Analysis of understanding of physics concepts through problem solving units review in free fall motion materials

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The purpose of this research is to understand the physics education concepts through solving unit review problems in free fall topic. This research is a quantitative descriptive study involving 19 students of Physics Education at the University of Tamansiswa. The test instrument consists of 2 essay questions that refer to problem-solving indicators. The results of the study obtained several findings. Analysis of understanding the concepts of physics education students through solving unit review problems in free fall topic had the highest percentage in the medium category. On the problem solving indicators Physics Approach, Specific Application of Physics, and Logical Progression students' abilities are in the low category.

Keywords: Understanding of concepts; problem solving; units; free fall motion.

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1. Introduction

The concept of free fall motion has been introduced to freshman students as part of their Basic Physics course. In general, the Basic Physics course begins with Kinematics which is at the peak of discovering misconceptions about physics, including the material of free fall motion [1]. This topics has also been discussed in senior high school [2]. The range, breadth and depth of topics discussed at each level vary according to the area of expertise of the lecturer/teacher [3]. Even though the concept of free fall motion has been obtained before and is often found in everyday life, there are still many students who experience misconceptions about speed, free fall acceleration and gravitational acceleration [4–6].

The use of visual aids in learning physics can improve the understanding of concepts and learning outcomes, such as the DC Series Parallels for Ohm's Law [7], Archimedes pulley props [8], as well as a hydraulic pump prop and Boyle's balloon [9]. The use of visual aids in learning activities can also overcome the abstractness of physics concepts that are difficult to understand and can improve students' scientific attitudes [10]. Teaching aids can be used as an effective medium to improve the quality of the learning process [11], improve the conceptual understanding of physics [12], develop critical thinking skills, better academic achievement [13], increase interest in learning [14], as well as increasing the innovation and creativity of students [15]. Free-body diagrams help students understand the concept of force and can be applied to many mechanics situations [16]. Free-body diagrams teaching aids also provide proper mastery of the problem [17].

Misconceptions with free falling material about speed, height, time and acceleration of gravity, can be reduced with falling motion experiments using FFM and MEC tools [18], a virtual laboratory, using video assisted tracker software [19] and interface analysis [20] . Free fall motion media is used in physics learning to visually explain to students the concept of free fall motion. This media is proven to reduce misconceptions and increase understanding of physics concepts [4]. It was also revealed that most students had misconceptions about acceleration, assuming that in each case it would have the same impact, namely acceleration depending on the motion of the object [3].

Much research on physics education only focuses on understanding the concept of free fall using media, even though learning physics is required not only to be able to master basic concepts but also to focus on and apply them to solve

TABLE I. Problem solving stages.

No	Stages	Information
1	*Useful Description*	Describe the problem-solving framework. For example: beginning with ”known”, ”asked”
2	*Physics Approaches*	Assessing the solver's process in selecting the appropriate physics concepts and principles to be used to solve the problem. An example of the GLBB concept is GJB. Principles such as the principles of Newton's laws
3	*Specific Application of Physics*	Assessing the solver's process in applying the concepts and principles of physics to certain conditions in a problem. For example using the concept of units
4	*Mathematical Procedures*	Assessing the solver's process in choosing the right mathematical procedure and following mathematical rules to get the target number in a coherent and systematic manner
5	*Logical Progressions*	Assess the solver process by prioritizing consistency

every problem [21]. It is known that physics learning in the classroom today still tends to emphasize mastery of concepts and overrides problem solving skills [22]. In this case students are required to be able to find concepts or principles that are in accordance with the problems at hand, and then use their knowledge to solve these problems [23].

In learning physics, there are still many students who solve problems/work on physics questions often using mathematical equations without doing analysis, guessing the formulas used and memorizing examples of questions that have been done to work on other questions [24]. It is known that students still often use plug and chug and memory based approaches in solving physics problems [25]. For that we need an effective learning strategy for problem solving [23]. Students' problem-solving abilities can be seen through several stages. The stages in solving the problem include a useful description, a physics approach, a specific application of physics, a mathematical procedure, and a logical conclusion [23].

There are several factors that affect students' weak problem-solving abilities, namely: students cannot solve problems including not enough practicum in the laboratory, confusion about writing unit conversions, lack of physics books used as Refs. [26]. The lack of problem solving skills includes a weak understanding of the principles and rules of physics, a lack of understanding of the problems, and insufficient motivation from students [27].

In the discussion of free fall about an object released from a height of h meters above the ground without initial velocity [22]. Then to find the speed of the object at the time t the solution that is widely used is through a review of the acceleration due to gravity using the formula [28]. In physics problems regarding free fall motion, students must be able to understand the concept of problem solving, not emphasizing memorizing formulas, but can be done through unit review. Students experience difficulties in converting units, topics and sequencing numbers when answering questions related to units [29]. Implications for science courses are discussed. This article is intended to reveal students' understanding of concepts through problem solving in terms of units on free fall motion material.

2. Method

This research is a survey research conducted on 19 students of the Department of Physics Education, Tamansiswa University, Yogyakarta. The research subjects were third year Physics Education students. The research method used is descriptive quantitative, namely by seeking information about existing symptoms so as to get an overview of the subject's status under certain conditions, so that it is expected to be able to determine the level of ability to understand concepts of physics education students through solving unit review problems on Free Falling Motion (GJB) topics. The instrument was a conceptual question consisting of 2 essay questions. The questions are adapted from `https://www.physpot.org/user/login.cfm`. The understanding of the concept of motion to be revealed is related free fall motion of objects at a certain height and problem solving taken based on unit review.

The level of calculating interval distances for understanding the concept of physics of matter of free fall motion is categorized by adopting the category. The category of understanding the concept in this study is presented in Table II. The problem solving rubric can be shown in Table III adopted from [22].

In this study, 2 physics questions were presented in the form of essays (Table VII) which were given to UST Physics Education Study Program students in semester 3 consisting of 19 people. Data from the analysis of understanding the concept and solving physics problems from a unit review by

TABLE II. Interval distance calculation criteria.

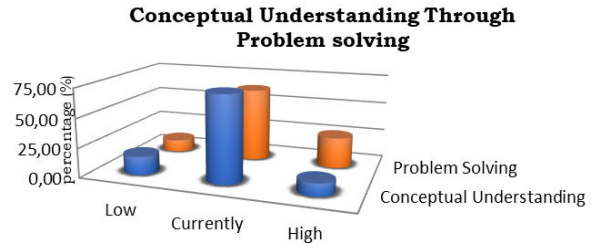
No	Criteria	Category
1	$X <$ Mean $- 1.SD$	Low
2	Mean $- 1.SD \leq$ Mean $+ 1.SD$	Currently
3	Mean $+ 1.SD \geq X$	High

students of the UST Physics Education Study Program are shown in Table IV and V. The representation of the analysis of conceptual understanding.

In Fig. 1 it is observed that understanding the concept through solving unit review problems the highest percentage in the medium category. This means that the ability to understand concepts through problem solving of UST physics education students is in the medium category.

TABLE III. Problem solving rubric.

Category	Score 4	Score 3	Score 2	Score 1	Score 0
Useful Description	Answers include a precise and complete description of the problem	One part of the problem description is incorrect or incomplete	More than one part of the description is incomplete, or contains errors	More than one part of the description is incomplete, and contains errors	The entire description is inaccurate and contains errors
Physics Approaches	Using a precise and complete physics approach	One physics approach used is imprecise or incomplete	More than one physical principle is imprecise or incomplete	More than one imprecise and incomplete physics principle	All the selected concepts and principles are not suitable
Specific Application of Physics	Answers using the physics concept application are precise, complete, and according to the problem	One of the uses of a specific physics concept that is incomplete or contains errors	More than one application of physics concepts is incomplete or contains errors	More than one application of a specific physics concept that is incomplete and contains errors	The entire specific application is not suitable and or contains errors
Mathematical Procedures	The mathematical procedures used are appropriate and complete	Complete mathematical procedure but contains few errors	A mathematical procedure is incomplete or contains errors	More than one mathematical procedure is incomplete and contains errors	All mathematical procedures are incomplete and/or contain errors
Logical Progressions	The overall answer to the problem is clear, focused, and logical	The answers to the problems were clear and focused but contained one error	More than one answer is unclear, unfocused, or inconsistent	More than one answer is unclear, unfocused, and inconsistent	The overall answer is unclear, unfocused and inconsistent



	Low	Currently	High
Conceptual Understanding	15,79	73,68	10,53
Problem Solving	10,53	63,16	26,32

FIGURE 1. The level of understanding of the concept of Physics Education students through solving unit review physics problems.

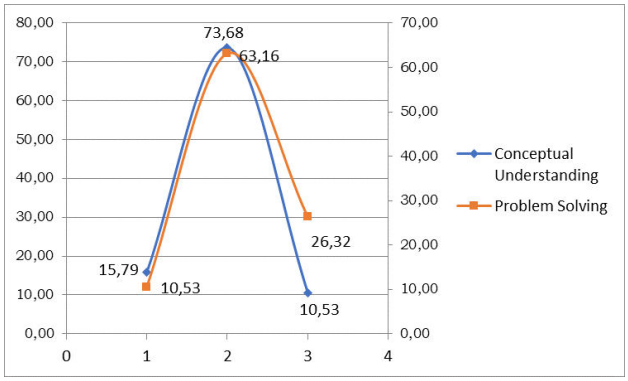


FIGURE 2. The trend of understanding the physics concept of Free Falling Motion (GJB) material through solving unit review physics problems.

The stages of problem solving measured in this study consist of 5 indicators, including useful description, physics approach, specific application of physics, mathematical procedure and logical progression. The results are scored with a problem solving assessment rubric. The data obtained in this study is problem solving data through essay test techniques using paper.

3. Results and discussion

In this study, 2 physics questions were presented in the form of essays (Table VII) which were given to UST Physics Education Study Program students in semester 3 consisting of 19 people. Data from the analysis of understanding the concept and solving physics problems from a unit review by students of the UST Physics Education Study Program are shown in Table IV and V. The representation of the analysis of understanding the understanding of concepts through problem solving is shown in Fig. 1. In Fig. 1 it is observed that understanding the concept through solving unit review problems the highest percentage in the medium category. This means that the ability to understand concepts through problem solving of UST physics education students is in the medium category.

TABLE IV. The results of the analysis of the level of understanding of the concept.

No	Category	Frequency	Percentage
1	Low	3	15.79
2	Currently	14	73,68
3	Tall	2	10.53

TABLE V. The results of the analysis of problem solving abilities.

No	Category	Frequency	Percentage
1	Low	2	10.53
2	Currently	12	63,16
3	Tall	5	26,32

TABLE VI. Analysis of problem solving for each indicator of UST Physics Education students.

No	Indicator	Frequency	Average score
1	Useful Description	19	9.56
2	Physics Approaches	19	0.70
3	Specific Application of Physics	19	0.50
4	Mathematical Procedures	19	3.06
5	Logical Progressions	19	1.17

In Fig. 2, it can be seen that the trend of Physics Education students who have low ability to understand concepts also has low ability to solve problems. This is in line with research conducted [27]. Based on Table I, it is observed that students' abilities in solving physics problems in Free Falling Motion material, on indicators Physics Approaches, Specific Application of Physics and Logical Progression fall into the low category. This means that students are not yet able to choose the appropriate physics concepts and principles to use in solving problems on Free Falling material through unit reviews, not being able to apply physics concepts and principles to certain conditions in a problem about the free falling motion material and also still prioritizing consistency to always use the formula in solve physics problems.

Table VII shows the physics questions used to analyze the ability to understand the concepts of physics education students through solving the unit review on free fall motion material. Description of the results of the analysis based on student answers based on problem solving indicators on the questions shown in Figs. 2a), 2b) and 2c), show that students are in the low category in incomplete answers andincomplete and contains errors. Students in the moderate category answer incomplete or contain errors. Students in the high category answer questions completely and do not contain errors.

Based on Fig. 3, it can be seen that students' understanding of concepts in solving free fall motion problems is still consistently guided by equations or formulas without going

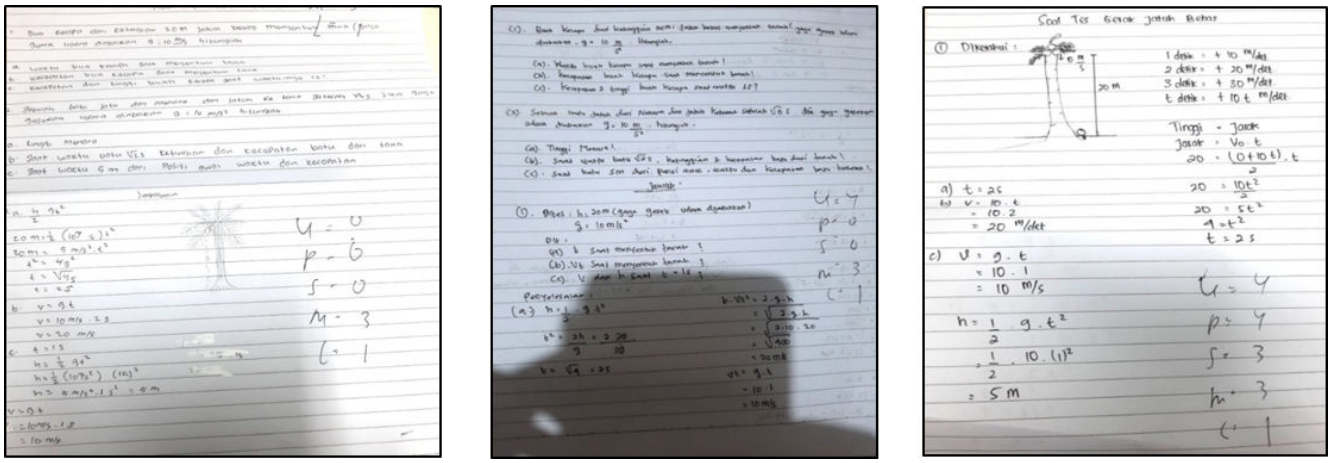


FIGURE 3. Description student problem solving onquestion number 1 indicator in category a) Low; b) Moderate; c) High.

TABLE VII. Description of physics essay questions on free fall motion material.

Questions
1. Coconuts from a height of 20 m, fall freely touching the ground (ignore air friction, $g = 10$ m/s^2 Coconuts from a height of 20 m, fall freely touching the ground (ignored air friction, $g = 10$ m/s^2) Calculate: a. When the coconut fruit hits the ground? b. How fast is the coconut when it hits the ground? c. The speed and height of the coconut when the time is 1 s?
2. A stone falls from the tower and hits the ground after $\sqrt{3}$ s. If the air friction force is neglected $g = 10$ m/s^2 a. Tower heights? b. When the stone takes $\sqrt{2}$ s, the height and speed of the stone from the ground? c. When the rock is 5 m from its initial position, the time and speed of the rock?

through proper procedures. This result is in line with research that found that many students in solving problems/working on physics questions given by the teacher often used mathematical equations without doing analysis, guessed the formulas used and memorized examples of questions that had been worked on to work on other questions. The advantage of this research is that it has not yet found a solution to the problem through unit review. In solving physics problems, especially in free-falling matter, this can be done through the unit concept. The weakness of this research is that the research has only reached the survey stage.

4. Conclusion

Analysis of understanding the concept of physics education students through solving unit review problems in free fall material with the highest percentage in the medium category. On the troubleshooting indicator Physics Approaches, Specific Application of Physics and Logical Progression of students' abilities in the low category.

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