INVESTIGAÇÃO DO ENTENDIMENTO CONCEITUAL DE ESTUDANTES DE GRADUAÇÃO SOBRE MOVIMENTO HARMÔNICO SIMPLES EM SISTEMA DE MASSA-MOLA

INVESTIGATION OF UNDERGRADUATE STUDENTS CONCEPTUAL UNDERSTANDING ABOUT SIMPLE HARMONIC MOTION ON MASS-SPRING SYSTEM

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RESUMO

O Movimento Harmônico Simples (SHM) é um dos tópicos básicos da física que subjaz a outros conceitos e está intimamente relacionado à vida cotidiana e à tecnologia. É usado para entender os fenômenos de movimento mecânico, som, luz e teoria quântica, em particular, osciladores harmônicos. O objetivo do estudo foi investigar a compreensão conceitual dos alunos sobre o movimento harmônico simples no sistema massa-mola. A coleta de dados foi realizada por meio de testes e entrevistas. Os sujeitos da pesquisa consistiram em 49 estudantes em uma universidade em Jacarta. Os instrumentos utilizados foram tarefas de múltipla escolha. Os resultados da investigação mostraram que a maioria dos estudantes não conseguiu dominar bem os conceitos básicos do movimento harmônico simples, determinar a magnitude da aceleração dos objetos devido à oscilação e encontrar o escopo do período de oscilação. Os resultados mostram que o desempenho médio dos alunos é inferior a 50%. A falta de compreensão da concepção do aluno é causada pelo fato de os alunos não conseguirem relacionar conteúdos anteriores (como a lei de Newton e a lei de Hooke) com estratégias para resolver problemas.

Palavras-chave: *Investigação, compreensão de conceitos, Lei de Hooke, movimento harmônico simples, sistema de massa-mola.*

ABSTRACT

Simple Harmonic Motion (SHM) is one of a primary physics topic that underlies other concepts and is closely related to everyday life and technology. It is used to understand the phenomena of mechanical motion, sound, light, and quantum theory, in particular, harmonic oscillators. This study aimed at investigating students' conceptual understanding of simple harmonic motion on the mass-spring system. Data collection was made using tests and interviews. The research subjects consisted of 49 students at a university in Jakarta. The instruments used were multiple-choice tasks. The results of the investigation showed that most students have not been able to name the basic concepts of simple harmonic motion, determine the magnitude of the acceleration of objects due to oscillation, and find the scope of the oscillation period. The results show that the average achievement of students is less than 50%. Lack of understanding of student conception is caused by students not being able to relate previous insights (such as Newton's law and Hooke's Law) with strategies for solving problems.

Keywords: *Investigation, Concepts Understanding, Hooke's Law, Simple Harmonic Motion, Mass-spring System.*

1. INTRODUCTION:

Nowadays, research in the field of physics education, in particular, understanding student concepts, is a research trend that is studied in depth. Understanding concepts is one of the main objectives in learning physics (Adolphus, Alamina, Aderonmu, Education, and State, 2013; Arista and

Kuswanto, 2018; Eldy and Wui, 2019; Krinks, 2016; Maison and Syamsurizal, 2019; Ogundéji, Madu, and Onuya, 2019; Olmstead, 2019; Somroob and Wattanakasiwich, 2017; Son, 2017), so that with a good understanding of the concept students can apply it in everyday life (Dimas, Suparmi., Sarwanto., and Nugraha., 2018; Nugraha, Suparmi, Masykuri, and Cari, 2016).

Physics is the study of matter, energy, and its interactions. Physics plays a key role in the progress of humanity; in this case, physics, as a basic concept for technological advancements needed to drive the world economy (Adolphus *et al.*, 2013). Simple Harmonic Motion (SHM) is one of the physical materials that is closely related to everyday phenomena; it is used to understand the phenomena of mechanical motion, sound and light, and quantum theory in particular harmonic oscillators (Adolphus *et al.*, 2013; Alho, Silva, Teodoro, and Bonfait, 2019; Greene, Gill, and Eyerly, 2016; Parnafes, 2010).

The application of SHM concepts in daily life can help students identify and shape their knowledge (Khowatim, Mahardika, and Alex, 2017). Some real-world phenomena, such as simple harmonic motion, require an understanding of the concepts of coordinates in various wave functions (Parnafes, 2010). So it can be said that the understanding of SHM concepts that must be understood by students both in theory and mathematical calculations (Adolphus *et al.*, 2013). By learning how students understand physics, and their attitude towards learning physics is something interesting to study (Angell, Guttersrud, Henriksen, and Isnes, 2004; Son, 2017). It aims to improve the quality of physics learning.

The quality of physics learning has a positive correlation between teacher mastery of physics material and better pedagogical practices (Dandare, 2018). The results of research conducted by Dandare (2018), revealed that there are gaps in physics teachers regarding simple harmonic motion material.

Therefore, the aim of this study was to investigate students' conceptual understanding of simple harmonic motion on the mass-spring system.

2. LITERATURE REVIEW:

Understanding the concept is a process of adaptation and transformation of science (Gardner, 1999). Concept mastery is the result of student learning in the form of achieving the competence of physics courses in the cognitive domain. A scientific concept is expressed in various levels and presented or generalized in curriculum standards (OECD, 1999). The concepts of students are explored and developed using logical reasoning skills, training, formulating theories, and participation in problem-solving so that students can create an accurate conclusion (Nurhuda, Rusdiana, and Setiawan, 2017).

Physics learning aims to make students obtain many concepts and apply or apply flexibly (Reif, 1995). To represent the concept of physics requires an exceptional understanding of the idea. In other words, the multi-representation ability is closely related to understanding student concepts. The representation can be interpreted as a description of the relationship between objects and symbols (Hwang, Chen, Dung, and Yang, 2007). The connection with learning physics representation aims to describe a concept/object/phenomenon using specific symbols, including words/verbal symbols, diagrams/pictures, graphs, and mathematical symbols.

While multi-representation is a way to represent a concept in the form of different representations. Waldrup *et al.* (2006: 87) define multiple representations as practices to describe the same idea through various ways, which include descriptive descriptions (verbal, graphs, tables), experimental, mathematical, figurative (pictorial, analogy, and metaphorical), kinesthetic, visual and operational-operational (Waldrup, Prain, and Carolan, 2006). Merging these representations complement each other, making it easier for students to understand concepts and solve problems.

Multirepresentations have three main functions, namely as a complementary, limiting interpretation, and understanding builder (Ainsworth, 2006). Multirepresentations support the inculcation of concepts by providing supplementary information about an idea, limiting the possibility of errors in the use of other representations, and helping to build deeper understanding by increasing abstraction, helping generalization, and building relationships between representations. Learning process by using multi representation models effectively to enhance students' understanding of concepts (Fatmaryanti and Nugraha, 2019).

Simple harmonic motion (SHM) is one of the materials taught in basic physics courses. Some research has been done on understanding concepts and learning from SHM material. Research by Somroob (Somroob and Wattanakasiwich, 2017) shows most students have misconceptions about the recovery style, and they have problems connecting mathematical solutions with real movements, especially phase angles. Also, they have issues with interpreting mechanical energy from charts and motion diagrams (Somroob and Wattanakasiwich, 2017).

3. MATERIALS AND METHODS:

3.1. Research Design

This research method was surveying with qualitative analysis. The instrument used in this research was developed from some source such as the Serway and Jewett physics textbook, AP Physics SHM test, and SHM-CS (Hammer, 1996; Nugraha, Cari, Suparmi, and Sunarno, 2019; Serway and Jewett, 2004; Somroob and Wattanakasiwich, 2017). The instrument have been validated before use. The tool consists of twelve items. The distribution of items used is presented in Table 1. The topic discussed in this study is the mass-spring system with six items. The data was analyzed qualitatively compared with the result of unstructured interviews with students. The interviews conducted to clarify student reasoning due to their answer (Lee and Park, 2013; Waldrup, Prain, and Sellings, 2013).

3.2. Research Subject

The sample used in the study were students in the physics education program at Indraprasta University. This study held in indraprasta with permission from the lecturer or physics education at Indraprasta University in 2019. The sample selection uses a purposive sampling technique with a total sample of 49 students. Purposive sampling is sampling based on specific considerations based on researchers' criteria (Patton, 2014; Teddlie and Tashakkori, 2009).

3.3. Instrument

The instrument was a conceptual survey that is used to determine the level of students' understanding after they have completed a series of physics learning. The instrument used was in the form of a reasonable multiple choice that was adopted. The instrument is developed from a daily phenomenon and combine with the theories. The validated instrument consists of some concepts about simple harmonic motion. The concepts included (1) Direction of the normal force vector and the gravity; (2) Basic concepts of simple harmonic motion; (3) Acceleration of the object due to oscillation, and (4) System oscillation period. The distribution of items in each concept is presented in Table 1.

Table 1. Distribution of Question Items for Concept Understanding Instrument

No	Sub Concept Material Mass-Spring System	Number of Items
1	Direction of the normal force vector and the gravity	1
2	Basic concepts of simple harmonic motion	2
3	Acceleration of the object due to oscillation	2
4	System oscillation period	1

Before an analysis of students' conceptual understanding is carried out, a study of the characteristics of the instrument is conducted. The features of the instruments used, referring to the modern test theory. Analysis of instrument characteristics using the Quest program, the results of the study are presented in Table 2.

Table 2. Characteristics of Concept Understanding Assessment Instruments

No	Review	Estimates for Items	Estimates for Testees
1	Average values and standard deviations	.00 ± .26	.03 ± .40
2	Reliability	.65	.79
3	Average values and standard deviations	1.00 ± .10	1.00 ± .39

The assessment instrument has a mean INFIT MNSQ of 1.00 and a standard deviation (SD) of 0.10, meaning that overall the items developed are fit with the Rasch model. This is following the opinion of Aminah (2017), which states that the mean INFIT MNSQ 1.01 and SD 0.09. It means that overall the items are under the Rasch model (Aminah, 2017). While the reliability estimation results obtained the value of person reliability 0.79, and item reliability 0.65. It can be concluded that the consistency of the answers both from the TESTEE (a person subjected to a test/One who takes or has taken a test) or from the item has high reliability.

4. RESULTS AND DISCUSSION:

4.1. Overall Performance

Investigating students' understanding of concepts is carried out on students who have to learn fundamental physics courses, especially simple harmonic motion (SHM). The results of the student answer analysis, in general, presented in

Figure 1.

Figure 1. Investigations on the Student Concepts Understanding in the Mass-Spring System Material. Source: The author

Figure 1 shows that the four aspects which consist of the basic concepts of simple harmonic motion, determining the magnitude of the acceleration of objects due to oscillation, and finding the importance of the system oscillation period are still below 50%. In contrast, the concept of the normal force and gravity vector is above 50%. These results indicate that most students have not been able to understand the concept of SHM in an elaborate manner. These results are consistent with Ambrose's research, which shows that students have difficulty mastering basic concepts to hamper their understanding of more complex ideas (Ambrose, 2007).

4.2. Normal force vector and the gravity

The investigation results of students' conceptual understanding in determining the direction of normal force and gravity vectors get an average percentage of about 58.16%. The items used were two items, in the first item as many as 19 (38.77%) students answered correctly, and in the second item as many as 38 (77.55%), students answered correctly. This result shows that most students have difficulty in answering the first problem. The basic concept in the first problem can be solved by knowing the concept of force resultant.

The resultant force on blocks placed on the floor is zero. Based on Newton's second law, there are two quantities of force that balance each other. For example, a block rests on the floor, and then the floor exerts a force upward. The upward (normal) force applied by the floor to the block is often called the touch force because it occurs in two objects that touch. When the normal force is perpendicular to the surface of the touch plane, the force is usually called the normal force. There are three types of the "zero" meaning in the equation

of Newton first law. Zero as (1) the "zero intuitive", which means "nothing", (2) a "zero number" which used to represent numbers and (3) a "mathematical zero" according to modern mathematics (Qiang and Dong, 2007). The problem given is in the form of two blocks connected by a massless spring when in a stationary position, which presented in Figure 2.

Figure 2. Item Problem about Concept of Gravity and Normal Force. Source: The author

Normal Force is a force acting on a plane that touches between two surfaces of an object, whose direction is always perpendicular to the touch plane. The normal force symbol is N and the International System unit is kg m/s^2 or Newton. Most students are able to answer this problem correctly. Examples of student answers are presented in Figure 3.

Figure 3. Examples of Student Answers on Item about Concepts of Gravity and Normal Force. Source: The author

Figure 3 is an example of a student who is unable to answer this problem well. This can be seen in the answers the student chooses the answer C. The reason given by the student is because the option C block shows masses of m_A and m_B as equal, and produces a force with equal pressure. These results indicate that the student is not able to master the basic concepts of the gravity

well. This finding proved that the mathematical presentation of students' understanding can be used to identify the zero intuition experienced of students (Handhika, Cari, and Suparmi, 2017). In any case some students can interpret that no forces are acting on the object on the Newton first law concepts (Hsu, 2001).

These results are consistent with Ambrose's research, which shows that students have difficulty mastering basic concepts to hamper their understanding of more complex concepts (Ambrose, 2007). Other research conducted Nugraha, *et al.* (2019) shows that the student's inability to master the basic concepts of the simple harmonic motion is in determining the relationship between distance, speed, and acceleration.

The concept of normal force direction is always perpendicular to the touchpad (Giancoli, 2019; Serway and Jewett, 2004). If the touch plane between two objects is horizontal, the direction of the normal force is vertical. If the plane of the touch is vertical, then the direction of the normal force is horizontal. If the plane of the tilt is tilted, then the direction of the normal force will also be tilted. The base or vector capture point starts from the point where two surfaces of objects touch and then draw a perpendicular line through the center of mass of the object.

4.3. Basic concepts of simple harmonic motion

The investigating results of students' understanding of concepts about basic concepts of simple harmonic motion get a percentage of 34.65% or as many as 17 students who managed to answer correctly. These results indicate that most students have difficulty in determining the basic concepts of simple harmonic motion. Oscillation motion is the movement of an object back and forth over the same path. An example of a simple case is the oscillation motion of an object with mass m placed at the end of spring, as in Figure 4.

Figure 4. Item of Basic Concepts of Spring Oscillation. Source: The author

Figure 4 is an example of an item that visualizes the concept of oscillating motion on a spring on a slippery floor so that there is no friction. If the spring is pushed to the left or right with a displacement of x , after the thrust is removed, the spring will try to return to the equilibrium position. The force applied by the spring to return to its original position is called the restoring force. Because the force acting on an object is not constant, the acceleration of the object is also not constant but is proportional to the magnitude of the restoring force. The acceleration is directly proportional to the position of the block, and the direction is opposite to the displacement from the equilibrium position. An object experiences simple harmonic motion when its acceleration is directly proportional to its position and in the opposite direction to its movement from equilibrium

The results showed that most students answered correctly on this item. However, there are still some students who have difficulty understanding the basic concepts of spring oscillations. One example of students who cannot solve this problem properly is presented in Figure 5.

Figure 5. Examples of Student Answers on Item Basic Concepts of Spring Oscillation. Source: The author

Figure 5 is an example of a student who is unable to answer this problem well. This can be seen in the answers students choose the answer choice D. The reason given by the student is that when A and B are pressed, the spring force will give the same restoring force to A and B.

These results indicate that the student is not able to master the basic concepts of the gravity well. These results are consistent with Ambrose's research, which shows that students have difficulty learning basic concepts to hamper their understanding of more complex concepts (Ambrose, 2007). This is in line with the results of the study (Parnafes, 2010) that in some problems, students have not been able to understand the basic concepts of mechanical motion as a basis for understanding simple harmonic motion. These concepts include the concept of instantaneous speed, frequency, and average speed.

4.4. Acceleration of the object due to oscillation

The results of investigating students' understanding of concepts in determining the magnitude of the acceleration of objects due to oscillation, with an average percentage of 32.65%. The items used were two items, in the first item as many as 18 (36.73%) students answered correctly, and in the second item as many as 14 (28.57%), students answered correctly. These results indicate that most students have difficulty in answering the second question. The basic concept in the second problem can be solved by knowing Newton's second law concept.

The restoring force is the force that leads to an equilibrium position and is, therefore, the opposite of the displacement of an object from its equilibrium. By using Newton's second law $\sum F_x = ma_x$, F_x is Hooke's law that is the force produced by a spring on a block is directly proportional to its position. The item used to determine the students' understanding of the concept of accelerating the oscillation of the mass-spring system is presented in Figure 6.

Figure 6. Item about the Concept of Acceleration of Mass-Spring System Oscillation. Source: The author

The results showed that most students answered correctly on this item. But there are still some students who have difficulty understanding the concept of accelerating the oscillation of the mass-spring system. One example of students who cannot solve this problem properly is presented in Figure 7.

Figure 7. Example of Student Answers on the Concept of Acceleration on Mass-Spring System Oscillation. Source: The author

Figure 7 is an example of a student who is unable to answer this problem well. This can be seen in the answers students choose the answer choice B. The reason given by the student is

because the recovery style is always in the opposite direction to the force given and is usually symbolized by a negative sign (-). This finding shows that the student answers the item using his perception without using the correct theoretical basis.

These results indicate that students have not been able to use mathematical equations in solving problems. They need guidance on mathematical operations, and which factors affect the acceleration of the oscillation of the mass-spring system (Ambrose, 2007). When block A moves at any time at the reference point symbolized by x_{1A} and Block B moves at all times at the reference point symbolized by x_{2B} . Then the length of the spring at any given moment is:

$$x_{2B} - x_{1A} \quad (1)$$

If the difference is the length of the spring $x_{2B} - x_{1A}$, then there is a long increase in the spring. The addition of spring length can be written:

$$X = (x_{2B} - x_{1A}) - x_0 \quad (2)$$

or

$$x_{2B} - x_{1A} = X + x_0 \quad (3)$$

Where x_0 , is the initial length of the spring, based on Newton's Second Law, the magnitude of

restoration force is obtained $F_p = m_A \frac{d^2 x_{1A}}{dt^2}$.

Remember that FP is a restorer style, by entering the Hooke Law equation, obtained:

$$\frac{d^2 x_{1A}}{dt^2} = \frac{kX}{m_A} \quad (4)$$

The results obtained are functions $x(t)$ that satisfy the second-order differential equation. This function is a mathematical representation of the position of objects as a function of time. Most of the students have not been able to master the mathematical representation of the concept of a mass-spring system.

4.5. Find the magnitude of the system oscillation period

The results of investigating students' understanding of the concept in determining the period of system oscillation get a percentage of

18.36%. Students who managed to answer correctly on this item were nine people. These results indicate that most students have difficulty in determining the period of system oscillation. The motion period (T) is the time interval required for the particle to go through one full cycle of its motion. The items used to find the magnitude of the system oscillation period is presented in Figure 8.

Figure 8. Item about Oscillation Period Mass-Spring System. Source: The author

The item in Figure 8 requires students to be able to find the system oscillation period. Based on the results obtained in the previous problem, obtained acceleration of object A. In the same way, the acceleration of object B is:

$$\frac{d^2x_2}{dt^2} = -\frac{k\Delta x}{m_B} \quad (5)$$

A negative value on the recovery force indicates the opposite direction of the force. Equations (4) and (5) are substituted:

$$\frac{d^2x_{2B}}{dt^2} - \frac{d^2x_{1A}}{dt^2} = -\frac{kX}{m_B} - \left(\frac{kX}{m_A}\right)$$

$$\frac{d^2(X+x_0)}{dt^2} = -k\left(\frac{m_A+m_B}{m_Am_B}\right)X$$

Since $\frac{d^2x_0}{dt^2} = 0$, then we get:

$$\frac{d^2X}{dt^2} + \frac{k}{\left(\frac{m_Am_B}{m_A+m_B}\right)}X = 0$$

Because the motion that occurs is a simple

harmonic motion, it applies $\frac{d^2x}{dt^2} + \omega^2x = 0$, then we get:

$$\omega^2 = \frac{k}{\left(\frac{m_Am_B}{m_A+m_B}\right)}$$

$$T = 2\pi\sqrt{\frac{\left(\frac{m_Am_B}{m_A+m_B}\right)}{k}} \quad (6)$$

The mathematical representation of the simple harmonic motion of the period of motion (T) is the time interval required for a particle to go through one full cycle of its motion. The size of the period depends on the mass of the block and the magnitude of the force of the bag and has no effect on the motion parameters (Triana and Fajardo, 2012). Like, amplitude A or phase angle ϕ . The results showed that most students were not able to answer correctly on this item. One example of students who cannot solve this problem properly is presented in Figure 9.

Figure 9. Examples of Student Answers in determining the Mass-Spring System Oscillation Period. Source: The author

Figure 9 is an example of an inability of students to answer this problem well. This can be seen in the answers students choose the answer choice B. The reason given by the student is because the choice B matches the harmonic motion equation. These results indicate that most students are not able to grasp the meaning or meaning of a concept. While the concept is an abstraction that represents an object or event obtained based on one's experience. Learning concepts is one of the main objectives of learning.

One of the goals of learning physics is to improve the understanding of student concepts through a quality teacher or lecturer teaching system. Thus, an effective teacher is one who must have a teacher who is more rooted in knowledge about the subjects being taught, the sharpness of teaching skills in the classroom,

following developments in the topic (field) and in education in general, generating and contributing new knowledge to the profession (Adolphus *et al.*, 2013).

The results of the study are generally based on four concepts: direction of the normal force vector and the gravity, basic concepts of simple harmonic motion, acceleration of the object due to oscillation, and system oscillation period is still below 50%. On the other hand, the concept of normal force and gravity vector is above 50%. These results indicate that most students have not been able to understand the concept of SHM in a complex manner. These results are consistent with Ambrose's research, which shows that students have difficulty mastering basic concepts to hamper their understanding of more complex concepts (Ambrose, 2007). The concepts students have can be obtained from daily experiences, learning processes, media, and so on (Aretz, Borowski, and Schmeling, 2016).

5. CONCLUSIONS:

Most students have not been able to master the concept well. The students' understanding of concepts is not good, namely, the basic concepts of simple harmonic motion, determine the magnitude of the acceleration of objects due to oscillations, and find the magnitude of the oscillation period. Based on the result, it shows that understanding concepts isn't as simple as it said. Lack of understanding of student concepts is caused by students not being able to relate previous insights (such as Newton's law concepts, and Hooke's Law) with strategies for solving problems. This is shown from the results of the average achievement below 50%. The low understanding of student concepts is due to the inability of students to interpret mathematical equations, and how to operate these equations in solving problems. The students' concepts understanding correlated with the students' basic concept of the basic concepts as required concepts, daily conception, multirepresentations (especially mathematical representation), and the students' intuition. Besides, it can be caused by the traditional learning process has not made students understand the concept well.

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