CHAPTER III

RESEARCH METHODOLOGY

3.1 Research Method

The study employed a quantitative research method, which focuses on collecting structured data that can be represented numerically. The data gathered from questionnaires and interviews is then subjected to statistical analysis to describe the responses to the research questions, gathering data from a large number of participants using pre-programmed instruments with standardized questions and response options (Creswell, 2012). Creswell (2014) further highlights that quantitative research aims to test objective theories by examining the relationships between variables. These variables are measurable and can be assessed using instruments, enabling statistical analysis of numerical data. The research process follows a predetermined structure for the final written report, typically including sections such as the introduction, literature review and theoretical framework, research methods, results, and discussion. By employing a descriptive quantitative research approach, the study sought to provide a detailed account and analysis of the numerical data collected, allowing for an objective examination of the research question or hypothesis under investigation.

The type of survey design employed in this research is the cross-sectional research design. In cross-sectional research, data is collected at a single point in time, even though the data collection process may take place over a day, several weeks, or an extended period (Wallen & Fraenkel, 2013). Cross-sectional research is particularly useful for assessing and understanding programs and situations at a specific moment in time. It provides decision-makers with valuable data to evaluate the effectiveness of educational programs and estimate the community's educational service needs (Creswell, 2012). By utilizing the cross-sectional research design in this study, the researcher aims to gather data from 8th-grade students at a specific moment to assess their understanding of mechanical and light wave topics. This approach allows for a snapshot view of students' knowledge and misconceptions, providing valuable insights for educational improvement and intervention strategies. The data collected through this cross-sectional design will offer a comprehensive picture of students' conceptual understanding and help inform decision-making processes in physics education.

3.2 Participant

The study is conducted at a Junior High School in Bandung City, West Java, with a specific focus on 8th-grade students who have been taught about mechanical and light waves topics. As depicted in Appendix A.1, the population of interest consists of 117 students. The research is conducted in Indonesian language based on the regulations and language policies of the participating schools. The choice of language is be determined to ensure compliance with school guidelines and to facilitate effective communication with the students during the data collection process. The research being conducted in this scenario utilizes convenience sampling as the sampling technique. Convenience sampling involves selecting participants based on their convenience and availability. Convenience sampling is a non-probability sampling method often employed when researchers need to quickly and easily access a sample. Participants are chosen based on their accessibility and willingness to participate in the study, making it a convenient approach for data collection. Nevertheless, convenience sampling remains a practical and commonly used sampling technique in various research fields, including social sciences, education, and psychology. (Creswell 2012).

3.3 Research Instrument

In this research, an essential instrument is used to collect data from the participants and diagnose students' conceptions levels and misconceptions. The instrument utilized for this purpose is a four-tier diagnostic test, the four-tier diagnostic test comprises 30 questions, which underwent a thorough validation phase. This process involved meticulous evaluation of question clarity, relevance, and suitability in identifying students' conceptions and misconceptions. Following validation, 14 questions were chosen, as indicated in Appendix A.2, to form the definitive set of questions for the actual test to be administered to the students. Table

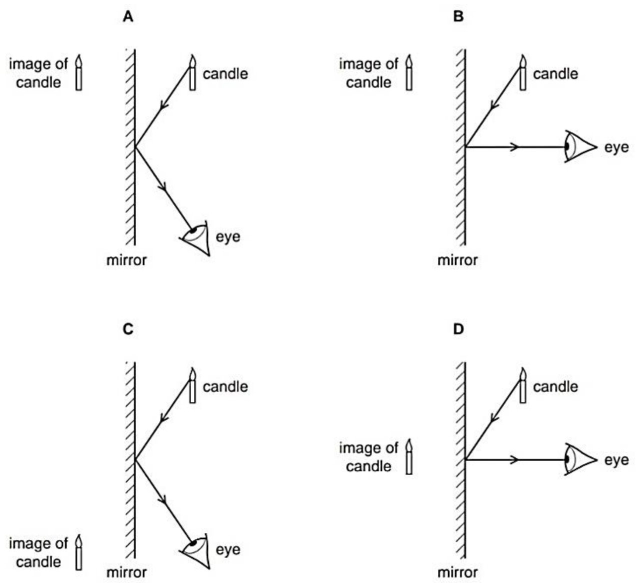
3.1 presents the concept of questions included in the four-tier diagnostic test. This table provides an overview of the topics and concepts covered by the selected questions, enabling researchers to understand the scope and focus of the diagnostic test. By using the four-tier diagnostic test as the instrument, this research aims to assess and diagnose the students' understanding and misconceptions related to the mechanical and light wave topics. The data collected through this instrument will serve as a valuable resource for analyzing students' conceptual understanding and identifying areas that require further attention in physics education.

Table 3.1 Concepts of question distribution

Sub-Concept	Concept	Question
Wave Properties	Vibration and propagation	2
	Frequency, period, wavelength	3
	Transversal and longitudinal wave	4, 5, 14
	Relation of amplitude and wavelength	9
	Wavefront	10
Wave Behavior	Application of dispersion of light	1
	Diffraction of light	6, 7, 13
	Reflection of light on daily life	8, 11, 12

The concepts presented to the students have been taught to them as part of their learning curriculum. The questions included in the four-tier diagnostic test are carefully designed to evaluate the students' understanding of these concepts, as well as to identify potential misconceptions. By incorporating trap answers that may appear plausible to students but are, in fact, distractions from the correct answer, the researchers can effectively gauge the students' misconceptions. Offering one correct answer and three distractor answers ensures that students' responses will vary, based on their level of understanding and potential misconceptions. The presence of trap answers and distractors provides valuable insights into students' thought processes and common misconceptions related to the concepts being tested. The varied responses help researchers analyze the prevalence of specific misconceptions and understand the reasoning behind students' incorrect answers. Table 3.2 presents examples of questions from the four-tier diagnostic test.

Table 3.2 The Sample of Question

<table>
<tr><th>No</th><th>Tier</th><th>Question</th></tr>
<tr><td rowspan="3">Q6</td><td>1</td><td>Look at the four diagram below, which diagram that shows reflection on a plane mirror correctly?


A. A
B. B
C. C
D. D</td></tr>
<tr><td>2</td><td>Are you sure about this answer?
A. Yes, I’m sure
B. No, I’m not sure</td></tr>
<tr><td>3</td><td>What is the reason for your answer?
A. The image of the candle on the mirror will be located directly beside the candle, and the angle of incident must be the same as the angle of reflection.</td></tr>
</table>

No	Tier	Question
		B. The image of the candle on the mirror will be located directly beside the eye, and the angle of incident must be the same as the angle of reflection. C. The image of the candle on the mirror will be located directly beside the candle, and the angle of incident must be the same as 90 degrees. D. The image of the candle on the mirror will be located directly beside the eye, and the angle of incident must be the same as 90 degrees.
	4	Are you sure about this answer? A. Yes, I’m sure B. No, I’m not sure

During the development stage of the four-tier diagnostic test, the researcher will start by constructing 30 initial questions. These questions will be carefully designed to assess the students' understanding of the mechanical and light wave topics and to identify potential misconceptions. The aim is to create a comprehensive and effective instrument for diagnosing students' conceptions and misconceptions. Following the construction of the initial question set, the instrument will undergo two validation phases to ensure its validity. In the first phase of validation, the initial pilot test will be conducted among two classes of the same grade, as depicted in Appendix A.3. The responses from this phase will be analyzed to assess the clarity, relevance, and appropriateness of the questions. Based on the results of the first validation phase, the researchers will refine and modify the questions if necessary. In the second validation phase, the revised set of questions will be administered to the same group of students from the same classes as before. This allows for the real test to be answered by students who have not been exposed to the questions previously, ensuring that the responses are unbiased and reliable.

3.3.1 Validity

To assess the relevance, representativeness, and appropriateness of the questions in measuring the intended construct. They will examine whether the questions adequately cover the key concepts and content areas of physics education and whether they effectively capture the range of knowledge and misconceptions that students may have. Through the content validity test, the experts will provide valuable feedback and insights on the clarity, accuracy, and overall quality of the questions. They will assess the alignment between the questions and the targeted content, ensuring that the questionnaire effectively measures the intended construct of students' conceptions and misconceptions in physics education. By involving experts in the field of physics education, the researchers can benefit from their expertise and judgment to enhance the content validity of the instrument. The feedback provided by the experts will guide the refinement and improvement of the questionnaire, ensuring that it is a valid and reliable tool for assessing students' understanding and misconceptions in the context of the research.

In this research, the content validity and homogeneity reliability coefficients proposed by Aiken were used to quantitatively evaluate the expert evaluations of the suitability of the criteria. The researchers aimed to assess the extent to which the criteria described in the initial test demonstrated content validity and homogeneity reliability. The content validity of an instrument involves analyzing how well the questions represent the construct to be measured and can be determined through expert agreement. To assess this agreement, the validity index introduced by Aiken (1980) is utilized, which is calculated as follows:

$$V = \frac{\Sigma s}{n(c-1)}$$

Where:

V is the rater agreement index regarding item validity.

Σs is the score determined by each rater minus the lowest score in the category used used ($s = r - l_o$, where r = score in the rater's chosen category; l_o = the lowest score in the scoring category)

n is the number of raters.

c is the number of categories the rater can choose.

The researchers set the expectation that the criteria described in the initial test would demonstrate reasonable content validity and homogeneity reliability with coefficients greater than 0.70. A content validity coefficient and homogeneity reliability coefficient exceeding 0.70 would indicate that the test items are appropriate, relevant, and consistent, thereby enhancing the credibility and validity of the diagnostic test. Subsequently, the obtained V index is utilized for categorizing each item according to Table 3.3, with the categorized information presented in Appendix A.4, which provides specific categories for content validity of the instrument. This categorization helps in understanding the overall quality of the instrument's content validity based on the level of agreement among expert raters.

Table 3.3 Content Validity Test Results

Test Item	Aiken's Index (V)	Test Item	Aiken's Index (V)
Q1	1.0	Q16	1.0
Q2	0.6	Q17	0.6
Q3	1.0	Q18	1.0
Q4	1.0	Q19	1.0
Q5	1.0	Q20	1.0
Q6	1.0	Q21	1.0
Q7	1.0	Q22	0.6
Q8	0.6	Q23	0.6
Q9	1.0	Q24	1.0
Q10	0.6	Q25	1.0
Q11	0.6	Q26	1.0
Q12	1.0	Q27	1.0
Q13	1.0	Q28	1.0
Q14	1.0	Q29	1.0

Test Item	Aiken's Index (V)	Test Item	Aiken's Index (V)
Q15	1.0	Q30	1.0
$V_{average}$	0.906	Valid	

In this study, the content validity of the instrument was evaluated through assessments made by three experts, including two experienced physics lecturers and one physics teacher. These experts thoroughly evaluated the 30 questions, and the results presented in Table 3.3 demonstrated that all of the questions were deemed valid. The average Aiken's Index, calculated at 0.906, signifies a high level of validity for the set of questions. This substantial index score indicates a strong consensus among the experts regarding the questions' ability to measure the intended construct effectively. As a result, the instrument's content validity is confirmed, thereby ensuring the reliability and accuracy of the questions utilized in the research.

After conducting the content validity, the instrument was revised based on the suggestions provided by the experts. The next step was to assess the construct validity of the instrument. To achieve this, two pilot tests were carried out on separate samples of 51 and 47 junior high school students who had already studied the relevant topics. The researchers utilized the Pearson Product Moment Correlation in SPSS to analyze the data from the pilot tests. The aim was to determine the relationship between two variables, specifically the students' responses to the test items and their level of understanding or misconceptions related to the physics topics. The validity of the items was assessed using the Pearson correlation coefficient (r). If the calculated r value (r_{count}) was greater than the critical r value (r_{table}) based on a 2-tailed test with a significance level of 0.05, the items were considered valid (Arikunto, 2005). The critical r values for a sample size of 49 and 45 were determined as $r(49) = 0.281$ and $r(45) = 0.294$, respectively (Pearson Education, 2017). Based on the findings presented in Table 3.4 and Appendix A.5, it was concluded that a total of 14 test items were valid. The results demonstrated that these items effectively measured the intended construct, accurately assessing the students' level of understanding and misconceptions in the mechanical and light wave topics. The successful validation of these 14 test items further strengthens the credibility and reliability of the four-tier diagnostic test as a valid instrument for diagnosing students' conceptual understanding and misconceptions in the specified physics topics.

Table 3.4 Result of Validity Construct First Pilot Test

Test Item	Tier	Pearson Correlation	Interpretation	Decision	Test Item	Tier	Pearson Correlation	Interpretation	Decision
Q1	1	0.184	Not Valid	Revise	Q2	1	0.069	Not Valid	Rejected
	3	0.055	Not Valid			3	-0.037	Not Valid	
Q3	1	0.189	Valid	Valid	Q4	1	0.119	Not Valid	Revise
	3	0.321	Valid			3	0.184	Not Valid	
Q5	1	0.499	Valid	Valid	Q6	1	0.323	Valid	Revise
	3	0.349	Valid			3	0.173	Not Valid	
Q7	1	0.390	Valid	Valid	Q8	1	0.054	Not Valid	Rejected
	3	0.622	Valid			3	-0.076	Not Valid	
Q9	1	0.509	Valid	Valid	Q10	1	0.221	Not Valid	Revise
	3	0.289	Valid			3	0.274	Not Valid	
Q11	1	-0.056	Not Valid	Rejected	Q12	1	0.262	Not Valid	Revise
	3	-0.035	Not Valid			3	0.210	Not Valid	
Q13	1	0.266	Not Valid	Rejected	Q14	1	0.514	Valid	Valid
	3	-0.033	Not Valid			3	0.401	Valid	
Q15	1	0.325	Valid	Valid	Q16	1	-0.025	Not Valid	Rejected
	3	0.295	Valid			3	0.281	Valid	

Test Item	Tier	Pearson Correlation	Interpretation	Decision	Test Item	Tier	Pearson Correlation	Interpretation	Decision
Q17	1	0.600	Valid	Revise	Q18	1	0.295	Valid	Valid
	3	0.250	Not Valid			3	0.563	Valid	
Q19	1	0.205	Not Valid	Revise	Q20	1	0.507	Valid	Valid
	3	0.125	Not Valid			3	0.566	Valid	
Q21	1	-0.120	Not Valid	Rejected	Q22	1	0.350	Valid	Valid
	3	-0.023	Not Valid			3	0.502	Valid	
Q23	1	0.390	Valid	Revise	Q24	1	0.320	Valid	Revise
	3	0.198	Not Valid			3	-0.009	Not Valid	
Q25	1	0.146	Not Valid	Rejected	Q26	1	0.242	Not Valid	Revise
	3	-0.050	Not Valid			3	0.011	Not Valid	
Q27	1	0.311	Valid	Revise	Q28	1	0.374	Valid	Valid
	3	0.075	Not Valid			3	0.405	Valid	
Q29	1	0.355	Valid	Valid	Q30	1	0.383	Valid	Valid
	3	0.402	Valid			3	0.617	Valid	

In the data analysis process, the researcher categorized the questions into three groups based on the interpretation of the data obtained from the pilot tests. These categories are determined by the validity of the questions as assessed by the Pearson correlation coefficient (r) compared to the critical t-table value. Valid questions is considered valid if the Pearson correlation value (r) is higher than the critical t-table value or the Pearson correlation coefficient (r). If both tiers of a question are valid, it is categorized as valid. These valid questions will be used in the real test to diagnose students' conceptual understanding and misconceptions. A question need Revision if one of the tiers of a question is valid, but the other is not, the question is categorized as needing revision. As long as the Pearson correlation value is not negative, there is a possibility that the question can be improved through revision to become valid.

Therefore, the revised question will undergo a second testing to re-evaluate its validity. A question is Rejected if the Pearson correlation value (r) for a question is negative, it is categorized as rejected. This means that the question will not be used again, either for revision or in the actual test. The negative correlation suggests that the question does not effectively measure the intended construct and should be discarded. Table 3.5 and Appendix A.6 presents the results of the second pilot test, which evaluates the revised questions. This second testing is conducted with the hope that the revised questions will become valid and can be used in the real test to assess students' understanding and misconceptions accurately. By applying this categorization and validation process, the researchers can ensure that the final set of questions used in the real test is reliable and valid, allowing for a comprehensive assessment of students' conceptual understanding and misconceptions in the field of physics education.

Table 3.5 Result of Validity Construct Second Pilot Test

Test Item	Tier	Pearson Correlation	Interpretation	Decision	Test Item	Tier	Pearson Correlation	Interpretation	Decision
Q1	1	0.171	Not Valid	Revise	Q3	1	0.086	Not Valid	Revise
	3	0.434	Valid			3	0.151	Not Valid	
Q4	1	0.234	Not Valid	Rejected	Q6	1	0.451	Valid	Revise
	3	-0.132	Not Valid			3	0.245	Not Valid	
Q10	1	0.035	Not Valid	Revise	Q12	1	0.449	Valid	Valid
	3	0.374	Valid			3	0.425	Valid	
Q17	1	-0.055	Not Valid	Rejected	Q19	1	-0.048	Not Valid	Rejected
	3	0.232	Not Valid			3	0.288	Not Valid	
Q23	1	0.149	Not Valid	Revise	Q24	1	0.442	Valid	Valid

Test Item	Tier	Pearson Correlation	Interpretation	Decision	Test Item	Tier	Pearson Correlation	Interpretation	Decision
	3	0.163	Not Valid			3	0.391	Valid	
Q26	1	0.404	Valid	Valid	Q27	1	0.222	Not Valid	Revise
	3	0.313	Valid			3	0.313	Valid	

Based on the results presented in Table 3.5, three questions were categorized as valid after the second pilot test, indicating that the revisions made to these questions were successful in improving their validity. These questions are considered suitable for inclusion in the final set of test items. On the other hand, some questions may have remained not valid or even become rejected after the second pilot test, indicating that the revisions were not sufficient to address their issues and become rejected. These questions might not effectively measure the intended construct or could have inherent flaws that hinder their validity. Considering that 14 questions were categorized as valid after the second pilot test, the researcher deemed this number to be sufficient for the real test. These 14 validated questions are considered reliable and appropriate for diagnosing students' conceptual understanding and misconceptions in the specified physics topics. Given the success of the revisions and the satisfactory number of validated questions, the decision was made to use only the 14 validated questions in the real test.

3.3.2 Reliability Test

Reliability testing is important in research to ensure that the measuring instrument can be consistently relied upon to produce accurate and consistent results. By assessing the reliability of the instrument, researchers can have confidence in the consistency of the data collected, which enhances the credibility and validity of their findings. the instrument will be 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 sum of questions;

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

Σt^2 = the total variant.

To facilitate the assessment of reliability, the index will be divided into distinct categories, ranging from "Very low" to "Very high." Categorizing the reliability levels will streamline the process of identifying which questions may require modification or deletion. By assigning these categories, it becomes easier to prioritize areas of improvement based on the reliability index, ensuring that the assessment instrument is refined and optimized for future use. For further information Table 3.6 will provide us the range.

Table 3.6 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

(Guilford 1956: 145)

As a result, the researcher can assess the reliability of the research by cross-referencing and analyzing the collected data. Through rigorous examination and validation of the data, the researcher can ensure the credibility and consistency of the findings, thereby enhancing the overall reliability of the research study. Table 3.7 and Appendix A.7 displays the results of the reliability test conducted on SPSS. For this test, all 30 questions from the questionnaire were included, along with the corresponding students' responses. The responses were coded into binary values, where "0" represents incorrect or misconceived answers, and "1" represents correct answers. The purpose of this reliability test is to assess the consistency and stability of the measuring instrument, in this case, the four-tier diagnostic test, in measuring students' conceptual understanding and misconceptions. The reliability coefficient calculated from the data indicates the degree to which the test items produce consistent and dependable results.

Table 3.7 The reliability test result

	Cronbach’s Alpha	N of Items
1st Tier Question	0.694	30
3rd Tier Question	0.603	30

A high reliability coefficient indicates that the test items are reliable and consistent in assessing the intended construct. The researcher used various statistical techniques in SPSS to determine the reliability coefficient, such as Cronbach's alpha, which is commonly used for assessing the internal consistency of a scale or test. By evaluating the reliability of the test instrument, the researcher can ensure that the data obtained from the real test is dependable and that the results accurately reflect the students' level of understanding and misconceptions in the relevant physics topics.

3.4 Research Procedure

As illustrated in Figure 3.1, the research is carried out through three distinct stages: the preparation stage, the implementation stage, and the completion stage. Each stage involves specific steps that are described in greater detail as follows:

A. Preparation Stage:

1. Identify the research topic: In this stage, the researcher identifies the research topic, which is "Misconceptions in Junior High School Students' Understanding of Mechanical and Light Waves."

2. Literature review: Conduct a thorough review of relevant literature on the topic to gain insights into previous studies and findings related to misconceptions in physics education.

3.Develop research questions: Based on the literature review, formulate specific research questions that will guide the study.

4. Develop the instrument: Create a four-tier diagnostic test instrument with questions related to mechanical and light waves topics. Ensure that the questions align with the research questions and target the identified misconceptions.

5. Conduct content validity: Seek expert opinions to validate the content of the instrument, ensuring that it accurately measures the intended constructs and concepts.

6. Revise the instrument: Based on the expert feedback, make necessary revisions to the instrument to improve its validity and reliability.

B. Implementation Stage:

1. Select participants: Choose a sample of 8th-grade students from a junior high school in Bandung, West Java, who have studied mechanical and light waves topics.

2. Administer the test: Conduct the first pilot test with the 30 initial questions to evaluate the instrument's construct validity and reliability.

3. Analyze the data: Use statistical analysis to determine the construct validity and reliability of the instrument based on the pilot test results.

4. Revise the instrument: Revise the instrument based on the findings from the first pilot test to enhance its validity and reliability.

5. Conduct the second pilot test: Administer the revised instrument to another sample of students to further validate its content and improve its reliability.

6. Analyze the data: Perform another round of data analysis to determine the instrument's content validity and reliability based on the second pilot test results.

7. Select valid questions: Identify the valid questions that will be used in the actual test based on the content validity and reliability results.

C. Completion Stage:

1. Conduct the actual test: Administer the final set of 14 valid questions to the target sample of 8th-grade students.

2. Collect data: Gather responses from the students and record the results for further analysis.

3. Analyze the data: Analyze the data from the actual test to determine the prevalence of misconceptions among the students and the overall effectiveness of the instrument.

4. Conduct interviews: Conduct semi-structured interviews with selected students to gain deeper insights into their misconceptions and understanding of the concepts.

5. Interpret the results: Interpret the findings from the data analysis and interviews to draw conclusions about the students' misconceptions and possible areas of improvement in physics education.

6. Publication: Disseminating the research findings through publication in a regional-level journal, as detailed in Appendix C.1.

The research follows a systematic approach, from the preparation stage to the completion stage, ensuring that the instrument is valid and reliable for assessing students' misconceptions. The use of multiple pilot tests, interviews, and statistical analysis helps to validate the instrument and provide valuable insights into students' conceptual understanding. The findings of the study can contribute to the field of science education and guide educators in developing effective strategies to address misconceptions and promote meaningful learning in physics.

The research documentation, as presented Appendix D.1 and in Appendix C.2 provides a comprehensive record of the research process and its approval. This study's methodology and outcomes are replicable and can be thoroughly reexamined in various other educational institutions and geographic contexts. The research has received approval from the faculty, as evidenced in Appendix C.3.

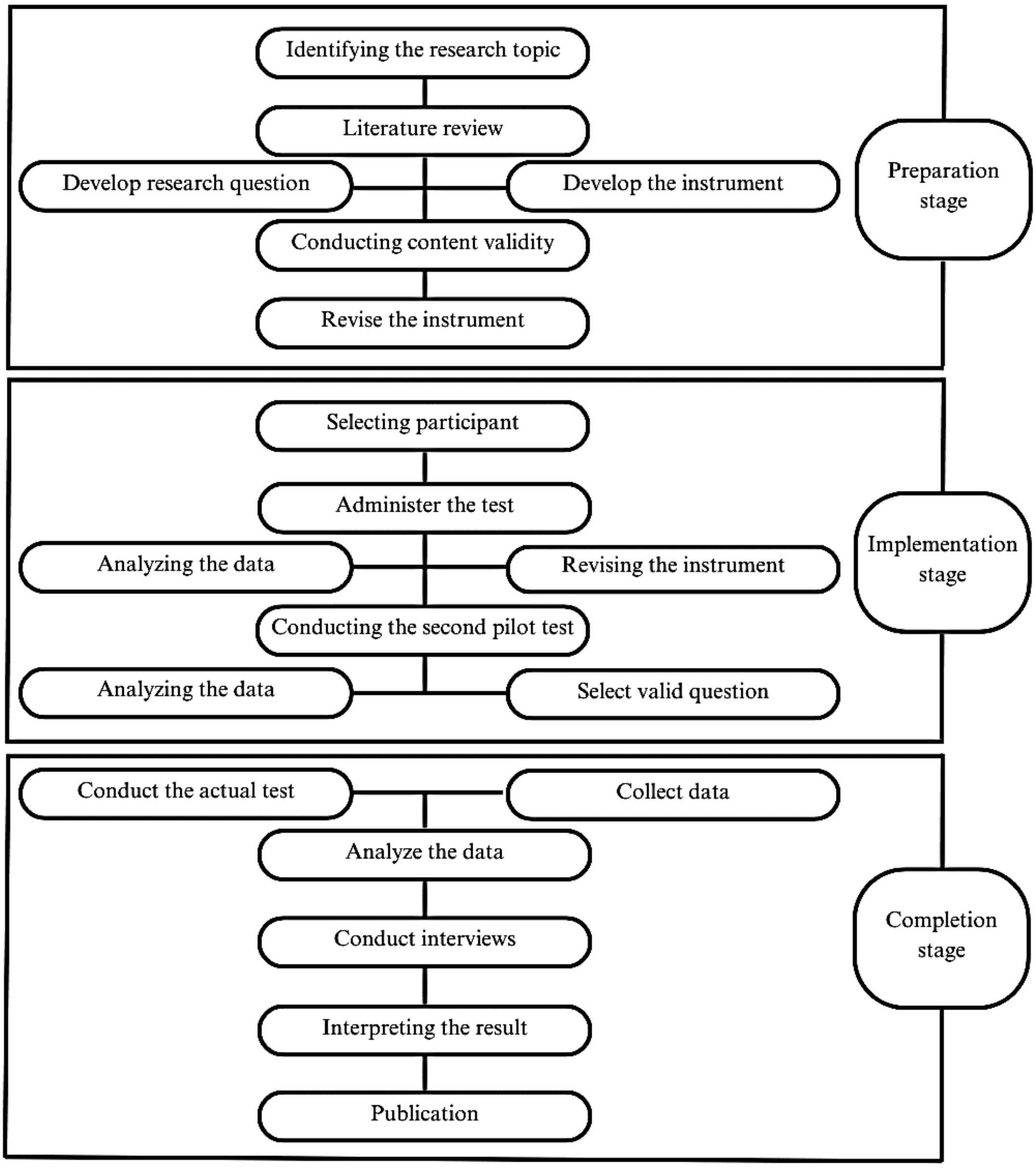


Figure 3.1 Stage of Research

3.5 Data Analysis

As shown in Table 3.8, responses to each question will be grouped into the following categories: scientific knowledge (SK), lack of knowledge (LK), misunderstanding (M), false negative (FN), and false positive (FP) (Kiray & Simsek, 2020). When students confidently answer the first and third tier correctly, they asserted scientific knowledge. False positive is when students confidently answer both tiers but give correct answer to the first tier and incorrect answer to the third tier. False negative occurs when students incorrectly answer the first tier while correctly answering the third tier and are confident about first and third tiers. When students incorrectly answer the first and third tiers but are confident about both tiers, this is referred to as misconception. Combinations different than those already described are classified as lack of knowledge.

Table 3.8 Concept level based on a possible answer

Tier 1	Tier 2	Tier 3	Tier 4	Decision of four-tier
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	LK1
True	Not Confident	True	Confident	LK2
True	Not Confident	True	Not Confident	LK3
True	Confident	False	Not Confident	LK4
True	Not Confident	False	Confident	LK5
True	Not Confident	False	Not Confident	LK6
False	Confident	True	Not Confident	LK7
False	Not Confident	True	Confident	LK8
False	Not Confident	True	Not Confident	LK9
False	Confident	False	Not Confident	LK10
False	Not Confident	False	Confident	LK11

Tier 1	Tier 2	Tier 3	Tier 4	Decision of four-tier
False	Not Confident	False	Not Confident	LK12

(Kiray & Simsek, 2021)

In this research, a coding system is used to label the students' responses based on their answers to the four-tier diagnostic test. The coding system is as follows:

1. Scientific Knowledge (SK): The correct answer for the first and third tiers is coded as "1," and the answer for the second and fourth tiers is confidently given and also coded as "1." The sequence of the code for SK is (1-1-1-1).

2. False Positive (FP): The answer for the first tier is correct, but the answer for the third tier is false. However, the student confidently answered both tiers, so the code for FP is (1-1-0-1).

3. False Negative (FN): The answer for the first tier is false, but the answer for the third tier is correct. The student confidently answered both tiers, resulting in the code (0-1-1-1).

4.Misconception (M): The answer for the first and third tiers is false, and the student confidently answered both tiers. The code for M is (0-1-0-1).

5. Lack of Knowledge (LK): If the student's response does not fit into any of the previous patterns, it is categorized as lack of knowledge.

By using this coding system, the researcher can categorize and analyze the students' responses based on their level of understanding and the presence of misconceptions as shown on Appendix A.8. This allows for a more detailed and nuanced analysis of the data, helping to identify patterns of misconceptions and areas where students may need additional support and intervention in their understanding of mechanical and light waves topics.

During the initial phase of data processing, the students' conceptions were categorized based on the classification presented in Table 3.8. Subsequently, the percentages for each category were computed. This calculation was achieved using a straightforward formula, which involved deriving the percentage of each category from the respective category's results. The specific formula utilized for these calculations is as follows:

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

Description:

Percentage of each category

Number of the students for each group

Total number of students

For example, let's say there were 100 students who participated in the study and their responses were classified into the following categories:

In this study, 100 students participated, and their responses were classified into different categories: 60 students demonstrated Scientific Knowledge (SK), 10 students had False Positive (FP) answers, 15 students had False Negative (FN) answers, 10 students had Misconceptions (M), and 5 students showed a Lack of Knowledge (LK). To calculate the percentage of each category, the number of students in each category was divided by the total number of participants (100) and then multiplied by 100. As a result, the percentages were determined as follows: 60% for SK, 10% for FP, 15% for FN, 10% for M, and 5% for LK. These percentages represent the distribution of students' conceptions in each category based on their responses to the four-tier diagnostic test. Once the percentages of misconceptions in each question are calculated, the researchers can further analyze and interpret the findings. This analysis can help identify which specific concepts or topics are causing the most misconceptions among students and may guide future teaching strategies or interventions to address these misconceptions effectively.