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Exploring Students' Misconception in the Frame of Graphic and Figural Representation on Projectile Motion Regarding to the COVID-19 Constraints

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ABSTRACT
Remote learning has reformed the normal tradition of physics instruction in the existence of COVID-19 pandemic. The previous documentation of student's misconception is mostly discovered in the normal condition of physics instruction. Regarding to the pandemic outbreak is necessary since distance learning routines have absolutely influence the physics education outcomes all over the world. To explore the issues, this quantitative study has descriptively identified students' misconception on projectile motion in the frame of graphic and figural representations. The six items of Busyairi and Zuhdi's three tier test were administered to the 76 students in a Javanese public high school, Indonesia. Overall, the Arslan, Cigdemolu, & Moseley's categorical framework classified that the whole participants still congregate in the misconception's groups on projectile motion. The lack of students' representation on projectile motion might be magnified by the pandemic restrictions in providing appropriate visualization on projectile concept. Finally, the author suggested that the alternative of online learning during the outbreak have not yet been effectively engaged to promote the physics representation on projectile motion.

INTRODUCTION

An anonymous disease caused by the new corona virus was first detected in Wuhan, China and was reported to the WHO (World Health Organization) on December 2019. WHO declared a public safety emergency that caught the world's attention on January 2020 and named it as COVID-19 (Coronavirus Disease-19) on February 11, 2020. Then, since February 26 the coronavirus has been detected on all continents except Antarctica. Currently more than 200 countries have been infected [1]. The spread of this virus is so fast and has infected thousands of Indonesian civilians.

This has an influence on all elements of life, one of which is the area of education [2]. On March 24, 2020 the Indonesian Minister of Education, issued Ministerial Circular No. 4 of 2020 concerning Implementation of Education Policies in an Emergency for the Spread of Coronavirus Disease (COVID-19), which instructed several things including the 2020 National Examination to be canceled, the learning process carried out from home, the School Examination for graduation is regulated by certain conditions and other rules. With the issuance of the Circular, the remaining learning activities are carried out remotely by utilizing virtual environments such as websites, social media, or learning management systems [3].

In fact, online learning is not always working as effectively as expected. Students experience that online learning is somewhat difficult especially in physics learning. One of topic with the worst reputation on physics is projectile motion. This topic is discussed particularly at the high school level. Even though the physical concept has only been studied at the high school level, it does not mean that students have not had prior understanding to the projectile motion. Students automatically continue to construct their concepts through their life experiences before entering the class. Students have observed much phenomena of projectile motion in everyday life, especially in sports such as ball movements in football, basketball, tennis, ping pong, shuttlecock movements in badminton and so on. Besides the sport activities, projectile motion can also be observed by students in the famous game application such as Angry Bird [4].

Therefore, students already have an initial conception related to projectile motion, but the students' initial conception may be still inappropriate or not the same as the conception held by experts or also known as a misconception. In the topic of projectile motion, recent documentations have discovered several misconceptions exhibit by students [5]. Research shows that 66% of students demonstrate misconceptions in Newton's Law [6], 39.9% of students possess misconceptions on dynamic electricity [7], 26.2% of students experience misconceptions on light [8], 51.27% of students experience misconceptions on temperature and heat [9], and 80.11% of students experience misconceptions on linear motion [10]. Based on these documentations, it can be captured that students still experience misconceptions in almost entire physics topics [11].

Moreover, there were several misconceptions in projectile motion, such as students' misconceptions in determining the farthest distance reached by a projectile influenced by the elevation angle and neglected to consider the initial velocity, the trajectory of a bomb that fell from an airplane flying in the direction of the x axis based on the position of the observer as pilot and observer in the ground, and the travel time of two objects that are dropped simultaneously at the same height by neglecting the initial velocity of vertical component [12]. Misconceptions may occur due to the monotonous physics class that only engaged more the mathematical formulas or equations without focusing on the conceptual understanding of physics. Physics learning should be done by observing and conducting experiments related to the process of scientific knowledge. This seems to imply that physics is dominant to the collection of formulas rather than understanding the concept [13].

There are two main reasons led to misconceptions on projectile motion. First, the terms is relatively difficult to understand thus majority of students only memorize them without understand the exact definition of the terms. Second, the projectile motion is reasonably one of the complex topic in physics [14]. In the discussion of projectile motion, students are required to be able to decompose the vector components, understand Uniform Linear Motion (ULM) and Accelerated Linear Motion (ALM) related to velocity vectors and velocity components in x and y directions, memorize the formula for the time taken by the bullet for the half-ball trajectory, maximum height and maximum range, understand the concept of the final velocity of the bullet when it hits the ground (free fall motion in the y axis direction), understand the velocity of the object at the top, namely the component of velocity in the y axis direction is zero and non-zero in the x-direction velocity component, understands the concept of acceleration, which is only acceleration in the y-axis direction and no acceleration in the x-

axis direction, and understand the basics and trigonometric identities in determining the amount of distance, time, height, speed and acceleration [15].

In order to help students in learning the concept of projectile motion, multi representational ability is crucially needed. By mastering multiple representations, including verbal, mathematical, graphic and figural representations, students can represent the same concept but in different formats [16]. This is because if students master more than one representation it will provide a better understanding and increase student interest in learning [17]. There are three main functions of multi-representation in learning, namely providing complementary information on cognitive processes, reducing the possibility of misinterpretation, and encouraging students to build a deep understanding of a physical condition [18].

In learning the concept of projectile motion, students are required to be skilled and master graphic and figural representation [19]. Graphical representations are used to summarize data sets, retrieve and interpret new information from complex data but research shows that students have problems in retrieving information, reading, interpreting and constructing graphical representations [20]. Research in Indonesia shows that the ability of verbal, image, mathematical and graphical representation is still very low [21], students still have difficulty solving problems related to graphical representation [22], graphical representation skills pre-service physics teachers are also still lacking [19] and even experience misconceptions in various types of representation [11]. This study aims to determine students' misconceptions on projectile motion material and to explore the impact of online learning during the COVID-19 pandemic on it. This research is compulsory to investigate how the pandemic outbreak influence the physics instruction that can be a referential findings to the further attempts on physics misconception.

METHOD

This quantitative research was purposed to descriptively figure out the misconceptions experienced by students on projectile motion in the frame of figural and graphic representations. This research was conducted in the pandemic condition of COVID-19. The key format of each three tier test problem is multiple choice along with reason why students choose a particular answer. Normally the duration of learning activities is 45 minutes per hour study but due to the Indonesian government policy the duration is reduced into 30 minutes per hour study. The learning activities is using school's elearning platform which is integrated with video conference platform like google meet. The time spent to complete the test was one study hour (30 minutes). The test was administered on 14th October 2020. The six items of Busyairi and Zuhdi's three tier test were administered to 76 students in one of senior high school in Central Java. The data collection was situated in the online format of Google Form. Then, quantified students' representation will be categorized in Table 1. Eventually, the physics misconception groups would be diagnosed with these categories.

Table 1. Students' Conception Category using Busyairi & Zuhdi's Three Tier Test

Answer	Reason	Confidence level	Categories
Correct	Correct	Certain	Scientific knowledge
Correct	Incorrect	Certain	Misconception
Incorrect	Correct	Certain	Misconception
Incorrect	Incorrect	Certain	Misconception
Correct	Correct	Uncertain	Lucky guess
Correct	Incorrect	Uncertain	Lack of understanding
Incorrect	Correct	Uncertain	Lack of understanding
Incorrect	Incorrect	Uncertain	Lack of understanding

RESULTS AND DISCUSSIONS

This research was aimed to answer two research questions. The first was identifying physics misconception students at the senior high school in central java using the three-tier test in the basis of graphic and figural representation (Table 1). The second purpose was qualitatively describing to what extent limitations of COVID-19 contexts contribute the discovered physics misconception on projectile motion. We will describe our answers to these questions in the following section respectively.

Using individual score of three tier test, this study has classified the students' conception into four categories: scientific knowledge (SK), misconception (M), lucky guess (LG), and lack of understanding (LU). In the context of whole class, it has been found that our participants of the study in one of the senior high school in Central Java ($N = 76$), congregate significantly lower for scientific knowledge (SK) groups (Figure 1) but higher assembly for misconception (M) and lack of understanding (LU) groups. Figure 1 shows the distribution of each kinds of representational classification (figural or graphic) in the entire of discovered groups. Probed by three figural representation items on three tier tests, students' gaining of 8.3% is classified as scientific knowledge (SK), of 48.7% is categorized as misconception (M), of 1.8% is classified as lucky guess (LG), and of 41.2% student's category as lack of understanding (LU). There were no significantly different trends between the format of graphical representations in students' conceptual performance on projectile motion measured with three tier tests in figural representation, most students are also categorized as misconceptions (M) and lack of understanding (LU)

Clearly in the Figure 1, a significant majority of students (48.7% ~ 55.3%) are concluded as misconception (M) learners in the average of class. This finding is similar with previous research of the projectile motion representation in the others senior high schools. The results of research in one of senior high school in Yogyakarta show that students with high, medium, and low abilities still have misconceptions about the material of projectile motion [23]. It should be paid attention that most senior high school students are categorized as misconceptions (M) and lack of understanding (LU) on projectile motion topic. Overall, the categorizations of students' conceptions in graphic and figural representations are shown in Figure 1.

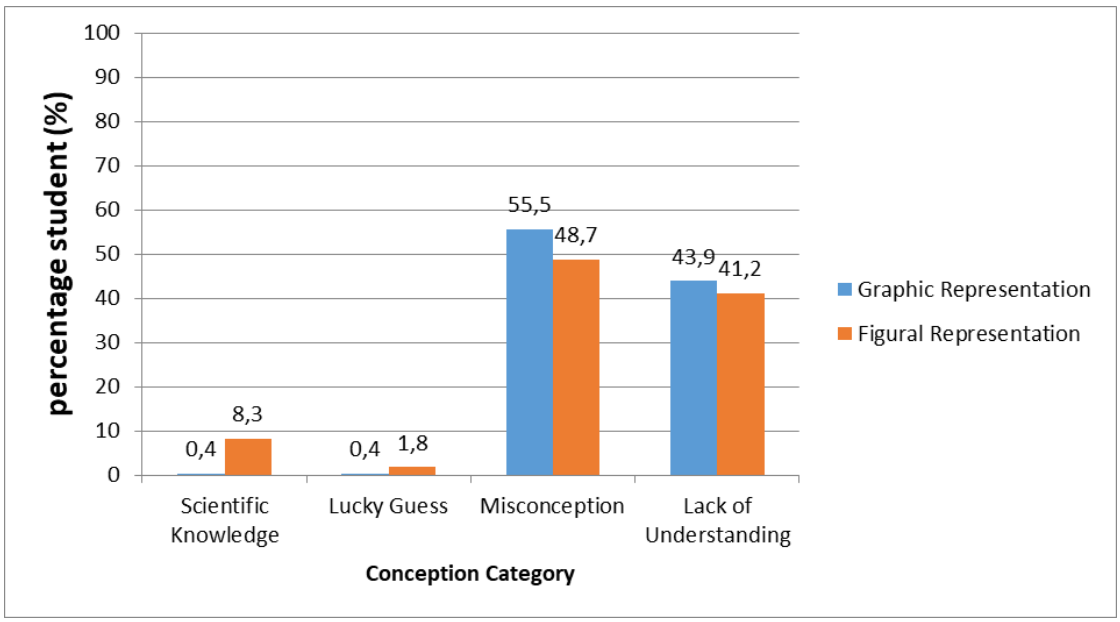

Fig 1. *Representational performance of students on projectile motion*

The first question of three tier test situated the context in the figural representation, described in Figure

2. The given two wooden blocks move to the end of table initiated with different horizontal velocity and student were asked to predict which blocks that first touch to the ground and other phenomena relating to this. Four option of answers and reasons should be paired by students and then they decide their confidence level after finishing those options. This item measured that the main groups of students congregate for misconceptions (M) category (61.8%) which is higher than the average findings in the whole class. There was no student classified in the lucky guess group (LG) and the second populous group was still located in the lack of understanding (LU) learners (30.3%).

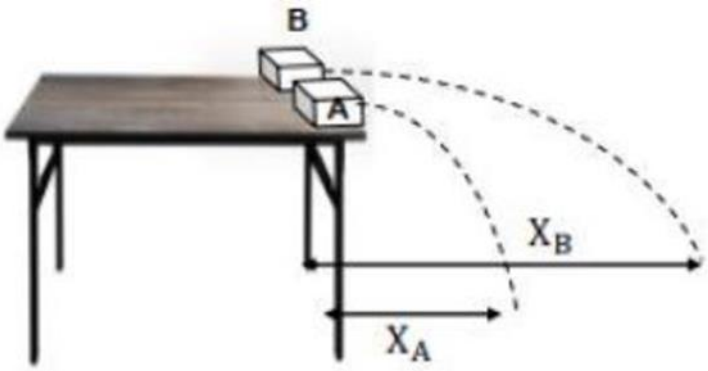

Fig 2. *The first items of figural representation. Two wooden blocks fall from the height of table in different horizontal velocity* [11]

The distributional results of students' answer in the first challenge shown that majority of students (46.1%) still have understanding that the initial velocity will affect the time to achieve the ground. The students' selection of reason was dominantly discovered that they still grasp the incorrect perception that bigger velocity, farther the maximum range (56.6%). Those preconception should be consulted with the experimental results that horizontal velocity and range quantity actually does not influence the time to ground. The time for the bodies reaching the ground is just determined by the height and gravitational acceleration in the surrounding systems.

The second figural representation of three tier test is assigned to the case of falling bomb released from the moving airplane, demonstrated in Figure 3. The illustrative aircraft is moving and suddenly throws the bomb to the ground. Students were asked to decide which appropriate path that will be followed by the released bomb. In the present challenge, students primarily still congregate for misconceptions (M) category (47.4%) and there are some students that make lucky guess (LG) (3.9%). there are still many students who are categorized as lack of understanding (LU) (36.8%) and only a small proportion of students are categorized as scientific knowledge (SK) (11.8%).

Students' choice in the second figural representations was mostly distributed in path number (1) (48.7%) and path number (2) (26.3%) surprisingly (see Figure 3). There is an implication that our participants still possess the ignorance of horizontal velocity in the case of moving airplane. Their answer of path (2) elaborates their inadequacy of vector components of velocity so they did not understand the importance of resultants. In addition of the "gedanken" thought assumes that the bombs will take the opposite direction from the moving parts as explained in the previous circular motion lesson. We predicted that the dashed line (1) of Figure 3 may be projected as the circular path of the bomb by the students. As students might review this consideration so they think that the bomb will follow the property of centrifugal force as a reactive result of the exert of centripetal force and in this case the bomb is the reactive parts towards the airplane.

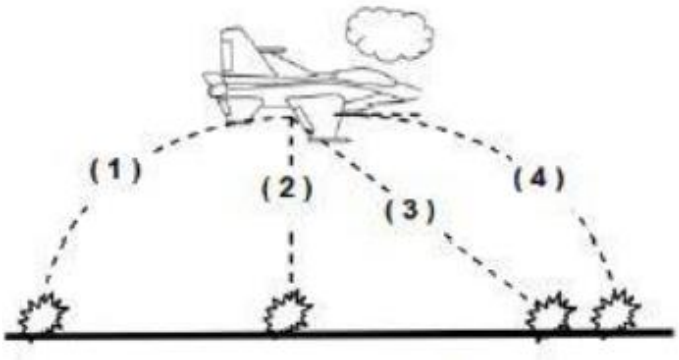

Fig 3. *The second items of figural representation in three tier test. The path followed by the falling bomb from the right-moved aircraft* [11]

The last problem of three tier test in figural representation requires the students' understanding about the maximum range respect to the various angle of elevation (α), illustrated in Figure 4. The different trends with the previous two items was discovered in this task. Most of students were assembled for lack of understanding (LU) groups (56.6%) instead of the misconception (M) (36.8%) that was slightly opposite with the two previous findings that conversely put them in different categories. This lack of understanding on maximum horizontal range may be occurred because of the limitation of students' mathematical sense making on physics. It was conformable by the tendency to the incorrect reason chosen by students in gravitational cause (40.8%), actually does not directly correlate with the case. They have not hold adequate knowledge to the physical explanation of extreme value in the mathematical context, so they guessed that the variety of horizontal range is correlated with the surrounding gravitational acceleration. Actually, it should be simply by common understanding that the maximum value of sinus α will vary between 0 and 1, so we obviously know that this results of 1 would lead to the maximum horizontal range as well.

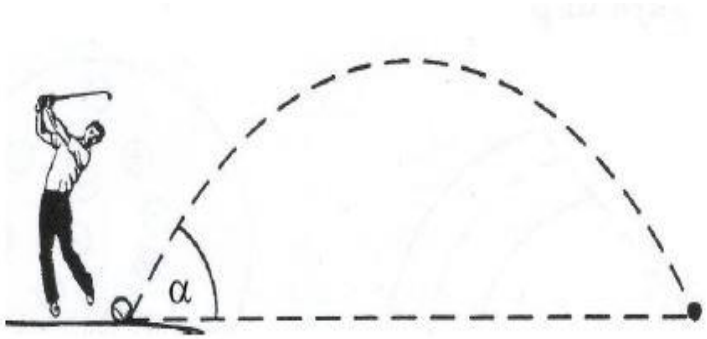

Fig 4. *The third questions of three tier test in figural representation. A golf ball that follows the projectile path after hit by the player*

In the next consecutive paragraphs, we will describe the conception students of graphical representation. The first item on graphical representation is shown in Figure 5. Students were asked to determine the appropriate relationship between velocity and time in the case of vertical component of velocity vector during projectile motion. In this item, the main groups of students congregate for misconceptions (M) category (69.7%). There was no student classified in scientific knowledge (SK) and lucky guess (LG) group. The second populous groups were still located in the lack of understanding (LU) learners (30.3%).

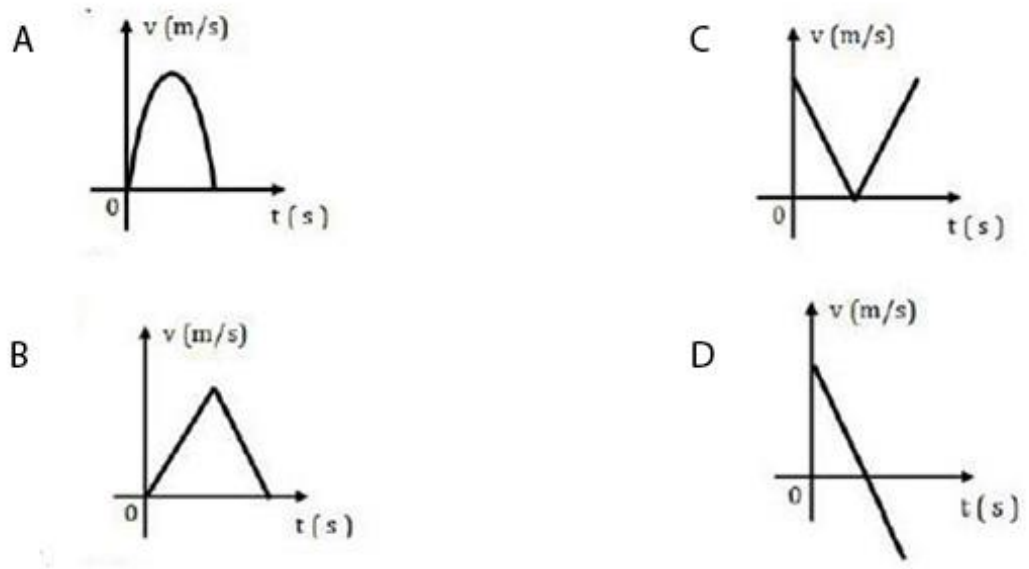

Fig 5. *The first items of graphical representation in three tier test. Vertical velocity plot respect to time [11]*

The distributional results of students' answer in the first graphical format revealed that majority of populations (72.4%) still have understanding that the correct plot will be in similar form as the projectile path. The inability to interpret the graph were greatly discovered in case of vector component on projectile motion. Even, in the whole class, there was no students assigned as scientific knowledge (SK) learner in this item. Those preconceptions should be consulted with the vector property of velocity in which it should engage the negative and positive sign in our analysis. The vertical velocity will gradually be decreased because of the gravitational diminisher in the surrounding systems until its vertical velocity raises the zero condition and backs to the ground with the accelerated movement. Therefore, the expected scientific knowledge (SK) learner should choose the right-above option in Figure 5.

The second graphical representation in three tier tests was assigned to the plot of height of the moving object respect to the ground (H) versus time (t), shown in Figure 6. Students were asked to interpret how the movement of body in the presented H versus t plot was. In the present challenge, students primarily still congregate for misconceptions (M) category (52.6%), lucky guess (LG) category (1,3%) and there are some students that lack of understanding (LU) (46.1%).

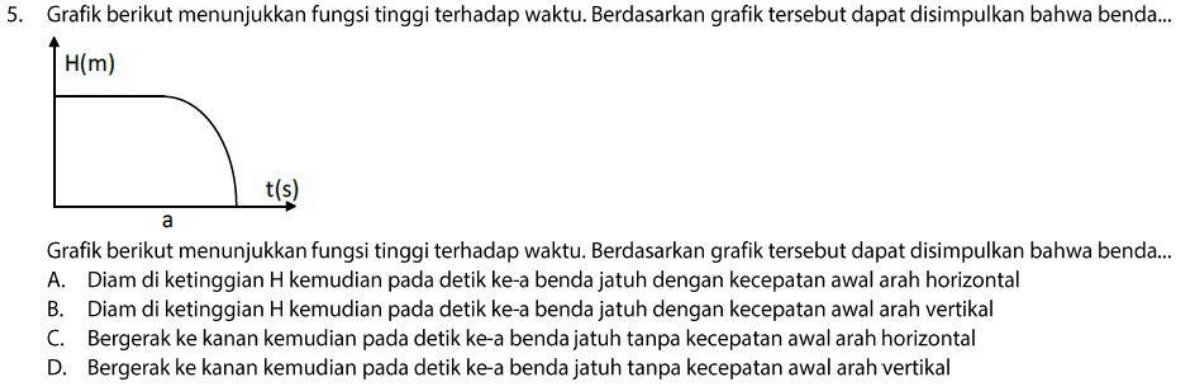

Fig 6. *The second question of graphical representation. The behavior plot of height versus the time* [11]

Students' choice in the second graphical representations was mostly distributed in the incorrect answer (44.7%) that body is still at rest in the height of H until time a and it falls to the ground with initial velocity vertically. This finding suggested that our participants still possess the ignorance of the nature of velocity vector as discovered in the first graphical representation. The curved shape of the graph leads them to the physics misconception (M) (43.4%) so they might have not possessed an adequate understanding either the physical or the mathematical interpretation of projectile curve. The valid explanation should be the body in the rest condition in the height H above the ground then after time t it falls with the initial velocity horizontally, not vertically. In other words, the body does not have the component of vertical velocity because of its initial condition. It also has to be noted that the typical of this graphical item is similar to the first figural situation, however, in this way the situation is described through the graphical situation.

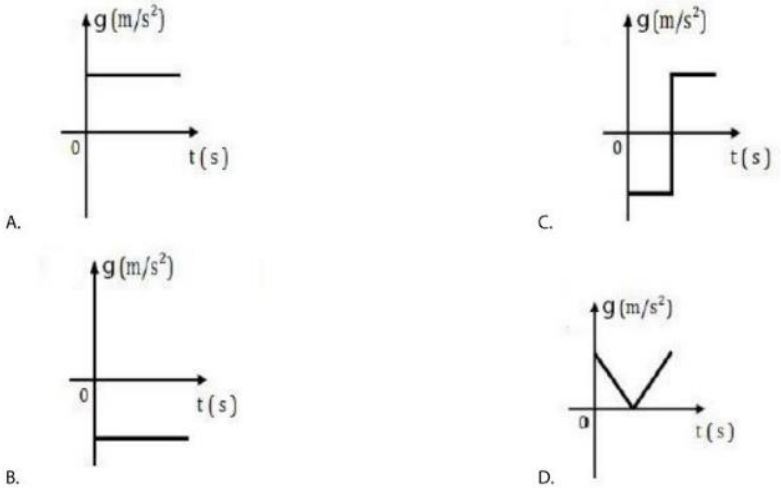

Fig 7. *The last questions of three tier test in the frame of graphical representation. Relationship between gravitational acceleration and time* [11]

The last problem of graphical representation requires the student's understanding about the nature of gravitational acceleration contributed in the discussion of projectile motion, illustrated in Figure 7. The similar trends with the third of figural format was also discovered in this task. Most of students were still assembled for lack of understanding (LU) category (55.3%) and fewer the misconception (M) (43.4%). The lack of understanding on constant properties of gravitational acceleration near the earth surface may be occurred because of the limitation of students' mathematical sense making in determining the positive or negative acceleration. It was conformable by the tendency to the incorrect reason chosen by students (39.5%) in positive value of g and the previous discoveries in the fourth and fifth of three tier tests. Actually, gravity has to be in negative way since the vector exerted to the center of earth. They might have not hold adequate knowledge on vector properties that should be mastered when analyzing the vertical parts of projectile motion. In detail, the distribution of student frequency data on projectile motion material related to its conception is shown in Figure 8. It can be seen that most students are still in the misconception (M) and lack of understanding (LU) categories both from graphical representations and figural representations.

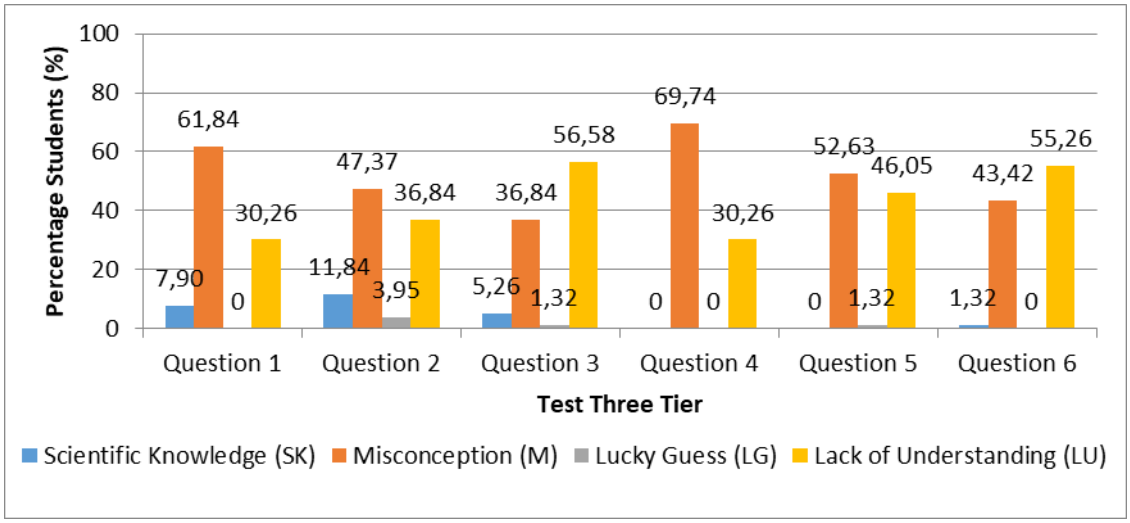

Fig 8. *Representational conception in three tier test*

Misconceptions were frequently investigated in the routine of physics education research. The urgency of this problems is addressed because of their important contribution to the students's success of physics. Online learning that is reframed by most of teachers over the pandemic condition has an impact to the students' conceptual understanding consequently. Figure 1 demonstrates that the number of students with the misconception (M) and lack of understanding (LU) state are relatively huge. In our prediction, these issues are personally contributed by the context of COVID-19 pandemic that might distract the focus of the students through the distance mode of instruction. Most of educators are forced to follow some debatable decisions by compromising this condition rather than attempting the perfection of practices. This diminishing educational atmosphere may affect our students' motivation so that they are critically possessed the major misconceptions. Autonomous property of remote learning actually is good to the adult learners but it seems to be adjusted if our environment are located in the below ages. Without the teacher guidance, the preconception of students will be often discovered in a kind of assumptions that deviate significantly with the valid explanation. It may be specifically for the physics instruction that usually requires some additional information's such as graphical knowledge or vector components to understand the phenomena. Therefore, these pandemic issues should be invited in some future investigations to stop the tendency of misconceptions that will propagate to the more complex physics misconceptions.

As previously mentioned, misconception is necessarily to be identified for future instruction. The present misconceptions will determine the future conceptual understanding of students [24]. Besides the context of COVID-19 pandemic, the occurrence of misconceptions actually might be related to some generated theory. The resources theory suggested that the students that are failed in activating their prior understanding to the present context often exhibit those misconceptions [25]. This theory implies that online instruction might not facilitate their students in conforming their prior knowledge to the recent discussed problems in class. Specifically, misconceptions are not only related to the obstacles of teachers but also the inability of students to recall their prior knowledge to the new concepts being learned. The prior knowledge (preconception) can be memorized from their experience or the lesson learned in the previous level of education.

Finally, misconception (M) and lack of understanding (LU) groups was greatly discovered in the case of the fifth question of three tier test. Even, there was no students' acquiring knowledge in this area of graphical representation. Majority of students were still discovered inadequate in utilizing their vector insights to the case of projectile motion. To our knowledge, the prior knowledge of vector is definitely compulsory in succeeding students on the vector based topic such projectile motion. Future investigation should address more attention to this graphical problem. Furthermore, the concerned COVID-19 pandemic in the context of study should be recognized as an existing obstacle in administering the consequential physics instruction. We hope our conditions will be recovered as soon

as possible so we are able to do better in educational practices normally. The author realizes that the selection of participants in this study might be not really representative to give a snapshot of physics education practices as a whole context of Indonesia. Projectile motion also actually cannot fully correspond to the entire understanding of physics misconception in the frame of figural and graphical representation. Therefore, we left the room of future research in addressing the large students administered for the context of study. Then, eliciting the more vector-based physics topics to be investigated is also recommended to inquire supportive findings in the field of representational ability on physics.

CONCLUSION AND SUGGESTION

In summary, six items of Busyairi and Zuhdi's three tier test have enumerated the occurrence of physics misconception on projectile motion at one of senior high school in Central Java. There was large number of students that possess physics misconception and lack of understanding on projectile motion investigated by Busyairy and Zuhdi's inventory. Furthermore, the graphical parts of three tier test demonstrate lower achievement in comparison to the figural representation of projectile motion. It implies that the discussion of graphical knowledge should be invited more frequently to address this need in physics, particularly in the topics that require the properties of vector in their physical explanation such projectile motion.

Although the implementation of distance pedagogy can be alternatively approached in managing the lesson during the COVID-19 circumstance, we realize that the nature of face to face-based activities cannot be replaced by the online mode at all. This study experienced that our population of students were more difficult with this tradition wholeheartedly. We also investigate no significant attainment on the three-tier test without explicit instruction in comparison with the normal pattern of learning qualitatively. This has several implications in teaching practices, such as the necessity of patient guidance in monitoring the students to grasp a valid conceptual representation, particularly in the vector properties and graphical knowledge that are still worse in the discussion of vector-based topics such projectile motion.

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