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The Impact of Simulation Based Formative Assessment on Student Problem Solving Skill in Learning Newton Law

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ABSTRACT
Simulation based formative assessment is one method for measuring comprehensive problem solving. The purpose of this study is to analyze the impact of simulation based formative assessment on student problem solving skills. Fifty high school students participated in this quantitative study with explanatory design and traditional class was used. The key instrument in this study was an adaptation of FCI (force concept inventory) and FVA (force velocity and acceleration), which were validated by two physicists and had a reliability of 0,804%. The data was analyzed using descriptive statistic as well as inferential statistics, specifically the independent sample t test. The result is significant differences in the problem-solving skills of students. The effect of simulation based formative assessment was that the problem of students solving the category of experts was improved by 11% and category of novice was reduced by 41%. It can be used to help students solve problems by visualizing physical phenomena and also as an explanatory tool in concept formation. However, this study cannot be generalized because the number of respondents is limited.

Keywords: *Problem solving, Simulation based formative assessment, Newton law.*

1. INTRODUCTION

Many studies have developed various methods to assist students in problem solving in the pandemic and digital eras. First, simulation games can be used to guide problem-solving students a small scale, simulation games can differentiate between novice and expert students, but the results cannot be generalized [1]. Second, Arnold Sommerfeld and Enrico fermi's approach is simple to apply. The drawback is that it cannot be used in all physics contexts [2]. Third, Monkeying around in mechanics, which is a video dialogue to improve with physics problem solving [3]. Fourth, while the concept map can reveal students 'problem-solving strategies, it is time-consuming [4]. Fifth, using simulation based formative assessment can also analyse students' problem solving strategies conveniently [5].

The findings of the preceding studies are mostly capable of assisting students with learning difficulties. It is frequently found in topics encountered in everyday life, such as Newton's Law. The average student has a misunderstanding of Newton's Law because they are naive in their translation of concepts when observing phenomena in everyday life [6-8]. This naive translation may interfere with students' understanding and application of the concepts [9]. Friction is one example of a student learning difficulty; more than 75% of students cannot describe the free body system of frictional forces on objects [10], and there is also a misconception about static friction [11]. It is due to the fact that the majority of students are incapable of analyzing system units, as well as providing a physical analysis of mathematical results and interpreting physical symbols [12], [13] Students' understanding of direction force is still intermediate, and those students are still analyzing the force acting on the object in a primitive manner. As a result, students' problem-solving strategies are mostly classified as intermediate [12], [14], [15].

Since the pandemic, all learning activities have been conducted online. This necessitates the use of media to aid in learning activities. One type of learning media is computer simulation. Computer simulation is useful for visualizing abstract phenomena, creating an interactive learning environment, increasing conceptual change, and assisting students in becoming expert problem solvers [5], [16-18]. Integrating formative assessment with simulation is an alternative in Park's study [5], [19] to explore problem solving students quickly and precisely. The goal of simulation-based formative assessment is to investigate problem solving based on students' concept formation [20]. Several studies have been conducted in order to develop formative assessments: 1. Park [5], [19] created simulation based formative assessment of kinematics and the law of conservation of energy, but the results cannot be generalized and necessitate additional research on other topics. 2. Wuff [21] created a formative assessment using computer-based classification; however, this research cannot be evaluated in depth by experts. 3. Chu [22] employs a digital simulation laboratory to assess pre-laboratory activities, which are conducted face-to-face. However, the use of online formative assessment in traditional classrooms has not been widely explained; thus, the purpose of this study is to solve student problems in Newton's law using simulation-based formative assessment. The hypothesis of this study is that simulation-based formative assessment can help students become problem-solving experts.

2. METHODS

The research method used is quantitative with an explanatory design.

2.1. Participant

This study involved 50 heterogenous students (age of 15-17) in grade 11 of a Senior High School in Surabaya as participants. They have learned the Newton's Law material through online classes. The learning experience in the classroom was conducted using class discussion method.

2.2. Instrument

The instruments used for measuring students' problem solving were 9 two-tier problems with a computer simulation. The problems have been validated by two physics experts. In this assessment process, the first step was students analysing the right and wrong answers of multiple choices problems, the next step was giving reasons for every answer they chose. The second step was observing the simulation given by the teacher. The final step was to assess their responses. This method was supposed to elicit students' problem-solving abilities quickly and precisely while reducing students' reliance on guessing

2.3. Scoring Technique

The following is the outcome at two tier (first tier is multiple choice and tier two is essay):

2.3.1. How to Score Multiple Choice Problems

Multiple choice problems-scoring using the binary method. The right answer gives 1 point and the wrong answer gives 0.

2.3.2. How to Score Essay Problems

The assessment rubric was used to score the essay problems. After coding the frequently appearing answers, the assessment rubric was created. Students' responses were divided into three categories: normative ideas (scientifically appropriate ideas), non-normative ideas (misconception ideas, analyzed using examples, analyzed using known variables), and off-task ideas (not relevant to the topic or repeated questions and answers). After analyzing student responses using the assessment rubric, they are grouped according to the holistic rubric, as shown in Table 1.

Table 1. Holistic rubric

Model	Score	Description	Category
Model 1	0	Off-task	Pure Novice
Model 2	1	Only non-normative ideas	Novice-memory-based approach
Model 3	2	The mix of non-normative and normative ideas	Novice – plug and chug
Model 4	3	Only normative ideas	Expert

Adapted [19], [23]

The distribution table of problems is as follows:

Table 2. Distribution and analysis of items

No	Indicator	Problem number	Discrimination power	Difficulty level	Biserial points	Reliability (Cronbach's alpha)
1	Students are able to analyze phenomena related to Newton's first law	1	0,29	0,58	0,13	0,804
		3	0,44	0,08	0,40	
		4	0,45	0,52	0,50	
2	Students are able to analyze phenomena related to Newton's second law	2	0,84	0,98	0,48	
		5	0,11	0,44	0,55	
		6	0,57	0,42	0,44	
3	Students can analyze phenomena related to static friction	7	0,30	0,14	0,36	
		8	0,84	0,88	0,51	
		9	0,79	0,46	0,47	

According to Table 2, questions one through nine can be used to assess student problem solving ability.

2.4. Procedure

The research flow is shown in Figure 1:

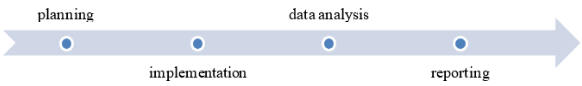

Figure 1 Research flow.

The planning stage included preparing question instruments. The assessment emphasized was on Newton's 1st law, Newton's 3rd law, and the application of Newton's law (friction). This refers to the research which states that students still have difficulties regarding Newton's third law, the direction of the force, and the frictional force [4], [15].

The data from the developed instruments was collected during the implementation stage. The first step in this assessment was for students to answer two-tier problems via a Google form link (https://forms.gle/R1P7unpNBCLfuWqy9) for 30 minutes. The form was created in such a way that students cannot cheat. The second step was for students to access the PhET Ramp: Force and motion (https://phet.colorado.edu/en/simulations/ramp-forces-and-motion) application, which was used to easily evaluate their answers for 30 minutes. The final step was for students to re-answer the questions using a different Google form link (https://forms.gle/ez29znMPhFUqyFSk9).

2.5. Data analysis

The results of the descriptive and inferential statistical test of students' problem solving can be tabulated as Table 3.

Table 3. Descriptive and inferential statistical tests

Descriptive analysis	Before simulation	After simulation	Inferential analysis	Result
Average	16,54	39,40	Independent t test	10,44
Standard deviation	11,66	17,10		
Maximum score	67,00	72,00	Significance Level	0,02
Minimum score	00,00	6,00		

3. RESULTS AND DISCUSSION

Based on inferential statistical analysis, it was obtained that the significance level was less than 0.05, meaning that there was a significant difference in the students' problem-solving results before and after conducting the simulation. These results explain that the effect of the simulation has a positive impact, as evidenced by the average score of students answering correctly increased after conducting the simulation. This is because students are able to evaluate problem-solving based on the simulation provided.

The percentage of correct answered problems before conducting the simulation was 10.7%, while after conducting the simulation it increased by 25.8%. In more detail, it can be described as Figure 2 regarding the percentage of students who answered correctly based on the indicators.

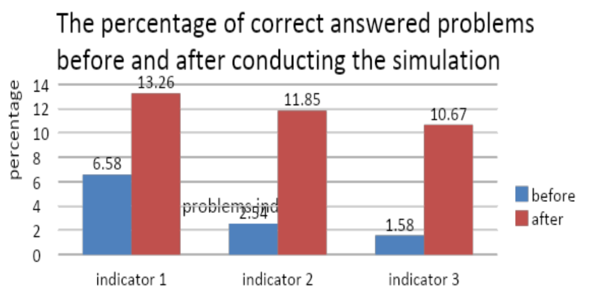

Figure 2 The percentage of correct answered problems before and after conducting the simulation.

The bar in Figure 2 explains that for each indicator, the percentages of correct answered problems always increase. The largest increase in the percentage of correct answers was in indicator 2 of 9.31% while the smallest was in indicator 1 of 6.68%. This can illustrate that indicator 2 is the easiest indicator while indicator 1 is the hardest indicator. However, the percentage increase in indicator 3 is not much different from indicator 2, which is 9.09%. This is because students still understand each concept separately.

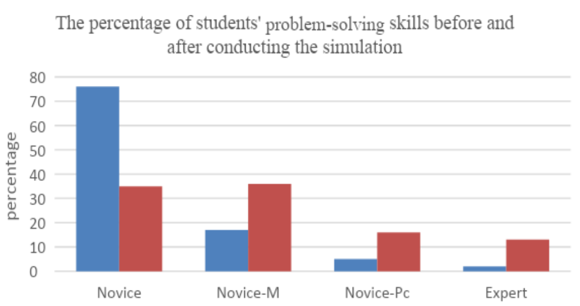

Figure 3 The percentage of students' problem-solving skills before and after conducting the simulation.

Students' problem-solving abilities are still classified as novices overall, but after the simulation, half of the students experience a change in their problem-solving abilities. This is demonstrated by a 41% decrease in novice students and an 11% increase in expert students. The increase in expert students was not statistically significant because students increased in the categories of memory-based approach Novice's type and Novice-Plug and Chug. Figure 3 depicts the improvement in students' problem-solving abilities.

Figure 3 also explains that the change in students' problem-solving skills is gradual. About 2% of students experienced a change from novice to expert. While the other 98% gradually from Novice to Memory-based approach Novice type or plug and chug and from memory-based approach Novice type or plug and chug to expert. These results can be described based on question indicators, as in Figure 4.

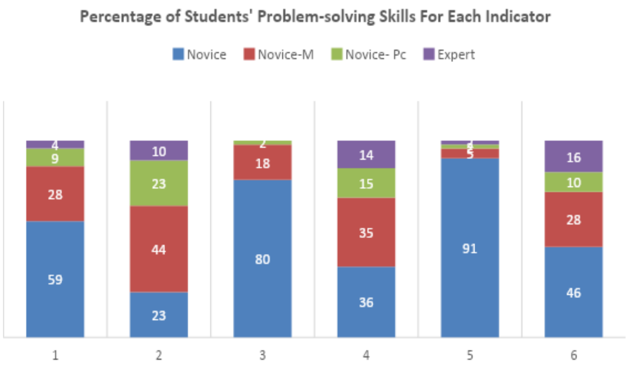

Figure 4 Percentage of students' problem-solving skills for each indicator.

Based on Figure 4, it is known that the overall problem-solving skills of novice students decreased after conducting the simulation. The biggest decrease in novice students was in indicator 2. This was because students were better at conceptualizing Newton's second law phenomena after conducting simulations than other indicators, making it easier for students to evaluate the answers of previous problem solving.

According to the findings of this study, simulations improve students' problem-solving abilities. This is due to a number of factors. The first factor is that students can correctly conceptualize after completing the simulation. Correct conceptualization guides students to provide expert-recommended solutions without the need for additional instructions. The second factor is that students can evaluate their solutions prior to running the simulation. Despite the fact that this finding was only around 2%, the three students were able to relate several concepts to support the solution. These findings are supported by Ceberio's [17] research, which claims that simulation-based problem-solving materials can improve students' problem-solving skills or that students can provide correct solutions based on standard textbooks. Furthermore, this finding is supported by Ryan's [18] research, which states that computer simulation assistance is useful in guiding students to become expert solvers without the need for additional instructions.

The majority of them show an increase in the number of correct answers for each indicator. Students, on the other hand, understood and analyzed each indicator separately. As a result, the percentage increase in correct answers is only about 8%, which is far from optimal. Students still do not understand Newton's Law thoroughly, which has an impact on problem solving. This finding is supported by Park's research [5], [19], which states that it is necessary to connect every relevant variable to assist students in solving the problem, as well as to conceptualize mathematical equations into physical meaning to assist students in solving the problem.

On average, problem-solving students are still classified as novices. After the simulation, the percentage of students' problem-solving skills in Novices decreased by only 11%. The decrease in the number of novice students is due to the fact that most students do not solve problems by analyzing physics situations and applying physics concepts to obtain solutions, but instead refer to random variables and respond naively from the given simulation observations. Furthermore, students memorize previously encountered problems. This study's findings are consistent with Riantoni's findings [24]. According to Riantoni's research, the majority of problem-solving students were classified as novices, with only about 2.27 percent being expert students.

Table 4 shows the results of an analysis of student problem solving. It can be seen that even after the simulation, each indicator of the percentage of pure novice students remains high. This is due to the fact that students do not use the same approach to solving similar problems, but instead use naive logic to solve the problem. The second position is for novice students using the memory-based approach, in which students answer based on examples or simulations that are unrelated to the correct physics concept. [24] and [25] found that about 52 % of 44 students used a pure novice problem solving strategy (no clear approach), with memory-based approaches coming in second (34 percent).

Based on the explanations in the preceding paragraphs, more treatment is required to improve students' conceptual understanding and make it easier for students to solve problems. This study relies on respondents who have had learning experiences with class discussion lecture methods; therefore, a more contextual and in-depth learning experience is required to help students build conceptual understanding to facilitate problem solving, such as problem-based learning and inquiry [25-27].

We argue that once students are able to correctly conceptualize everyday phenomena scientifically, they should not be taught with a mathematical approach to understanding physics, but rather with an approach that combines the meaning of physics with a mathematical approach [5], [28]. It is suggested that future research look into students' problem solving using various learning methods and materials such as thermodynamics, fluid mechanics, electricity, and magnetism.

4. CONCLUSION

Simulation based formative assessment can assist students in evaluating problem solving. According to the findings of this study, there are significant differences in students' problem-solving abilities before and after using the simulation. The use of simulation-based formative assessment increased the problem-solving skills of students in the expert category by 11%, while the pure novice category decreased by 41%. Based on result, physics educator may give students the opportunity to visualize physics phenomena this procedure could be aided by the use of models or computer simulation.

AUTHORS' CONTRIBUTIONS

Hellmy Nur Pratama Annuari Putri: conceptualizasion, method and drafting manuscript. Siti Farida Wadlikh: collecting data and editing manuscript. Sentot Kusairi: review and editing of manuscript. Arif Hidayat: data curation and editing.

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