

ANALYSIS OF STUDENTS' ANSWER ABOUT THE CONSERVATION OF MECHANICAL ENERGY CONCEPT IN PHYSICS EDUCATION BENGKULU UNIVERSITY

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Abstract

Purpose of study: This research aims to analyze students' answers about the conservation of mechanical energy assessment in the form of essay tests.

Methodology: Descriptive quantitative methods chosen by the researchers involving 46 students of physics education in physics education at Bengkulu University. Students are asked to answer tests on the conservation of mechanical energy consisting of 5 essay questions, which involve verbal, mathematical, and picture representations. Interviews will also be conducted to ascertain student answers.

Main findings: This research found that 38% of students answered correctly and others still answered incorrectly because they asked for difficulties in mastering the concepts of physics.

Applications of this study: The implication of this research is to help students improve their conceptual understanding, so students can solve problems about physics correctly.

The novelty of this study: The researcher explains about what is important in building students' conceptions in-depth and directing students to solve problems about physics, especially about the conservation of mechanical energy.

Keywords: *Student's Answer, Understanding Concept, Conservation of Mechanical Energy Concept, Physics, Education.*

INTRODUCTION

Physics is a branch of science that studies natural phenomena or natural phenomena. Learning about physics must have a good initial understanding of the concepts to be learned to be able to explain the concepts they obtained from school and applied in their environment (Wulandari, 2018). In physics, many concepts are very closely related to everyday life. The subject of physics is the science of analyzing the structure and natural events accompanied by experimentation and systematic measurement and presentation to encourage students' thinking skills (Hudha et al., 2019; Wiwin & Kustijono, 2018) Students' thinking skills can be seen from their daily lives, especially those related to natural phenomena so that they can be linked to classroom learning material. Many things can be learned from nature; especially about natural phenomena that occur in daily life. One material that studies about natural phenomena is the concept of work-energy theory.

The work-energy theorem theory is derived from Newton's law theory, Newton's II law, this law applies to the displacement of a particle or an expanded center of mass that is treated as a particle (Arons, 1999; Singh & Rosengrant, 2016). In physics, many concepts are very closely related to everyday life. Physics is the science of analyzing the structure and natural events accompanied by experiments and systematic measurement and presentation. In the process of learning physics in work-energy concepts it appears that they are still experiencing problems with the basic concepts of energy. Many factors experienced by students that still consider physics is a subject that is very difficult to understand let alone to be applied in daily life. There are five main reasons that science concepts are still considered difficult to understand are (1) the concept is abstract, (2) the system is very complex, (3) limited knowledge/understanding of students that teachers don't pay enough attention to, and (4) understanding of symbols that is very lacking, and (5) there are often misunderstandings by students (Koba & Mitchell, 2011). Individual interpretation of many concepts is often different; this is what causes misunderstanding of the concept in students. Learning physics must be based on beliefs and focus on understanding concepts (Dunlosky et al., 2013; Handhika et al., 2016). If students are focused and enthusiastic in the physics learning process, this will reduce the level of misunderstanding of concepts that are often experienced by students. The initial ability of students is the main thing the teacher needs to focus on providing concepts that they want to be taught to students, especially in physics concepts. The theoretical beliefs about knowledge and learning also become a benchmark in the process of forming students' understanding of concepts

Conservation of mechanical energy concept is one of the chapters in business and energy materials. The total mechanical energy in a system (total potential energy and kinetic energy) remains constant as long as the only force acting is a conservative force; this is the principle of conservation of mechanical energy. The Principle of Conservation of mechanical energy is very important in the process of learning physics at all levels, from junior high, high school to

university level ([Lindsey et al., 2009](#)). Conservation of mechanical energy is the most difficult concept answer by the student ([Kassiavera et al., 2019](#)). Every concept cannot be understood by students in the same way but must be adapted to the character of the student and the character of the concept.

The purpose of this research according to researchers is to analyze the students' answers about Conservation of mechanical energy so they can find out the difficulties students experience in solving physical problems in daily life.

LITERATURE REVIEW

A person's ability to learn abstract ideas or ideas correctly, without changing the meaning of the concept is called concept understanding. Understanding concepts can assist students in explaining definitions, procedures, conclusions with their sentence structure based on the sources they have obtained and can provide other examples of what has been given by the teacher ([Duffin & Simpson, 2015](#); [Viyanti et al., 2016](#)). Students who have understanding true concepts are expected to be able to solve each problem correctly ([Abraham et al., 1994](#); [Cari et al., 2019](#)). Understanding concepts is considered a complex phenomenon, consisting of factual, procedural, and conditional knowledge. Understanding the concept in question emphasizes the ability of students to apply scientific phenomena that have been learned in everyday life are useful to strengthen the acquisition of information of a concept.

Students' conceptual understanding can occur by increasing their beliefs about science and its application from the beginner level to a more professional level ([Sahin, 2010](#)). Student conceptions are very important to improve the development of physics in learning ([Kurniawati et al., 2018](#)). Learning about physics education recommends using several presentations to find out students' conceptions, for example in the form of images ([Wulandari et al., 2017](#)). Learning physics means learning from all forms ranging from drawing, mathematical, graphic, and verbal which is a multi-representation skill. It purposes to increase the level of understanding of students' concepts towards learning abstract physics.

Students are said to have understood the concept well if the concepts understood are in accordance with what is understood by physicists, and can relate the concepts to one another. Understanding the correct concepts can help them solve problems quickly and accurately ([Doktor & Mestre, 2014](#)). Understanding the concept is a broad area that can be used in research in physics education. Conceptual understanding is an action to understand correctly about abstract thought patterns that requires someone to determine the object/event & conceptual understanding obtained through the teaching and learning process ([Alatas, 2014](#)). The poor learning process will affect students' understanding of concepts and will disrupt the learning process at school. This misunderstanding will remain long for students if not immediately addressed by the teacher. The teacher must also innovate in the teaching and learning process in order to reduce the level of misunderstanding by students.

Students still consider concepts that are considered difficult to be in accordance with the pre-conceptions they have obtained previously. Often, students' interpretations are not in accordance with the concept by experts, these different concepts often lead to wrong conceptions or misconceptions ([Tompo et al., 2016](#)). The concepts students have been influenced by various factors, such as the environment, learning resources, and experience ([Lee & Yi, 2013](#)). The preconceptions or initial concepts students have are not the same. Some students' preconceptions are only a few students' preconceptions are in accordance with scientific studies correctly which usually comes from a variety of personal experiences ([Gurel et al., 2016](#)). The low understanding of concepts owned by students is caused by students not playing an active role and low student skills in the learning process at school ([Leasa et al., 2017](#); [Leasa & Talakua, 2016](#)). The wrong concept that is not by the scientific view of experts is called a misunderstanding ([Alwan, 2011](#); [Gurel et al., 2016](#)). The environment is the main factor that gives rise to misunderstandings that are often experienced by students.

Initially, in the context of physics learning these are problems when something that is known and believed by someone but is not in accordance with what is scientifically understood, then most people who experience the misunderstanding are "NOT" aware of their ideas. Many conceptions developed by students themselves, which not yet scientifically compatible facts, are called preconceptions, misconceptions that create major obstacles to learning the following year ([Cardak, 2009](#)). There are 7 basic statements when hearing the word misconception include; 1) misconceptions are already present in every student. 2) previous learning is the origin of the emergence of misconceptions. 3) misconceptions can spread to other students. 4) misconceptions will disrupt the learning process activities in class. 5) misconceptions must be corrected immediately. 6) there are instructions in dealing with misconceptions and 7) a study must be able to identify students' misconceptions.

Obstacles felt by them in understanding a concept can cause misconceptions of attention that are important to be investigated especially on some concepts of physics. The cause of misconception itself according to ([Dermici, 2005](#); [Rosa et al., 2017](#)) can be categorized into (1) initial ability. Early abilities make it difficult for students to accept the material being taught. Many scientists consider that misunderstanding should not occur, but students often do it because the knowledge is considered correct. After learning activities, this belief can remain so that it can hinder the learning process; (2) non-scientific belief or intuition, is a feeling in someone who spontaneously expresses his attitude or ideas about something before being examined objectively and rationally. Intuitive thinking or understanding usually comes from observing constant objects or events; (3) conceptual misunderstanding. Conceptual misconceptions when information about scientific studies is studied by them in a way that does not provoke them to discover their knowledge

through the scientific process; (4) verbal misunderstanding. This mistake often arises from the use of words that mean something to ordinary people, but becomes something very different when talking about science; (5) factual misunderstanding, is the falsity of facts that are often learned at an early age and remain unchanged into adulthood.

In learning the concepts of Physics the things that need to be known are Conception and misunderstanding. This is considered important because conception and misunderstanding will affect the overall level of understanding of physics, especially in problem-solving. Problem-solving is a must to learn. The method of memorizing is not the only way to solve a problem, but how to find a solution to that problem (Cari et al., 2016). There are 2 basic ideas about student understanding, namely 1) Students' understanding is supported by the similarity between personal experience and scientific conception, and 2) Students' alternative conceptions are reinforced by the contrast between personal experience and scientific conception (Alwan, 2011). So the attempt to correct the misconceptions that occur really requires identification of the cause of the misconception itself.

METHODOLOGY

This quantitative descriptive study selected as the research method with the sample taken by purposive random sampling consists of 3rd semester year 2019/2020. The study had 46 subjects of physics education program students from Bengkulu University which have taken the first basic physics and mechanics courses.

There are three ways that can be used to determine students' initial knowledge and misconceptions that are found in students, namely: (1) diagnostic tests through written tests, (2) interviews, and (3) presentation of concept maps. Based on the answers put forward by students on the test sheet, the students' initial knowledge and misconceptions and background can be traced. This research the data was collected using an instrument test and interview. The test that is tested on students is in the form of essay questions on the conservation of mechanical energy adapted from (Serway & Jewett, 2004).

Data collection techniques using essay tests that have been validated by physicists with an instrument of 5 questions. Interviews are used to provide an explanation and ensure answers from students. Through interviews, students can state the reasons for their decision to provide answers based on the conceptions they already have. Interviews are conducted after students complete the test. The questions in this interview phase aim to assess understanding and knowledge to conceptualize the material of conservation of mechanical energy.

RESULTS AND DISCUSSION

The results of the research showed found that most Students still have a very low understanding of the concept even some of them experience a misconception in the material of conservation of mechanical energy. They answer the questions given with intuition. Students do not have a correct understanding of the concept, even though they have learned the material of conservation of mechanical energy in the previous semester. Student concept understanding retention is still relatively low. The results of the tests tested are shown in table 1.

Table 1: The percentage of students correct answer

Conceptual	Item	Percentage (%)
Conservation of mechanical energy on curved paths	1, 5	42%
Conservation of mechanical energy in the pendulum	2, 3, 4	34%
Average		38%

The conceptual area that most students answer is the concept of conservation of mechanical energy on curved paths. They need a high level of understanding of the conservation of mechanical energy in the pendulum. The results were obtained that question no.1 and no.4 were the most difficult questions for students to solve.

Question 1.

A car in an amusement park crosses the roller-coasters without friction around the track as shown in the picture. The movement of the car starts from point A at height h above the bottom of the loop. By considering the car as a particle. What is the minimum value h (in terms of R) so that the car can moves over the loop without falling above (point B)?

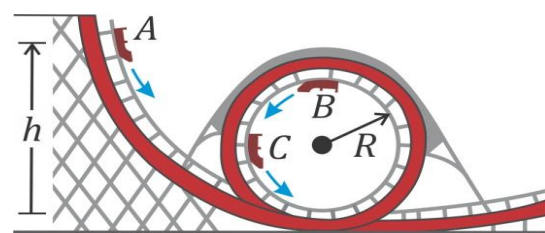


Figure 1: Question of Number 1

There are no students who are able to analysis t (h_{\min}) so that the car can move around the loop without falling over (point B) the students only answer using the formula itself and do not do it fully, so the concepts they have mastered are not yet seen. Student answers are shown in figure 2.

① a. $V_A = 0$;
 $a = \frac{V_B^2}{R}$
 Hukum Newton
 $\Sigma F = M \cdot g = M \cdot a$
 $M \cdot g = M \cdot \frac{V_B^2}{R}$
 $V_B^2 = gR$
 $V_B = \sqrt{gR}$
 $y_B = 2R$

Untuk mencari h minimum guna
 kan Hukum kekekalan energi
 $E_A = E_B$
 $\frac{1}{2} M V_A^2 + M g y_A = \frac{1}{2} M V_B^2 + M g y_B$
 $\frac{1}{2} M (0)^2 + M g h = \frac{1}{2} M g R + M g 2R$
 $M g h = \frac{1}{2} M g R + 2 M g R$
 $h = \frac{1}{2} R + 2 R$
 $h = \frac{5 R}{2}$

(A)

a). $E_{MA} = E_{MB}$
 $\frac{1}{2} m v_A^2 + mgh = \frac{1}{2} m v_B^2 + m g 2R$
 $0 + mgh = \frac{1}{2} m v_B^2 + m g 2R$
 $gh = \frac{1}{2} v_B^2 + 2gR$
 $h = \frac{\frac{1}{2} v_B^2 + 2gR}{g}$ ($g = 10 \text{ m/s}^2$)
 $= \frac{\frac{1}{2} v_B^2 + 20R}{10}$
 $= \frac{1}{20} v_B^2 + 2R$

$E_{MA} = E_{MB}$
 $\frac{1}{2} m v_A^2 + mgh = \frac{1}{2} m v_B^2 + m g 2R$
 $0 + m \cdot 10 \cdot 70 = \frac{1}{2} m v_B^2 + m \cdot 10 \cdot 2(20)$
 $700m = \frac{1}{2} m v_B^2 + 400m$
 $700m - 400m = \frac{1}{2} m v_B^2$
 $300m = \frac{1}{2} m v_B^2$
 $v_B^2 = 300(2)$
 $v_B^2 = 600$
 $v_B = \sqrt{600}$
 $= 10\sqrt{6} \text{ m/s}$

$E_{MB} = E_{MC}$
 $\frac{1}{2} m v_B^2 + m g 2R = \frac{1}{2} m v_C^2 + 0$
 $\frac{1}{2} m (10\sqrt{6})^2 + m \cdot 10 \cdot 2(20) = \frac{1}{2} m v_C^2$
 $300m + 400m = \frac{1}{2} m v_C^2$
 $700m = \frac{1}{2} m v_C^2$
 $v_C^2 = 700(2)$
 $v_C^2 = 1400$
 $v_C = \sqrt{1400}$
 $= 10\sqrt{14} \text{ m/s}$

$h = 3,5R = 3,5(20) = 70 \text{ m}$
 $R = 20 \text{ m}$

(B)

Figure 2: Example of students answer on question 1 (A) students answered correctly, (B) students answered incorrectly

Figure 2B shows that most of them are still confused and have difficulty answering question number 1. Based on the analysis conducted of student answers, it was found that some students did not apply the energy conservation equation related to Newton's II law.

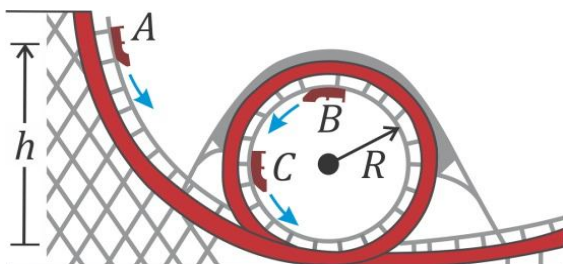


Figure 3: the roller-coasters

To determine the (h_{\min}) in the case of (R) so the car can move around the loop without falling above (point B), we can apply the energy conservation equation. By applying the energy conservation equation $K_1 + U_1 + W_{NC} = K_2 + U_2$ related to h and velocity at point B (v_B), and Newton's II law $\sum \vec{F} = N + mg = ma$ at point B to determine the minimum value at point B so that the car does not fall. At point B, there is a radial acceleration $a = \frac{v_B^2}{R}$ downward. The

minimum velocity when $mg = m \frac{v_B^2}{R}$, so the minimum speed required is $v_B = \sqrt{gR}$.

At point A, the kinetic energy of car 0 (quiescent), using the conservative energy concept is obtained:

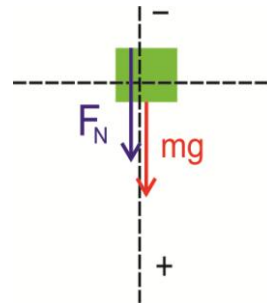
$$E_A = E_B$$

$$\frac{1}{2}mv_A^2 + mgy_A = \frac{1}{2}mv_B^2 + mgy_B$$

$$0 + mgh = \frac{1}{2}mgR + mg2R$$

$$h = \frac{R}{2} + 2R$$

$$h = \frac{5}{2}R$$



In other words, when $K_A + U_A = K_B + U_B$ applied to point A and B $U_A - U_B = \frac{1}{2}mv_B^2$ is obtained. Velocity at the

highest point is minimal $v_B = \sqrt{gR}$. And then $mg(h - 2R) > \frac{1}{2}mgR$ or $h > \frac{5}{2}R$.

Question number 4 is the most difficult level of questions is the concept of conservation of mechanical energy. Question 4 examples of right and wrong answers are shown in Figure 4.

Question 4.

Review a system consisting of two pendulums. The first pendulum has mass M with length $2L$, and the second pendulum has mass m with length L , as shown in the picture below. The first pendulum is removed from the angle of (90°) and collides with the second pendulum. After the collision, the first pendulum reaches an angle of (90°), while the second pendulum manages to spin with a full circle. Determine: (a). restitution coefficient, e ? and (b) the mass ratio of these 2 pendulums, M / m ?

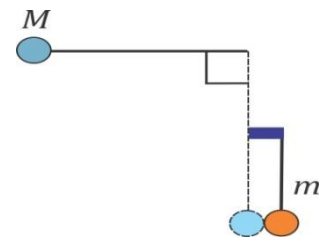


Figure 4: Question of Number 4

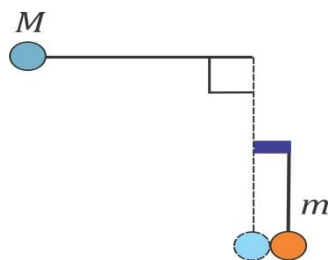
(A). Kec. sesaat sebelum $V_1 = \sqrt{2gL}$ dan $V_2 = 0$
 Kec. sesaat sesudah $V_1' = \sqrt{2gL}$
 $\frac{1}{2} m (V_2')^2 = \frac{1}{2} m (V_2')^2 + mgl$
 $V_2 = \text{sampai}$ $\frac{m (V_2')^2}{2} = mgl$
 $V_2 = V_2' = \sqrt{(V_2')^2 + 2gl} = \sqrt{2gl}$
 Koef $e = - \frac{V_1' - V_2'}{V_1 - V_2} = \frac{\sqrt{2gl} - \sqrt{2gl}}{0 - 2\sqrt{2gl}} = \frac{\sqrt{2} - \sqrt{2}}{2}$
 $m_1 V_1 + m_2 V_2 = m_1 V_1' + m_2 V_2'$
 $\frac{M}{m} = \frac{V_1 - V_2}{V_2' - V_1'} = \frac{-\sqrt{2gl} - 0}{\sqrt{2gl} - 2\sqrt{2gl}} = \frac{\sqrt{2}}{2 - \sqrt{2}}$

(A)

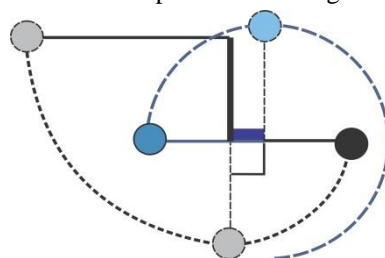
a. $e = \frac{-v_1' - v_2'}{v_1 - v_2}$
 $\frac{1}{2} m v_1^2 = mgl$ (Diubah ke h)
 $\frac{1}{2} m v_1^2 = gh$
 $v_1^2 = 2 \cdot g \cdot 2L$
 $v_1^2 = 4gL$
 $v_1 = \sqrt{4gL}$
 $\frac{1}{2} m v_1^2 = mgl$
 $\frac{1}{2} m v_2^2 = g \cdot 0$
 $v_2^2 = 2g \cdot 0$
 $v_2^2 = 0$
 $v_2 = 0$
 $\frac{1}{2} m v_1^2 = mgh$
 $\frac{1}{2} m (v_1')^2 = mgh$
 $\frac{1}{2} m (v_1')^2 = 2mgl$
 $\frac{1}{2} (v_1')^2 = 2gL$
 $(v_1')^2 = 2 \cdot 2gL$
 $v_1' = \sqrt{4gL}$
 $e = \frac{-v_1' - v_2'}{v_1 - v_2} = \frac{-\sqrt{2gl} - \sqrt{2gl}}{\sqrt{4gl} - 0} = \frac{-2\sqrt{2gl}}{2\sqrt{gl}} = \frac{-\sqrt{2} - \sqrt{2}}{2}$
 b. menggunakan hukum lenting sempurna
 $m_1 v_1 + m_2 v_2 = m_1 v_1' + m_2 v_2'$
 $m_1 v_1 - m_1 v_1' = m_2 v_2' - m_2 v_2$
 $m_1 (v_1 - v_1') = m_2 (v_2' - v_2)$

(B)

Figure 5: Example of students answer on question 4 (A) students answered correctly, (B) students answered incorrectly
 Figure 5(B) shows that most of them are still confused and have difficulty answering question number 4. Based on the analysis conducted of student answers, it was found that some students did not understand to review a system consisting of two pendulums. This is what makes there are still misconceptions or initial abilities of students who are still relatively low about the conservation of mechanical energy (Lindsey et al., 2012).



The first pendulum is removed from an angle of (90°) and collides with the second pendulum. After the collision, the first pendulum reaches an angle of (90°), while the second pendulum manages to spin with a full circle



Velocity just before the collision

$$v_1 = \sqrt{4gL} \text{ dan } v_2 = 0 \dots\dots\dots (1)$$

The velocity immediately after the collision is

$$v_1' = \sqrt{2gL}$$

$$\frac{1}{2}m(v_2')^2 = \frac{1}{2}m(v_2'')^2 + 2mgL \dots\dots\dots (2)$$

(v_2'') is velocity when it reaches the top point. (v_2'') obtained from centripetal force

$$\frac{m(v_2'')^2}{L} = mg \dots\dots\dots (3)$$

So the value of (v_2') is:

$$v_2' = \sqrt{(v_2'')^2 + 4gL} = \sqrt{5gL} \dots\dots\dots (4)$$

The coefficient of restitution:

$$e = -\frac{v_1' - v_2'}{v_1 - v_2} = \frac{\sqrt{5gL} - \sqrt{2gL}}{0 - 2\sqrt{gL}} = \frac{\sqrt{5} - \sqrt{2}}{2} \dots\dots\dots (5)$$

The mass ratio can be obtained from the conservation of momentum:

$$Mv_1 + mv_2 = Mv_1' + mv_2'$$

$$\frac{M}{m} = -\frac{v_2' - v_2}{v_2' - v_2} = -\frac{\sqrt{5gL} - 0}{\sqrt{2gL} - 2\sqrt{gL}} = \frac{\sqrt{5}}{2 - \sqrt{2}} \dots\dots\dots (6)$$

From the data obtained that there are still many students there are misconceptions of concepts or misconceptions, especially in the material conservation of mechanical energy. The cause of misconception itself according to [\(Dermici, 2005\)](#) is one of them, namely the initial ability. Early abilities make it difficult for students to accept the material being taught. Many scientists consider that misunderstanding should not occur, but students often do it because the knowledge is considered correct. Important points in learning, understanding, and applying physics in everyday life are concepts in learning Physics [\(Wulandari, 2018\)](#).

CONCLUSION

The results of data analysis obtained that overall students' physics answers to Conservation of mechanical energy get an average score of 38%. This shows that this material is still very difficult for students to complete. This is what causes students' misconceptions because students' initial abilities are still very low. Based on these results the authors suggest conducting further and detailed research to develop students' conceptions to reduce the level of misunderstanding they are at understanding the concept of Conservation of mechanical energy. This is a small part of a study in developing a learning process to improve students' conceptions of Work-Energy.

LIMITATIONS

This research has a limitation that is the low understanding of students about physics materials, especially the conservation of mechanical energy and the questions that are still considered difficult by students. This study also only examined at one university, not to several other universities.

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AUTHORS CONTRIBUTION

Sujiyani Kassiavera is a science education doctoral student at Universitas Sebelas Maret, her role in this research was making articles, instruments, taking data, and managing data. Suparmi is a professor at the Universitas Sebelas Maret,

her role in this research was to analyze the concepts of physics. Cari is a professor at the Universitas Sebelas Maret, her role in this research was to analyze the data and review the entire article. Sukarmin is a lecturer at the Universitas Sebelas Maret, her role in this research was to evaluate the instruments used in this study.

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