Student’s Problem Solving Skills in Collaborative Inquiry Learning Supplemented by Formative E-Assessment: Case of Static Fluids

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Abstract. This research aims to analyze the development of the static fluid problem-solving skills of high school students in collaborative inquiry supplemented by formative e-assessment. This research used a mixed-method approach with the research design of an embedded experimental design model involving 34 students of class XI MIPA in SMA Negeri 4 Malang. The data on the problem-solving skills were obtained through pretest and posttest using three problem-solving questions in the form of descriptions and supplemented by interviews. The calculation results of N-gain score showed the improvement of student’s problem solving skills for a moderate category and the calculation result of Cohen’s d-effect size in for strong effect category, as many as 79% of the students are categorized as experts. The expert students have good skills in the useful description indicator followed sequentially on the indicator of physics approach, specific application of physics, mathematical procedures, and logical progression. Meanwhile, the novice students are only capable on the indicator of useful description and physics approach. Students’ skill to solve problems still need to be trained intensively using contextual problems in daily life.

1. Introduction

Problem-solving is the individuals or groups skills to finding solutions for a problem in physics learning that is conceptual and related in daily life, which involves the knowledge and actions possessed [1–4]. This skill has been a core part of education for decades in developing knowledge and understanding in various learning contexts [5], as well as the most important learning outputs in the field of science especially physics [6–7]. One physics concept that is often found in the application of daily life is static fluid [8]. Some researches still find student difficulties in solving problems in Hydrostatic Pressure, Pascal’s Law, and Archimedes’ Law.

Students have difficulty in solving static fluid problems such as the use of buoyant force formulas, the resultant determination of forces and forces on the plane in the fluid, and the determination of the depth of field in fluid [9]. The difficulty is also found in the research by Datur (2016) which states, students have not been able to describe the problem correctly and still use solutions with a wrong physics approach, thus influencing students’ mathematical procedures [10]. These difficulties cause the problem-solving skills possessed by students who are still in the low category. This is shown in the research by Purwanto & Yuliati (2017) who found that the average problem solving of students was only
48.88 on a scale of 0-100 which was categorized as still low [11]. The same results were also obtained in the research by Purnamasari (2018) who found that student’s problem solving skills in the good category were less than 50% of the number of students with the rest of the students with not good problem-solving categories. Therefore, it takes a series of learning processes that can improve problem-solving skills, namely through collaborative inquiry learning [12–15].

Collaborative inquiry learning is collaborative learning process for students to construct their knowledge through investigations to learn strategies in finding solutions of a problem [16–18]. This is supported by socio-constructivist learning theory which says that knowledge and cognitive conflict arise by finding collaborative solutions to problems, based on information distributed among group members on ongoing learning [13, 15]. Also, a system is needed to monitor student learning both before, during, and after learning through formative assessment [19–20]. However, in the formative assessment, giving feedback quickly to students during learning is still not effective, because it takes a long time to be implemented for many students in the class [21]. Therefore, alternatives are used to support their implementation, namely through formative e-assessment [22]. Formative e-assessment is applied by teachers outside of school hours and provides broad opportunities for students to help students relearn and has a repetitive exercise on the material that has been taught [23–26]. Based on this, so that students can investigate and solve problems in daily life with the right concepts and solutions, and receive feedback quickly, it is necessary to combine the two variables. The lack of research results that examine the combination of collaborative inquiry learning supplemented by formative e-assessment on the analysis of students’ problem-solving skills in the static fluid, so that this research is important.

2. Method

This study used a mixed-methods approach with an embedded experimental model design by Creswell (2011) as presented in Figure 1.

![Figure 1. Embedded Experimental Model (Creswell, 2011)](image)

The design of this study consisted of quantitative research methods as main and qualitative data as supporting data carried out simultaneously [27]. The research phase begins with giving a pretest to find out the students’ initial problem-solving skills. The results of the pretest were analyzed quantitatively to provide information on the student scores and qualitatively for grouping categories of students based on students’ answers according to the criteria on the five indicators of problem-solving, and strengthened from the results of interviews to representatives of student categories. The second stage is implementing collaborative inquiry learning supplemented by formative e-assessment. Some learning activities are documented in the form of photos and videos. After that, the posttest is given to find out the student’s final skills. The results were analyzed quantitatively and qualitatively to determine the increase in the problem-solving categories of students based on student answers reinforced from the results of interviews. All data are interpreted to make conclusions in answering research questions.

The subjects in this study consisted of 34 students of class XI MIPA in SMA Negeri 4 Malang, East Java, Indonesia, who studied static fluid and were selected by sampling technique using purposive sampling. The research instrument used was a problem-solving skills test in the form of three description questions with Cronbach’s Alfa Reliability of 0.783. The student answer assessment rubric refers to Doctor (2016) rubric with the range of scores set in this study is a score of 0 to 4 for each indicator on
each question with a maximum score of 4. Data analysis was carried out with quantitative analysis in the form on non-parametric analysis using further tests Wilcoxon, N-gain test, and Cohen’s d-Effect Size and qualitative analysis by categorizing the novice and expert student’s problem solving skills as presented in Table 1 [28–31].

| No | Indicator | Novice | Expert |
|----|-----------|--------|--------|
| 1. | Useful Description | Describe the problem by writing an influential variable that is incomplete, partly missing or contains an error | Describe the problem by summarizing relevant information in a symbolic form of variables that are influential, images, and verbally appropriate and complete |
| 2. | Physics Approach | Some of the physics approaches that are written are not right, are still wrong, even past this step | Writing down a physics approach that is useful as a solution to the problem correctly and completely |
| 3. | Specific Application of Physics | Only write general equations without applying to the problem, not complete, containing errors, and not writing it down | Choosing the relevant equation as a solution to be applied to the problem correctly and completely |
| 4. | Mathematical Procedures | Processing and obtaining data is still inaccurate, incomplete, not even doing calculations at all | Perform calculations according to the procedures to obtain the right and complete results |
| 5. | Logical Progression | The resolution process used is unclear, unfocused, only rewrites the results obtained, and does not link the results to the process used as a solution | The settlement process that is used is clear, focused, and precise so that it is able to prove the suitability of the results obtained with the solutions used |

This study applied collaborative inquiry learning supplemented by formative e-assessment in the learning process with the stages as presented in Table 2.

| Syntax | Activities |
|--------|------------|
| Formative e-assessment is carried out through [http://e-learning.fmipa.um.ac.id/](http://e-learning.fmipa.um.ac.id/) | Students follow quizzes and discussion forums, receive feedback, and learn learning videos. |
| Phase 1 Attention and explain the learning process | Students respond to questions related to learning objectives that are displayed through interactive powerpoint (Learning goals) and pay attention to problems through learning videos. |
| Phase 2 Orienting and asking question | Students listen and understand questions related to the problem given. |
| Phase 3 Hypothesis generation | Students discuss making hypothesis. |
| Phase 4 Planning | Students design experiments with their groups. |
| Phase 5 Investigation | Students investigate and collect experimental data. |
| Phase 6 Analysis | Students independently analyze experimental data and interpret it in graphical form to train students’ problem-solving skills. Every student has a record during learning (Active involvement of students in their own learning). |
| Phase 7 Conclusion | Students make conclusions to prove the previous hypothesis. |
| Phase 8 Communication | Students pair outside the group members to present their results (rich conversations). One group member presents the results of the discussion in front of the class and the teacher gives applause (learning needs and strength). Students respond to learning through teacher questions and reinforcing examples of application in the daily life (timely feedback). |

Table 1. Categorization of Criteria for Novice and Expert Students

Table 2. Syntax of Collaborative Inquiry Learning with Formative E-Assessment
Formative e-assessment is carried out through http://e-learning.fmipa.um.ac.id/

3. Results and Discussion

Students’ problem solving skills experience better changes after being given collaborative inquiry learning supplemented by formative e-assessment, namely in the acquisition of the average posttest value of students of 2.87 has increased from the average pretest value of 0.96. Obtaining the score for the problem-solving skills oh the students has approached the expected score with a maximum score of 4 [29]. This can be seen in the highest posttest score achieved by students at 3.67 with the criteria for the expert category, but there are still the lowest posttest scores of some students at 1.67 with the criteria for novice category answers to static fluid problems [25, 28, 29, 30]. The percentage of students in the novice and expert categories based on data on the distribution of scores for problem-solving skills after learning is shown in the form of a diagram as shown in Figure 2.

![Diagram showing percentage of students in novice and expert categories](image)

**Figure 2. Percentage of Categories of Problem-Solving Skills for Novice dan Expert Students**

Figure 2 shows, as many as 79% of students have been categorized as experts before all students were in the novice category. This shows, more and more students have better problem-solving skills, but there are also skills of students who are not appropriate in solving problems after being given learning. This is supported by the N-gain data of 0.63 which is in the medium category [32] and the effect size of 3.79 which is included in the strong effect [33], so collaborative inquiry learning supplemented by formative e-assessment significantly influences students’ problem-solving skills. The results of this study are in line with the findings made by Yuliati (2018) which states that through inquiry learning skill to solve problems increases in the experimental class by 64.99 which is higher than the ability of students in the control class at 54.67 [34].

This is following the theory which said that when collaborative inquiry learning is implemented, the cognitive conflict of the students is built to assist students in carrying out investigations of the problems presented [13]. The process of the investigation carried out can train students’ skill to solve problems based on relevant concepts as a solution to the problem [35]. The learning helped train students’ skills through a collaborative inquiry process in experiments with Hydrostatic Pressure, Pascal’s Law, and Archimedes’ Law, to prove the hypothesis of a problem based on the solution found [12]. Students are also trained to solve problems through formative e-assessment based on quiz and formative tests related to static fluid problems to determine the appropriate solution. If the student’s solution is incorrect, students may immediately improve it based on the feedback that students receive immediately during the online test [9]. Also, students are trained to work on problem-solving questions to understand the process of the five problem-solving indicators [22].

Students’ problem-solving skills after learning can also be determined based on the percentage of students in the novice and expert categories in each problem-solving indicator as shown in the form of a diagram as shown in Figure 3.
Based on Figure 3 it can be seen that, after collaborative inquiry learning supplemented by formative e-assessment, the percentage of expert category students on each indicator of problem-solving has reached more than 50% of the number of students previously only on indicators useful description. This shows, most students have been able to solve static fluid problems according to expert criteria for each problem-solving indicator [25, 28, 29, 30]. The highest problem-solving skills of students is in the first indicator, namely useful description, which is that most students can describe the problem with the missing variables. The skill to describe good problems can help students determine problem-solving strategies [36–37]. The highest percentage of expert students is also on the physics approach indicator, which shows that most students can determine the appropriate physics concepts on the given problem so that students will help apply the principles of physics as a solution to problems [29, 38].

The percentage of expert students on indicators of the specific application of physics and mathematical procedures obtained is the same. This shows that most students can determine the right and complete equation. This shows that expert students identify variables that influence the problem given, connect with mathematical procedures and consider theories, concept, laws, principles that underlie problems, analyze, and solve with the right concept [3, 30, 39, 40]. Also, the logical progression indicator shows that the percentage of students in the expert and novice categories is the same. The expert student has carried out the process of solving the problem correctly, completely, and giving appropriate conclusions from the results obtained from the solution used. Meanwhile, the novice student does not understanding the meaning of the results obtained from the solutions that are applied. This shows that novice students still experience difficulties in the previous problem-solving process because they have not mastered the application of static fluid concepts to the problems of daily life. Therefore, the skill to solve students’ static fluid problems after being given treatment is far better than before, because there are already expert students in each indicator that reaches a percentage above 50%.

Students’ problem-solving skills after learning can be known more deeply based on the analysis of criteria for the answers of novice students and experts on the five indicators of problem-solving and strengthened from the results of interviews with two students from both categories. As for one example of the problem solving Hydrostatic Pressure as presented in Figure 4 and example of student answers categorized as novice and expert as presented in Table 3.

**Figure 4. Problem Solving Hydrostatic Pressure Question**

1. Carles, Doni, and Eko are students of SMA Negeri 4 Malang who are currently following the Environmental Recognition Study to Wisata Bahari Lamongan. They want to prove the law of hydrostatic principle when swimming. Carles and Doni decide to swim in the sea, while Eko prefers to swim in a swimming pool. After they finished swimming they gathered to discuss the depth they were swimming and the hydrostatic pressure they felt. (Remarks: Their depth swim is 3 meters, $\rho_{\text{seawater}} = 1,025 \text{ kg/m}^3$, and $\rho_{\text{water}} = 1,000 \text{ kg/m}^3$). Based on the data collected, analyze the relationship between density and fluid depth to hydrostatic pressure on the three students while swimming!
Table 3. Example of Novice and Expert Students’s Answer of Hydrostatic Pressure Problem

| No | Indicator | Kategori Kemampuan Pemecahan Masalah |
|----|-----------|-------------------------------------|
|    |           | Novice                              | Expert                              |
| 1. | Useful Description | ρ_seawater = 1.025 kg/m³                   | ρ_seawater = 1.025 kg/m³                  |
|    | N= 12% | ρ_water = 1.000 kg/m³                   | ρ_water = 1.000 kg/m³                  |
|    | E = 88% | Their depth swim 3 meters             | Carles and Doni swim in the sea       |
|    |        |                                       | Eko swim in the swimming pool         |
|    |        |                                       | Asked: The relationship between density (ρ) and depth (h) of fluid to the hydrostatic pressure (ρh) of the three students? |
| 2. | Physics Approach | The deeper and wider the place, the greater the hydrostatic pressure | The concept of hydrostatic pressure is the greater the density of the fluid and the depth in the fluid, the greater the hydrostatic pressure. Because, the relationship is directly proportional. |
|    | N = 24% |                                       |                                       |
|    | E = 76% |                                       |                                       |
| 3. | Specific Application of Physics | Formula: P = ρ . g . h | The relationship between hydrostatic pressure is: P ≈ h; P ≈ ρ |
|    | N = 26% |                                       | Then the equation used: P = ρ . g . h |
|    | E = 74% |                                       | At sea: P_Carles = ρ_seawater . g . h_Carles |
|    |        |                                       | P_Doni = ρ_seawater . g . h_Doni       |
|    |        |                                       | At swimming pool: P_Eko = ρ_air . g . h_Eko |
| 4. | Mathematical Procedures | P_water = ρ_water . g . h = 1.000 × 10 × 3 | Swim in the sea |
|    | N = 21% | P_seawater = ρ_seawater . g . h = 1.025 × 10 × 3 | P_Carles = (1.025 kg/m³)(10 m/s²)(3 m) = 30.750 Pa |
|    | E = 79% | P_Doni is the same as P_Carles is 30.750 Pa, because h and its density are the same | Swin in the swimming pool |
|    |        | Swin in the swimming pool P_Eko = ρ_water . g . h_Eko | P_h = (1.000 kg/m³)(10 m/s²)(3 m) = 30.000 Pa |
| 5. | Logical Progression | P_seawater = 30.750 Pa dan P_seawater = 30.000 Pa | The greater pressure experienced by Carles and Doni than Eko is because the density of seawater is greater than the density of water in the pool so that the relationship of hydrostatic pressure is directly proportional to the density. |
|    | N = 41% |                                       |                                       |
|    | E = 59% |                                       |                                       |

Based on the data in Table 3, it can be seen that in the problem-solving indicators useful description students can describe the problem correctly and completely, only four students are still incomplete in describing it. Student difficulties are no longer found in this indicator, except that there are still a few shortcomings in some novice student answers. The lack of novice students found in the variable in questions in not written down, the units in the physics scale are also not included, and students have not applied the quantities known to the problem given. This result was also found in De Cock (2012) & Doctor (2015) ‘s study that, a small number of students in the novice category did not fully describe the problem because they did not write down some quantities and satan of the variables known and asked [41–42]. The second highest problem-solving skill of students is found in the fourth indicator, namely mathematical procedures. Inaccurate processes are still found in the novice category students, which only do calculations from known values without based on concepts or similarities. This can be seen in indicators of specific application of physics, namely novice students do not write down the equations that will be used as solutions and still write incorrect equations. The ability of some students
is still based on mathematical knowledge, because novice students have not mastered physics approaches and concepts well [43–45].

The problem-solving process of the students on the physics approach indicator has been done correctly namely, students use the concept of hydrostatic pressure related to the relationship of fluid density to the amount of hydrostatic pressure experienced by someone swimming in the sea and the pool at the same depth. This is confirmed by the opinions of expert students during interviews, namely the deeper the object is from the surface of the water, the greater the hydrostatic pressure it experiences. The same is true for the events of the three people who are swimming at the same depth, except that the difference in pressure is large because there is a different mass factor in the type of fluid. However, there are still students who are in the novice category who have not mastered the concepts correctly and have difficulties in determining students’ solutions to problem-solving. Students still consider the volume of water to also affect the amount of hydrostatic pressure. This was also expressed by students at the interview who assumed that the hydrostatic pressure experienced by people swimming in the sea was of greater value than in the swimming pool because the volume of seawater was more. This is in line with previous research which found students’ difficulties in explaining the magnitudes that affect hydrostatic pressure, so students consider the vessel area and fluid volume to be influential [43, 46]. However, student statements regarding the size of the vessel that affected hydrostatic pressure were not found in this study. Also, in the indicator of logical progression, the except student can explain the results obtained from the physics concepts used. However, the novice student only writes the hydrostatic pressure in the sea greater than the number in the pool based on the value obtained. The students did not associate the results obtained with the physics concept, so they were unable to prove the truth of the approach and application of physics used as a solution to the problem.

The results of these studies indicate, broadly speaking students already have better problem-solving skills, so they can solve complex problems in daily life [6, 39]. The students’ skills are supported by collaboration between students when organizing important information in the form of symbols and physical quantities on the problems given [16]. Students who study collaboratively in small groups compared to individuals will have cognitive benefits. Students’ knowledge grows through reciprocity of sometimes conflicting opinions and ideas or through learning from more experienced ones [15]. The feedback element through rapid formative e-assessment will help correct student conceptual errors that students use to solve physics problems [47, 48]. Therefore, collaborative inquiry learning supplemented by formative e-assessment can help train and improve students’ skills in solving physics problems related to application of daily life.

4. Conclusion

The students’ problem-solving skill on the subject of static fluid develops better after collaborative inquiry supplemented by formative e-assessment. About 79% of students have been categorized by expert problem solving skills. The data shows that, when students are given complex problems, more students have been able to analyze the factors that influence, determine, and prove the truth of the appropriate physics approach as a solution to solving problems. This research is recommended for further research that wants to analyze deeper problem-solving skills on the object of static fluid especially the difficulties experienced by novice and students when solving problems.

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