ISSN 2987-4270
PLE
Physics Learning and Education
Vol. 2 No. 3 (2024)

Analysis of Student Misconceptions and Their Causes on Parabolic Motion Using a Six-Tier Multiple Choice

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ABSTRACT

The goal of learning physics in institutions using the 2013 curriculum is to develop a solid conceptual grasp of each subject. Students experience misconceptions while having a solid conceptual grasp that contradicts accepted notions. Learning about parabolic motion might lead to misconceptions, which are common in physics. Teachers need to be aware of the causes in addition to the misconceptions. This study attempts to identify students' misconceptions and determine the root causes of the parabolic motion material. The Six-Tier Multiple Choice Instrument, which has 18 items, was the tool utilized in this study. The sort of research used is descriptive research using the survey method. pupils from class X MIPA MAN in Padang City made up the population of this study, with a total sample size of 514 pupils. Overall, this investigation of the three MANs in Padang City discovered a 28.0% misunderstanding. According to the study's findings, there were 25.8% misconceptions in MAN 3, 29.2% mistakes in MAN 1, and 26.6% misconceptions in MAN 2. With a percentage of 45.4%, students' individual opinions are the primary source of misconceptions.

Keywords: *Parabolic Motion; Misconceptio; Six-Tier Multiple Choice.*

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I. INTRODUCTION

The learning process is an activity that involves teachers and students in order to implement the curriculum at an educational institution in order to achieve the expected goals. To achieve these educational goals, students interact with the learning environment using the understanding that has been given by the teacher. This understanding is developed by students based on concepts that have been obtained through the learning process. In the course of learning physics, it is intended that students will be able to apply the material and comprehend it completely. This is indicated in the 2013 curriculum, which states that one of the objectives of learning physics is that it is anticipated that concepts will be fully understood in every physics material.

Concept understanding is the mastery possessed by students in re-expressing existing concepts in a simpler and easier to understand form and being able to reapply them. Concept understanding is a requirement for success in physics learning [1]Concept understanding is needed in learning so that the next material learned can be understood properly. This is in line with [2] who state that other concepts will have an impact if the understanding of the previous concept is wrong. This is also in line with research conducted by [3], namely the ability of students to understand concepts is very important. If the understanding of the concept that students have is strong, but the understanding is contrary to the concept that is scientifically accepted according to experts so that it can lead to misconceptions.

Misconceptions are differences in the initial knowledge that students have, with those of experts. According to [4] misconceptions are the use of concepts that are not in accordance with scientifically proven expert statements. According to [5]) misconceptions are differences in understanding of a concept that a student has with a science expert. Based on several expert opinions, misconception is a situation where the knowledge possessed by students is contrary to actual knowledge due to conceptual errors.

Students' conceptual mistakes might make it difficult to understand concepts, which causes weak material mastery at the following learning stage. This is consistent with [6] finding that students' misconceptions about

physics can influence their subsequent grasp of the subject. In order to increase students' knowledge in an organised way and address numerous problems that arise when learning physics, it is necessary to understand the proper ideas. One of them happens in the material of parabolic motion.

In parabolic motion material, students have difficulty in understanding some of the indicators contained in the parabolic motion learning material so that misconceptions occur. This is in line with [7] students at SMAN 3 Pontianak experienced misconceptions in parabolic motion material with an average of 82.75%. According to [8] in Kubu Raya district, West Kalimantan identified misconceptions on parabolic motion material that occurred in students include:

Class X students at SMAN 1 Padang had 63.6% misconceptions about the subject related to parabolic motion, according to [9]. According to [10] who based his findings on data identified in Tanjung Balai City, 12.0% of pupils have a conceptual understanding level, 49.9% have a conceptual misperception level, and 30.5% have a conceptual understanding level. Misconceptions in the continuing learning process are not only brought on by students but also by teachers..

Teachers need to identify misconceptions of students in order to improve concept understanding and reduce student misconceptions [11] To effectively address students' misunderstandings, it is necessary to identify misconceptions in learning. Diagnostic test tools can be used to pinpoint misconceptions and the reasons why they arise. A diagnostic test is one that is used to determine a student's learning strengths and limitations, including any misconceptions they may have. The findings of diagnostic tests can be a guide for structuring instruction in accordance with student aptitudes. A good diagnostic test can show misconceptions faced by students based on information on errors made [12] Diagnostic tests consist of interviews, multiple choice, and others. Interviews are less effective than multiple choice test at identifying misconceptions, claim [13] The use of multiple choice questions can make students not need to understand the material from the questions given, because students can guess the answers available without having to understand the concept. Multilevel multiple choice tests, including those with one, two, three, four, and most recently, five tier, were created to address these issues[14].

Students' misconceptions regarding the parabolic motion topic are examined using the five tier multiple choice Wijaya (2022) instrument. It is important to add one more level, namely the six tier, in order to determine the sources of misconceptions. Six-tier multiple choice questions can also be used to examine how well students comprehend the concepts of parabolic motion and the reasons behind their misunderstandings. Students' understanding of the topics related to parabolic motion is evaluated using this graded multiple-choice test. Based on these issues, accurate identification is required to find students' misconceptions of the parabolic motion. So, the purpose of this study is to examine students' misconceptions about parabolic motion and the reasons behind them using the six-tier multiple choice instrument at MAN Kota Padang.

II. METHOD

Researchers use descriptive research techniques using survey methods. Descriptive research is a research method that shows the characteristics of the population or phenomenon under study which focuses on explaining the object of research and answering what events or phenomena occur. Survey method is a method with sources of information and data obtained from respondents using a questionnaire as a data collection tool. This research was conducted from 11 November 2022 to 17 December 2022. The total sample was 514 students consisting of 136 students of MAN 1, 250 students of MAN 2, and 128 students of MAN 3.

Look at the following picture to answer questions number 1– 3!

A soccer player kicks the ball in a parabolic path as shown in the picture above. The ball is kicked at an angle α so that the ball moves up to the highest point. then move down again until it reaches the ground.

(1)

1.1 Based on the motion of the ball described in the Cartesian graph above, it can be seen that the motion of the ball forms a parabolic trajectory. The motion acting on component X is ….

A. Motion in a Straight Line Changes Uniformly
B. Uniform Straight Motion
C. Downward Vertical Motion
D. Upward Vertical Motion

Jawaban : A B C D E

1. 2 **What is the level of confidence in the answers above?**

A	Sure	B	Not sure

1.3 **Reason for answer**

A. The motion on the X component is horizontal motion with a constant velocity
B. The motion on the X component is a motion with a speed that always changes regularly
C. The motion of the X component is affected by the acceleration due to gravity
D. Because there is a change in style
E. Because the motion of the parabola is perfectly curved

Jawaban : A B C D E

1.4 **What is the Confidence Level for the reasons above?**

A	Sure	B	Not Sure

1.5 Draw the trajectory of the parabolic motion along with the direction of the ball's velocity with respect to the X and Y components when the object is about to move.

1.6 Sources used to answer questions

A Book
B Teacher
C Personal Thoughts
D Internet
E Other:

Jawaban : A B C D E

Figure 1. *Six-tier Multiple Choice* Instrument

The six-level multiple-choice instrument consists of instruments consisting of six levels. There are multiple choice questions on the first level. The first level's confidence level in responding to questions is reflected in the second level. The reason pupils respond to inquiries is the third level. The pupils' confidence in providing explanations is the fourth stage. The fifth level requires students to create an image, conclusion, or succinct justification based on the given questions. And the sixth level is the cause of students' misunderstanding of concepts [15]. Students' misconceptions about parabolic motion material can be identified by using this six-tier multiple choice test. This instrument has also gone through a validity test and all of the items are valid [16]

The conceptual understanding category table proposed by Anam, et al. in table 1 below was then used to process and analyze data on student responses.

Table 1. Category of Students' Concept Understanding

No.	Tier I	Tier II	Tier III	Tier IV	Tier V	Category
1	Correct	Sure	Correct	Sure	As per	PK
2	Correct	Sure	Correct	Sure	Not suitable	HPK
3	Correct	Sure	Correct	No	As per	KPD
4	Correct	Sure	Correct	No	Not suitable	KP
5	Correct	No	Correct	Sure	As per	KPD
6	Correct	No	Correct	Sure	Not suitable	KP
7	Correct	No	Correct	No	As per	KPD
8	Correct	No	Correct	No	Not suitable	KP
9	Correct	Sure	Wrong	Sure	As per	MSC
10	Correct	Sure	Wrong	Sure	Not suitable	KP
11	Correct	Sure	Wrong	No	As per	KP
12	Correct	Sure	Wrong	No	Not suitable	KP
13	Correct	No	Wrong	Sure	As per	KP
14	Correct	No	Wrong	Sure	Not suitable	KP
15	Correct	No	Wrong	No	As per	KP
16	Correct	No	Wrong	No	Not suitable	KP
17	Wrong	Sure	Correct	Sure	As per	KP
18	Wrong	Sure	Correct	Sure	Not suitable	KP
19	Wrong	Sure	Correct	No	As per	KP
20	Wrong	Sure	Correct	No	Not suitable	KP
21	Wrong	No	Correct	Sure	As per	KP
22	Wrong	No	Correct	Sure	Not suitable	KP
23	Wrong	No	Correct	No	As per	KP
24	Wrong	No	Correct	No	Not suitable	KP
25	Wrong	Sure	Wrong	Sure	As per	MSC
26	Wrong	Sure	Wrong	Sure	Not suitable	MSC
27	Wrong	Sure	Wrong	No	As per	KP
28	Wrong	Sure	Wrong	No	Not suitable	KP
29	Wrong	No	Wrong	Sure	As per	KP
30	Wrong	No	Wrong	Sure	Not suitable	KP
31	Wrong	No	Wrong	No	As per	KP
32	Wrong	No	Wrong	No	Not suitable	TPK

Overall, based on Table 1, the level of student understanding is grouped into six conception level categories consisting of Understanding Concepts (PK), Almost Understanding Concepts (HPK), Lack of Confidence (KPD), Lack of Knowledge (KP), Misconception (MSC), and Not Understanding Concepts (TPK). Students who fall into the misconception category, meaning that these students have an understanding that is not in accordance with the concepts put forward by experts

III. RESULTS AND DISCUSSION

A. Profile of Student Misconceptions in Physics Learning on Parabolic Motion Material

The categories of understanding concepts, almost understanding concepts, lack of confidence, lack of knowledge, misconceptions, and not understanding concepts in each item are the places where students' misconception profiles are displayed. The questions tested on students at MAN Padang with numbers 1 to 18 are determined by the frequency and proportion of students in Padang who understand the concept, and the results are as follows.

Table 2. Frequency and Percentage of Students' Concept Understanding Levels

Question No.	Concept Understanding (PK)		Almost Understand the Concept (HPK)		Lack of Knowledge (KP)		Misconception (MSC)	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Position, Velocity, and Acceleration Vector Relationships in Parabolic Motion								
1	198	38,5	100	19,5	116	22,6	100	19,5
2	177	34,4	113	22,0	102	19,8	122	23,7
4	167	32,5	109	21,2	97	18,9	141	27,4
13	154	30,0	101	19,6	117	22,8	142	27,6
17	179	34,8	113	22,0	105	20,4	117	22,8
Analysis of Position, Velocity, and Acceleration Vectors in Parabolic Motion								
3	162	31,5	114	22,2	108	21,0	130	25,3
5	173	33,7	89	17,3	104	20,2	148	28,8
7	126	24,5	117	22,8	96	18,7	175	34,0
9	175	34,0	90	17,5	112	21,8	137	26,7
10	160	31,1	104	20,2	114	22,2	136	26,5
11	159	30,9	100	19,5	113	22,0	142	27,6
12	165	32,1	116	22,6	95	18,5	138	26,8
Application of the Concepts of Position, Velocity, and Acceleration Vectors in Parabolic Motion								
6	178	34,6	94	18,3	78	15,2	164	31,9
8	188	36,6	124	24,1	68	13,2	134	26,1
14	160	31,1	110	21,4	97	18,9	147	28,6
15	143	27,8	118	23,0	126	24,5	127	24,7
16	152	29,6	110	21,4	122	23,7	130	25,3
18	166	32,3	110	21,4	105	20,4	133	25,9

According to the table above, all of the test items show that pupils have misconceptions. 175 students had the most misconceptions about the concepts of position vector analysis, velocity, and acceleration in parabolic motion. The average percentage of students' concept knowledge level, as determined by additional data analysis, is depicted in the following figure.

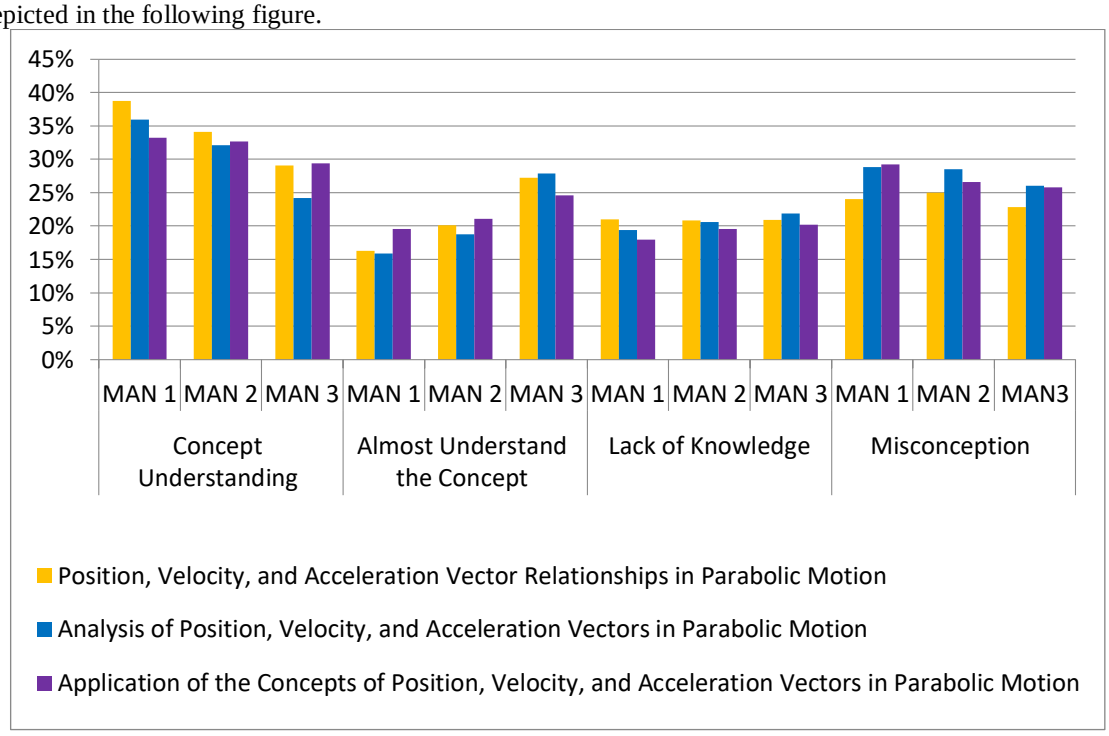

Figure 2. Bar diagram of the average percentage of students' concept understanding level of MAN 1, MAN 2, and MAN 3

Based on the figure above, it can be seen that the average percentage level of understanding of the concept of parabolic motion material that occurs in class X students at MAN Padang City was identified using a six-tier multiple choice diagnostic test. There are many variations of students who experience misconceptions, understand concepts, almost understand concepts and lack knowledge. The percentage of misconceptions as a whole occupies the highest position at 29.2%. The highest percentage of conceptual understanding overall was 38.7% with a medium category. A total of 18 items multiplied by a sample size of 514 students, namely 9252 items that have been answered, students who experience the highest misconceptions in question number 7

indicators about analyzing position vectors, velocity, and acceleration in parabolic motion are 175 students with a percentage of 34.0%. While the lowest misconception category occurred in the indicator of question number 1, namely explaining the relationship between position, velocity, and acceleration vectors in parabolic motion with a total of 100 students and a percentage of 19.5%.

On average in each parabolic motion material there are students who experience misconceptions. The following discussion provides specifics on the categories of concept knowledge that students exhibit for each idea.

1. Concept of Position, Velocity, and Acceleration Vector Relationships in Parabolic Motion

The five components that make up the concept of location, velocity, and acceleration vector connections in parabolic motion are 1, 2, 4, 13, and 17. The link between the position, velocity, and acceleration of a parabolic motion is determined by the item indicators in questions 1, 2, and 13. There are misconceptions in this question's item. The first item's inquiry is the one with the fewest misconceptions. 19.5% of people have a misperception about item number 1. Furthermore, 122 pupils misunderstood item number 2 in total. With a percentage of 27.6% on item number 13, quite a few students also have misconceptions.

The indicator for item number 4 is to determine the velocity versus time graph for parabolic motion. In this item, 27.4% of students experienced misconceptions. Evidenced by 141 students who were wrong with the answer and believed in the answer. The indicator for item number 13 contains inferring the relationship between the distance of an object and the time it takes for it to travel. In this item there are 142 students who experience misconceptions. With questions from the cognitive category C4, students are still giving incorrect reasoning for their answers even though they are confident in their responses. The conclusion of the link between the object's initial angle and its overall displacement in parabolic motion serves as the signal for item number 17. 22.8% of students had misconceptions about this question.

2. Analysis of Position, Velocity, and Acceleration Vectors in Parabolic Motion

The concept of vector analysis of position, velocity, and acceleration in parabolic motion is represented by 7 items, namely items number 3, 5, 7, 9, 10, 11 and number 16. The indicator for items number 3 and 5 is to analyze the speed component of parabolic motion with the C4 level of thinking ability. A total of 130 students experienced misconceptions. 25.3% of students are still wrong in giving reasons.

The indicator for question items number 7 and 11 is to analyze the acceleration of objects when moving along a parabolic trajectory. The level of thinking ability in this item is C4. A total of 34.0% of students had misconceptions. Students who understand the concept in question number 11 are quite a lot, namely 30.9%. Students who understand this concept answer that distance is a scalar quantity while displacement is a vector quantity.

The indicators of question items number 9 and 10 are analyzing the shape of a parabolic trajectory presented in the form of a picture. Item number 9 is a question that has quite a lot of misconceptions. Likewise, item number 10 also has a lot of misconceptions of 31.1%. The indicator of item number 12 is about analyzing the initial velocity, acceleration and time of an object in the air when traveling a parabolic trajectory with a C4 level of thinking ability. In this question indicator, 165 students experienced misconceptions.

3. Application of the Concepts of Position, Velocity, and Acceleration Vectors in Parabolic Motion

The application of the concept of position, velocity, and acceleration vectors in parabolic motion is represented by question items number 6, 8, 14, 15, 16, and number 18. In this item, there are 31.9% of students who experience misconceptions and 34.6% of students understand the concept. The indicator of question number 8 is to determine the travel time of two objects when moving along a parabolic trajectory. A total of 26.1% of students had misconceptions. Indicators of questions number 14, 15, 16, namely determining the velocity and acceleration vectors on a parabolic trajectory. On average, 26.2% of students have misconceptions. Indicator item number 18 is about determining the velocity and acceleration vectors on a parabolic trajectory in an inclined plane. Quite a lot of students have misconceptions, namely 25.9%.

The data above will be presented in more detail in the following three public madrasah aliyahs in Padang City.

1. MAN 1

Based on the analysis of research data collected utilizing a six-tier multiple choice test that included 18 items and involved 136 students. Figure 3 depicts the percentage of students who fall into the categories of comprehending concepts, almost knowing concepts, lack of confidence, knowledge, misunderstandings, and don't understand concepts

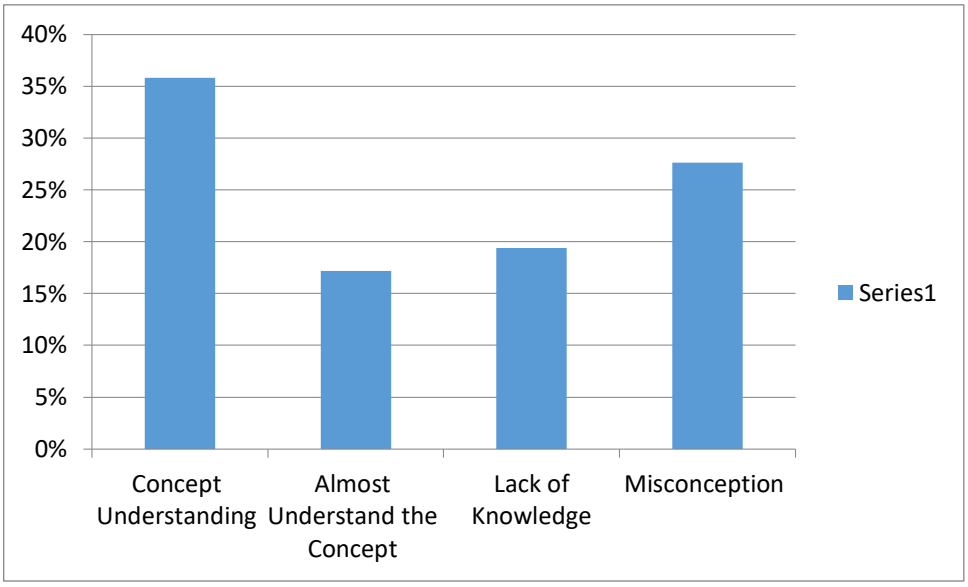

Figure 3. Bar diagram of the percentage of students' concept understanding level at MAN 1

Based on the figure above, the average percentage of students who experienced misconceptions at MAN 1 was 27.6% with a low interpretation. Most students are categorized as understanding the concept with a percentage of 35.8% with a medium interpretation.

2. MAN 2

Based on the analysis of research data collected utilizing a six-tier multiple choice test that included 18 items and involved 250 students. Figure 4 depicts the percentage of students who fall into the categories of comprehending concepts, almost knowing concepts, lack of confidence, knowledge, misunderstandings, and don't understand concepts.

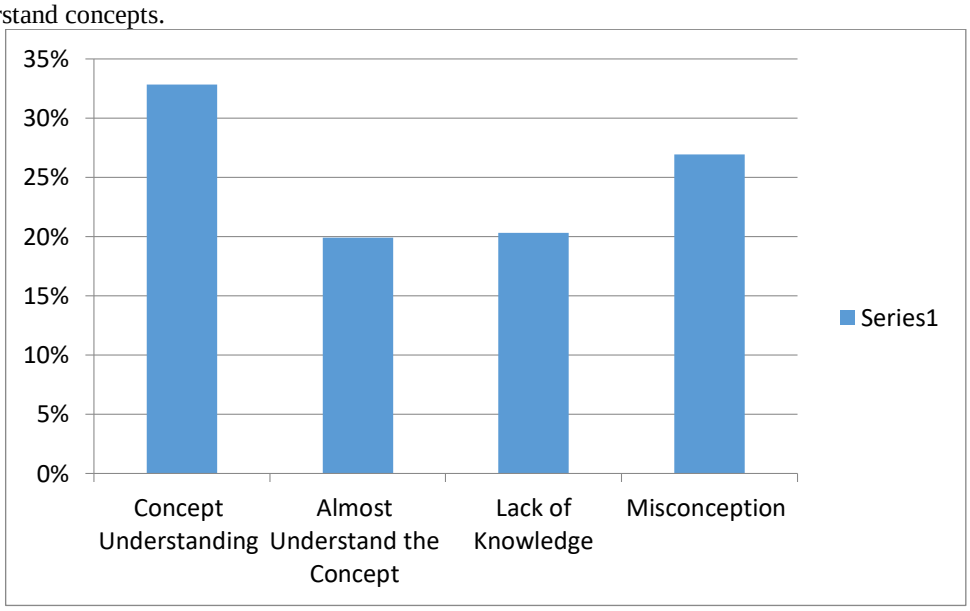

Figure 4. Bar chart of the percentage of students' concept understanding level at MAN 2

Based on the figure above, the average percentage of students who experienced misconceptions at MAN 2 was 26.9% with a low interpretation. Most students are categorized as understanding the concept with a percentage of 32.8% with a medium interpretation.

3. MAN 3

Based on the analysis of research data collected utilizing a six-tier multiple choice test that included 18 items and involved 128 students. Figure 5 depicts the percentage of students who fall into the categories of

comprehending concepts, almost knowing concepts, lack of confidence, knowledge, misunderstandings, and don't understand concepts

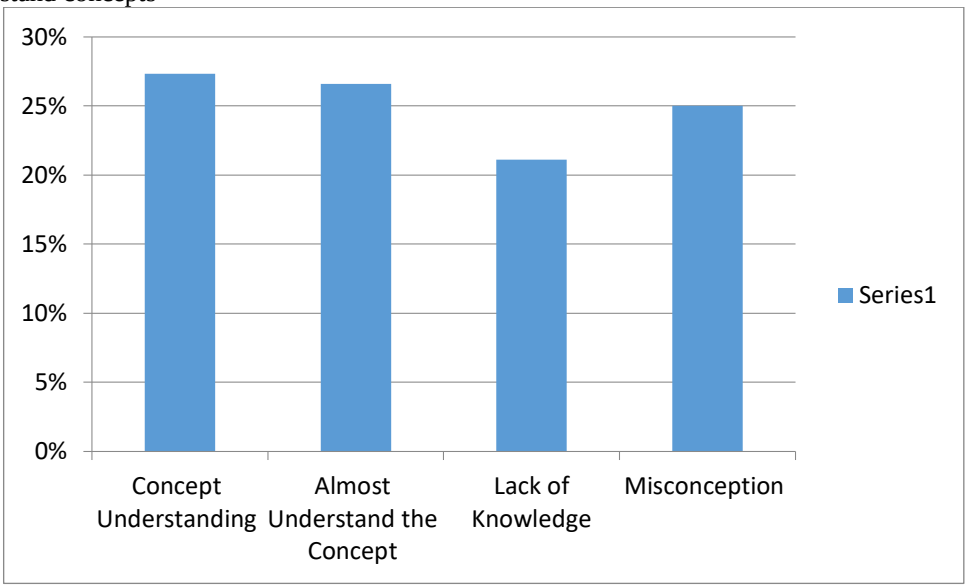

Figure 5. Bar chart of the percentage of students' concept understanding level at MAN 3

Based on the figure above, the average percentage of students who experienced misconceptions at MAN 3 was 25.0% with a low interpretation. Most students are categorized as understanding the concept with a percentage of 27.3% with a low interpretation.

B. Causes of Misconception in Physics Learning on Parabolic Motion Material

The causes of misconceptions among MAN students in Padang City were identified from tier-6 which is shown in Figure 6 below.

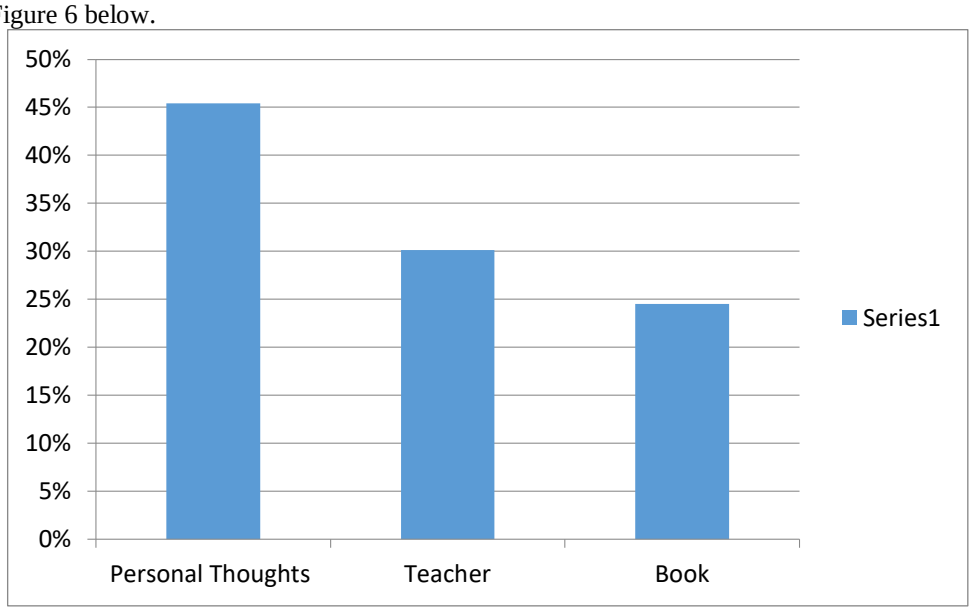

Figure 6. Bar diagram of the causes of misconceptions on parabolic motion materials

The causes of student misconceptions are closely related to the misconceptions themselves. According to this survey, personal thoughts accounted for 45.4% of the misconceptions among MAN students in Padang City. This is consistent with the findings of a study done in 2012 by Fakhruddin et al, who found that personal thoughts cause misconceptions among students to increase by 80%. Sources of misconceptions that come from personal thoughts occur when students have an opinion about a concept that is always the same as another concept even though the concept they believe at that time is different from that of the experts. The cause of the next misconception is the teacher. According to Mufit et al (2019), the cause of misconceptions and students' difficulties in understanding physics concepts is teacher-centered learning

IV. CONCLUSION

Based on the results of research and data analysis on student misconceptions and the causes of their occurrence in parabolic motion material at MAN Padang City, the overall average percentage of misconceptions that occur is 26.4%. There are 3 MANs in Padang City, student misconceptions that occur in MAN 1 amounted to 27.6%, MAN 2 experienced misconceptions of 26.9%. and MAN 3 with misconceptions of 25.0%. The highest misconceptions occurred in MAN 1 Padang City. From the analysis of the causes of student misconceptions in parabolic motion material, the main cause of misconceptions is students' personal thinking.

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