer constructive and positive input that can inform improvements for the developer of educational websites based on formative feedback.

This study employed a pre-test and post-test design in the control and experimental classes. In each class, students were asked to complete five problem-solving questions. The control class received regular learning, while the experimental class utilized student self-learning media. After implementation, students in the control and experimental classes were assessed. The pre-and post-test results of each class exhibited distinct characteristics and values. The pre-test results for the control and experimental classes are presented in Table 7 and illustrated in the accompanying graph.

The pre-test results of the control and experimental classes exhibit a nearly identical graph between the two classes. These results vary, with the lowest point occurring precisely on the physics approach indicator. The diversity

observed in each indicator is more pronounced in the low average range. However, students have included numerous known variables in the Useful Description indicator. Table 7 presents the pre-test and post-test results for control and experimental class students.

The results demonstrated that the pre-test and post-test scores in the control class were within the low range and exhibited minimal improvement. This is because the students are not yet familiar with problem-solving procedures. Furthermore, the final results of the students' answers exhibited many errors due to the omission of specific preceding indicators. In the "useful description" indicator, the values observed in both tests are relatively high, indicating that in this class, students are accustomed to recording the information they possess before addressing the problem.

In addition, the pre-test and post-test results for the experimental class are presented in Table 8.

This experimental class's pre-test and post-test results demonstrate a specific increase in each problem-solving indicator. However, the post-test results on the helpful description indicator exhibit a minimal difference, indicating a limited improvement. This is attributed to the valuable description stage being widely recognized and utilized by students in previous problem-solving endeavors. In contrast, students have not employed other indicators. As with logical progression, which exhibited a significant increase, this was due to the fact that students were not accustomed to writing conclusions based on the results obtained and the solutions provided being logically connected. The pre-test and post-test results were then subjected to various tests described below.

Normality Test

In parametric statistics, there are two normality tests: the Kolmogorov-Smirnov and the Shapiro-Wilk tests. The analysis results indicate that the Kolmogorov-Smirnov and Shapiro-Wilk tests yielded significance values greater than 0.05, so this data is normally distributed.

Independent T-test

The results of this research indicate significance values less than 0.05, which indicates a significant difference between the scores of students who use media and those who do not.

N-gain Score

Based on the research conducted by administering pre-tests and post-tests to students before and after using the media, the N-gain Score results were obtained according to the problem-solving indicators for the control class. The N-gain score and its characteristics in the control class are presented in Table 9.

The obtained N-gain score in the control class indicates that the maximum score range is 0.5. This suggests that the N-gain scores on the Logical Progression and Physics Approach indicators are in the low category, and the other

Table 8 Results of pre-test and post-test from experiment class

Indicator	Experiment	
	Pre	Post
Useful Description	4.15	4.69
Physics Approach	1.12	4.27
Specific Application of Physics	2.68	4.86
Mathematical Procedure	2.22	4.81
Logical Progression	0.60	4.58

Table 9 Category of N-gain effectiveness from control class

Problem-Solving Stages	N-gain	Percentage (%)	Category
Useful Description	0.395	39.5	Ineffective
Physics Approach	0.0218	2.18	Ineffective
Specific Application of Physics	0.371	37.1	Ineffective
Mathematical Procedure	0.493	49.3	Less effective
Logical Progression	0.0608	6.08	Ineffective

Table 10 Category of N-gain effectiveness of experiment class

Problem-Solving Stages	N-gain	Percentage (%)	Category
Useful Description	0.636	63.6	Effective Enough
Physics Approach	0.813	81.3	Effective
Specific Application of Physics	0.94	94	Effective
Mathematical Procedure	0.932	93.2	Effective
Logical Progression	0.904	90.4	Effective

three indicators fall into the medium category. Many students have been able to write equations and solve problems despite reaching incorrect conclusions or misapplying previous steps. Consequently, the N-gain score results from the pre-test and post-test acquisition of the control class demonstrated ineffective outcomes.

In the experimental class, the average N-gain score was interpreted according to the established score criteria presented in Table 10.

The N-gain category, which has been adjusted to reflect the score of each indicator, implies that useful description falls into the moderately effective category. In contrast, the other four indicators fall into the effective category. Table 11 indicates that the useful description category has the lowest N-gain score. This is due to the results of the pre-test and post-test of this class mainly having similar good scores, resulting in no discernible increase in effectiveness. Compared to the results of the N-gain score of the control class that uses traditional learning without a website, the increase in problem-solving is more significant in the experimental class that uses the website.

The results of this study align with the research by Fajarudin (2023), which indicates that the use of interactive

website media can enhance students' problem-solving abilities. The study demonstrated an N-gain value of 0.33 for students who utilized the website and 0.26 for students who did not. Similarly, another study demonstrated that formative feedback instruments can enhance student problem-solving abilities (Fuadia et al., 2023). Correspondingly, the findings of this study indicate that the formative feedback-based hydrostatic pressure educational website is valid, practical, and effective for increasing students' problem-solving and is suitable for use as a tool for learning.

4. CONCLUSION

The development of an educational website based on formative feedback on hydrostatic pressure material in this study significantly impacts student interest in learning and problem-solving skills. The website, which has been tested for validity in terms of material and media, is highly effective. The media has also been tested for practicality according to students and teachers, with an average score of 90%, indicating that it is highly practical. The effectiveness of the media, as determined by the pre-test and post-test scores in both classes, yielded significant results ($p < 0.05$). This demonstrates a notable distinction between the control and experimental classes' student scores. The N-gain score results in the experimental class suggest that the developed media has been moderately effective in enhancing one indicator of problem-solving. Simultaneously, it is efficacious in improving the other four problem-solving indicators. However, the N-gain scores in the control class demonstrated ineffective results. Based on the findings of this study, the formative feedback-based hydrostatic pressure educational website can facilitate the enhancement of students' problem-solving abilities. The website's efficacy has been validated by experts, deemed practical by students and teachers, and demonstrated effectiveness.

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