

# Students' Reasoning on Physics Related to Visual Representation

## Case Study of College Students

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**Abstract**—This paper present the description of students' reasoning on physics related to visual representation. This research used descriptive qualitative method. The subjects consist of 25 college students. Given some physics problem with visual representation, students answer it with different reasoning. Students that give reasoning appropriate with the visual representation choose the right answer and the other not appropriate it describe as student lack of knowledge or experience misconception.

**Keywords**—college students; reasoning; visual representation

### I. INTRODUCTION

Human beings rely on visual information to learn about the environment around them, construct representation of the world, and control their action [1]. Representation is something that represents, describes, or symbolizes objects and or processes [2,3]. There are many kinds of representation to give information about humans concept, namely multi representation. Representation is to re-represent the same concept with different formats, including verbally, image, graph, and mathematical [4]. Representation has three functions, namely complementary functions, interpretation constraint functions, and understanding building functions [5]. Some concrete representations help in constructing more abstract representations (e.g formulas), some other concrete representations are useful for qualitative reasoning, abstract mathematical representations are used for quantitative reasoning [6]. In Physics, there are several forms of representation that can be raised, namely verbal representations, image/diagram representations, graphical representations, and mathematical representations.

To evaluate the consistency of student representation, Nieminen developed a quantitative R-FCI evaluation test to evaluate the consistency of student representation [5]. Furthermore, Kurnaz and Arslan found that multi-representation learning was effective for teaching energy concepts [7].

Representation of an object or process can be analyzed based on a concept that is represented so that it can train students' reasoning in learning. Jean Piaget said that this is a series of four distinct intellectual growth as they search for

patterns and relationships [8]. The theory of stages of intellectual development (sensory-motor, pre-operational, concrete reasoning, and formal reasoning) - are characterized by distinctive features in the patterns of a person reasoning [8].

Human can analyze a representation using reason so that he has confidence in the answers and reasons he has. Sometimes the beliefs that a person has are in accordance with the scientific concept. However, there are times when there is an error in believing in a concept. The abstract questions are asked out of context, but also extend to cognitive, perceptual, and developmental aspects of knowledge [1]. "For example, it is physically true that a pendulum will take the same amount of time to swing through its, however wide the arc (deviations are small for all practical purposes). But Bozzi found that people will only accept certain speeds that appear "natural" to them and for long periods of expression appear unnaturally fast "[1]. Humans' reasoning can be in the form of representation or perception of a phenomenon associated with the concept adopted.

Reasoning can be defined as the ability to think logically to solve the problems using the scientific method [9]. Reasoning is important to know students' thinking patterns on the choice of answers given. Reasoning can be done through a process of representation of the object or process being analyzed. Reasoning can be the result of interpretation or perception of the visual representation observed by someone. Reasoning can be consistent or inconsistent, depending on reason that is owned by someone. Therefore, several researchers developed test instruments to explore the reasoning skills of students. Muslims develop test instruments for exploration of TIMSS framework based reasoning with enough category [9].

Reasoning generated from the results of one's thinking can be logically, nor is it so. Essential logical reasoning skills for student mastery of many concepts and more complex problem solving strategies required to arrive in subject matter [10]. Logical reasoning can bring students' confidence in answering a choice of answers so that it can be known that the student really understands the given case study or not.

To find out how student reasoning for a question / problem is presented in the form of visual representation, a test instrument is made containing questions, visual representation, answer choices, students are asked to explain the reasons, and the level of confidence in the choice of answers or reasons stated. Through this instrument, qualitatively the students' reasoning for visual representation can be described qualitatively. In addition, it can be described also how understanding the concept of students through the thought process as outlined in the answers to the test items provided.

## II. RESEARCH METHOD

This research used descriptive qualitative method. The subjects are 25 college students in physics education program study Universitas Negeri Surabaya (UNESA). 25 students were given untreated tests through learning. Tests are carried out to capture students' reasoning when giving answers to questions or problems given

The form of the test given to the research subject is a problem/question illustration, choice of answers, reason, and the level of confidence of the answers to explore students' reasoning when choosing the answer choices provided.

Illustration of the problems displayed using visual representation, can be in the form of graphics or illustration images. Answer options are three number of choices. The reason for being given an empty space to be filled by students as a research subject is in accordance with their reasoning so that students choose a particular answer option. The range of answer beliefs includes being very confident, sure or confident, doubtful or hesitant, unsure, and very uncertain. This range of beliefs can also be used to determine the level of self-confidence of students in choosing answers that match their reasoning.

Number of item test	Problem illustration
	Visual representation
	Question
	A. } B. } Multiple choice C. }
	Reasoning:
beliefs line answer <input type="checkbox"/> Very confident <input type="checkbox"/> Sure <input type="checkbox"/> doubtful <input type="checkbox"/> Not sure <input type="checkbox"/> Very unsure	

Fig. 1. Form of tests item given to students

Through the form of tests provided, students fill in the answers, reasons, and answer lines of answers. Data in the form of student answers, reason reviews as a form of reasoning in determining answers, as well as answer line beliefs as a form of confidence in answering questions / problems provided. The results obtained were then analyzed to

describe students' reasoning on physics related to visual representation.

## III. RESULT AND DISCUSSION

### A. Students' reasoning related to visual representation of kinematics

Test items are given in the form of graphs of velocity with time (v-t) produced by moving objects (see Fig. 2.). Then students are asked to choose answers based on graphical representation then explain the reason for the choice of answers.

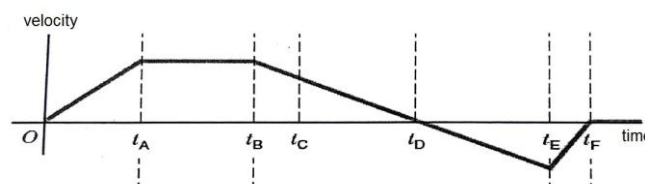


Fig. 2. Visual representation for kinematics motion

Based on the graph in Figure 2, given the choice of answers: (a) objects move straight at a constant speed and move straight with constant acceleration without ever reversing, (b) objects move straight at a constant speed, move straight with constant acceleration and reverse direction when pointing  $t_E$ , (c) objects move at a constant speed, move straight with constant acceleration, and reverse direction when pointing  $t_D$ . Through the visual representation in the form of graphs, 15 of the 25 students answered correctly, namely the answer choice (c). 6 of the 15 students who answered correctly were confident in the answers and the reasons, even though 1 of 6 students who were sure did not give a reason for the choice of answers. In general, the reason stated by 5 students who answered correctly and confidently in this answer carried out visual representations based on the graphs presented in the test items and related them to the concept of motion with a certain speed by looking at velocity as a vector quantity. Students 2, 8, 10, 15, and 25 see that at the point  $t_D$  the speed is zero and then is negative towards the point  $t_E$ . This negative speed indicates that the object changes direction. A negative sign on the velocity magnitude indicates that the direction of the velocity is opposite to the direction of motion, meaning that at this time the object is reversing. Next, the object accelerates to the point of  $t_E$  and decelerates until it stops at the  $t_F$  point. Graph representations made by these five students have used reason that is in accordance with the context of Physics that sees speed as a vector quantity. That is, these five students understand the concept of motion based on visual representations (in the form of graphs) presented. Student 20 does not give a reason for the answer even though the answer choices are correct. 9 out of 15 students who answered correctly were hesitant about the answers and reasons raised despite the answers and reasons stated correctly. There are two possibilities that occur in 9 of these students, namely lack of understanding of the concept or actually they understand the concept but are not confident in the answers and reasons stated [11].

1 student (student 9) chooses the answer (a) on the grounds that there are only 2 straight movements, namely straight motion with constant velocity and straight motion with constant acceleration. Straight motion with constant acceleration is accelerated and some are slowed down. Student 9 considers that there is no straight motion that reverses direction. Student 9 uses the initial concept it has to answer this question without analyzing the direction of motion generated through the analysis of the visual representation provided by the problem. This initial concept can be the initial cause of misconceptions if not given treatment to show the correct concept to students [11,12]. Moreover, student 9 provides answers and reasons with the highest confidence range, which is very confident. Even though student 9's answer is wrong, the reason stated is less precise because without doing a visual representation of the graph provided. According to previous research, if students answer wrongly and give wrong reasons and show high confidence, then this student experiences misconceptions [12].

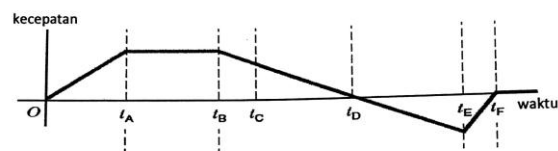
There are 3 students who answer the choice of answers (b) for this case, namely Student 3, Student 7, and Student 24. Student 3 has performed a visual representation of the graph presented, but is less accurate in interpreting the negative sign in the context of speed. Student 3 represents the v-t graph if linear rises to the right, the object accelerates, whereas if the linear v-t graph goes down to the right, the object experiences a slowdown, regardless of the negative sign on the graph. Whereas in this case, a negative sign of velocity indicates the direction of motion of an object. Student 3 means reversing the point at  $t_E$  because at this point the graph shows the turning point, where after the graph goes down  $t_C$  to  $t_E$  then it rises from  $t_E$  to  $t_F$ . Students understand this graph representation as understanding graphics in Mathematics about turning points. Students do not analyze more in the representation they observe on the physical concept of velocity which is a vector quantities, the amount of velocity has values and directions which are indicated by negative and positive values. Positive values indicate the direction of velocity in the direction of the object's motion, and a negative sign indicates that the direction of velocity is in the opposite direction to the direction of motion of the object. This reasoning error also leads to misconceptions in Student 3 because he is very confident in the answers and reasons stated. Student 7 hesitated with the answer and gave no reason for the choice of answer. While student 24 is very confident in the answer, even though it does not provide a reason for the choice of answer. It can be said that Student 7 does not understand the concept of motion based on the visual representation presented. Student 12 also does not understand the concept of motion based on the visual representation presented. Student 12 does not provide answers and reasons for this test item.

While 5 out of 25 other students gave other answers, did not choose the 3 answer choices presented. 3 of the 5 students gave more complete answers than the 3 answer choices presented. Student 11 is very confident in the choice of answers and review of the reasons, Student 18 is hesitant about the choice of answers and the reasons, while Student 19 is not sure of the choice of answers and reasons stated even though the reason given is correct. Student 11, Student 18, and

Student 19 represent graphs in detail starting from the starting point of the graph at position O. When  $O-t_A$  objects experience accelerated straight motion with constant acceleration, at position  $t_A-t_B$  the object experiences straight motion at a fixed speed, at when  $t_B-t_D$  objects experience straight motion slowed down with constant acceleration, then stop at  $t_D$  point and reverse direction then move straight accelerated to the point  $t_E$  then move straight accelerated with fixed acceleration to  $t_F$  point then stop. Student 11 gives very detailed reasoning and performs visual representation very well, it can be said that Student 11 understands the concept of motion based on the graph representation presented. Student 18 and Student 19 experience lack of confidence in the reasoning, even though the visual representation is correct.

Student 22 chooses another answer but does not write that the object moves straight at a constant speed, moves straight with constant acceleration, stops at  $t_D$  and turns towards  $t_E$ . Based on this answer, Student 22 has carried out visual representations such as those conducted by 3 other students who chose other answers. However, the reasons given in more detail are 3 previous students. However, Student 22 is hesitant about the choice of answers and the reasons stated. So, Student 22 still less understand the concept of motion in kinematics.

Gerak suatu benda menghasilkan grafik sebagai berikut.



Berdasarkan grafik di atas,

- benda bergerak lurus beraturan dan bergerak lurus berubah beraturan tanpa pernah berbalik arah
- benda bergerak lurus beraturan, bergerak lurus berubah beraturan, dan berbalik arah saat waktu menunjuk  $t_E$
- benda bergerak lurus beraturan, bergerak lurus berubah beraturan, dan berbalik arah saat waktu menunjuk  $t_D$

Jawaban lain: benda bergerak lurus beraturan, benda bergerak lurus  
Argumentasi: diperlambat  
Bpt dilihat di grafik kecepatannya berkurang.

Fig. 3. The answer, reasoning, and beliefs line answer of Student 14

Student 14 chooses another answer by directly explaining the reason, namely that the object moves in an orderly straight direction and then the moving object is slowed down. Student 14 also stated the reason that the answer he gave was based on a graph that showed that the speed was reduced (see Fig. 3). Based on the answer statement, Student 14 has performed a visual representation in the form of a graph presented in the test item. However, the reason given by Student 14 is the same as the reason given by Student 9. They understand that objects experience straight motion without regard to how the object moves when the speed is negative. This reinforces statement before which states that "Many student difficulties with graph interpretation were documented and identified in studies that were carried out in physics (mostly kinematics) or mathematics" [13].

### B. Students' reasoning related to visual representation of energy

Given the problem illustration, "The beam is released on a curved path as shown in figure 3 with kinetic energy equal to its potential energy. If the friction between the beam and the trajectory is ignored, then the ratio of the kinetic energy of the beam at point A and starting point O is ..."

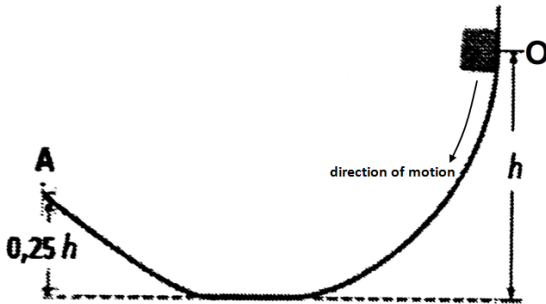


Fig. 4. Visual representation of energy for block motion in curved trajectory

Based on the illustration of the problem above, three answer options are provided, namely: (a) 3: 4, (b) 4: 7, and (c) 7: 4. Based on the students' answers on this topic, 5 from 25 students give true choice answer, that is option (c). All of the five students (Student 2, Student 6, Student 8, Student 13, and Student 25) give the same reasoning. They do reason through the analysis of visual representation in the image then the representation of the image is expressed through a mathematical representation with provisions such as the law of conservation of mechanical energy by observing the situation as in the test item. Mathematical representation is done to calculate the ratio of kinetic energy when the beam at point A with kinetic energy when the beam is at the starting point O. Fig. 4. shows the results of student representation so as to produce a reasoning in the form of a mathematical representation and produce an answer of 7: 4, namely option (c).

Balok dilepas pada landasan lengkung di samping ini dengan energi kinetik sama dengan energi potensialnya. Bila gesekan antara balok dan landasan diabaikan, maka perbandingan energi kinetik balok di titik A dan di titik awal adalah ....

a. 3:4  
b. 4:7  
X 7:4  
d. Jawaban

$h_1 = h$   
 $h_2 = 0,25 h$

Argumentasi:

$$E_{k1} = E_{p1} \rightarrow E_{k1} + E_{p1} = E_{k2} + E_{p2}$$

$$E_{k1} = mgh_1$$

$$E_{p1} = mgh$$

$$2 mgh = E_{k2} + 0,25 mgh$$

$$E_{k2} = 2 mgh - 0,25 mgh$$

$$E_{k2} = 1,75 mgh$$

$$E_{k2} = 1,75 E_{k1}$$

$$\frac{E_{k2}}{E_{k1}} = 1,75$$

$$\frac{E_{k2}}{E_{k1}} = \frac{7}{4}$$

Garis keyakinan menjawab:

☒ sangat yakin ☐ ☐ ☐ ☐ sangat tidak yakin

Fig. 5. The answer, reasoning, and beliefs line answer of Student 25

2 out of 25 students choose the answer option (a). Student 5 answered incorrectly and was unsure of the answer. Student 5 also does not provide reasons for the choice of answers.

Based on the analysis of thinking using three levels, Student 5 does not understand the concept presented in the visual representation of energy for block motion in curved trajectory [12]. Student 22 experiences misconceptions because the answers chosen are wrong, do not provide reasons for the choice of answers, and are confident in the choice of answers [14].

6 out of 25 students choose option (b). 3 of 6 students (Student 4, Student 10, and Student 18) who answered the choice of answers (b) experienced misconceptions because they were convinced of the choice of answers even though the choice of answers was wrong [14]. Student 4 and Student 10 do not provide reasons for the choice of answers even though they are confident in the choice of answers. Student 18 performs a representation of the visual representation that is presented and then performs mathematical representations as done by 5 students who understand the concept. However, at the end of the mathematical representation results, Student 18 reverses in concluding the results of the comparisons that have been calculated. Reasoning in the form of mathematical representations presented by Student 18 is logical and correct, but Student 18 is wrong in choosing answers. This can happen because of the students' lack of accuracy in drawing conclusions based on the results of mathematical representations made. 3 of the 6 students who chose the answer (b) were included in the category of lack of understanding of concepts (Student 12 and Student 21) and did not understand the concept (Student 23) [12]. The three students gave no reason for the choice of answers.

Balok dilepas pada landasan lengkung di samping ini dengan energi kinetik sama dengan energi potensialnya. Bila gesekan antara balok dan landasan diabaikan, maka perbandingan energi kinetik balok di titik A dan di titik awal adalah ....

a. 3:4  
b. 4:7  
X 7:4  
d. Jawaban

$h_1 = h$   
 $h_2 = 0,25 h$

Argumentasi:

$$E_{k1} = E_{p1} \rightarrow E_{k1} + E_{p1} = E_{k2} + E_{p2}$$

$$E_{k1} = mgh_1$$

$$E_{p1} = mgh$$

$$2 mgh = E_{k2} + 0,25 mgh$$

$$E_{k2} = 2 mgh - 0,25 mgh$$

$$E_{k2} = 1,75 mgh$$

$$E_{k2} = 1,75 E_{k1}$$

$$\frac{E_{k2}}{E_{k1}} = 1,75$$

$$\frac{E_{k2}}{E_{k1}} = \frac{7}{4}$$

Garis keyakinan menjawab:

☒ sangat yakin ☐ ☐ ☐ ☐ sangat tidak yakin

Fig. 6. The answer, reasoning, and beliefs line of Student 18

While 11 of the 25 students gave another answer to this visual representation. Student 19 does not understand the concept because the answer is wrong, the reason is incorrect, and is not sure about the choice of answer. 5 students (Student 1, Student 7, Student 9, Student 14, and Student 20) fall into the category of not understanding the concept. While the other 5 (Student 3, Student 11, Student 15, Student 16, Student 17) experience misconceptions because they are confident in the choice of answers and the reasons even though they are wrong, even Student 11 is very confident in the answer.

This profile shows that through good visual representation, students can form logical reasoning to choose the right answer to a problem presented visually representation. Although in



fact there are findings which state that the student reasoning shows different patterns during different behavioral modes [15].

#### IV. CONCLUSION

This research describe that students can make logical reasoning through visual representation ability. We know that for that case, students can explain their reasoning very well when they can interpret the visual representation given in test item. Student that haven't visual representation ability can't give the explanation about the reasoning of the answer choice.

From this finding, the researchers recommended to teachers or lectures to give visual representation in learning physics. So, the students have good representation ability and have good logical reasoning in physics.

#### REFERENCES

- [1] M. Bertamini, A. Spooner, and H. Hechi, "The representation of naive knowledge about physics," *Stud. in Multidisciplinary*, vol. 2, pp. 27-36, 2004.
- [2] D. Rosengrant, E. Etkina, and A. V. Heuvelen, "An Overview of Recent Research on Multiple Representation," *Rutgers*, vol. 883, pp. 149-152, January 2007.
- [3] G. A. Goldin, *Handbook of International Research in Mathematics Education*, New Jersey: Lawrence Erlbaum Associates, 2002.
- [4] S. Ainsworth, *A Conceptual Framework for Considering Learning with Multiple Representation*, Elsevier *J. of Learning Instruction*, vol. 16, pp. 183-198, June 2006.
- [5] P. Nieminen, A. Savinainen, and J. Viiri, "Force Concept Inventory-based multiple-choices test fir investigating students representational consistency," *J. of Education Res.*, vol. 6, August 2010.
- [6] X. Zhou and A. Hauvelen, "The Use of Multiple Representation and Visualization in Student Learning of Introductory Physics: An Example From Work and Energy," 2000, Ohio, Dissertation.
- [7] M. A. Kurnaz and A. S. Arslan, "Effectiveness of Multiple Representation for Learning Energy Concept: Case of Turkey," *Soc. Behavioral Sci.*, pp. 627-632, February 2014.
- [8] R. G. Fuller, R. Karplus, and A. E. Lawson, "Can Physics Develop Reasoning?" *Physics Today*, February 1977.
- [9] Muslim, A. Suhandi, and M. G. Nugraha, "Development of Reasoning Test Instruments Based on TIMSS Framework for Measuring Reasoning Ability of Senior High School Student on the Physics Concept," *J. Phys: Conf. Ser.*, vol. 812, 2017, 012108.
- [10] L. Bird, "Logical Reasoning Ability and Student Performance in General Chemistry," *J. Chem. Educ.*, vol 87(5): 541-546. March 2010.
- [11] M. N. R. Jauharyah, N. Suprpto, Suliyanah, S. Admoko, W. Setyarsih, Z. Harizah, and I Zulfa, "The Student's Misconceptions Profile on Chapter Gas Kinetic Theory," *J. Phys: Conf. Ser.*, vol 997, 2018, 012031
- [12] M. N. R. Jauharyah, I Zulfa, Z. Harizah, and W. Setyarsih, "Validity of Student's Misconceptions Diagnosis on Chapter Kinetic Theory of Gases Using Three-Tier Diagnostic Test," *J. Phys: Conf. Ser.*, vol. 1006, 2018, 012005.
- [13] L. Ivanjek, A. Susac, M. Planinic, and A. Andrasevic, "Student Reasoning About Graph in Different Contexts", *Phys. Review Phys. Educ. Res.*, vol. 12, pp. 010106-1 – 010106-13, February 2016.
- [14] Suliyanah, H. N. A. Putri, and L. Rohmawati, "Identification of Heat and Temperature Using Three-Tier Diagnostic Test," *J. Phys. Conf.: Ser.*, vol. 997, 2018.
- [15] L. D. Conlin, A. Gupta, R. E. Scherr, and D. Hammer, "The Dynamics of Students' Behaviors and Reasoning during Collaborative Physics Tutotial Session," *Phys. Educ. Res. Conf.*, vol. 951 , pp. 69-72, August 2007.