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EXPLORATION OF HIGH SCHOOL STUDENTS' PROBLEM-SOLVING ABILITY BASED ON GENDER IN FLUID MATERIAL

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Abstract

This research explores high school students' problem-solving abilities based on gender in a static and dynamic fluid material. The type of research is quantitative descriptive research design. The population of this research was class XII students at one of the state schools in Malang, East Java. The sampling technique was purposive sampling, which was done by selecting students taught by the same teacher. The selected sample consisted of 115 students, 34 males and 81 females. The data in this study was collected by giving a test, where the test instrument used was seven essay questions on fluid material, which had a reliability coefficient of 0.70 (high). The data obtained was then analyzed using descriptive statistics, t-test, and the ANOVA test**.** The research results show differences in problem-solving ability between male and female students, where female students have higher problem-solving ability than male students in all problem-solving processes. The physics approach is the highest process mastered by students, while the mathematical procedure is the lowest. A physics problem-solving process is still in the low category, indicating that efforts are needed to improve students' problem-solving ability.

Keywords Fluid Material; Gender; Problem-solving Ability

INTRODUCTION

Problem-solving ability is an important competency that students must master. Problem-solving ability are needed in finding a solution to a problem considered foreign or new, which involves the knowledge and skills possessed (Docktor & Mestre, 2014). Mastery of problem-solving ability will familiarize individuals with determining appropriate attitudes and actions when facing problems. Therefore, in learning, students should be trained to get used to solving problems.

Problem-solving in learning involves students using a systematic thinking process to find a solution to a problem. Problem-solving includes understanding the problem and the stages involved (Mandina & Ochonogor, 2018). In physics learning, problem-solving involves several processes that students must go through. Problem-solving requires a good understanding of concepts and high-level thinking skills (Hermansyah et al., 2019; Yuliati et al., 2018). Problem-solving involves the ability to focus on problems, describe problems into physical concepts, plan solutions, implement solutions, and evaluate solutions (Docktor et al., 2016). There are five problem-solving processes proposed (Docktor et al., 2016): useful description, physics approach, specific application of physics, mathematical procedures, and logical progression. Useful description involves students' ability to describe problems and quantities useful in solving problems. The physics approach involves students' ability to choose appropriate physics concepts or principles. Specific application of physics involves the ability to apply appropriate concepts or principles. Mathematical procedures involve students' ability to correctly use equations and perform mathematical operations. Logical progression involves students' consistency in completing solutions from the beginning to the end, including evaluating the solutions that have been created. Students can be considered experts in solving physics problems if they have fulfilled these five processes.

Just like other research that discusses student skills, problem-solving abilities in research have been reviewed from various variables, such as initial abilities, learning styles, scientific attitudes, and gender (Annam et al., 2020; Aprianti et al., 2020; Febriani et al., 2021; Musdiana & Herianingrum, 2015). Gender is one of the variables used in research, but it shows different conclusions from one study to another. Previous research (Kawengian & Edouardo, 2016; Wahyudi & Astriani, 2014) stated that male students' learning outcomes were greater than female students. The other research showed that female students were higher than male students (Ali, 2019; Barnas & Ridwan, 2019; Darmaji et al., 2022; Harso & Merdja, 2019). Other research results show no difference in learning achievement between male and female students (Afriana et al., 2016; Latifah et al., 2022; Malik et al., 2023). Furthermore, (Scheiber et al., 2015) found that female students were more dominant in reading and writing, but there was no difference in mathematics. In the Olympics, which required in-depth analysis to solve questions, men's achievements were more prominent than women's (Steegh et al., 2019).

Several exploratory studies of problem-solving abilities based on gender have been conducted previously. Previous research has drawn different conclusions. Previous studies suggest that female students solve problems better than male students (Duran, 2016; Haeruddin et al., 2022). Using the attitudes and approaches to problem-solving (AAPS) rubric, Haeruddin, in his research, stated that the attitudes and approaches to problem-solving shown by female students were more expert than male students. In contrast, other studies show that male students have better quantitative problem-solving abilities than female students (Gok, 2014; Kost et al., 2009). Other studies also say that there is no significant difference between the problem-solving abilities of male and female students (Atqiya et al., 2020; Darsikin & Jarnawi, 2021; Gunawan et al., 2020; A. Ramdani et al., 2021; Trianggono & Yuanita, 2018).

However, it is still rare to find exploratory research on differences in the five problem-solving abilities processes regarding student gender. This discussion is important because solving physics problems like static and dynamic fluid materials involves solving qualitative and quantitative problems. The problem-solving rubric proposed by Docktor involves a comprehensive assessment of problem-solving ability, from carrying out useful descriptions, selecting appropriate concepts, applying concepts, and operating mathematical equations to re-evaluating the solutions created. Based on this description, this research aims to identify differences in five processes of high school students' problem-solving ability based on gender in fluid material.

METHOD

The research aims to describe the differences in problem-solving ability between male and female students. So, the relevant type of research is quantitative descriptive research. Quantitative descriptive research design is a type of research methodology that involves collecting and analyzing numerical data to describe the characteristics of a population or a particular group. The population of this research was class XII students at one of the state schools in Malang, East Java, who had previously taken static and dynamic fluid material. The data in this research was obtained from giving written tests to 115 selected students consisting of 34 males and 81 females. These students were selected because they came from classes taught by the same physics teacher. This research used an essay test instrument on fluid material with a total of 7 questions (Cronbach Alpha = 0.70), including the sub-materials hydrostatic pressure (item 1), Pascal's law (item 2), hydrostatic pressure (item 3), discharge (item 4), continuity principle (item 5), Bernoulli's principle (item 6), and Toricelli's theorem (item 7).

Student answers obtained from giving tests are then assessed based on the problem-solving ability rubric developed by Docktor (2016), where the problem-solving process includes useful descriptions, physics approaches, specific applications of physics, mathematical procedures, and logical progression. Each problem-solving process is assessed in the range of 0 to 5. After correction, the problem-solving ability scores are analyzed using SPSS to calculate the average, standard deviation, t-test (hypothesis test), and ANOVA test to compare problem-solving ability scores based on student gender. The hypothesis in this research is:

Ho: Male and female students have no difference in problem-solving abilities.

Ha: There are differences in problem-solving abilities between male and female students.

Apart from that, problem-solving ability scores are also categorized into levels of solving ability, as shown in Table 1 (Saifuddin, 2010).

Table 1. Levels of Problem-solving Ability

Range	Category
$\mathbf{75 < x \leq 100}$	Very High
$\mathbf{58 < x \leq 75}$	High
$\mathbf{42 < x \leq 58}$	Medium
$\mathbf{25 < x \leq 42}$	Low
$\mathbf{0 < x \leq 25}$	Very Low

FINDINGS AND DISCUSSION

Findings

The distribution of the average score of problem-solving ability can be seen in Table 2. Based on Table 2, it is found that the average score of students' problem-solving ability is 51.32 (medium), with the average score of male students being 39.50 (low) and female students being 56.28 (medium). The t-test results in Table 3 show a significance value of 0.000 ($p<0.05$), which means there is a significant difference between the average problem-solving ability of female and male students. Based on the average score and t-test, it can be concluded that female students' problem-solving abilities are higher than male students.

Table 2. Distribution of Average Scores of Students' Problem-solving Ability by Gender

Gender	N	Mean	Min	Max	Std Deviation
Male	34	39.50	8.57	71.00	18.16
Female	81	56.28	6.29	85.14	19.21
Total	115	51.32	6.29	85.14	20.34

Table 3. Student Problem-solving Ability T-test Results based on Gender

Gender	T	Df	Sig. (2-tailed)
Equal variances assumed	-4,343	113	0,000
Equal variances not assumed	-4,445	65,343	0,000

Table 4 shows the level of students' problem-solving ability based on gender. When viewed from gender, most female students are at a high level, while most male students are at a low level. In addition, female students dominate solving ability at high and very high levels.

Table 4. Levels of Students' Problem-solving Ability Based on Gender

Level	N		
	Male	Female	Total
Very High	0 (0%)	8 (10%)	8 (7%)
High	7 (21%)	38 (47%)	45 (39%)
Medium	8 (24%)	21 (26%)	29 (25%)
Low	11 (32%)	5 (6%)	16 (14%)
Very Low	8 (24%)	9 (11%)	17 (15%)

Table 5 shows the results of the ANOVA test to see differences in students based on gender in each process of problem-solving ability. The ANOVA test results show that the significance value in each process is 0.000 ($p<0.05$), so it can be concluded that there are differences in the problem-solving ability of male and female students in each process.

Table 5. ANOVA Test Results for Students' Problem-solving Ability for Each Process by Gender

Problem-solving Ability Process		Sum of Squares	Df	Mean Square	F	Sig.
Useful Description	Between Groups	6268.360	1	6268.360	20.095	.000
	Within Groups	35248.659	113	311.935		
	Total	41517.019	114			
Physics Approach	Between Groups	11911.419	1	11911.419	18.432	.000
	Within Groups	73024.409	113	646.234		
	Total	84935.829	114			
Specific Application of Physics	Between Groups	6267.865	1	6267.865	15.084	.000
	Within Groups	46953.677	113	415.519		
	Total	53221.542	114			
Mathematical Procedures	Between Groups	4904.888	1	4904.888	13.031	.000
	Within Groups	42533.249	113	376.400		
	Total	47438.137	114			
Logical Progression	Between Groups	5730.696	1	5730.696	18.959	.000
	Within Groups	34157.060	113	302.275		

Total	39887.756	114	

Table 6. Levels and Mean Problem-solving Ability Scores for Each Process by Gender

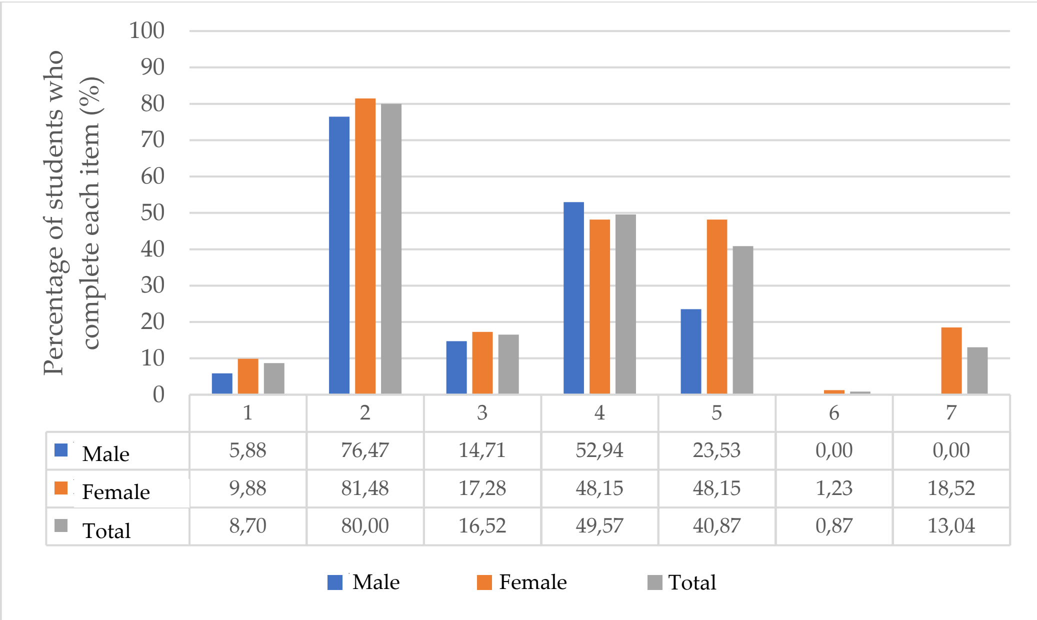
Problem-solving Ability Process	Level	N Students			Average Score		
		Male	Female	Total	Male	Female	Total
Useful Description	Very High	0 (0%)	10 (39%)	10 (9%)	43.14 (Medium)	61.88 (High)	52.51 (Medium)
	High	5 (15%)	36 (22%)	41 (36%)			
	Medium	16 (47%)	23 (28%)	39 (34%)			
	Low	5 (15%)	9 (11%)	14 (12%)			
	Very Low	8 (24%)	3 (4%)	11 (10%)			
Physics Approach	Very High	3 (9%)	39 (48%)	42 (37%)	44.71 (Medium)	64.41 (High)	54.56 (Medium)
	High	9 (26%)	22 (27%)	31 (27%)			
	Medium	8 (24%)	8 (10%)	16 (14%)			
	Low	7 (21%)	5 (6%)	12 (10%)			
	Very Low	7 (21%)	7 (9%)	14 (12%)			
Specific Application of Physics	Very High	0 (0%)	5 (6%)	5 (4%)	38.40 (Low)	54.25 (Medium)	46.33 (Medium)
	High	7 (21%)	39 (48%)	46 (40%)			
	Medium	7 (21%)	22 (27%)	29 (25%)			
	Low	12 (35%)	6 (7%)	18 (16%)			
	Very Low	8 (24%)	9 (11%)	17 (15%)			
Mathematical Procedures	Very High	0 (0%)	13 (16%)	13 (11%)	35.63 (Low)	49.77 (Medium)	42.70 (Medium)
	High	3 (9%)	36 (44%)	39 (34%)			
	Medium	0 (0%)	0 (0%)	0 (0%)			
	Low	0 (0%)	2 (2%)	2 (2%)			
	Very Low	31 (91%)	30 (37%)	61 (53%)			
Logical Progression	Very High	0 (0%)	2 (2%)	2 (2%)	35.26 (Low)	51.60 (Medium)	43.43 (Medium)
	High	2 (2%)	28 (35%)	30 (26%)			
	Medium	10 (12%)	33 (41%)	43 (37%)			
	Low	13 (16%)	8 (10%)	21 (18%)			
	Very Low	9 (11%)	10 (12%)	19 (17%)			

The differences in problem-solving abilities between males and females for each process can be seen in Table 6. Table 6 shows that the percentage of female students in the high and very high categories in each problem-solving process is always better than that of male students. Likewise, the average score obtained, where the average score of female students in each process is greater than that of male students.

If we look at each question item, Figure 1 shows the percentage of male and female students who successfully solved the problem in each item. Students are said to successfully solve a problem in one question if they score 4 (minor errors in processing) or 5 (no errors in processing) in each process. Based on Figure 1, the percentage of students who succeeded was less than 50% in each item, except item 2 (Pascal's law sub-material). Figure 1 also shows that the percentage of female students who succeeded in solving problems was higher than male students in the sub-materials of hydrostatic pressure, Pascal's law, Archimedes' law, continuity principle, Bernoulli's principle, and

Toricelli's theorem. Meanwhile, male students only excel in the debit sub-material.

Figure 1. Graph of the Percentage of Students Completing Each Question Item



Discussion

Based on Table 1, the overall average score or stuaents' problem-solving ability is 51.32 in the medium category. These results are in line with previous research, which states that the ability to solve physics problems in static fluid materials (Estianinur et al., 2020) and dynamic fluids (Widiawati, Ririn; Hikmawati, Hikmawati ; Ardhuha, 2022) is in the medium category. The same thing can also be seen in the average problem-solving ability of students in each process, where the useful description, physics approach, specific application of physics, mathematical procedures, and logical progression processes are in the medium category.

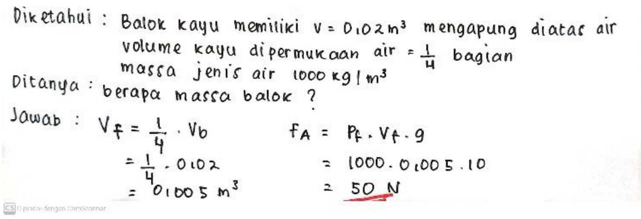
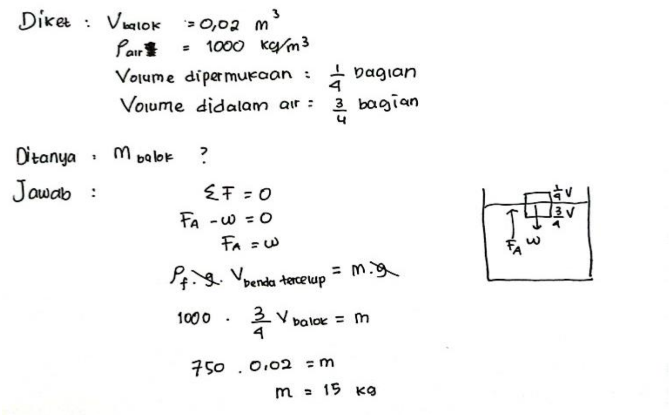
Even though each problem-solving process is always in the medium category, the average score tends to decrease in each process. The average score on specific applications of physics, mathematical procedures, and logical progression tends to be smaller than the two initial problem-solving processes (useful description and physics approach). Apart from that, the percentage of students with low and very low ability in specific applications of physics, mathematical procedures, and logical progression also tends to be higher than that of the useful description and physics approach processes. Based on this, it can be concluded that students are quite good at describing problems and choosing what concepts or principles to use but still experience difficulties when applying physics principles and concepts, carrying out mathematical operations, and evaluating solutions to solve problems. This aligns with research by Fitroh et al., (2020) where students have difficulty connecting one concept to another and only memorize mathematical equations. Research by (Yuliana et al., 2019) also found the same thing, where mathematical procedures and logical progression were at low criteria.

Female students exhibit a superior overall average in problem-solving abilities compared to their male counterparts. This advantage is particularly evident in the medium category of problem-solving processes, where female students consistently excel. In contrast, male students often fall into the low category, especially in mathematical procedures and logical progression. This disparity highlights a notable gender difference in specific problem-solving skills, suggesting that female students are adept at general problem-solving and excel in the critical processes contributing to successful outcomes (Stadler et al., 2018) (Wismath et al., 2014).

The analysis results show significant differences between the problem-solving abilities of female and male students. Female students have better problem-solving abilities than male students. This can be seen from the average problem-solving ability in each process, which female students dominate. This result is in line with the results of previous research that show that the problem-solving ability of female students is better than that of male students (Balta et al., 2016) (Duran, 2016) (Haeruddin et al., 2022). Female students tend to imitate teachers' behavior during the learning process more than males, and they observe and try to internalize the strategies used by their teachers, even implicitly (SELÇUK et al., 2007). This allows female students to remember better what strategies are appropriate when faced with problems. It also stated something similar, where the average aspect of female students' cognitive ability in solving problems was quite better than that of male students—stated that female students are more likely to solve physics problems by thinking about the right principles and concepts and seeing reasonable solutions, in contrast to men who tend to use mathematical equations by matching the problem with the appropriate equation then Enter the value to get the answer.

If viewed from the problem-solving process, female students are superior to male students in every process. Differences in problem-solving between male and female students are also visible in each process. Table 7 shows one of the differences in solving physics problems in the sub-material of Archimedes' law. The narrative of the question is as follows: "A wooden block with a volume of 0.02 m^3 floats on river water. If the volume of wood visible at the water's surface is 1/4, then what is the mass of the block as a whole?"

Table 7. Example of Male and Female Students' Problem-solving Answer (Archimedes' Law)

Student Answer	Problem-solving Process
Male Student  Diketahui : Balok kayu memiliki v = 0,02 m³ mengapung diatas air volume kayu dipermukaan air = $\frac{1}{4}$ bagian massa jenis air 1000 kg/m³ Ditanya : berapa massa balok ? Jawab : $V_f = \frac{1}{4} \cdot V_b$ $= \frac{1}{4} \cdot 0{,}02$ $= 0{,}005\ m^3$ $f_A = \rho_f \cdot V_f \cdot g$ $= 1000 \cdot 0{,}005 \cdot 10$ $= 50\ N$	**Useful Description:** Students describe known problems and quantities in written form. However, he did not write down an important quantity that would have been useful, namely the volume of wood submerged in water. **Physics Approach:** The choice of physics concept used was appropriate, namely using lifting force in the material of Archimedes' law. **Specific Application of Physics and Mathematical Procedures:** In applying the lifting force, students use the plug and chug method to enter the lifting force equation to solve the problem directly. **Logical Progression:** Students are inconsistent in writing solutions to problems. The question in the problem is the mass of wood, while the student's answer is the lifting force.
Female Student  Diket : $V_{balok} = 0{,}02\ m^3$ $\rho_{air} = 1000\ kg/m^3$ Volume dipermukaan : $\frac{1}{4}$ bagian Volume didalam air : $\frac{3}{4}$ bagian Ditanya : m_{balok} ? Jawab : $\Sigma F = 0$ $F_A - w = 0$ $F_A = w$ $\rho_f \cdot g \cdot V_{benda\ tercelup} = m \cdot g$ $1000 \cdot \frac{3}{4} V_{balok} = m$ $750 \cdot 0{,}02 = m$ $m = 15\ kg$ 	**Useful Description:** Students describe known problems and quantities in written and pictorial form. All descriptions provided are useful in troubleshooting. **Physics Approach:** The choice of physics concept used was appropriate, namely using lifting force in the material of Archimedes' law. Students also use the concept of Newton's First Law to analyze problems. **Specific Application of Physics and Mathematical Procedures:** In applying lifting force to solve problems, students also use Newton's first law equation and use descriptions in the form of force diagrams to assist in appropriate analysis. The mathematical operations used are also precise. **Logical Progression:** Students are consistent in writing the correct solution.

Female students demonstrate a superior ability to describe problems and identify useful descriptions for solving them, as evidenced by their more comprehensive and detailed problem descriptions. Table 7 reveals that female students excel in writing descriptions that significantly aid in problem-solving, including diagrams to illustrate the forces at play. In contrast, male students describe problems only in explicitly stated terms, lacking the additional insightful elaboration seen in their female peers. This thoroughness in female students' approach enhances their understanding and facilitates a more effective problem-solving process (R. Ramdani et al., 2019).

Furthermore, this proficiency extends to selecting and applying relevant physics concepts and principles. Female students consistently employ a complete and accurate physics approach, such as fully utilizing Archimedes' and Newton's first law to address problems comprehensively (Busari, 2023). While using Archimedes' law, male students often fail to incorporate Newton's first law, thereby missing a critical component of the problem-solving process. This discrepancy underscores the depth of understanding and methodical approach that female students bring to problem-solving in physics, positioning them ahead of their male counterparts in terms of both completeness and accuracy in their solutions (Hamerski et al., 2022; Leak et al., 2017; Lindfors et al., 2020).

Significant differences can be seen in the application of physics concepts to solve problems as well as the use of mathematical equations and operations (specific application of physics and mathematical procedures), where, based on Table 6, female students are in the high category, while male students are in the low category. Based on Table 7, female students use force diagrams, Newton's first law, and lifting force to solve problems, while male students directly enter known quantities into the lifting force equation. This follows the research results ￼, where female students think more about principles, concepts, and reasonable solutions than male students, who tend to apply plug-and-chug when solving problems. The logical progression process also shows that female students are significantly higher than male students (Shishigu et al., 2017), which shows that female students are better able to evaluate the solutions than male students. Based on Table 7, female students consistently solve problems to find the mass of a wooden block, while male students stop to find the lifting force (Gates, 2019).

If we look at the questions, the percentage of female students who succeeded in solving problems was higher than male students in the sub-materials of hydrostatic pressure, Pascal's law, Archimedes' law, the principle of continuity, Bernoulli's principle, and Toricelli's theorem, while male students only excelled in the sub-materials (YeckehZaare & Resnick, 2019). However, only 1 question, namely Pascal's law, had a high percentage of students who successfully solved the problem. In contrast, seven other questions had percentages below 50%, especially on hydrostatic pressure, Archimedes' law, and Bernoulli's principle. These results follow the research (Kusairi et al., 2021), where the number of students who can solve problems in fluids is 50%.

Based on the student answer sheet, students often have difficulty determining the depth reference point for an object in the hydrostatic pressure subtopic. This difficulty is in line with research by (Koes-H et al., 2018) that students have difficulty determining the reference point for the depth of a point in an underwater cave, whether calculated from the sea surface, cave ceiling, or the seabed. Another difficulty was experienced in the sub-material of Archimedes' law, where students had difficulty only focusing on the lift force equation to find the mass of an object in the case of a partially floating object. This was also found in previous research (Koes-H et al., 2018), where students had difficulty involving the use of gravity, buoyancy force, and Newton's 2nd law to determine the acceleration of a floating block released from a rope tied under the sea (Tymms, 2015).

Regarding Bernoulli's law, most students forget the form of Bernoulli's equation, so they prefer to stop working after the physics approach.

CONCLUSION

There is a significant difference between the problem-solving ability of male and female students ($p<0.05$), where the problem-solving ability of female students is higher than that of male students, both in the overall average and the average per problem-solving process. The process most mastered by students is the physics approach, while the lowest is mathematical procedures. Hopefully, this can become an additional reference for teachers in preparing appropriate methods to train students' problem-solving abilities, especially in fluid material.

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