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Design and development of web-based problem-solving ability test instruments on fluid Physics material

M Misbah[1,2], Ida Hamidah*[1], Siti Sriyati[1], and Achmad Samsudin[1]

[1]Universitas Pendidikan Indonesia, Bandung, Indonesia
[2]Universitas Lambung Mangkurat, Banjarmasin, Indonesia

ABSTRACT

This study designed and developed a web-based problem-solving ability test instrument for fluid physics materials. This study utilized four steps of design-based research (DBR): needs analysis, design planning, development, and reflection of usage results. Based on the needs analysis, a fluid physics material test instrument was designed and developed based on indicators of problem-solving ability: describing problems, describing situations in physics concepts, planning solutions, implementing plans, and checking and evaluating. Seven expert validators validated this instrument and then reflected. The study results indicated the valid preparation of a web-based problem-solving ability test instrument on fluid material. The instruments were prepared and associated with local wisdom. The content validity based on the expert judgment showed the suitable instrument for testing problem-solving skills.

*Corresponding author
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INTRODUCTION

Optimizing problem-solving skills in students is increasingly recognized as a fundamental component of education across disciplines. These skills are essential not only for academic success but also for facing real-world challenges. Problem-solving encompasses a range of cognitive processes, including critical thinking, analysis, and synthesis, which are essential for students to effectively address complex problems they face in educational settings and everyday life (Azizah and Nasrudin 2022; Kartini et al. 2021; Syukri et al. 2018).

Problem-solving skills refer to an individual's ability to identify, analyze, and solve problems effectively. They involve critical, creative, and analytical thinking processes that enable an individual to find optimal solutions to challenges. These skills are an integral part of learning and professional development, allowing individuals to deal with complex situations in a structured and planned manner (Jonassen 2020).

Problem-solving skills encompass identifying, analyzing, and resolving issues effectively. These skills are crucial for academic success and professional competence, enabling individuals to tackle complex challenges and develop innovative solutions. Recent literature emphasizes the role of problem-

KEYWORDS

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solving skills in fostering critical thinking and adaptability in various contexts, including education and the workplace (Smith and Jones 2019).

Physics problem-solving skills include recognizing problems, implementing strategies, planning strategies, and evaluating solutions (Sujarwanto et al. 2014). Not only that, problem-solving skills can also be planned by creating strategies. Several stages of the process for solving a problem can also go through the stages of understanding, making plans, implementing plans, and reviewing problem-solving situations (Selçuk and Çalýskan 2008). In this study, the indicators of physics problem-solving skills are taken to refer to Heller et al. (1992). Regarding problem-solving skills, namely the ability to visualize problems, describe problems in terms of physics, plan solutions, implement plans, and finally check and evaluate.

In today's rapidly changing world, the ability to solve problems effectively contributes to adaptability and creativity. Good problem-solving skills enable individuals to adjust to unexpected changes and challenges and develop innovative solutions (Martinez et al. 2021). This is particularly relevant in dynamic work environments and situations where conventional approaches may be inadequate. Therefore, teachers and pre-service teachers need this skill.

In addition, the importance of problem-solving skills is not limited to academic contexts. These skills are essential for personal and professional development. Students equipped with strong problem-solving skills are better prepared to face the complexities of modern life, including decision-making in their careers and personal relationships (Hadiprayitno et al. 2022; Widodo et al. 2017). Therefore, developing these skills in educational settings is essential to developing well-rounded individuals who can make meaningful contributions to society.

Problem-solving abilities are a crucial aspect of learning physics that students must own in dealing with obstacles and problems that need critical, systematic thinking, and the ability to make the right judgments (Tanjung et al. 2024). The development of digital technology has changed various aspects of education, including evaluation methods. In physics and engineering education, assessing problem-solving ability in fluid topics is becoming increasingly important (Al-Qoyyim et al. 2024; Datur 2017; Desriah and Setyarsih 2021). Recent studies have shown that problem-solving skills lead to an understanding of fluid dynamics and related concepts. Several studies have highlighted the importance of online assessment instruments in evaluating students' problem-solving skills in fluid topics (Kusairi et al. 2017).

Fluid mechanics is divided into two main categories: static fluid and dynamic fluid. Fluid statics deals with fluids at rest and focuses on pressure distribution and forces exerted by the fluid. Fluid dynamics, conversely, concerns fluids in motion and involves studying flow behavior, forces, and energy transfer.

The study of static fluids, or hydrostatics, focuses on the pressure distribution within a stationary fluid. The principles governing static fluids are essential for understanding pressure, buoyancy, and hydrostatics concepts. Faizah (2023) emphasized that students must grasp the principles of static fluids to build a solid foundation for more complex fluid mechanics topics. Kusairi et al. (2021) illustrated the practical applications of static fluid concepts, such as buoyancy and blood pressure, which students encounter daily. This connection to real-world phenomena can enhance students' understanding and retention of static fluid principles.

Dynamic fluid mechanics involves studying fluid motion, including laminar and turbulent flows. Recent advancements have improved our understanding of turbulence and its impact on flow behavior. Studying dynamic fluids is vital for understanding fluid flow, energy transfer, and various engineering applications. The need for relevant learning models to support students' problem-solving abilities in dynamic fluid topics, as many students struggle to connect theoretical concepts with practical applications.

Developing a web-based test instrument to measure problem-solving ability in fluid topics is an essential advancement in educational assessment methodology. With the increasing complexity of scientific concepts such as fluid dynamics, there is an urgent need for innovative approaches to evaluate students' problem-solving abilities effectively. Recent studies have emphasized the importance of creating valid and reliable assessment tools to measure students' understanding and application of fluid concepts in real-world scenarios (Ilahi et al. 2024; Rusmawati 2023; Verawati et al. 2020).

Web-based test instruments are online tools designed for administering, scoring, and analyzing assessments. They facilitate the evaluation of knowledge, skills, and competencies through a digital platform, offering automated scoring, real-time feedback, and detailed analysis. These instruments have evolved significantly with the advancement of technology, providing a more interactive and efficient testing experience (Clarke and Dede 2020; Setiawan 2023).

Web-based test instruments provide greater accessibility by allowing users to take the test from any location with internet access. Increased accessibility can result in higher participation rates and a more inclusive testing environment, expanding the scope of who can be assessed (Brown et al. 2019).

Web-based testing instruments simplify the management and analysis of assessment data. Automated scoring systems and sophisticated analysis tools reduce the time and effort required for scoring and interpreting results. Wilson and Thompson (2022) noted that these capabilities increase the efficiency of the assessment process and provide valuable insights into user performance, which can inform educational strategies and decision-making.

Ensuring the security and integrity of online assessments is critical. Modern web-based testing systems incorporate robust security measures, including encrypted data transmission and secure authentication protocols. These features help protect against cheating and maintain the credibility of test results (Adams and Garcia 2023).

Several studies have emphasized the need for valid and reliable online assessment tools for fluid topics. These studies suggest the need to develop targeted assessment tools to provide insight into students' understanding and application of fluid concepts (Qotrunnada and Susilowibowo 2021). By adopting modern pedagogical approaches and tailoring assessment tools to students' problem-solving skill profiles, the results can improve their understanding of fluid dynamics and their overall problem-solving skills.

This study developed a web-based test instrument and designed a system to assess the problem-solving abilities of prospective physics teachers in fluid topics. The novelty of this study lied in developing a test instrument integrating with technology (web-based) and local wisdom, and compiled based on problem-solving ability indicators, according to Heller et al. (1992).

MATERIALS AND METHODS

This study used Design-Based Research (DBR). In this study, DBR was adapted to produce a web-based problem-solving ability test instrument product on fluid physics material. This DBR included four steps: analysis, design, development, and reflection of results (Mahmudin et al. 2024; Nurzaman et al. 2024) as shown in **Figure 1.** In the analysis stage, we identified the needs of lecturers related to the required test instruments. Based on the results of this analysis, the initial design of the web-based problem-solving ability test instrument on fluid physics material was developed at the planning and development stage. Finally, the test instrument's success was evaluated at the reflection stage. The development stage in this study involved seven validators who were experts in their fields. The seven validators came from four public universities in Indonesia, namely the Universitas Pendidikan Indonesia, Universitas Lambung Mangkurat, Universitas Mulawarman, Universitas Tadulako, and Universitas Cenderawasih. Data collection was carried out through interviews and documentation. The research instrument used was the problem-solving ability test instrument validation sheet.

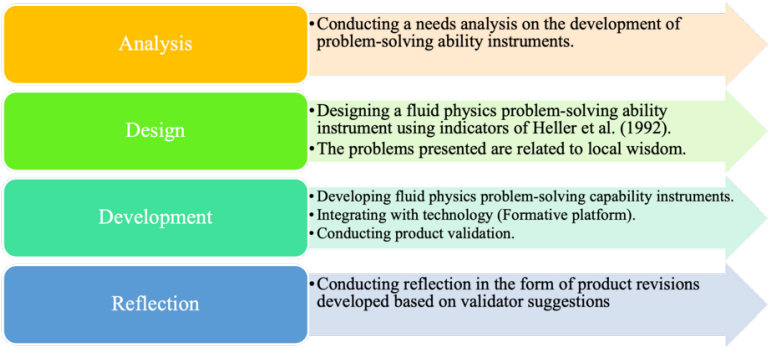


Figure 1: Design-based research steps.

RESULTS AND DISCUSSION

The results of interviews with two lecturers in charge of fluid physics courses at one of the state universities in Banjarmasin show that no problem-solving skills test instrument is compiled in detail based on the stages of Heller et al. (1992); the existing instruments still use paper and pencil tests; the instrument has not been linked to local wisdom and has not been integrated with technology. Therefore, further development of problem-solving ability instruments on fluid material is needed.

The test instrument is designed based on indicators of problem-solving ability: describing problems, describing problems in physics concepts, planning solutions, implementing plans, and checking and evaluating. This indicator refers to Heller et al. (1992). Specifically, this test instrument consists of 5 essay questions consisting of topics on hydrostatic pressure, Pascal's Law, Archimedes' Law, continuity equations, and Bernoulli's equations. The instruments developed are integrated with technology using a formative platform. In addition, the testing instruments developed are also related to local wisdom. For example, the problem in the physics question is related to the Riam Kanan dam and floating houses. The following test instrument design and answer key are shown in **Figures 2, 3, 4,** and **5**.

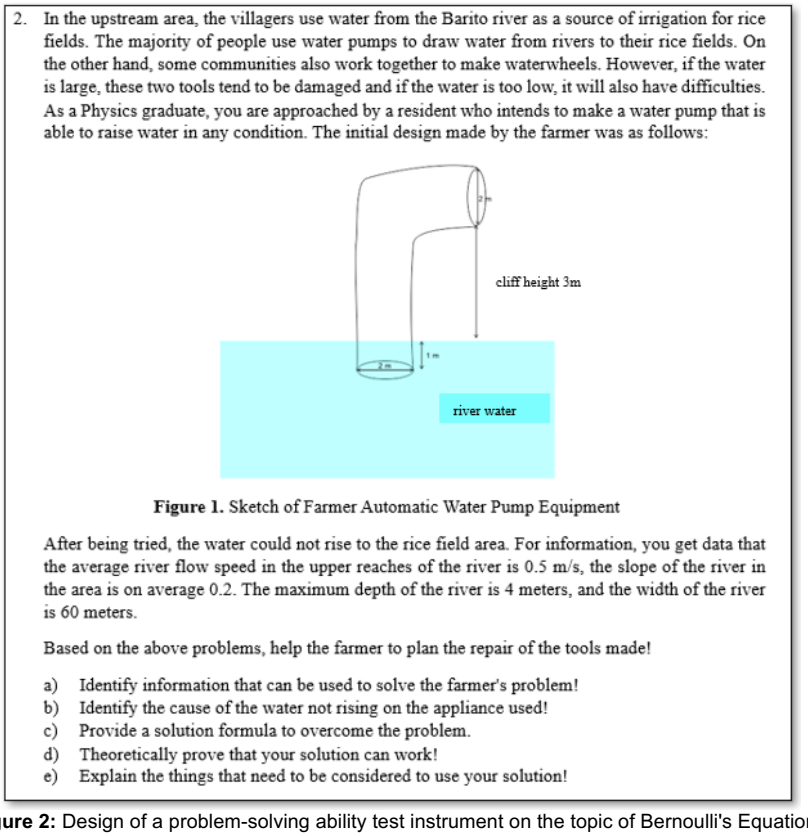

2. In the upstream area, the villagers use water from the Barito river as a source of irrigation for rice fields. The majority of people use water pumps to draw water from rivers to their rice fields. On the other hand, some communities also work together to make waterwheels. However, if the water is large, these two tools tend to be damaged and if the water is too low, it will also have difficulties. As a Physics graduate, you are approached by a resident who intends to make a water pump that is able to raise water in any condition. The initial design made by the farmer was as follows:

Figure 1. Sketch of Farmer Automatic Water Pump Equipment

After being tried, the water could not rise to the rice field area. For information, you get data that the average river flow speed in the upper reaches of the river is 0.5 m/s, the slope of the river in the area is on average 0.2. The maximum depth of the river is 4 meters, and the width of the river is 60 meters.

Based on the above problems, help the farmer to plan the repair of the tools made!

a) Identify information that can be used to solve the farmer's problem!
b) Identify the cause of the water not rising on the appliance used!
c) Provide a solution formula to overcome the problem.
d) Theoretically prove that your solution can work!
e) Explain the things that need to be considered to use your solution!

Figure 2: Design of a problem-solving ability test instrument on the topic of Bernoulli's Equation.

In **Figure 2**, the physics problem on the Bernoulli Equation topic is related to the Riam Kanan Dam. This dam is the largest in South Kalimantan and was built to utilize the reservoir as an electricity supply in the region. The problem-solving ability question in **Figure 2** is related to designing a water pump to irrigate rice fields. However, the tool made from the design cannot flow water. This needs to be solved using the Bernoulli equation.

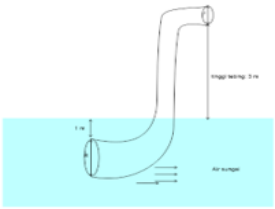
In viscous and incompressible fluids, the **equation (1)** can be written as (after integrating):

$$\frac{p}{\rho}+\frac{V^2}{2}+gz=\text{konstan} \tag{1}$$

Equation (1) is known as Bernoulli's equation. Try multiplying all the terms by ρ, then we get a form that we often see in Indonesia-language reference books (**Equation (2)**), that is:

$$p_1+\frac{1}{2}\rho V_1^2+\rho g z_1=p_2+\frac{1}{2}\rho V_2^2+\rho g z_2 \tag{2}$$

1. Useful information
   a) River flow speed
   b) Cliff height (3 meters)
   c) Bottom pipe diameter
   d) Diameter of the top pipe
   e) Pipe depth
2. The appliance cannot work because the water entering the pipe does not have a pressure difference. So it needs to be redesigned
3. Solution formulation
   To be able to work as it should,
   the design of the tool must be changed as follows:



4. Theoretical proof

$$P_1+\frac{1}{2}\rho v_1^2+\rho g h_1=P_2+\frac{1}{2}\rho v_2^2+\rho g h_2$$

P_1 caused by the pressure of the water and in order for the water to flow, then $P_1 > P_2$.

$$\rho g h+\frac{1}{2}\rho v_1^2+0=P_2+\frac{1}{2}\rho\left(\frac{A_1 v_1}{A_2}\right)^2+\rho g h_2$$

$$\rho g(1)+\frac{1}{2}\rho v_1^2=P_2+\frac{1}{2}\rho\left(\frac{(\pi R^2)v_1}{(\pi r^2)}\right)^2+\rho g(1+3)$$

$$P_2=\rho g+\frac{1}{2}\rho v_1^2-\frac{1}{2}\rho\left(\frac{(R^2)v_1}{(r^2)}\right)^2-4\rho g$$

$$P_2=\frac{1}{2}\rho\left(v_1^2-\frac{R^4}{r^4}v_1^2\right)-3\rho g$$

$$P_2=\frac{1}{2}\rho v_1^2\left(1-\frac{R^4}{r^4}\right)-3\rho g$$

It can be seen that to raise the water from the river depends only on the comparison of the size of the pipe in the river and the pipe above the river.

5. To implement this solution, there are several things that need to be considered, including:
   a) The placement of the pipeline direction must be consistent and in line with the direction of the river flow.
   b) The depth of the pipe should be made deeper so that it gets more pressure
   c) The pipe inlet must be cleaned so that it is not obstructed by garbage

Figure 3: Answer key for problem solving skills questions based on Heller et al.'s (1992) stages on the topic of Bernoulli's Equation.

3. Lately, people have begun to leave traditional lanting houses by replacing them with more modern equipment. This is due to the rampant cases of sunken lanting houses as shown in the following figure:

Figure 2. Sinking Traditional Lanting House

Mr. Tono thinks that the buoys used by the Traditional Lanting house are not strong enough to withstand the weight because they are made of Gelonggongan Wood. Mr. Tono suggested replacing it with a float from a used plastic drum.

Based on the above problems, help the farmer to plan the repair of the tools made!

a) Identify the cause of traditional wooden houses sinking easily!
b) Based on your analysis, explain why the use of bereger wood is considered ineffective as a buoy!
c) Analyze ideas and input from Mr. Tono from a physics point of view!
d) Prove theoretically that the solution provided by Mr. Tono can work!
e) Explain the things that need to be considered to use your solution!

Figure 4: Design of a problem-solving ability test instrument on Archimedes' law topic.

Figure 4 shows the physics problem of Archimedes' Law with the local wisdom of "lanting house". Lanting House is a traditional house that floats on the rivers of South Kalimantan, symbolizing the Banjar people's local wisdom. The problem-solving ability in **Figure 4** is related to the increasing number of cases of sinking floating houses. Then, an in-depth analysis of the causes and solutions based on Archimedes' Law is carried out.

The principle of buoyancy states that when an object is placed on a static fluid, it will be lifted upwards due to a force equal to the weight of the fluid being moved. The force that causes the object to lift is called the buoyancy force. This buoyancy force is caused by an increase in hydrostatic pressure as the object moves further and further inward and the pressure at the bottom of the object is greater than the pressure at the top of the object. The magnitude of this force (see **Equation (3)**) is,

$$F_B = \rho g V = \gamma V \tag{3}$$

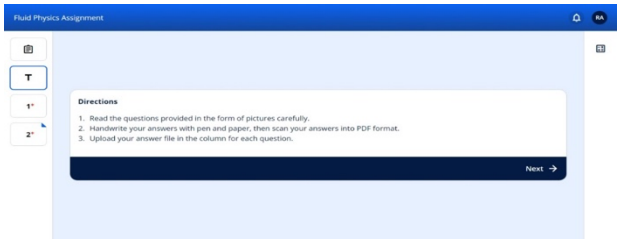
The symbol FB (index B to refer to “buoyancy”) is used.

1. Causes of traditional Lanting houses sinking
   Based on the brief information provided, the lanting house has a float in the form of a wooden plank. The wood has a specific gravity that changes along with the length of the wood in the water so that one day it will sink.
2. Wood for a long period of time will undergo a change in its density because water can enter the pores of the wood. When water has mixed into the wood, the density of wood can change to be equal or greater than water and will cause drowning.
3. The idea given by Mr. Tono is good because by using drums, the density of the buoy and the total housing system will tend to be stable and lower compared to the density of water.
4. Theoretically proof!
   Known:
   V_{drum} = 150 L; massa: 5.4 kg; ρ_{drum} =36 kg/m^3
   ρ_{air} = 1000 kg/m^3

   This means that 1 drum can withstand a load of 964 kg
   If 1 house is equipped with 8 drums, then the maximum load that can be withheld is 1200 kg.
   $F_a = \rho_{fluida} g V_{drum}$
   $F_a = 1000\,{}^{kg}/_{m^3} \times 10\,{}^{m}/_{s^2} \times (8 \times 150 \times 10^{-3})\,m^3$
   $F_a = 12.000 N$
5. The use of drums as buoys must pay attention to several things, including:
   a) The position of the drum, this aims to ensure that there is an equilibrium
   b) The number of drums is adjusted to the maximum load in the house

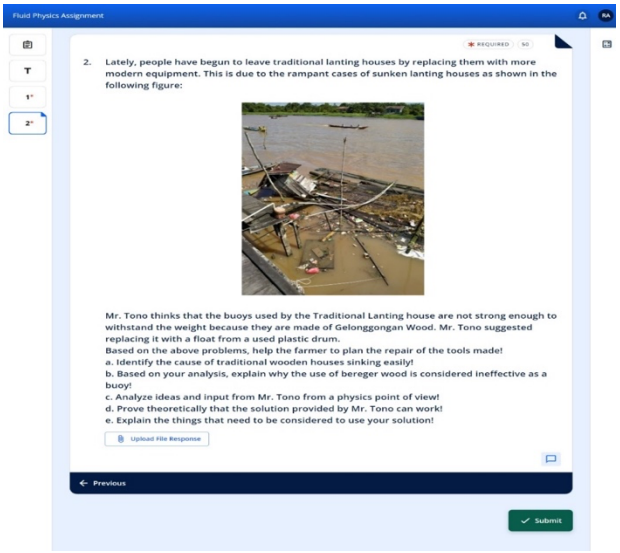
Figure 5: Answer key for problem-solving skills questions based on Heller et al.'s (1992) Stages on the topic of Archimedes' law.

The test instrument is based on the Newsela Formative Platform. Newsela Formative Platform is a tool designed to assist educators in learning by providing access to relevant news content and articles. The platform offers features that allow teachers to create formative assessments, measure student understanding, and provide immediate and constructive feedback. The platform also provides a free version. The following is a display of fluid physics test instruments on a Formative Platform as shown in **Figure 6.**



(a)

(b)



(c)

Figure 6: A display of fluid physics test instruments on a Formative Platform (a) Directions, (b) Questions on the topic of Bernoulli's Equation, and (c) Questions on the topic of Archimedes' Law.

The results of the validation of the problem-solving ability test instrument from the seven validators are listed in **Figure 7**. Validation was carried out on five aspects of the five problem-solving skills questions compiled in the sub-materials of hydrostatic pressure, Pascal's Law, Archimedes' Law, Continuity equation, and Bernoulli's equation. The five aspects are the appropriateness of good and correct use of language in questions (ALQ), readability of questions (RQ), suitability of physics concepts in problems (SPC), compatibility of the answer key with the question (CAQ), compatibility of questions with indicators of problem-solving ability (CIP), and compatibility of questions with question indicators (CQI).

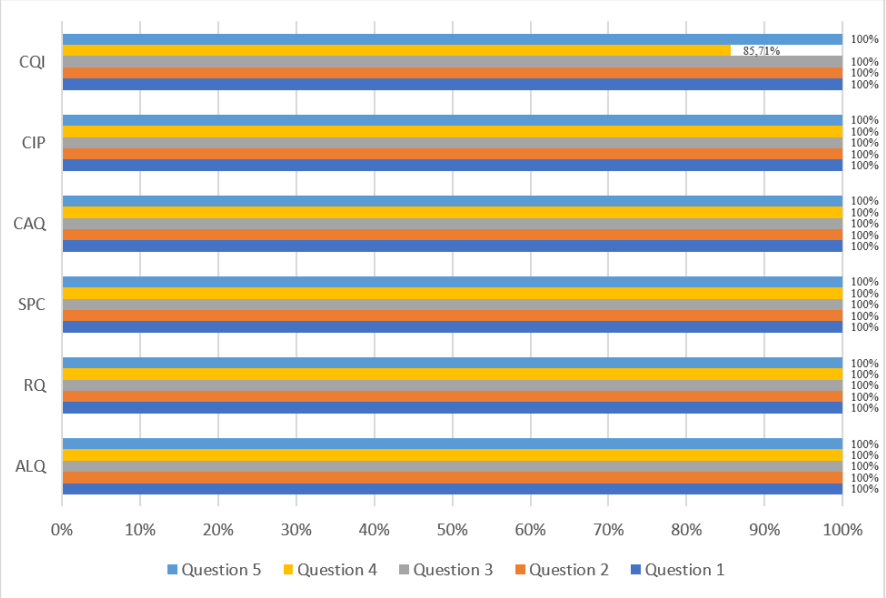


Figure 7: Results of the validation of the problem-solving ability test instrument.

The assessment of the seven validators was good for the fluid physics problem-solving ability test. Based on the validation results, revisions were made to certain parts of the instrument. The following are suggestions given by the validators as listed in **Table 1**.

Table 1: Suggestions given by validators to the developed test instruments

No	Suggestions from validators
1	Questions 1-5: Revise the word "theoretical" to "theoretical"
2	Question 2: Fix question No. 2a (Identify information that can be used to solve the farmer's problem!) because it does not measure the ability to understand the problem in the aspect of describing the problem
3	Question 3: Improve the problem indicator to Presented a case about a sinking floating house and its causes, students can analyze the ideas or solutions presented.
4	Question 5: Sub-CPMK: Students can calibrate the design of hydraulic bridges Problem indicators: Presented a case about the use of hoses to clean ships, students can predict the appropriate size. However, the questions displayed are not in the context of the same question indicators
5	Question 1: Does the width/area of the leak area need not be mentioned/assumed?
6	Question 2: - The letter s for 'River' capital - Writing mistakes to 'plan' in the last sentence question
7	Question 3: - The letter H is capitalized for 'Archimedes' Law - The letter R is capitalized for 'Lanting House' - In the answer key part b 'logs'
8	Question 1: How is the score scored if the student gives a different answer from the key given
9	Question 3: It is also necessary to estimate how long the drum will be used because the longer it will be damaged by rust
10	Question 4: • Whether the cross-sectional area of the hose end is not considered • Answer key e number 3 clarified again

Developing a web-based problem-solving ability test instrument is essential in improving the effectiveness of learning and assessment at various levels of education. The validity of this instrument is one of the crucial aspects that must be considered to ensure that the measuring instrument can accurately measure students' problem-solving abilities. Validation is carried out through evaluations involving material experts and users, ensuring that the instrument is relevant and reliable in the educational context (Sadhu and Laksono 2018). It is essential to develop valid instruments that can provide helpful information for teaching and learning (Marwanda et al. 2021). Overall, based on the results in Figure 8, the development of a web-based problem-solving ability test instrument can be declared valid through expert review. All validators stated that the five questions of the fluid physics test instrument developed followed the use of good and correct language in the questions, good readability of the questions following the concept of physics, the answer key and the questions, the problem-solving ability indicators, and the question indicators. Although, in general, the validator's assessment was stated as good, revisions were needed in certain parts. As suggested in Table 1. This validity is very important to ensure that the instrument can be relied on to measure students' problem-solving abilities accurately and contribute to improving the quality of education.

The validity of a test instrument can be interpreted as the extent to which the instrument can measure what it should measure. Several studies have shown that the instrument can be declared valid through various evaluation methods when developing a web-based problem-solving ability test instrument. Research

shows that the instruments developed not only meet the criteria for content validity but are also able to significantly improve student learning outcomes (Rahmiati and Musdi 2018). This is in line with research stating that developing an assessment instrument to measure physics problem-solving abilities, where the validation results show that the instrument meets the established standards. (Permatasari et al. 2019). Finally, this study adds new ideas and information relating to physics education as reported elsewhere (Abosede et al. 2024; Al Husaeni 2022; Azizah et al. 2022; Hidayat et al. 2020; Ibrahim 2023; Lestrai et al. 2024; Nandiyanto et al. 2022; Nandiyanto et al. 2020; Susilowati et al. 2023).

CONCLUSION

A web-based problem-solving ability test instrument has been developed based on the needs analysis results in the field. In addition, it has been designed and developed based on indicators of problem-solving ability integration with local wisdom and technology in the development process. Based on the results of expert validation, the validity results were obtained with a good category. This instrument can be continued to be tested (empirical validity). The final reflection shows that using this instrument can measure the problem-solving ability of prospective physics teachers on fluid material.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

CONTRIBUTIONS OF INDIVIDUAL AUTHORS

MM: General concept, problem-solving ability instrument development, field data collection, data analysis, drafting the article. IH: General concept and problem-solving ability instrument development. SS: problem-solving ability instrument development and data analysis. AS: problem-solving ability instrument development, data analysis, drafting the article.

REFERENCES

Abosede PJ, Onasanya SA, Ngozi OC. Students self-assessment of demonstration-based flipped classroom on senior secondary school students' performance in physics. Indonesian Journal of Teaching in Science 2024; 4(1): 27-40.

Adams R, Garcia M. Enhancing security and integrity in web-based testing: Best practices and innovations. Journal of Educational Technology 2023; 18(1): 45–62.

Al Husaeni DN. Development analysis research on physical education by mapping keywords using the vosviewer application. ASEAN Journal of Physical Education and Sport Science 2022; 1(1): 9-16.

Al-Qoyyim TM, Wahyudi W, Gunawan G, Doyan A. The influence of problem based learning model assisted by video on student's problem-solving skills in static fluid material. Journal of Science and Science Education 2024; 5(1): 22–30.

Azizah U, Nasrudin H. Problem solving thinking skills: effectiveness of problem-solving model in teaching chemistry college students. Jurnal Penelitian Pendidikan IPA 2022; 8(3): 1462–1469.

Azizah EV, Nandiyanto ABD, Kurniawan T, Bilad MR. The effectiveness of using a virtual laboratory in distance learning on the measurement materials of the natural sciences of physics for junior high school students. ASEAN Journal of Science and Engineering Education 2022; 2(3): 207-214.

Brown K, Smith J, Thompson L. The impact of accessibility on participation rates in online assessments. Assessment & Evaluation in Higher Education 2019; 44(6): 870–882.

Clarke D, Dede C. The evolution and impact of web-based test instruments. Educational Technology Research and Development 2020; 68(3): 345–360.

Datur IS. Kemampuan pemecahan masalah materi fluida statis melalui pembelajaran berbasis masalah berbantuan thinking map. Jurnal Inspirasi Pendidikan 2017; 7(2):118–127.

Desiriah E, Setyarsih W. Tinjauan literatur pengembangan instrumen penilaian kemampuan berpikir tingkat tinggi (HOTS) fisika di sma. Jurnal Hasil Kajian, Inovasi, dan Aplikasi Pendidikan Fisika 2021; 7: 79–89.

Faizah R. Exploration of novice students in problem solving of static fluid physics materials. Edusains 2023; 15(2): 124–135.

Hadiprayitno G, Lestari N, Kusmiyati K, Sukri A, Irawan J. Analysis on students problem-solving skill and scientific literacy based on higher order thinking skills (HOTS) viewed from gender. Jurnal Penelitian Pendidikan IPA 2022; 8(5): 2508–2512.

Heller P, Keith R, Anderson S. Teaching problem solving through cooperative grouping. Part 1: Group versus individual problem solving. American Journal of Physics 1992; 60(7): 627–36.

Hidayat DS, Rahmat C, Fattah N, Rochyadi E, Nandiyanto A, Maryanti, R. Understanding Archimedes law: What the best teaching strategies for vocational high school students with hearing impairment. Journal of Technical Education and Training 2020; 12(1): 229-237.

Ibrahim AO. Impact of blended learning method on secondary school physics students' achievement and retention in Lokoja, Nigeria. ASEAN Journal of Science and Engineering Education 2023; 2(2): 57-66.

Ilahi DP, Utami L, Ratih A. Pengembangan dan validitas instrumen metakognitif siswa pada pembelajaran fisika sma. Jurnal Biogenerasi 2024; 9(2): 1087–1098.

Jonassen DH. Toward a design theory of problem solving. Educational technology research and development 2000; 48(4): 63-85.

Kartini FS, Widodo A, Winarno N, Astuti L. Promoting student' s problem - solving skills through stem project - based learning in earth layer and disasters topic. Journal of Science Learning 2021; 4(3): 257–66.

Kusairi S, Alfad H, Zulaıkah S. Development of web-based ıntelligent tutoring (iTutor) to help students learn fluid statics. Journal of Turkish Science Education 2017; 14(2): 1-11.

Kusairi S, Hardiana H, Swasono P, Suryadi A, Afrieni Y. E-formative assessment integration in collaborative inquiry: A strategy to enhance students' conceptual understanding in static fluid concepts. Jurnal Pendidikan Fisika Indonesia 2021; 17(1): 13–21.

Lestari DA, Suwarma IR, Suhendi E. Feasibility analysis of the development of STEM-based physics e-book with self-regulated learning on global warming topics. Indonesian Journal of Teaching in Science 2024; 4(2): 1-10.

Mahmudin M, Herman T, Prabawanto S, Supriyadi E, Susilawati A. Game design application of trigonometry integrating numeration in daily life using augmented reality. Journal of Engineering Science and Technology 2024; 19(5): 103–110.

Martinez A, Rodriguez L, Sanchez P. Bridging the gap in problem-solving skills: Current challenges and solutions. International Journal of STEM Education 2023; 11(2): 141–158.

Marwanda T, Yusrizal Y, Johar R. Developing pisa-like problems to assess students'mathematical communication and problem solving abilities. MaPan: Jurnal Matematika dan Pembelajaran 2021; 9(1):136–152.

Nandiyanto ABD, Hofifah SN, Girsang GCS, Trianadewi D, Ainisyifa ZN, Siswanto A, Putri SR, Anggraeni S, Maryanti R, Muslimin Z. Distance learning innovation in teaching chemistry in vocational school using the concept of isotherm adsorption of carbon microparticles. Journal of Technical Education and Training 2022; 14(1): 14-26.

Nandiyanto ABD, Raziqi GY, Dallyono R, Sumardi K. Experimental demonstration for enhancing vocational students' comprehension on heat transfer through conduction and radiation of light bulb. Journal of Technical Education and Training 2020; 12(3): 189-195.

Nurzaman I, Damaianti1 VS, Hartati T, Nurdiansah N. Flipping the script: Boosting reading proficiency with water cycle interactive read-alouds (IRA). Journal of Engineering Science and Technology 2024; 19(5): 174–182.

Permatasari A, Istiyono E, Kuswanto H. Developing assessment instrument to measure physics problem solving skills for mirror topic. International Journal of Educational Research Review 2019; 4(3): 358–366.

Qotrunnada F, Susilowibowo J. Pengembangan bahan ajar e-book akuntansi keuangan kelas xii SMK pada materi aset tetap berwujud berbasis pendekatan saintifik. Jurnal Riset Pendidikan Ekonomi 2021; 6(2): 34–46.

Rahmiati R, Musdi E. Pengembangan perangkat pembelajaran matematika berbasis discovery learning untuk meningkatkan kemampuan pemecahan masalah siswa kelas viii smp. Mosharafa Jurnal Pendidikan Matematika 2018; 6(2): 267–272.

Rusmawati I. Development of electronic teaching materials with the savi approach to enhance students' problem-solving skills. Jurnal Pendidikan Fisika Dan Teknologi 2023; 9(2): 331–342.

Sadhu S, Laksono EW. Development and validation of an integrated assessment for measuring critical thinking and chemical literacy in chemical equilibrium. International Journal of Instruction 2018; 11(3): 557–572.

Selçuk GS, Çalýskan S. The effects of problem solving instruction on physics achievement, problem solving performance and strategy use. Latin-American Journal of Physics Education 2008; 2(3): 151-166.

Setiawan H. Revolutionizing math education: Unleashing the potential of web-based learning media for enhanced mathematical problem solving skills. JDIME 2023; 1(2): 01–11.

Smith J, Jones K. The role of problem-solving skills in academic and professional success. Educational Psychology Review 2019; 31(2): 223–240.

Sujarwanto E, Hidayat A, Wartono. Kemampuan pemecahan masalah fisika pada modeling instruction pada siswa sma kelas xi. Jurnal Pendidikan IPA Indonesia 2014; 3(1): 65–78.

Susilowati NI, Liliawati W, Rusdiana D. Science process skills test instruments in the new Indonesian curriculum (merdeka): Physics subject in renewable energy topic. Indonesian Journal of Teaching in Science 2023; 3(2): 121-132.

Syukri M, Halim L, Mohtar LE, Soewarno S. The impact of the engineering design process in teaching and learning to enhance students science problem-solving skills. Jurnal Pendidikan IPA Indonesia 2018; 7(1): 66–75.

Tanjung YIT, Festiyed F, Diliarosta SD, Jubaidah J, Sanjaya APS. Analysis of students' problem solving skills based on heller indicator. Pegem Journal of Education and Instruction 2024; 14(4): 421–433.

Verawati NNSP, Prayogi S, Yusup MY, Taha H. Development of the test instrument for measuring students' critical thinking abilities on fluid material. Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram 2020; 8(1): 46–56.

Widodo S, Purnami A, Prahmana R. Team accelerated instruction, initials and problem-solves ability in junior high school. International Journal on Emerging Mathematics Education 2017; 1(2): 193-204.

Wilson K, Thompson J. Efficiency and analytics in web-based test systems: A comparative study. Journal of Educational Measurement 2022; 59(2): 185–202.