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A Project-Based Learning Approach: Validating an Instructional Supplement for Phys-Fluids

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Abstract - *The low level of students' understanding of the concept of hydrostatic pressure, as revealed by the internal assessment of the Science Education Study Program (2024), highlights the need for developing instructional supplements that are not only informative but also capable of fostering analytical skills. This study addresses this gap by aiming to develop and validate a Project-Based Learning (PjBL)-based instructional supplement on the topic of hydrostatic pressure. The research followed a Research and Development (R&D) approach using the ADDIE model, limited to the Develop stage. Validation was conducted by three subject matter experts and three media experts using a Likert scale assessment sheet. The assessed aspects included content quality, instructional quality, and technical quality. The results showed that all aspects received average scores in the "very valid" category. Specific revisions, such as refining contextual illustrations, clarifying project work steps, enhancing visual design, and standardizing scientific terminology, were implemented to improve the final product's quality. This validated supplement is deemed suitable for use in higher education physics learning, particularly to support the development of students' analytical and higher-order thinking skills. The study's findings demonstrate a promising alternative for creating effective, PjBL-based learning materials that can significantly improve students' understanding of complex physics concepts.*

Keywords: *Instructional Supplement, Project-Based Learning, Content Validity, Hydrostatic Pressure, Analytical Skills.*

I. INTRODUCTION

Physics is a constantly evolving field that plays a crucial role in helping humans address complex challenges from a scientific and historical perspective [1]. However, many students still face difficulties and harbor misconceptions, especially in topics related to fluids [2]. To effectively analyze static fluid concepts in real-world situations, a strong grasp of both foundational principles and scientific processes is essential. Hydrostatic pressure, a core topic in static fluids, has numerous practical applications in daily life, such as in dam systems, pipelines, and pressure gauges. Yet, its abstract nature and complex calculations often make it a significant challenge for students, particularly at the university level.

The findings from an internal assessment of the Science Education Study Program (2024) revealed that only 25% of students could accurately explain the concept of hydrostatic pressure and the factors influencing it, such as depth, density, and gravity. The average test score for second-semester students on this topic was only 58.2, well below the minimum B grade standard of 71.0. This low achievement highlights the urgent need for instructional strategies that are explicitly designed to strengthen students' analytical skills in understanding and applying hydrostatic pressure in real-world contexts. Furthermore, current learning resources are often theoretical and lack the real-world scenarios or problem-solving activities needed to develop the analytical skills required for 21st-century learning.

The 21st-century learning paradigm centers on student-centered approaches aimed at equipping students with the four core competencies: critical thinking, effective communication, collaboration, and creativity [3]. Project-Based Learning (PjBL) is a highly relevant model for developing these skills, as it engages students in collaborative, real-world projects to build a deeper and more meaningful understanding of scientific concepts [4]. PjBL is an active learning approach that emphasizes autonomy, constructive inquiry, goal-setting, collaboration, and reflection within authentic problem contexts. It has been successfully implemented across various educational levels, from elementary schools to higher education [5]. The model's seven key elements—including a need to know, a driving question, student voice and choice, inquiry and innovation, and a publicly presented product—provide a robust framework for developing 21st-century skills [6]. Therefore, there is a need for a PjBL-based instructional supplement specifically designed to address the challenges in learning hydrostatic pressure and to strengthen students' analytical competencies.

Instructional supplements are additional educational materials designed to enrich and expand upon the content found in textbooks [7]. They can enhance student motivation, provide remediation, and promote deeper engagement with the subject matter. The PjBL-based instructional supplement developed in this study is specifically designed to complement traditional teaching and to provide a platform for developing students' analytical skills.

Analytical skills are a cognitive process comprising three main stages: (1) breaking down a complex concept or problem into its constituent parts; (2) examining the specific characteristics and functions of each part; and (3) communicating how these parts interrelate to form the whole. These skills are a critical component of 21st-century competence, alongside critical thinking, creativity, and problem-solving [8]. They refer to the capacity to gather, evaluate, and interpret information to find solutions to a

problem [9]. Therefore, the PjBL-based instructional supplement is expected to help cultivate students' analytical skills in response to 21st-century demands and the identified gap in conceptual understanding of hydrostatic pressure. However, before implementation, the supplement's content validity must be established.

In this study, content validity refers to the extent to which the instructional supplement covers all essential aspects of the intended learning competencies. The supplement must include content that is relevant to hydrostatic pressure and capable of fostering students' analytical skills without omitting key elements or including irrelevant content. Content validity is determined by three core characteristics: completeness of coverage, content relevance, and expert review [10]. These aspects serve as the foundation for validating the developed instructional supplement.

This study specifically aims to validate a PjBL-based instructional supplement for the Phys-Fluids topic of hydrostatic pressure. The primary focus is to assess its content validity based on four key aspects: (1) content quality, which includes the alignment of material with hydrostatic pressure concepts and learning objectives; (2) instructional quality, which evaluates clarity of presentation, the PjBL approach, and its ability to facilitate analytical skills; (3) technical quality, covering visual design, readability, and ease of use; and (4) additional findings, including identification of conceptual, factual, or grammatical errors [11]. The assessment of these four aspects ensures that the developed supplement is a valid and reliable resource for learning, capable of supporting the development of 21st-century skills, particularly analytical skills.

This research contributes directly to educational practice by providing an innovative instructional resource that not only complements existing materials but is also specifically designed to train students' analytical skills through a project-based approach. The novelty of this study lies in its integration of the hydrostatic pressure topic within a contextual PjBL framework tailored to the needs of 21st-century learning. By providing a validated instructional supplement, this research is expected to strengthen the quality of university-level physics education, particularly in the areas of conceptual understanding and higher-order thinking. Furthermore, this study supports the achievement of Sustainable Development Goal (SDG) 4: Quality Education by providing inclusive and relevant learning materials that enhance students' competence in understanding and solving real-world problems.

II. METHODS

The ADDIE model was used to develop and validate the instructional supplement. This study was limited to the Analysis, Design, and Development phases, with the Implementation and Evaluation phases planned for future research.

Analysis Phase: This phase began with a needs analysis based on an internal assessment from the Science Education Study Program. The findings revealed that 75% of students scored below the "good" category (below 71 points) in their understanding of hydrostatic pressure concepts. An item analysis of the test questions showed that many students struggled with analytical skills, such as distinguishing variables in hydrostatic pressure, organizing data, and linking concepts to real-world contexts. This highlighted a clear need for developing a Project-Based Learning (PjBL)-based instructional supplement specifically designed to foster these skills in a targeted and contextual manner.

Design Phase: An instructional supplement on hydrostatic pressure using a PjBL approach was developed in print format to train students' analytical skills. The supplement includes project-based activities, worksheets, contextual case studies, and conceptual visualizations. These components were designed to facilitate active student engagement in identifying, analyzing, and solving real-world problems related to hydrostatic pressure. The design of the supplement was aligned with the Design stage of the ADDIE model, focusing on the synergy between content, learning objectives, the PjBL approach, and analytical skill indicators. This design ensures that the supplement serves as an effective and contextual learning resource in higher education.

Development Phase: The instructional supplement was developed based on the design that incorporates hydrostatic pressure concepts within a PjBL framework to enhance students' analytical skills. The content validity of the supplement was assessed by six validators: three material experts and three media experts. Material experts evaluated content quality, instructional quality, and additional findings, including the alignment of the material with hydrostatic pressure concepts, the effectiveness of the PjBL approach, and the accuracy of scientific terms and language. Meanwhile, media experts evaluated technical quality, content quality, and additional findings, focusing on visual design, readability, ease of use, the effectiveness of illustrations in supporting conceptual understanding, and the absence of visual or layout errors. The results of this validation were used as the primary guide for revision to ensure the supplement is feasible, appealing, and effective for learning.

Research Instruments and Data Analysis: This research was conducted at Bhinneka PGRI University. Data were collected using validation sheets from the three material experts and three media experts. The instrument utilized a 5-point Likert scale. The scores obtained were averaged to determine the level of content validity based on the criteria.

Table 1. Validity Criteria

Score ($\dot{x}$)	Criteria
$\dot{x} > 4.20$	Very valid
$3.40 < \dot{x} \leq 4.20$	Valid
$2.60 < \dot{x} \leq 3.40$	Moderately valid
$1.80 < \dot{x} \leq 2.60$	Less valid
$\dot{x} < 1.80$	Not valid

III. RESULTS AND DISCUSSION

A. Results

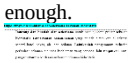
This section presents the analysis and interpretation of data focusing on the content validity of the Project-Based Learning (PjBL)-based instructional supplement. The supplement was developed to enhance students' analytical skills in hydrostatic pressure, addressing an identified gap where 75% of students in the Science Education Study Program scored below the "good" category (score <71) and struggled with analytical skills.

The instructional supplement was validated based on four key aspects: (1) content quality, (2) instructional quality, (3) technical quality, and (4) additional findings. These aspects assess the material's alignment with hydrostatic pressure

concepts, the clarity of the PjBL presentation, the quality of its visual design, and the identification of any content errors.

During the initial validation phase, three subject matter experts and three media experts first provided feedback on the preliminary draft of the instructional supplement. This feedback was used to revise the supplement before the final assessment. The detailed suggestions and improvements provided by the validators are outlined in Table 2.

Table 2. Summary of Suggestions and Revisions

No.	Aspect	Before Revision	Suggestions/ Feedback	Follow-up Action
1	Content Quality	The explanation of pressure concepts lacked real-world context. 	The explanation of pressure concepts should be accompanied by practical illustrations.	Added illustrations of hydrostatic pressure applications in daily life. 
2	Instructional Quality	The project steps were not detailed enough. 	Project steps need to be explained more clearly and in a more detailed manner.	Added a systematic sequence of project work steps. 
3	Technical Quality	The background color was too vibrant, affecting readability. 	The background color is too striking and interferes with readability.	Replaced the background color with a more neutral color. 
4	Additional Findings	There were several spelling errors in physics terms. 	Correct some physics terms that are misspelled.	Corrected the inappropriate terms to align with scientific principles. 

After the revision, the validators reassessed the supplement based on four aspects: content, instructional, technical, and additional findings, which are detailed in Table 3.

Table 3. Recapitulation of the Content Validity Assessment Results of the Instructional Supplement by Material and Media Experts

No.	Aspect	Assessment Indicators	V1	V2	V3	Average	Criteria
Material Expert							
1	Content Quality	The material supports student learning outcomes and basic competencies.	5	5	4	4.67	Very Valid
		The material is consistent with the concept of hydrostatic pressure and does not lead to misconceptions.	5	4	4	4.33	Very Valid
		Scientific information is accurate and from credible sources.	4	4	5	4.33	Very Valid
		The connection between subtopics is logical and sequential.	4	5	5	4.67	Very Valid
		Integration of real-world contexts in questions and material.	5	4	5	4.67	Very Valid
		The project supports students' critical and analytical thinking skills.	5	5	4	4.67	Very Valid
2	Instructional Quality	he presentation of the material is systematic and follows a scientific reasoning flow	5	4	4	4.33	Very Valid
		PjBL activities are contextual and authentic.	5	4	5	4.67	Very Valid
		Project instructions are clear and encourage critical thinking.	4	5	4	4.33	Very Valid
		The supplement facilitates students' analytical skills.	4	5	5	4.67	Very Valid
2	Additional Findings	There are no typos or grammatical errors.	5	5	4	4.67	Very Valid
		No conceptual or factual errors were found.	4	5	4	4.33	Very Valid
Media Expert							
1	Technical Quality	The visual design is appealing, consistent, and educational.	5	4	5	4.67	Very Valid

No.	Aspect	Assessment Indicators	V1	V2	V3	Average	Criteria
		The font, font size, and spacing support readability.	5	4	4	4.33	Very Valid
2	Content Quality	Visualizations support conceptual understanding and the PjBL approach.	4	5	4	4.33	Very Valid
3	Additional Findings	No illustration errors were found.	5	5	4	4.67	Very Valid

B. Discussion

This section outlines the assessment results of the content validity of the Project-Based Learning (PjBL)-based instructional supplement. The supplement was designed to foster students' analytical skills in the topic of hydrostatic pressure. The validation process involved three material experts and three media experts, with the assessment covering four key dimensions: content quality, instructional quality, technical aspects, and additional findings.

Prior to the quantitative assessment, the validators provided feedback on the initial draft of the supplement. For content, they recommended adding real-world illustrations of hydrostatic pressure. This recommendation aligns with Contextual Teaching and Learning principles, which posit that concepts are more easily understood when linked to real-world situations [12]. Furthermore, Paivio's Dual Coding Theory suggests that combining verbal and visual information enhances information absorption and retention by activating both cognitive processing channels simultaneously [13].

Using illustrations from real-world situations is also consistent with the constructivist principles of Bruner and Vygotsky, who emphasized the importance of building understanding through meaningful, active, and guided learning experiences [[14], [15]]. For example, showing water spurting from holes at different depths in a container helps students realize that the deeper the hole, the greater the water pressure. Therefore, presenting material with contextually relevant illustrations not only clarifies the link between theoretical concepts and their real-world applications but also strengthens the learning process by making it more visual, practical, and aligned with the nature of science education.

Another key suggestion from the validators was to clarify the project stages systematically. This is crucial for students to follow the learning process effectively. Thomas's framework on PjBL emphasizes that successful implementation requires a logical and sequential progression, from defining a driving question to the final product and reflection [16]. He highlights five key characteristics of PjBL—centrality of the project, a driving question, in-depth investigation, student autonomy, and authenticity—all of which are optimally achieved when project steps are clear and well-structured [16]. Vygotsky's concept of scaffolding also highlights the importance of gradual guidance in helping learners build new conceptual understanding [15]. Systematic steps support the principles of effective instructional design, as reflected in the ADDIE model, which places instructional design as a key element in material development [17]. Thus, adding systematic project steps not only clarifies instructions but also reinforces the successful implementation of PjBL for developing analytical skills.

A key finding from the technical aspect was the use of an overly vibrant background color that interfered with readability. Validators recommended replacing it with a more neutral color to enhance visual comfort and accessibility. This revision aligns with the Coherence Principle from Mayer's Multimedia Learning Theory, which states that visual design should support cognitive processes, not overload them. Bright or high-contrast backgrounds can distract learners and disrupt their focus on the core content [18]. Additionally, according to Universal Principles of Design by Lidwell et al., appropriate color selection is crucial for readability, as poor color contrast can cause eye strain and reduce learning effectiveness [19]. By using a more neutral background, the supplement becomes more visually friendly, improves readability, and conforms to user-centered design principles in educational media development.

Validators also identified several inaccuracies in the physics terminology. This finding was critical as such errors could lead to misconceptions. According to Dick, the accuracy of terminology is an essential component of content validity that must be maintained in instructional material development [20]. Furthermore, Heinich emphasizes that clear scientific terminology plays a vital role in building students' conceptual understanding, especially in science, which demands linguistic precision [21]. Therefore, adjusting the physics terms to academic standards was a crucial step to ensure conceptual clarity and instructional effectiveness.

The quantitative validation results show that the developed PjBL-based instructional supplement is highly valid overall. As shown in Table 3, the Content Quality aspect received a high average score, indicating that the material is aligned with hydrostatic pressure concepts, supports learning objectives, and provides accurate and relevant scientific information. This is consistent with Dick's principle of content validity, which asserts that learning materials must contain accurate information that supports learning goals and prevents misconceptions [20].

For the Instructional Quality aspect, all indicators also scored in the "very valid" category. The material is presented systematically, with contextual and authentic PjBL activities. The clear project instructions and activities that stimulate analytical skills are a major strength of this product. This aligns with Thomas's PjBL syntax, which emphasizes active student engagement in authentic projects [16], as well as Vygotsky's scaffolding theory, which states that effective learning occurs when students are guided through systematic and challenging cognitive stages [15].

The Technical Quality aspect, assessed by media experts, also received a high score. The appealing visual design, appropriate font choices, and consistent layout support readability and user comfort. This demonstrates that the Multimedia Learning principles from Mayer have been accommodated, ensuring that the visual design enhances, rather than detracts from, cognitive understanding [18]. In addition, media experts also validated the visual content quality and additional findings like illustration and terminology errors, which were all corrected based on prior feedback.

Finally, the Additional Findings aspect, covering typos, scientific terms, and visual illustrations, also received a very valid score. The revisions made demonstrate a strong commitment to academic accuracy and linguistic precision. This supports Heinich's view that clarity of terminology and linguistic accuracy are critical components of effective instructional media [21]. Therefore, the validation results confirm that the developed PjBL-based supplement is not only pedagogically sound and visually appealing but also a valid resource with strong and relevant content that aligns with modern learning theories and instructional design principles.

IV. CONCLUSION

The validity of the Project-Based Learning (PjBL)-based instructional supplement on hydrostatic pressure is very high, as confirmed by the comprehensive assessments of both material and media experts. This high validity is reflected in the average scores across all evaluated aspects content, instructional quality, technical design, and additional findings all of which fall into the "very valid" category. The material successfully meets the principles of scientific accuracy, aligns with learning objectives, and is free from misconceptions. Revisions based on expert feedback, such as the addition of contextual illustrations, the systematic arrangement of project steps, the correction of scientific terminology, and the improvement of the visual design, further enhanced the supplement's overall quality and pedagogical soundness.

The high level of validity confirms the supplement's suitability as a learning resource. This research provides a direct and practical contribution to educational practice by offering a validated, innovative alternative to traditional teaching materials for developing students' analytical skills in physics.

Given its high validity, this supplement is recommended for implementation in science education to strengthen students' analytical skills. As a next step, a limited field trial is necessary to assess the supplement's practicality and effectiveness in an authentic classroom setting. Furthermore, future development could focus on integrating interactive technologies to enhance the supplement's appeal and relevance in the digital age.

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