CHAPTER III
METHODOLOGY

The methodology chapter provides a detailed approach to collecting and analyzing data. It outlines the research design, population and sample, research instrument, procedure, and data analysis.

3.1 Research Design

Many samples are needed to determine student misconceptions about force and motion using a four-tier diagnostic test. Therefore, this research uses a survey design, specifically a cross-sectional one (Cresswell, 2012). The survey method takes a population sample by collecting information through surveys or interviews, designing data-collecting equipment, getting many responses, and measuring attitudes, beliefs, opinions, or practices. (Cresswell, 2012).

3.2 Population and Sample

This research assessed 174 secondary school students in 8^{th} grade who have studied force and motion in two public schools (SMPN "X" Bandung and SMPN "Y" Padalarang). The sample used convenience sampling. Convenience sampling is when a selected group of people who are (conveniently) available for research are included in the study sample (Fraenkel et al., 2017). This research approach assesses the students' willingness by asking them to complete tasks related to the force and motion topics they have learned. The duration of their learning of these topics to the take data is within the same semester.

3.3 Research instrument

In this research, an instrument is necessary to gain data. A multiple-choice question instrument was used in this research. This research instrument was developed and constructed from a preliminary study of test items. The test items have one correct answer with three Tier 1 and Tier 3 distractors. Also, the confidence level in Tier 2 and Tier 4 is two options: "Sure" and "Not Sure". The test items in the force and motion topic are divided into several concepts of friction, gravitation, Newton's law, pressure, vectors, and displacement.

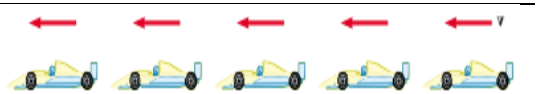
3.3.1 Preliminary Study

The preliminary study was the initial stage of this research. Data from the preliminary study was used to verify the validity and reliability of the questionnaire

items before conducting the actual study (Suziana, 2019). In this research, the preliminary study assessed 39 students who learned about force and motion in secondary school. The preliminary study used open-ended questions from 14 questions in two-level form without confidence, referring to 7 concepts. This preliminary study assessed the students' prior understanding of force and motion. Table 3.1 shows the preliminary study test items.

Table 3.1 Preliminary study test items

Instrument Test			
No	**Concept**	**Tier**	**Test Item**
1	Friction force	1	Two people want to move the box by pushing it. Person A moves the box on a rough surface, while Person B moves the box on a slippery surface. Which person will move the box quickly?
		3	What is your reason?
2	Friction force	1	A student erases pencil writing using a rubber eraser. Such rubber erasers become small after prolonged use. What caused the eraser to be small?
		3	What is your reason?
3	Newton law	1	There is a phenomenon where a man drives a car at high speed. Suddenly, he brakes the car because he will crash another car in front of him. What is the body position of the man who drives the car?
		3	What is your reason?
4	Newton law	1	If someone pushes us hard, our bodies move forward, but our body position is leaning backward. What influences the body is leaning backward?
		3	What is your reason?
5	Acceleration	1	Four trucks drive from the mountain. The mass of truck A is 1500 kg, truck B is 2000 kg, truck C is 1000 kg, and truck D is 1700 kg. Which of the trucks gives more effort on the brake?
		3	What is your reason?

Instrument Test			
No	**Concept**	**Tier**	**Test Item**
6	Acceleration	1	There are two cars on the road. Car A has a speed of 20 km/h, and car B has a speed of 80 km/h. Both cars crash the tree. Which car would get more damage?
		3	What is your reason?
7	Displacement	1	The car moves with the velocity 30 km/h constant. What is the phenomenon if the velocity increases?
		3	What is your reason?
8	Displacement	1	The picture shows the cars moving at the same speed. Does the car have a vector value if the car is moving? 
		3	What is your reason?
9	Vector	1	The person wants to jump from the airplane by using the parachute. After landing, the person is safe despite jumping from a high position. What is the cause of the person that makes he has a safe landing?
		3	What is your reason?
10	Vector	1	The helicopter with a huge mass wants to fly up. The helicopter could fly against gravity, even though its mass is huge. What force makes the helicopter fly?
		3	What is your reason?
11	Speed	1	There are sedan cars and buses. The sedan car is faster than the bus. What makes the sedan car move faster than the bus, besides the engine size?

Instrument Test			
No	**Concept**	**Tier**	**Test Item**
		3	What is your reason?
12	Speed	1	The man playing flyboard in the picture Why did the man not fall because of gravity? 
		3	What is your reason?
13	Gravity force	1	We throw a stone into the air and the stone goes back to the ground. How is the speed of a stone if a stone goes up and the speed of a stone if a stone goes down?
		3	What is your reason?
14	Gravity force	1	Which faster do we release the 50 kg of stone on the earth or 50 kg of paper in the moon?
		3	What is your reason?

After the preliminary study, the researcher divided the test items into 28. The various answers from the students in the preliminary study become the options for the 28 test items. The results of the preliminary study are provided in Appendix A.1.

The researcher added the correct answer if there were no correct answers in the test items. The code is students' answers collected from preliminary data and grouped with the same meaning. Analyzing the options with a code means that choices come from the students' answers to open-ended questions in the preliminary study and grouping the answers with the same meaning. After that, the result of the preliminary study is developed into

Each concept has 4 test items with the same amount of multiple choices. Analyzing the option with a code means that choices come from the students' answers to open-ended questions in the preliminary study. After developing 28 test items, this research was conducted on validity and reliability. The developed test items from 7 concepts of force and motion topics are shown in Table 3.2.

Table 3.2 Test Items in Pilot Study

No	Concept	Tier	Test items
1	Friction force	1	Two people want to move the box by pushing it. Person A moves the box on a rough surface. Meanwhile, person B moves the box on a slippery surface. Which person will easily move the box? A. Person A 1.T1.1 B. Person B 1.T1.2 C. Both D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Smaller friction Force 1.T3.1 B. Easy to drive 1.T3.2 C. No reason 1.T3.3 D. Because of the difference in Force
		4	Are you sure? A. Yes B. Not
2	Friction force	1	Children in the park want to play slides. However, the slide did not slide perfectly. The workers gave oil to the slide. What will happen to the slide after applying oil? A. The slide will be no different B. The slide will slide worse C. The slide will slide better D. Not enough information

No	Concept	Tier	Test items
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Oil does not affect frictional forces B. Oil makes the friction force greater C. Oil makes the friction force smaller D. Oil makes the frictional force disappear
		4	Are you sure? A. Yes B. Not
3	Friction force	1	A student erases pencil writing using a rubber eraser. Such rubber erasers become small after prolonged use. What caused the eraser to be small? A. Long service life 2.T1.3 B. Rough deleted objects 2.T1.2 C. Great frictional force 2.T1.1 D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Large frictional forces erode an object for a long time B. Long service life reduces the mass of the eraser C. The occurrence of Newton's law 3 on rubber erasers and rough objects D. Pressure on a large rubber eraser against an object

No	Concept	Tier	Test items
		4	Are you sure? A. Yes B. Not
4	Friction force	1	When we are in the parking building. There are road carvings when we are going up or down. What would happen if there were no road carvings on the parking building? A. The speed of the vehicle will increase B. The vehicle will derail C. The speed of the vehicle will decrease D. The vehicle will not derail
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Road carving will reduce the friction force between the tire and the road, so the vehicle will slip B. The carving of the road will reduce speed because the ground is uneven C. Road carving will increase the friction force between the tire and the road, so that the vehicle will not slip D. Engraving will increase speed because it increases the frictional force between the ground and the tire
		4	Are you sure? A. Yes B. Not
5	Newton law	1	There is a phenomenon when men drive cars at high speed. Suddenly, he braked the car because he was about to hit another car in front. What is the position of the driver's body when braking his car? A. Lean forward 5.T1.1 B. Fall forward

No	Concept	Tier	Test items
			C. Stay behind 5.T1.2 D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Due to the existence of Newton's law 1 5.T3.1 B. Due to the force of gravity that attracts the person 5.T3.2 C. Due to the existence of Newton's law III D. Because the force of gravity is centered on the man
		4	Are you sure? A. Yes B. Not
6	Newton law	1	Two rhinos are pushing each other. The first rhino has a heavier mass than the second rhino. What will happen to the two rhinos? A. Rhino A failed to push Rhino B B. Rhino B successfully pushed Rhino A C. Rhino A successfully pushed Rhino B D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The force in rhino A is greater than the force in rhino B B. The force in rhino B is greater than the force in rhino B C. The force in rhino A is the same as the force in rhino B

No	Concept	Tier	Test items
			D. Not enough information
		4	Are you sure? A. Yes B. Not
7	Newton law	1	If someone pushes us hard, the position of our body is like maintaining its original position. What influences our body in maintaining its original position? A. Newton's Law 1 7.T1.1 B. The force that rests on the feet C. Resisting legs 7.T1.2 D. Balanced gravitational force
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Resultant force close to zero 7.T3.1 B. Newton's law stating force equals zero 7.T3.2 C. Body holding position 7.T3.3 D. Greater resultant force
		4	Are you sure? A. Yes B. Not
8	Newton law	1	A worker pushes two tables. Table A has a mass of 7 kg, table B has a mass of 12 kg. Which table will workers be slower pushing? A. Table B B. Table A C. Both

No	Concept	Tier	Test items
			D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Acceleration is inversely proportional to mass B. Acceleration is directly proportional to mass C. The Force owned has a value of 0 D. Acceleration has no relation to mass
		4	Are you sure? A. Yes B. Not
9	Motion	1	There are four trucks driving from the mountain. The mass of truck A is 1500 kg, truck B is 2000 kg, truck C is 1000 kg and truck D is 1700 kg. Which of the trucks uses the brakes more? A. Truck B 9.T1.1 B. Truck C 9.T1.2 C. Truck D 9.T1.3 D. Truck A
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The small mass has a high velocity of 9.T3.2 B. Mass is directly proportional to the kinetic momentum of 9.T3.3 C. Large mass requires high friction force 9.T3.4 D. Weight affects the force of gravity 9.T3.1

No	Concept	Tier	Test items
		4	Are you sure? A. Yes B. Not
10	Motion	1	Rockets are capable of flying into space despite the force of gravity on earth. What makes the rocket capable of flying into space? A. Reduced gravitational force B. Large lifting force C. Small air resistance D. The force of gravity has a value of 0
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The lifting force is greater than the gravitational force B. Air resistance affects speed C. In air it has no gravitational force D. The force of gravity is inversely proportional to speed
		4	Are you sure? A. Yes B. Not
11	Motion	1	There are two cars on the road. Car A at a speed of 20 km/h and car B at a speed of 80 km/h. Which car gets more damage when colliding with a stationary object? A. Car A 11.T1.1 B. Car B 11.T1.2 C. Both D. Not enough information

No	Concept	Tier	Test items
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. High kinetic energy affects damage 11.T3.1 B. Due to the occurrence of Newton's law 3 action = reaction C. The potential energy in the car is affected by speed D. Big trees have Newton's law 1
		4	Are you sure? A. Yes B. Not
12	Motion	1	A man wants to move a box. There were four places he passed. Flat, uphill, bumpy, and downhill areas. Which place can the man easily push the box? A. Flat area 3.T1.1 B. Declining area 3.T1.2 C. Undulating areas D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Smaller friction force 3.T3.1 B. Greater frictional force C. Unidirectional gravitational force 3.T3.2 D. Opposite gravitational force

No	Concept	Tier	Test items
		4	Are you sure? A. Yes B. Not
13	Resultant	1	The car moves at a constant speed of 30 km/h. What is the phenomenon's name if the car's speed increases? A. Acceleration 13.T1.1 B. Speed 13.T1.2 C. Regular straight motion 13.T1.3 D. Accelerated regular straight motion 13.T1.4
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Speed increases and changes on the car 13.T3.2 B. Straight motion with increased speed 13.T3.3 C. Due to displacement in the vehicle 13.T3.1 D. Not enough information
		4	Are you sure? A. Yes B. Not
14	Resultant	1	A car is seen changing places several times until finally, the car stops at its original place. What is the vector value of the car? A. Vector = 1 B. Vector = 0 C. Vector = -1 D. Not enough information

No	Concept	Tier	Test items
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Vector indicates the movement of an object B. The vector must have a clear direction C. The vector indicates the value of the beginning and end distance of the object D. Vector shows the speed of an object
		4	Are you sure? A. Yes B. Not
15	Resultant	1	 The image shows the car moving at the same speed. Does the car have a vector value after moving? A. Yes 15.T1.1 B. No 15.T1.2 C. Constant vector value D. Not enough information
		2	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
		3	What is your reason? Give a brief explanation of your previous answer! A. Vector value decreases when the car moves 15.T3.2 B. The vector value indicates the direction the car is moving 15.T3.1 C. Object moved using the same vector 15.T3.3 D. The vector value will not change because the object is the same
		4	Are you sure? A. Yes B. Not
16	resultant	1	Two balls move down from the top of the road to the bottom. Ball B reaches down the road first than ball A. What is the vector value of the two spheres? A. Ball A > Ball B B. Ball A < Ball B C. Ball A = Ball B D. Not enough information
		2	What is your reason? A. Yes B. Not
		3	What is your reason? A. The vector value indicates the speed of the object B. The vector value indicates the displacement of the object C. The value of the vector has an effect on the weight of the object D. Vector values have an effect on time
		4	What is your reason? A. Yes B. Not

No	Concept	Tier	Test items
17	Force	1	Someone jumped from the plane using a parachute. After landing, is the person safe even if jumping from a high position using a parachute? A. Small potential Force 17.T1.2 B. Small gravitational force 17.T1.3 C. Presence of air resistance 17.T1.1 D. Small kinetic force
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Parachute makes friction in the air greater 17.T3.3 B. Potential energy that turns into low kinetic energy 17.T3.2 C. Lower force of gravity in air 17.T3.1 D. Parachute causes air pressure in air 17.T3.4
		4	Are you sure? A. Yes B. Not
18	Force	1	Someone threw two bags from the same height. Bag A weighs 5 kg and bag B weighs 14 kg. Which bag reaches the ground first? A. Bag A first reaches the ground B. Bag B first reaches the ground C. Both bags A and B reach the ground at the same time D. Not enough information
		2	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
		3	What is your reason? A. The falling motion of an object is influenced by the shape and size of the bag B. The motion of falling objects to the surface of the earth is influenced by the weight of objects C. The falling motion of an object is influenced by great potential energi D. The falling motion of an object is influenced by the rising force of a large object
		4	Are you sure? A. Yes B. Not
19	Force	1	Helicopters with large masses want to fly upwards. Helicopters can fly against gravity. Although, the mass of the helicopter is huge. What force influenced the helicopter to fly? A. Regular straight Force B. Newton's Law 2 19.T1.3 C. Lifting force 19.T1.1 D. Regular changing straight Force 19.T1.2
		2	Are you sure? A. Yes B. Not
		3	Are you sure? A. Lift force greater than gravity 19.T3.3 B. Negligible gravitational force due to propeller speed 19.T3.4 C. Lifting force that compensates for the force of gravity 19.T3.2 D. The mass of a helicopter is overcome by the velocity of the movement of rotating rotor blades 19.T3.1
		4	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
20	Force	1	A child opens a glass packaging using a straw with a large and small cross-sectional area. Which straw is able to open the glass packaging? A. Small straws are capable of opening packaged glasses, but large straws are not B. Small and large straws are capable of opening the glass of the packaging C. Large straws are capable of opening packaged glasses, but small straws are not D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Pressure on straws is large when the cross-sectional area is large B. Pressure on straws is large when cross-sectional area is small C. Pressure on straws is large when the cross-sectional area is large D. Pressure on straws is small when cross-sectional area is small
		4	Are you sure? A. Yes B. Not
21	Displacement	1	Sedan cars are faster than trucks. What makes a sedan car move faster than a truck other than engine size (cc)? A. Mass 21.T1.1 B. Size 21.T1.2 C. Car Shape 21.T1.3 D. Fuel type
		2	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
		3	What is your reason? A. Mass affecting speed 21.T3.1 B. Large frictional forces on vehicles 21.T3.2 C. Wind movement affects friction force 21.T3.3 D. Fuels that affect engine performance
		4	Are you sure? A. Yes B. Not
22	Displacement	1	A child threw two stones of different masses. Stone A has a mass of 4 kg and rock B has a mass of 9 kg. What is the distance between the two stones when thrown? A. Stone A has a greater distance than stone B B. Stone A has a closer distance than stone B C. Stone A has the same distance as stone B Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The energy required is large when with a large mass B. The energy required is large if it is with a small mass C. The energy required is small when with a large mass D. The energy required is small if it has a small mass
		4	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
23	Displacement	1	The man playing the flyboard as in the picture  Why didn't the man fall? A. Balanced lifting force with gravitational force 23.T1.3 B. Lifting force greater than gravity 23.T1.2 C. Lift force smaller than gravity D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The lifting force of water pressure is greater than the gravitational force of 23.T3.1 B. A small gravitational force occurs from the water C. A balanced force can make the force of gravity = 0 D. The lifting force does not affect the force of gravity
		4	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
24	Displacement	1	Someone and the tire push a tire can stop by itself. What caused the sump to stop? A. Constant force of gravity B. Large tire mass C. Frictional force with the ground D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. Frictional forces with the ground can reduce speed B. The center of gravity on the tire reduces speed C. The presence of a regular straight force that is not constant D. The center of mass on the tire reduces the speed force on the tire
		4	Are you sure? A. Yes B. Not
25	Gravity force	1	We throw the stone up and the stone back down. What about the speed of the stone when the stone is upward and the speed of the stone when the stone is downward? A. The speed of the stone decreases when it rises, and the speed increases when it falls below 25.T1.1 B. The speed of the stone will be constant upwards and increase as it goes down 25.T1.2 C. The speed of the stone will increase when it is upward and constant when it is downward 25.T1.3 D. The speed of the stone will be faster when upward than downward 25.T1.4
		2	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
		3	What is your reason? A. Because there is a regular changing straight motion that affects the stone 25.T3.1 B. The mass of the stone thrown down is heavier than the top 25.T3.2 C. Because the air pressure is greater than in the ground 25.T3.3 D. Due to the presence of a gravitational force opposite to the direction of the rock 25.T3.4
		4	Are you sure? A. Yes B. Not
26	Gravity force	1	There were two mobile phones that fell from a height. Mobile phone A dropped from a height of 5 meters and mobile phone B fell from a height of 10 meters. What is the condition of the two mobile phones? A. Mobile phone A is more damaged than mobile phone B B. Mobile phone B is more damaged than mobile phone A C. Both phones have the same condition D. Not enough information
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The potential energy in mobile phone A is greater than that of mobile phone B B. The potential energy in mobile phone B is greater than that of mobile phone A C. The kinetic energy of mobile phone A is greater than that of mobile phone B D. The kinetic energy of mobile phone A is greater than that of mobile phone B
		4	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
27	Gravity force	1	If we release 50 kg of rock on Earth or 50 kg of paper on the moon, which gets to the bottom faster? A. Earth 27.T1.1 B. Both 27.T1.2 C. Neither: 27.T1.3 D. Moon
		2	Are you sure? A. Yes B. Not
		3	What is your reason? A. The mass of both equals 27.T3.3 B. The gravity on Earth is less than the gravity of the moon C. The Moon has no gravity 27.T3.2 D. The gravity on the moon is less than the gravity of the Earth 27.T3.1
		4	Are you sure? A. Yes B. Not
28	Gravity force	1	Someone wants to drop paper and stones. The person wanted to drop the paper faster than a stone of the same height. What should the person do? A. Increase the mass of stones B. Increase paper mass C. Reducing paper mass D. Not enough information
		2	Are you sure? A. Yes B. Not

No	Concept	Tier	Test items
		3	What is your reason? A. The mass of a body is inversely proportional to the kinetic energy B. The mass of an object is directly proportional to the kinetic energy C. The mass of an object is inversely proportional to potential energy D. The mass of an object is directly proportional to the potential energy
		4	Are you sure? A. Yes B. Not

After developing 28 test items from the preliminary study. The instrument needs to measure the validity and reliability. The validity test in this research was conducted on content validity by expert judgment and construct validity using SPSS. Thus, the instrument of this research is accurate based on the validity test and consistent based on the reliability test.

3.3.2 Validity

Validity is a study that determines how effective and relevant the instrument of the research is to addressing the aim of the study (Knapp & Mueller, 2010). According to Cronbach & Meehl (1955) validity has various types: validity, concurrent, content, and construct validity. However, this research uses content validity and construct validity.

Content validity is demonstrated by illustrating that the test items represent a sampling of the participants the researcher is hoping to explore (Cronbach & Meehl, 1955). The content validity of this research used Aiken's Test index. The Aiken's validity index uses raters or experts to examine the decision of the single items in terms of yes or no, agree or disagree, valid or invalid (Aiken, 1980). The Aiken Test formulation is shown below:

$$V = \sum S/[n(c-1)]$$

Note:

V = validity index (Valid, medium valid, invalid)

S = rater or the expert suggestion (agree/revise/rejected)

N = sum of the experts' judgment

C = sum of the rater

After the content validity measure, the value of the validity index is calculated by the equation, and the result of the validity index in interpreted as as summarized in Table 3.3.

Table 3.3 Aiken validity interpretation

Validity Index (V)	Interpretation
$0 \leq V \leq 0.4$	Invalid
$0.4 < V \leq 0.8$	Medium validity
$0.8 < V \leq 1$	Very valid

This research conducts the content validity of the instrument, which the expert judgment are three persons that expertise for the topics. The topics of this research are Force and Motion, therefore the instrument needs to be judged by the experts in the physics field. The experts for content validation are two physics lecturers and one science teacher. The procedure and details are attached in Appendix A.3 which shows the rater or the agreement of the three expert judgements. The result of the content validity of the Aiken Test is shown briefly in Table 3.4.

Table 3.4 Content Validity Aiken Result

Item	**Tier**	**Validity**	**Decision**
1	1	1.00	Valid
	3	0.67	Medium valid
2	1	1.00	Valid
	3	1.00	Valid
3	1	0.67	Medium valid
	3	1.00	Valid
4	1	1.00	Valid
	3	1.00	Valid
5	1	1.00	Valid
	3	1.00	Valid
6	1	1.00	Valid
	3	1.00	Valid
7	1	0.67	Medium valid
	3	0.67	Medium valid
8	1	1.00	Valid
	3	1.00	Valid

Item	Tier	Validity	Decision
9	1	1.00	Valid
	3	1.00	Valid
10	1	1.00	Valid
	3	1.00	Valid
11	1	1.00	Valid
	3	1.00	Valid
12	1	1.00	Valid
	3	1.00	Valid
13	1	1.00	Valid
	3	1.00	Valid
14	1	0.67	Medium valid
	3	0.33	Invalid
15	1	0.67	Medium valid
	3	0.67	Medium valid
16	1	0.67	Medium valid
	3	0.67	Medium valid
17	1	0.67	Medium valid
	3	1.00	Valid
18	1	1.00	Valid
	3	1.00	Valid
19	1	1.00	Valid
	3	1.00	Valid
20	1	1.00	Valid
	3	1.00	Valid
21	1	0.33	Invalid
	3	0.67	Medium valid
22	1	1.00	Valid
	3	1.00	Valid
23	1	1.00	Valid
	3	1.00	Valid
24	1	0.67	Medium valid

Item	Tier	Validity	Decision
25	3	0.67	Medium valid
	1	1.00	Valid
	3	0.67	Medium valid
26	1	1.00	Valid
	3	1.00	Valid
27	1	1.00	Valid
	3	1.00	Valid
28	1	0.67	Medium valid
	3	0.67	Medium valid
Average	1	0.88	Valid
	3	0.88	Valid

The average of the test items by using Aiken's Validity in Tier 1 and Tier 3 shows the same score. The score on average is included in very valid criteria. All test items are used for the construct validation, despite the test items having medium valid or rejected criteria in content validation. Those test items need to be revised as per the experts' suggestions.

Construct validity is always involved when a test is to be interpreted as a quality that has no "operational definition" (Cronbach & Meehl, 1956). The construct validity decision from the number of the Corrected Item Total Correlation that is higher than the r Table is then decided valid. Then, if the Corrected Item Total Correlation number is lower than the r Table, it is invalid (Sugiyono, 2011). This research analyzes the validation of the Tier 1 and Tier 3. The valid test items when Tier 1 and Tier 3 are both valid. If Tier 1 is valid and Tier 3 invalid, then the questions are revised for the invalid and reassessed tier. Then, if Tier 3 is valid in the second pilot test, the test item decision is valid in Tier 1 and Tier 3 and vice versa. Also, there are "Not Identify" categories means the answers of all students are correct or incorrect.

The First Pilot Test assessed 28 questions to 31 students about force and motion topic. Due to n=31, the r value at 5% significance is 0.355 see Appendix A.3. The test items after revisions based on suggesstion from experts is shown in the appendix A.2. Therefore, the result of first Pilot Test is show in Table 3.5 below.

Table 3.5 First Pilot Test

Item	Tier	r value	r Table	Decision
1	1	0.081	0.355	Invalid
	3	0.186	0.355	Invalid
2	1	Not identify	0.355	Invalid
	3	0.133	0.355	Invalid
3	1	0.144	0.355	Invalid
	3	0.216	0.355	Invalid
4	1	0.297	0.355	Invalid
	3	0.323	0.355	Invalid
5	1	0.451	0.355	**Valid**
	3	0.393	0.355	**Valid**
6	1	0.054	0.355	Invalid
	3	Not identify	0.355	Invalid
7	1	0.054	0.355	Invalid
	3	0.018	0.355	Invalid
8	1	0.265	0.355	Invalid
	3	0.331	0.355	Invalid
9	1	0.021	0.355	Invalid
	3	0.021	0.355	Invalid
10	1	0.119	0.355	Invalid
	3	0.373	0.355	**Valid**
11	1	Not identify	0.355	Invalid
	3	-0.045	0.355	Invalid
12	1	0.148	0.355	Invalid
	3	0.609	0.355	**Valid**
13	1	0.021	0.355	Invalid
	3	0.034	0.355	Invalid
14	1	0.147	0.355	Invalid
	3	0.509	0.355	**Valid**
15	1	0.226	0.355	Invalid
	3	0.041	0.355	Invalid

Item	Tier	r value	r Table	Decision
16	1	0.160	0.355	Invalid
	3	0.127	0.355	Invalid
17	1	-0.127	0.355	Invalid
	3	0.202	0.355	Invalid
18	1	0.090	0.355	Invalid
	3	-0.146	0.355	Invalid
19	1	0.563	0.355	**Valid**
	3	0.328	0.355	Invalid
20	1	0.286	0.355	Invalid
	3	0.221	0.355	Invalid
21	1	-0.107	0.355	Invalid
	3	-0.170	0.355	Invalid
22	1	0.367	0.355	**Valid**
	3	0.386	0.355	**Valid**
23	1	0.045	0.355	Invalid
	3	0.318	0.355	Invalid
24	1	0.143	0.355	Invalid
	3	0.143	0.355	Invalid
25	1	0.385	0.355	Invalid
	3	0.250	0.355	Invalid
26	1	0.483	0.355	**Valid**
	3	0.271	0.355	Invalid
27	1	-0.084	0.355	Invalid
	3	0.373	0.355	**Valid**
28	1	0.367	0.355	**Valid**
	3	0.292	0.355	Invalid

The validity questions of Tier 1 are the following question 5, question 19, question 22, question 26, and question 28. While, the result of validity in Tier 3 are question 5, question 10, question 12, question 14, question 22, and question 27. As the result of the first Pilot Test in Tier 1 and Tier 3, the validation results are question 5 and question 22.

Second Pilot Test, this research took out the validated questions of the Four-Tier Diagnostic Test. This research continues the Pilot Test for the rest of the questions. The validation assesses 44 students (n=44), then the r Table is 0.297. Table 3.7 shows the second Pilot Test in Tier 1.

Table 3.6 Second Pilot Test

Item	Tier	r value	r Table	Decision
1	1	-0.030	0.297	Invalid
	3	0.095	0.297	Invalid
2	1	0.402	0.297	**Valid**
	3	0.367	0.297	**Valid**
3	1	0.292	0.297	Invalid
	3	0.138	0.297	Invalid
4	1	0.018	0.297	Invalid
	3	-0.009	0.297	Invalid
5	**Already valid in a first pilot test**			
6	1	0.158	0.297	Invalid
	3	0.223	0.297	Invalid
7	1	0.022	0.297	Invalid
	3	-0.055	0.297	Invalid
8	1	Not identify	0.297	Invalid
	3	Not identify	0.297	Invalid
9	1	Not identify	0.297	Invalid
	3	Not identify	0.297	Invalid
10	1	-0.059	0.297	Invalid
	3	0.123	0.297	Invalid
11	1	Not identify	0.297	Invalid
	3	Not identify	0.297	Invalid
12	1	-0.021	0.297	Invalid
	3	-0.096	0.297	Invalid
13	1	Not identify	0.297	Invalid
	3	Not identify	0.297	Invalid

Item	Tier	r value	r Table	Decision
14	1	0.058	0.297	Invalid
	3	-0.009	0.297	Invalid
15	1	-0.140	0.297	Invalid
	3	-0.104	0.297	Invalid
16	1	Not identify	0.297	Invalid
	3	Not identify	0.297	Invalid
17	1	0.278	0.297	Invalid
	3	0.343	0.297	**Valid**
18	1	-0.068	0.297	Invalid
	3	-0.236	0.297	Invalid
19	1	0.278	0.297	Invalid
	3	0.369	0.297	**Valid**
20	1	0.533	0.297	**Valid**
	3	0.329	0.297	**Valid**
21	1	Not identify	0.297	Invalid
	3	Not identify	0.297	Invalid
22	**Already valid in a first pilot test**			
23	1	-0.126	0.297	Invalid
	3	0.079	0.297	Invalid
24	1	0.425	0.297	**Valid**
	3	0.166	0.297	Invalid
25	1	0.385	0.297	**Valid**
	3	0.026	0.297	Invalid
26	1	0.469	0.297	**Valid**
	3	0.370	0.297	**Valid**
27	1	0.539	0.297	**Valid**
	3	0.446	0.297	**Valid**
28	1	-0.156	0.297	Invalid
	3	0.009	0.297	Invalid

The results of the second pilot test are Tier 1 and Tier 3 are question 2,

question 20. question 26, and question 27 in pairs. However, there is question 19 which is valid in Tier 1 in the first pilot test, then valid in Tier 3 in the second pilot test. Therefore. after two times of Pilot Tests, it has 6 questions in total, but the 6 questions were not properly for assessing the conceptions because there are concepts that are not valid yet. Then, the validation conducted a third Pilot Test that assessed 48 students (n=48), so the r Table is 0.284. The third Pilot Test First Tier is shown in Table 3.7.

Table 3.7 Third Pilot Test

Item	Tier	r value	r Table	Decision
1	1	Not identify	0.284	Invalid
	3	Not identify	0.284	Invalid
2	**Already valid in a second pilot test**			
3	1	0.393	0.284	**Valid**
	3	0.188	0.284	Invalid
4	1	0.397	0.284	**Valid**
	3	0.511	0.284	**Valid**
5	**Already valid in a first pilot test**			
6	1	0.207	0.284	Invalid
	3	0.181	0.284	Invalid
7	1	0.358	0.284	**Valid**
	3	0.426	0.284	**Valid**
8	1	0.507	0.284	**Valid**
	3	0.380	0.284	**Valid**
9	1	0.343	0.284	**Valid**
	3	0.462	0.284	**Valid**
10	1	0.449	0.284	**Valid**
	3	0.371	0.284	**Valid**
11	1	0.168	0.284	Invalid
	3	0.257	0.284	Invalid
12	1	0.041	0.284	Invalid

Item	Tier	r value	r Table	Decision
	3	0.303	0.284	**Valid**
13	1	0.116	0.284	Invalid
	3	0.141	0.284	Invalid
14	1	0.450	0.284	**Valid**
	3	0.365	0.284	**Valid**
15	1	0.293	0.284	**Valid**
	3	0.311	0.284	**Valid**
16	1	0.444	0.284	**Valid**
	3	0.290	0.284	**Valid**
17	1	0.133	0.284	Invalid
	3	0.420	0.284	**Valid**
18	1	0.189	0.284	Invalid
	3	0.543	0.284	**Valid**
19	1	Not identify	0.284	Invalid
	3	Not identify	0.284	Invalid
20	**Already valid in a second pilot test**			
21	1	0.050	0.284	Invalid
	3	0.196	0.284	Invalid
22	**Already valid in a first pilot test**			
23	1	0.158	0.284	Invalid
	3	0.336	0.284	Invalid
24	1	0.496	0.284	**Valid**
	3	0.228	0.284	Invalid
25	1	0.265	0.284	**Valid**
	3	0.475	0.284	Invalid
26	**Already valid in a second pilot test**			
27	**Already valid in a second pilot test**			

Item	Tier	r value	r Table	Decision
28	1	0.071	0.284	Invalid
	3	0.353	0.284	Invalid

The result of the third pilot test shows the valid test items in question 4, question 7, question 8, question 9, question 10. question 14, question 15, and question 16 that have valid decisions in pairs. There are test items that become valid because of the Tier is valid and pairs with the previous pilot test. Question 25 is valid in Tier 1 in second pilot test and valid in Tier 3 in third pilot test. While, question 28 is valid in Tier 1 in first pilot test and valid in Tier 3 in third pilot test Therefore, the test item that become an instrument for this research are question 2, question 4, question 5, question 7, question 8, question 9, question 10. question 14, question 15, question 16, question 19, question 20. question 22, question 25, question 26, question 27, and question 28 as the valid instrument of Four-Tier Diagnostic Test in Force and Motion Topics.

3.3.3 Reliability

A measuring device's reliability is determined by how much it can be depended upon or trusted (Cronbach & Meehl, 1956). Reliability can be used to ascertain the measuring instrument's consistency, or whether the instrument stays consistent when the measurement is repeated. When measurements are consistent even after numerous repetitions, a measuring tool is considered dependable. The instrument reliability was determined using Cronbach's Alpha test with the following equation:

$$r_{11} = \frac{k}{k-1}\left(1 - \frac{\Sigma {\sigma_b}^2}{{\sigma_t}^2}\right)$$

Note:

r_{11} = reliability coefficient of the developed instrument;

k = the total number of questions;

$\Sigma \sigma b^2$ = the sum of variant in each question;

Σt^2 = the total variance.

The reliability index result is shown on Cronbach's Alpha number. Cronbach's alpha is a measure of reliability that compares the amount of shared

variance, or covariance, between the items that make up an instrument with the amount of total variance (Collins, 2007). Guilford (1956) developed a way to interpret the reliability coefficient or reliability index obtained as summarized in Table 3.8.

Table 3.8 The Categories of Reliability Index

Reliability index (r)	Criteria
0.80 – 1.00	Very High
0.60 – 0.79	High
0.40 – 0.59	Moderate
0.20 – 0.39	Low
-1.00 – 0.19	Very Low

The result of the reliability test in this research followed by the questions in Tier 1 and Tier 3. Also, the reliability test was conducted three times the same as the test items' validity. The reliability index of Tier 1 and Tier 3 in pilot tests is shown in Table 3.9.

Table 3.9 The Reliability Result in the First Pilot Test

Test	Tier	N of Item	Cronbach's Alpha
I	1	28	0.518
	3	28	0.450
II	1	26	0.702
	3	26	0.710
III	1	22	0.721
	3	22	0.779

As this research analyzes the reliability index, it appears that Cronbach's Alpha value shows that Tier 1 is 0.518 and Tier 3 is 0.450. If the result categorizes these values in Table 3.11, it shows that Tier 1 and Tier 3 are categorized as moderate. After second pilot test conducted, it shows the Cronbach's Alpha value in Tier 1 and Tier 3. The value of the reliability index in Tier 1 is 0.702 and Tier 3 is 0.780 mean both of the reliability index categorized as high reliability test items. In this third pilot test, the result of the reliability index shows a high category. The

Cronbach's Alpha in Tier 1 is 0.721 and in Tier 3 is 0.775, mean the categorize is higher than first and second pilot test. The reliability also influences the validity of the test items. If the reliability shows high categorize, then the validity of the test items is a lot and vice versa.

3.3.4 Sample Test Item for Research Data Collection

Testing students' understanding of force and motion topic material, the question consists of Tier 1 to Tier 4 by using 17 test items that are valid and reliable. The complete test items are shown in Appendix B.1 and Table 3.10 shows the sample in one of all the test items that assess students.

Table 3.10 Sample test item

Tier	Question
1	A man drives his car at high speed. Suddenly, he brakes because he was about to hit another car in front. What is the position of the driver's body when braking his car? A. Leaning forward into the steering wheel B. Falling forward into the steering wheel C. Steady behind the steering wheel D. Not enough information
2	Are you sure about your answer? A. Sure B. Not sure
3	What option best matches your reasoning? A. Due to inertia B. Due to the attractive force of gravity C. Due to Newton's third law D. Due to the force of gravity being centered on the man
4	Are you sure about your answer? A. Sure B. Not sure

3.4 Research Procedure

1. Preparation stage

To prepare for the research, the researcher finds the research gap to find the novelty from previous research. After that, The research problem and research

questions is identified as the findings. Also, the research need to formulate the objectives and benefits of the research and analyze the literature review of students' misconception, four-tier diagnostic test, and force and motion topic in secondary school.

Before assessing students, 14 test item in 7 topics construct as preliminary data. The preliminary study questions in the essay questions consist of the first tier such as the questions of topics and third tier is the reason of their first tier. The preliminary data assesses 30 students as the minimum participant.

After assessing 30 students the result is analyzed by assigning a code to student answers with the same meaning. This student answers create the multiple choice options of the research in assessing the conceptions of the students. Before assessing students, the questions need to judged by the experts. The experts consist of two lecturers which professional in the topics and one science teacher which has teach the students in one topic.

2. Implementation stage

The instrument distributed to 100 students in secondary school level which has study about force and motion topic and collecting the data to determine the conception of the students and determine the concept of force and motion topic which most misconception of students.

3. Completion stage

After assessing at least 100 students with validated test items, the next stage is analyzing the data to complete the research. Then, determining each student whether the students have no conception, misconception, partially understand, or understand the concept would be classified in discussion and determining the concept of force and motion topic which have a lot of misconceptions among students.

The result of assessing students conception in force and motion topic interpret in the results and discussion. The research questions in this research is discussed in the conclusion. Besides answering research questions in the conclusion, the researcher gives suggestions and implications for-future research about students conceptions. The pattern of this research is show in Figure 3.2.

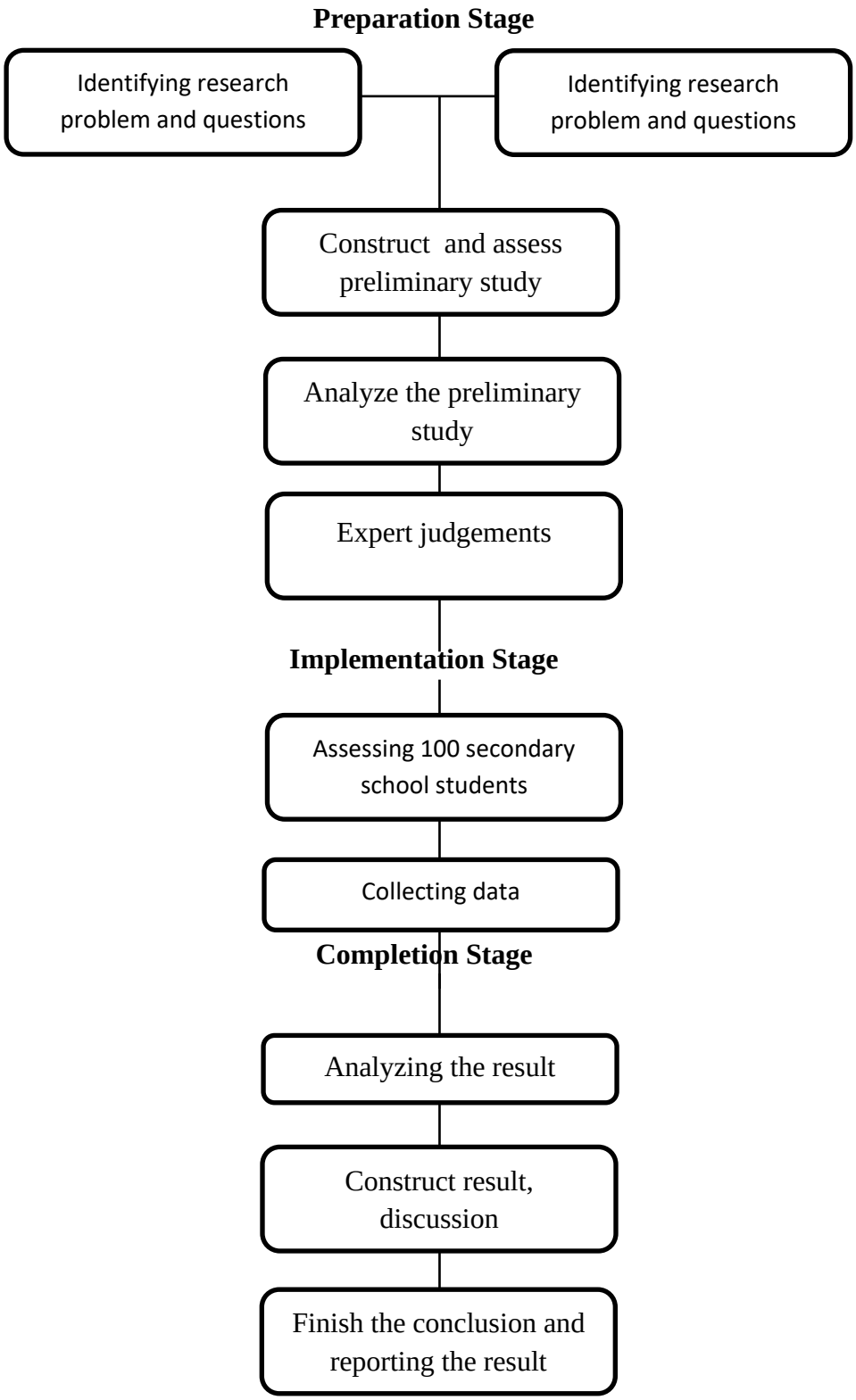


Figure 3.1 Pattern of Research

3.5 Data Analysis

To assess the validity of the content in terms of material aspects and construction aspects, such as the adherence between test questions and indicators, as well as language and cultural aspects, data collection is done using non-test techniques. These techniques include the examination of test instruments by material experts and evaluation experts (expert judgment) (Negoro & Karina, 2019).

Data analysis determines the conceptions of the students. The conceptions are Scientific Knowledge (SK), False Positive (FP), False Negative (FN), Misconception (M), and Lack of Knowledge (LK). Specific answers will result in various concept decisions, so the data can be analyzed easily. Table 3.11 illustrates the choices that can be made depending on this four-tier diagnostic test by (Kiray & Simsek, 2021).

Table 3.11 Comparison of Decisions of Four-Tier Test

Tier 1	Tier 2	Tier 3	Tier 4	Decision of four-tier test
True	Confident	True	Confident	SK
True	Confident	False	Confident	FP
False	Confident	True	Confident	FN
False	Confident	False	Confident	M
True	Confident	True	Not confident	LK 1
True	Not confident	True	Confident	LK 2
True	Not confident	True	Not confident	LK 3
True	Confident	False	Not confident	LK 4
True	Not confident	False	Confident	LK 5
True	Not confident	False	Not confident	LK 6
False	Confident	True	Not confident	LK 7
False	Not confident	True	Confident	LK 8
False	Not confident	True	Not confident	LK 9
False	Confident	False	Not confident	LK 10
False	Not confident	False	Confident	LK 11
False	Not confident	False	Not confident	LK 12

SK: Scientific knowledge; LK: Lack of knowledge; M: Misconception; FN: False negative; FP: False positive.

Student responses can be coded based on a four-tier diagnostic test to simplify the answers. The code would follow the conception.in Table 3.11 The correct answer in each tier is giving code "1" and incorrect answer is giving code "0" and the code is in order (Tier 1 – Tier 2 – Tier 3 – Tier 4). The coding system is following below:

1. Scientific Knowledge (SK): Tier 1 and Tier 3 are correct and confident in Tier 2 and Tier 4. Then, the code for SK is (1-1-1-1)
2. False Positive (FP): Both of confident in Tier 2 and 4 answer correctly in Tier 1, but the incorrect answer is Tier 3. Then the code for FP is (1-1-0-1)
3. False Negative (FN): Both of confident in Tier 2 and 4 answer correctly in Tier 3, but the incorrect answer is Tier 1. Then the code for FN is (0-1-1-1)
4. Misconception (M): The answer in Tier 1 and Tier 3 is incorrect and confident answer in Tier 2 and Tier 4. Then the code for M is (0-1-0-1)
5. Lack of Knowledge (LK): The answers of the students that's not fit into previous code and it categorize into lack of knowledge

By using this type of code system, this research could simplify to analyze the presence of the students' conception. This enables a more thorough and nuanced examination of the data, identifying misconceptions patterns and places in which students' comprehension of the force and motion issue may require extra assistance and intervention.

In the first stage of data processing, the concepts of the students were classified according to their conception. The percentages for every category were then calculated. A simple method was used to accomplish this computation, which involved calculating the percentage of each category based on the outcomes of that category. The particular formula that was applied in these computations is as follows:

$$P = \frac{S}{N} \times 100\%$$

Note:

P = Percentage of category

S = Number of the student in each group

N = Total of students

For example, the result shows students' conception of Scientific Knowledge (SK) is 10 students, 40 students had False Positive (FP), 20 students had False Negative (FN), 15 students had misconception (M), and 15 students had Lack of Knowledge (LK). Therefore, the calculation into the percentage of 10% for Scientific Knowledge, 40% for False Positive, 20% for False Negative, 15% for Misconception, and 15% for Lack of Knowledge. Based on the way they answered the four-tier diagnostic test, the students' concepts in each area are distributed according to these percentages. The researchers can proceed with additional analysis and interpretation of the data after calculating the percentages of misconceptions in each question. In order to successfully address these misconceptions, future teaching tactics or interventions may be guided by the identification of the particular concepts or themes that are causing the most misconceptions among students, as a result of this study.