CHAPTER III

METHODOLOGY

3.1 Research Method and Research Design

This research employs a quantitative method, which consists of analyzing scores collected on the instruments to answer research question or test the hypothesis. Besides that, this quantitative method serves to test theories objectively by analyzing the relationships between variables that are measured numerically. These variables can be quantified, often using standardized instruments, allowing the data to be analyzed instruments, so that the results can be analyzed systematically using statistical techniques, producing findings that are measurable, structured, and generalizable (Creswell & Creswell, 2018).

This study uses a quasi-experimental approach with a non-equivalent pretest–posttest design to support the implementation of quantitative methods. According Fraenkel et al. (2011), a quasi-experimental approach in quantitative research is used when researchers cannot randomly assign subjects to research groups.

This design involved two groups of students who received different treatments, namely the experimental group and the control group. Both groups were given a pretest before the treatment and a posttest after the treatment to measure changes in learning outcomes. The experimental group participated in project-based learning using the STEM learning model integrated with the Engineering Design Process (EDP). Meanwhile, the control group followed the STEM learning model without EDP integration, but still with the same project, namely the construction of a simple wind turbine. This difference in treatment aims to evaluate the effectiveness of EDP integration in STEM on improving student learning outcomes.

The performance of both groups was evaluated based on pretest and posttest results using a performance assessment instrument, which was conducted by the researcher and assisted by observers. Through this design, the researcher was able to quantitatively measure the extent to which the application of the STEM learning model integrated with the Engineering Design Process (EDP) yielded better results than the STEM model without EDP in the same learning project. The design is illustrated in Table 3.1.

Table 3.1 Non-Equivalent Pre-test Post-Test Control Group Design

Group	Pre-test (O_1)	Treatment	Post-test (O_2)
Experiment class	O_1	X_1	O_2
Control class	O_1	X_2	O_2

(Creswell & Creswell, 2018)

According to Table 3.1, the variable O_1 represents the pre-test, while O_2 refers to the post-test. The symbol X_1 refers to the treatment applied, which is the STEM with Engineering Design Process, whereas the symbol X_2 represents the treatment using the STEM Project-Based Learning.

3.2 Population and Sample

The population in this study was eighth-grade students at a public junior high school in Bandung, West Java, which implements the *Merdeka* Curriculum. The sampling technique used in this study was convenience sampling based on the availability of classes determined by the school. A convenience sampling refers to a group of individuals who are selected for a study based on their availability and ease of access (Fraenkel et al., 2011). The participant distribution can be seen in Table 3.2.

Table 3.2 Participant Distribution

Gender	Experiment Class		Control Class	
	Frequency	Percentage	Frequency	Percentage
Male	16	51.6%	14	45.2%
Female	15	48.4%	17	54.8%
Total	31	100%	31	100%

Based on Table 3.2, the sample consisted of 62 students from two classes, aged around 14-15 years old. They had not learned about renewable energy in their school curriculum. Therefore, they were selected as the participants of this study.

3.3 Hypothesis

The hypothesis proposed in this study is formulated as follows:

3.1 Students' Renewable Energy Awareness

H_0 = There are no significant differences between the experimental class and control class regarding students' renewable energy awareness

H_1 = There are significant differences between the experimental class and control class regarding students' renewable energy awareness

3.2 Students' Critical Thinking Skills

H_0 = There are no significant differences between the experimental class and control class regarding students' critical thinking skills

H_1 = There are significant differences between the experimental class and control class regarding students' critical thinking skills

3.3 Correlation between Learning Model Implementation with Students' Renewable Energy Awareness and Students' Critical Thinking Skills

H_0 = There are no significant differences between learning model implementation regarding students' renewable energy awareness and critical thinking skills

H_1 = There are significant differences between learning model implementation regarding students' renewable energy awareness and critical thinking skills

3.4 Research Instrument

Research instruments are essential for collecting data in a study. In this study, instruments were used to assess students' renewable energy awareness and critical thinking skills. The research instruments used are shown in the Table 3.3.

Table 3.3 Research Instrument

No	Data Collected	Instrument
1.	Students' Renewable Energy Awareness	20-item Likert scale questionnaire from Kacan (2015)
2.	Students' Critical Thinking Skills	10 open-ended questions from Ennis & Weir (1985) adopted by Ijirana et al.
3.	Student Performance	Student worksheet aligned with the stages of the learning model

3.4.1 Students' Renewable Energy Awareness

In this study, a questionnaire was used as an instrument to measure the extent of students' awareness of the importance of renewable energy. This instrument was administered before the learning implementation (pre-test) and after the learning implementation. This instrument consists of 20 items developed based on five indicators by Kacan (2015). These items have been tested for validity and reliability through factor analysis, specifically principal component analysis, with a Cronbach's Alpha reliability coefficient of 0.944, indicating a very high level of reliability. Therefore, this questionnaire is considered valid and reliable for measuring students' renewable energy awareness. The indicators in the instrument are shown in Table 3.4.

Table 3.4 Indicators of Students' Renewable Energy Awareness Questionnaire

No	Category indicator	Category definition	Number of Item
1	Awareness and Knowledge	Understanding of renewable energy and its importance	4
2	Environmental Impact	Views on environmental issues, such as fossil fuels, greenhouse gases, and global warming	4
3	Policy and Investments	Opinions on policies, global support, and financial investments in renewable energy	4
4	Attitudes and Opinions	Personal feelings, doubts, or preferences toward renewable energy	4
5	Education and Social Responsibility	Importance of education, media, and global perspectives in promoting renewable energy	4
		Total	20

Table 3.4 explains the distribution of indicators in the students' renewable energy awareness questionnaire. Each indicator consists of four statements. The awareness and knowledge indicator consists of four negative statements. The environmental impact indicator consists of two negative statements and two positive statements. The policy and investment indicator consists of four positive statements. The attitude and opinion indicator also consists of four negative statements. Meanwhile, the education and social responsibility indicator consists of four positive statements.

This questionnaire uses a Likert scale with a value range of 1 to 5 for each statement item. This scale aims to determine the extent to which students agree with the statements presented. For positive statements, the scale is rated directly, as follows: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Meanwhile, for negative statements, the scale is reversed: 1 = strongly agree, 2 = agree, 3 = neutral, 4 = disagree, and 5 = strongly disagree. The scale is reversed for negative statements to ensure that the scoring results remain consistent; that is, the higher the score obtained by students, the higher their level of awareness of renewable energy. According to (Schmitt & Stuits, 1985), negative items are usually scored in reverse so that all items on the scale point in the same direction, helping to avoid misleading results caused by inattentive or careless answers. Thus, both positive and negative statements can be analyzed in the same direction, where higher scores always represent a more positive attitude or awareness of renewable energy. Before the questionnaire was distributed, the instrument underwent validation through the expert judgement involving three lecturers. The experts advised that the wording of questionnaires be simplified by using vocabulary familiar to students, to enhance clarity and comprehension (see Appendix A.1). Furthermore, the revised questionnaire resulting from the expert judgment suggestions was then utilized as the research instrument administered to the students, which is presented in Appendix A.3.

3.4.2 Students' Critical Thinking Skills

To measure students' critical thinking skills, the instrument used in this study was a test item. This instrument consists of 10 open-ended essay questions based on five categories adopted by Ijirana et al. (2022) and it was distributed before the learning implementation (pre-test) and after the learning implementation. The indicators are shown in Table 3.5.

Table 3.5 Indicators of Students' Critical Thinking Skills in Open-Ended Essay Questions

No	Indicators	Indicator definition	Questions number	Total
1	Determine actions	Identifying problems related to renewable energy, selecting appropriate actions or solutions based on the given conditions and scenarios.	1,2	2
2	Developing basic skills/observing	Analyzing data or visuals about renewable energy and selecting the correct mechanism or process.	3,4	2
3	Evaluating statements	Analyzing statements about renewable energy phenomena and selecting the most relevant option based on data or facts.	5,6	2
4	Identifying assumption	Recognizing hidden assumptions or logical errors in statements about renewable energy and selecting responses that demonstrate critical analysis.	7,8	2
5	Clarification and evaluation	Evaluating data from renewable energy projects or case studies, and selecting the most accurate interpretation or recommendation.	9,10	2
		Total		10

Before the questionnaire was distributed, the instrument underwent validation through expert judgment involving three lecturers. The experts advised that the wording of the test items be simplified by using vocabulary familiar to students, to enhance clarity and comprehension (see Appendix A.1). Following this feedback, the instrument was revised and tested on students. After getting the results, the test items were assessed using the scoring rubric consisting of indicators and criteria to assess students' critical thinking skills. The indicator and criteria of the assessment rubric are presented in Table 3.6, which can also be seen in Appendix A.7.

Table 3.6 Indicator and Criteria of Assessment Rubric of Critical Thinking Skills (Ijirana et al., 2022)

Indicators	Assessment criteria	Score
Strategies and tactics/ determining actions	Identifying problems, deciding on appropriate actions based on the students' conditions and logical solutions to problems, and drawing conclusions	4
	Writing down the problems, deciding on appropriate actions based on the students' conditions and logical solutions to problems	3
	Writing down the problems, deciding on appropriate actions based on the students' conditions	2
	Writing down the problems	1
	No response	0
Developing basic skills/observing	Writing down the problems in the form of questions, mechanisms of making an authentic assessment, problem-solving strategies, and drawing conclusions	4
	Writing down the problems in the form of questions, mechanisms of making an authentic assessment, problem-solving strategies, and drawing conclusions	3
	The students have the ability to write down the problems in the form of questions and the mechanisms of making an authentic assessment	2
	The students have the ability to write down the problems in the form of questions	1
	No response	0
Inferring/making and evaluating statements	Assessing the use of appropriate media/materials, selecting other media/materials that can be used, and providing logical explanations correctly	3
	Assessing the use of appropriate media/materials, selecting other media/materials that can be used	2
	Assessing the use of appropriate media/materials	1
	No response	0

Indicators	Assessment criteria	Score
Providing further explanation/identifying assumptions	Assumption-based decision making, providing elementary clarifications, conducting an assessment, and providing advanced clarifications	4
	Assumption-based decision making, providing elementary clarifications, and conducting an assessment	3
	Assumption-based decision making and providing elementary clarifications	2
	Assumption-based decision making	1
	No response	0
Providing elementary clarification/focusing questions	Estimation-based decision making, selecting appropriate methods, making assessment, and giving elementary clarification	3
	Estimation-based decision making, selecting appropriate methods	2
	Estimation-based decision making	1
	No response	0

After measuring the score of test items, the data were analyzed using IBM SPSS to see the validity and reliability. According to Sullivan (2011), in research, validity shows how accurate and appropriate the results are, and whether the instrument truly measures what it is meant to measure, while reliability refers to the consistency or stability of a measurement instrument. Table 3.7 presents the interpretation of the validity score.

Table 3.7 Validity Interpretation

Correlation Coefficient	Validity Interpretation
$0.80 < r \leq 1.00$	Very High
$0.60 < r \leq 0.80$	High
$0.40 < r \leq 0.60$	Enough
$0.20 < r \leq 0.40$	Low
$0.00 < r \leq 0.20$	Very Low

(King & Minium, 1993)

The raw data of the instrument validation are provided in Appendix A.4. The result of validation analysis of students' critical thinking skills in open-ended essay questions is presented in Table 3.8, while the detailed results of the validation analysis can be seen in Appendix A.5.

Table 3.8 Result of Validation Test Item

Number of Test Item	Validity
1	.527
2	.113
3	.743
4	.701
5	.617
6	.808
7	.839
8	.878
9	.721
10	.742

Table 3.8 shows the results of the item test validation analysis using IBM SPSS software. From the table, it can be seen that of the ten test items analyzed, nine of them fall into the category of enough to very high validity, so they can be considered suitable for use in research. However, there is one test item, question number 2, which falls into the very low category and is therefore considered invalid and needs to be revised. Therefore, the item was revised by simplifying the sentence and adapting it to the students' understanding context so that it is easier to understand and relevant to the indicators being measured.

After the validity was conducted, the next step was to analyze the reliability of the test items. This reliability analysis was performed using IBM SPSS software. The interpretation of the reliability analysis is presented in Table 3.9.

Table 3.9 Reliability Interpretation

Correlation Coefficient	Reliability Interpretation
> 0.90	Very High
0.80 – 0.90	High
0.70 – 0.80	Enough
0.60 – 0.70	Low
< 0.60	Very Low

The result of the reliability analysis of students' critical thinking skills in open-ended essay questions is presented in Table 3.10, while the statistical analysis of the reliability can be found in Appendix A.5.

Table 3.10 Result of Reliability

Subject	Cronbach's Alpha Score
Reliability Analysis	.875

Table 3.10 shows the results of the reliability analysis using IBM SPSS software. From the table, it can be seen that the reliability score falls into the high category. A high reliability score indicates that the instrument has good internal consistency. This means the test items consistently measure the same construct. High reliability also reflects that the instrument is suitable for use as a measuring tool in research because it produces stable and reliable data. Based on the results of the validity and reliability analysis, revisions were made to the essay test items that showed low validity. The revised version of the test was then used as the instrument administered to the students, with the complete set of items provided in Appendix A.6.

3.4.3 Students' Performance

Student performance in this study was assessed based on the students' worksheets completed during the learning activities. The worksheets served as the main instrument to evaluate students' ability to apply concepts, follow procedures, and complete the assigned project tasks. The student worksheets were designed in alignment with the stages of the learning model implemented in each class. Consequently, the worksheets used in the experimental class differed from those in the control class to reflect the respective learning approaches. The worksheets for the experimental class are provided in Appendix B.1, while those for the control class can be found in Appendix B.2. Furthermore, the assessment of student performance was carried out using a rubric specifically developed for the worksheets. The rubric served as a reference for evaluating the completeness, accuracy, and quality of students' work in line with the learning objectives. The rubric for student worksheet assessment is provided in Appendix B.4.

In addition, the module experiment was employed as a common guideline to support the implementation of the project activities in both classes. This module contained step-by-step procedures, materials, and instructions that assisted students in carrying out the experiment effectively. Module experiment can be found in Appendix B.3.

3.5 Data Analysis

The data collected in this study includes two types of variables, which are students' renewable energy awareness and students' critical thinking skills. Since these two variables have different characteristics and data types, they are analyzed using different statistical approaches. The analysis was conducted using IBM SPSS software. The analysis procedures for each variable are described below.

3.5.1 Renewable Energy Awareness

Since this instrument uses a Likert scale, the data produced is ordinal. Therefore, data analysis does not require parametric prerequisite tests such as normality and homogeneity tests, and is directly analyzed using appropriate non-parametric statistical tests.

1. Wilcoxon Signed Ranks Test

   The Wilcoxon Signed-Rank test is used to analyze differences in pretest and posttest scores within the same group, especially when the data is ordinal or does not meet the assumption of normality (Rosner et al., 2006). In this study, the Wilcoxon test was used to determine the significance of changes in students' awareness of renewable energy after the implementation of the learning model. The results of the Wilcoxon test will show whether there is a significant difference between the conditions before and after the treatment. This test is applied both to the overall energy awareness score analysis and to each indicator separately. The decision criteria are based on the significance value (Asymp. Sig. 2-tailed), namely:

- If the significance value (p) is less than 0.05 (< 0.05), then there is a significant difference between pre-test and post-test scores.
- If the significance value (p) is more than 0.05 (> 0.05), then there is no significant difference between pre-test and post-test scores.

2. Mann-Whitney U-Test

   The Mann-Whitney U test is a nonparametric statistical test used to compare two different (independent) groups, such as an experimental class and a control class (Kusumaningtyas et al., 2025). This test is used when the data is ordinal or not normally distributed. The purpose of this test is to determine whether there is a significant difference between the two groups. Therefore, if the test results show a significant difference, it means that the treatment (such as a learning model) has a different effect on student outcomes in the two groups. This test also applied both to the overall energy awareness score analysis and to each indicator separately. The decision criteria are based on the significance value (Asymp. Sig. 2-tailed), namely:

   - If the significance value (p) is less than 0.05 (< 0.05), then there is a significant difference between pre-test and post-test score.
   - If the significance value (p) is more than 0.05 (> 0.05), then there is no significant difference between pre-test and post-test score.

3. Calculate N-Gain Score

   The N-Gain Score (Normalized Gain Score) is a measure used to determine the extent of improvement in student learning outcomes after participating in a learning program (Karnawati, 2020). This score indicates the effectiveness of the learning process based on the difference between pre-test and post-test scores. To calculate the N-Gain score, we used the equation as follows based on (Coletta & Steinert, 2020).

$$N - Gain\,Score\ < g >= \frac{posttest\ score - pretest\ score}{maximum\ score - pretest\ score}$$

The interpretation of N-Gain score is present in Table 3.11.

Table 3.11 N-Gain Score Category

N-Gain score (g)	Category
g < 0.3	Low
0.3 ≤ g ≤ 0.7	Medium
g > 0.7	High

(Karnawati, 2020)

4. Effect Size
   To determine the extent of the influence of the treatment given in this study, an effect size analysis was performed using Rank Biserial Correlation (*r*). According to Kerby (2014), rank biserial correlation is a measure of "how much influence" a treatment (learning model) has on two groups of data being compared, such as pretest and posttest scores. This test was used after the Wilcoxon and Mann-Whitney tests because the data analyzed was ordinal and used a nonparametric approach. The interpretation of rank biserial correlation (*r*) score is shown in Table 3.12.

Table 3.12 Rank Biserial Correlation Score Interpretation

Rank Biserial Correlation Score (*r*)	Interpretation
0.10 – 0.29	Small effect
0.30 – 0.49	Medium effect
≥ 0.50	Large effect

By using this test, researchers can determine not only whether a difference is statistically significant, but also how large the impact of the treatment is on changes in student scores.

3.5.2 Critical Thinking Skills

Data processing on critical thinking instruments began with a scoring process based on the assessment rubric listed in Table 3.6. After the assessment process was completed, the data was analyzed through several stages to test the differences and effects of treatment on students' critical thinking skills.

1. Pre-requisite test

Pre-requisite tests in SPSS are carried out to ensure and determine which data are suitable for use in further statistical analysis. Prerequisite tests include normality test and homogeneity test.

a. Normality test

The normality test aims to determine whether the data distribution for a group or variable follows a normal distribution, which is usually tested using Shapiro-Wilk or Kolmogorov-Smirnov (Mohd Razali & Bee Wah, 2011). In this study, the normality of the data was tested using the Shapiro-Wilk test with a significance level (α) of 0.05. This test was selected because each class consisted of fewer than 50 students. As noted by Mohd Razali & Bee Wah (2011), the Shapiro-Wilk test is more appropriate for smaller sample sizes (less than 50), although it can also be applied to larger samples. In contrast, the Kolmogorov-Smirnov test is generally recommended for sample sizes greater than 50.

b. Homogeneity Test

According to Odoi et al. (2019), the homogeneity test is conducted to determine whether the samples from the control and experimental groups originate from populations with uniform variance, which is usually tested using Levene test. The criteria for evaluating the Homogeneity Test in the SPSS program are as follows:

- If the significance value is less than 0.05 (<0.05), then the data is not homogeneous
- If the significance value is more than 0.05 (>0.05), then the data is homogeneous

2. t-test

The T test would be used as the following test once the prerequisite test was completed and it was determined that the data were homogeneous and normally distributed.

a. Paired Sample t-test

The Paired Sample t-Test was used in this study to determine whether there was a significant difference between the pre-test and post-test scores in the same group. This test was appropriate because the data being compared came from the same students before and after the treatment was administered. According to Wirasanti et al. (2012), the purpose of this test was to see whether the treatment administered, such as the application of the learning model, had a significant effect on student learning outcomes. The decision criteria in this test are based on the significance value (Sig. 2-tailed). If the significance value is < 0.05, there is a significant difference between the pre-test and post-test results; conversely, if the significance value is ≥ 0.05, there is no significant difference.

b. Independent Sample t-test

The Independent Sample t-Test is used to determine whether there is a significant difference between two unrelated groups, namely the experimental class and the control class (Nurcahyati et a, 2020). This test is conducted on post-test data that is interval scaled and meets the requirements of normal distribution and homogeneity. The purpose of this test is to compare the average results between the two groups after being given different treatments. In this study, the t-test helps determine whether the learning model used in the experimental class has a greater effect than that in the control class. The decision criterion is based on the significance value (Sig. 2-tailed), i.e., if the value is < 0.05, there is a significant difference between the two groups; if ≥ 0.05, there is no significant difference.

3. Calculate N-Gain Score

   In addition to being used in analyzing the increase in students' awareness of renewable energy, the N-Gain Score calculation is also applied to data on students' critical thinking skills to see the extent to which the learning model is effective in improving these skills. The N-Gain score is calculated based on the difference between the posttest and pretest scores, then compared to the maximum score and pretest score difference, as explained earlier. The N-Gain calculation results for critical thinking ability data were then categorized based on the same criteria as the previous variables. The N-Gain categories can be seen in Table 3.12.

4. Effect Size

   The Partial Eta Squared (η^2) test is used to determine the extent of the influence or contribution of a treatment on the dependent variable in an analysis, particularly after a t-test has been performed. This value represents the proportion of total variance in the data explained by the treatment. The larger the Partial Eta Squared value, the greater the influence of the treatment. The interpretation criteria for Partial Eta Squared shown in Table 3.13.

Table 3.13 Partial Eta Squared Score Interpretation

Partial Eta Squared score (η^2)	Effect Category
$\eta^2 < 0.01$	Not significant or very small
$0.01 \leq \eta^2 < 0.06$	Small effect
$0.06 \leq \eta^2 < 0.14$	Medium effect
$\eta^2 \geq 0.14$	Large effect

In this study, the Partial Eta Squared value was calculated to support the results of the t-test, enabling researchers not only to determine whether the difference was significant but also to assess the extent of the treatment's effect on student learning outcomes.

3.5.3 Correlation Analysis

To determine the relationship between the quality of learning implementation and student learning outcomes, a correlation analysis was conducted. The type of correlation test used depends on the type of data being analyzed.

1. Pearson Product Moment Correlation

   If the variable is interval-scaled and normally distributed, the Pearson Product Moment test is used. The Pearson test aims to measure the strength and direction of the linear relationship between two numerical variables. The correlation value (*r*) ranges from -1 to +1. A positive value indicates a direct relationship, while a negative value indicates an inverse relationship.

   The significance criteria for both tests are determined by the Sig. value (2-tailed). If the *p* value is < 0.05, there is a significant relationship between the implementation of learning and student learning outcomes. The interpretation of Pearson Correlation is shown in Table 3.14.

Table 3.14 Pearson Correlation Interpretation

Coefficient Interval	Correlation Interpretation
0.00 – 0.199	Very Weak
0.20 – 0.399	Weak
0.40 – 0.599	Moderate
0.60 – 0.799	Strong
0.80 – 1.000	Very Strong

(Jabnabillah & Margina, 2022)

2. Spearman’s Rho Correlation

   Spearman's Rho (ρ) is a non-parametric statistical analysis technique used to measure the strength and direction of the relationship (correlation) between two ordinal variables or data that are not normally distributed. The values and interpretations are similar to Pearson Correlation (see Table 3.14), but this test is based on rankings rather than raw values.

   The significance criteria for both tests are determined by the Sig. value (2-tailed). If the *p* value is < 0.05, there is a significant relationship between the implementation of learning and student learning outcomes.

3.6 Research Procedure

In conducting research, procedures need to be prepared so that the research runs well. This research is divided into 3 stages, namely preparation, implementation, and completion. The development of the procedure is described as follows:

1. Preparation Stage

   In the preparation stage, the researcher carried out several activities to ensure the readiness of the research. The process began with determining the focus of the study on renewable energy sources, formulating the research problem, and conducting a literature review related to renewable energy, particularly wind energy. Furthermore, the researcher developed and tested the project as a preliminary trial. A research proposal was then prepared, which included a literature review, problem formulation, research questions, and operational definitions that served as research guidelines. The researcher also developed research instruments and learning materials. These instruments were validated by expert judgment, after which revisions were made based on the experts' feedback. Following the revision, a student readability test was conducted on the research instrument to ensure clarity and comprehension (see Appendix A.2). Furthermore, validity and reliability tests were performed on the instruments to confirm their quality. In addition, the researcher prepared lesson plans—two versions, one for the experimental class (see Appendix C.1) and one for the control class (see Appendix C.2)—as well as student worksheets.

2. Implementation Stage

   The implementation stage was carried out from May 5 to June 5, 2025. Before the implementation, the researcher contacted a junior high school in the Bandung area and submitted permission letters to conduct the research (see Appendix E.1). After obtaining permission, the research was conducted and the instruments were distributed to the school, with the letter feedback provided in Appendix E.2. The documentation of the research implementation can be seen in Appendix C.3. During this stage, the control class was taught using the STEM learning model, while the experimental class was taught using the STEM with Engineering Design Process (EDP) learning model. Students in both classes also took a pre-test before the lessons and a post-test after the lessons. There were five meetings in total, and each meeting lasted for two lesson hours (2 × 35 minutes). A complete explanation of each meeting for both classes can be seen in Table 3.15. In addition, during the implementation, observation sheets were completed by observers to monitor the learning process (see Appendix E.3).

Table 3.15 The Implementation Activities

Meetings	Experiment Class	Control Class
	STEM with EDP	**STEM**
1st meeting	Students take a pre-test	Students' take a pre-test
2nd meeting	**Step 1: Identify the need or problem** Students identify the problem given by the teacher through a video and answer questions related to the video in the student worksheet.	**Step 1: Identify the problem** Students identify the problem given by the teacher through a video and answer questions related to the video and formulate one main question related to the problem in the student worksheet.
	Step 2: Research the need or problem Students research the problem further by searching for information on the internet and answering questions on the student worksheet.	**Step 2: Think** Students brainstorm ideas, search for supporting information, and discuss possible solutions with their group.
	Step 3: Draw/sketch possible ideas/solutions for the problem Students create several sketches as possible ideas or solutions to the problem.	**Step 3: Design** Students make sketches of possible solutions and select one design that they consider the most suitable.
	Step 4: Select the best solution Students analyze and compare the proposed	

Meetings	Experiment Class	Control Class
	STEM with EDP	STEM
	designs, then decide on the most appropriate solution to develop.	
	Step 5: Construct a prototype Students build a prototype of the selected solution using the provided materials.	**Step 4: Create** Students construct a prototype of the chosen design using the materials provided.
3rd meeting	**Step 6: Test the prototype** Students test their prototype to observe its performance and record the results systematically in the worksheet.	**Step 5: Test** Students test the prototype, observe the results, and record their findings in the worksheet.
4th meeting	**Step 7: Redesign** Students reflect on the strengths and weaknesses of their prototype and write down possible improvements for the future. **Step 8: Communicate the solution** Students present their work and findings to the class, explaining their process, results, and reflections.	**Step 6: Redesign** Students reflect on the prototype's weaknesses and propose improvements or modifications that could make it work better.
5th meeting	Students' take a post-test	Students' take a post-test

3. Completion Stage

At the completion stage, the researcher processed the data that had been obtained during the implementation stage. The processed data was then analysed to observe the results of the study. After that, the researcher formulated a conclusion and discussion as a report on the research findings. Furthermore, the researcher validated the data with the supervisor, compiled and reported the thesis research results, and placed all supporting data evidence in the Appendix. To ensure academic integrity, a similarity check using Turnitin was performed on Chapters 1 through 5 (see Appendix E.4), followed by an AI-generated text percentage check on the same chapters (see Appendix E.5). Finally, the researcher prepared and uploaded a journal article based on the thesis research to a Scopus Q2-indexed journal (see Appendix E.6). The scheme of research procedure stages is shown in Figure 3.1.

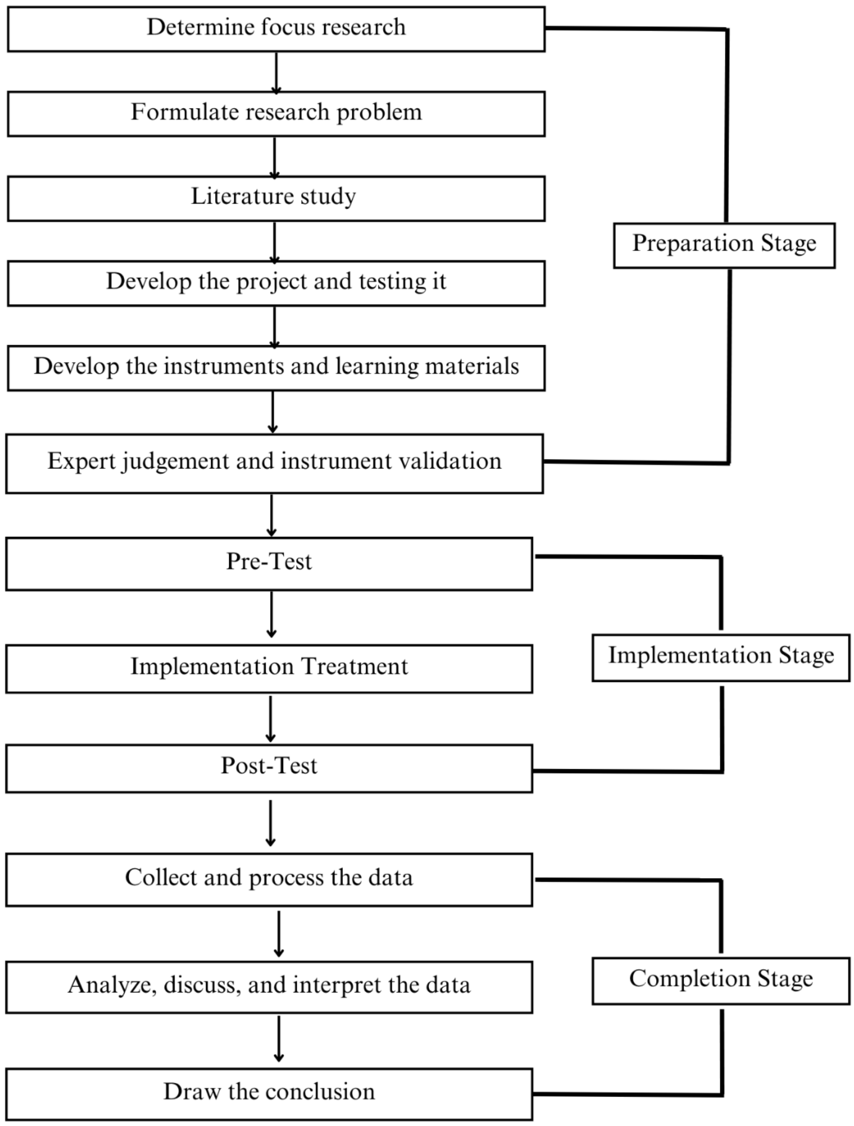

Figure 3.1 The scheme of research procedure