

CHAPTER III

RESEARCH METHODOLOGY

3.1. Research Method and Research Design

3.1.1. Research Method

The method of this research was quantitative method with a quasi-experiment by using the pretest-posttest non-equivalent control group design. There were two groups that were observed in this study: the experimental group and the control group and since the researcher did not randomly divide the students into groups, a quasi-experiment was chosen.

3.1.2. Research Design

The Pretest-Posttest Non-Equivalent Design is a quasi-experiment wherein two groups were observed with different treatments. Both groups were measured both before and after receiving treatment by using pretest and posttest, as represented in the table that follows:

Table 3. 1 Pretest-Posttest Non-Equivalent Design

Class	Pretest	Experiment	Posttest
Experiment	O ₁	X	O ₂
Control	O ₁	-	O ₂

O₁ : Pre-test of students' sustainability action

X : Implementation of ESD-STEM learning through a solid waste management project

- : Teacher's regular model with inquiry-based learning

O₂ : Post-test of students' engineering design skill and sustainability action

Table 3.1 shows that this research involved two groups of students who received different treatments. Experimental class studied with ESD-STEM learning on a solid waste management project with the STEM stages by Widodo, A. (2021) through the steps of problem formulation, think, create, test, and redesign with the project outcomes were technology products. The control group studied with the steps of the teacher's regular model using the inquiry-based learning by Pedaste et al. (2015) through four phases: orientation, conceptualization, investigation, and conclusion. Students learned about the problem of environmental pollution that caused by the poor solid waste management, came up with simple questions, discussed them, and then did research. As a result, they made simple project outcomes like posters or tools that did not use technology.

3.2. Population and Sample

The population in this study was 7th-grade students in Bandung public school who used the Merdeka Curriculum. The research license is attached in Appendix 1. The sample was divided into two classes, which are the experimental class and the control class. This research used the non-probability sampling technique, which is convenience sampling, because the sampling was conducted by the school due to the availability and classes that were considered to have the same basic knowledge about environmental pollution issues.

3.3. Assumptions

- a. Through the ESD-STEM solid waste management project, students can learn about and develop technology solutions to waste-related environmental problems.
- b. The ESD-STEM solid waste management project helps students discover the importance of sustainability initiatives and how their engineering design skills can help with environmental problems.

3.4. Hypothesis

The following are the hypotheses that form the foundation of the study:

H₁: There is a significant difference in students' sustainability action between the experimental class and the control class in working on the solid waste management project.

3.5. Research Instrument

The research instrument used in this research is shown in Table 3.2.

Table 3. 2 Research Instrument

No	Data Needed	Instrument
1.	Engineering design skill	A Performance-Based Evaluation Rubric
2.	Sustainability action	Questionnaire

3.5.1. Engineering Design Skill PBER

Students' engineering design skills was measured using A Performance-Based Evaluation Rubric for Assessing and Enhancing Engineering Design Skills (PBER) as the basis for development of an instrument for engineering design skills. The PBER is a validated measure for assessing students' engineering design skills. The PBER can facilitate the engineering design activities of students. students are encouraged to collaborate with team members to propose innovative conceptual solutions to open-ended challenges using engineering design process in the beginning of the class (Jin, S.H., 2015).

The PBER consists of four phases, which are problem, solution, implementation, and process management phases. The first is the problem phase which assess how students can define problems in detail with design requirements and constraints by identifying problems and analyzing related information. Second, the solution phase is where students can develop several solutions for design problems by using creative idea generation methods and select optimal solutions.

Third, students can prepare reports and present them by using the whole design process and results after giving some shape to solutions at the implementation phase, and the last is that students can manage the design process systematically through collaboration with team members at the process management phase.

The data collected based on the process of conducting a solid waste management project until its final product in ESD-STEM learning. Students were being graded on a scale of 1 to 4 for each step of the phases, with a minimum score of 1 and a maximum score of 4. The instrument of PBER can be seen in Table 3.3 below.

Table 3. 3 Instrument for PBER

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
Problem Recognition	Students are able to identify the issue of solid waste in what's around them.	Students identify problems that are not clear and are not based on observation	Students identify problems based on observation, but the problems are still unclear.	Students identify problems that are specific and clearly based on observation	Students identify problems that are specific, clearly based on observation, and supported by a literature study.
Problem Definition	Students are able to analyze the impacts of the solid waste problems.	Students analyze only 1 impact of the problem.	Students analyze 2 impacts of the problem.	Students analyze 3 impacts of the problem.	Students analyze 4 or more impacts of the problem.
	Students are able to identify the technological solutions or	Students identified the solutions but not in	Students identify technological solutions, but they are not feasible	Students identify technological solutions, but they are feasible and	Students identify technological solutions, but they are feasible and

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
	mitigations of the solid waste problems.	the form of technology.	and do not address the problem	do not address the problem.	address the problem.
	Students are able to analyze the limitations of the technological solutions/tools.	Students only identify the limitations but could not provide solutions from existing tools.	Students identify the limitations and provide a solution that is not feasible and do not address the solid waste problem.	Students identify the limitations and provide a solution that is either feasible or addresses the solid waste problem, but not both.	Students identify the limitations and provide a solution that is feasible and addresses the solid waste problem.
Idea Generation	Size: Students determine the appropriate size for the solid waste sorting prototype.	The size is unrealistic and not proportional to the ideas.	The size is realistic but not proportional to the ideas.	The size is realistic and proportional, but only partially supports the effectiveness of the ideas.	The size is realistic, proportional, and fully supports the effectiveness of the ideas.
	Shape: Students are able to determine the appropriate shape of the waste sorting prototype to ensure efficient sorting and functionality.	The shape of wasting sorting prototype is unrealistic, does not support functionality, and is not suitable for waste sorting.	The shape of wasting sorting prototype is realistic but not efficient in sorting and lacks structural stability.	The shape of wasting sorting prototype is realistic, supports sorting, and is functional, but lacks structural stability.	The shape of wasting sorting prototype is realistic, highly efficient for sorting, structurally stable, and allows all parts to work well together.

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
	Materials: Students are able to determine the materials that are affordable, eco-friendly, and easy to find, which can be used to separate different types of solid waste.	The materials are not affordable, not ecofriendly , and not easy to find.	The materials meet only one of the criteria. (e.g., only affordable OR only easy to find.)	The materials meet two of the criteria. (e.g., affordable and easy to find, but not eco-friendly.)	The materials meet all three criteria: they are affordable, eco-friendly, and easy to find.
	How it works: Students are able to explain the optimal way to separate solid waste by placing it according to its place.	The explanation does not include any detection or sorting process.	The explanation includes a general idea of detection and sorting but lacks important steps or details to show how waste is separated.	The explanation is mostly clear and includes a logical process of detection, sorting, and collection, but some parts are missing or unclear.	The explanation describes a complete process of detection, sorting, and collection that works well.
	Cost: Students are able to estimate the costs of materials and components needed to build the waste	The cost is not listed at all.	The cost is listed, but lacks detail and is not logical.	The cost is listed in detail, but somehow it was not logical.	The cost is listed, detailed, and logical.

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
	sorting prototype.				
Optimal Solution Selection	Students are able to select the best solution through team discussion, ensuring it is creative, applicable, and effective.	No team discussion was done. The chosen solution is simple and not helpful in solving solid waste problems.	Students do team discussion, but the chosen solution does not clearly solve the solid waste problem.	Students do team discussion, and the chosen solution helps solve the problem but is not creative or different from common ideas.	Students do team discussion. The chosen solution is creative, different, and helpful in solving solid waste problems.
Solution Improvement	Students are able to make designs of the prototypes of the best options they've chosen.	The design does not include materials, size, or function. The design does not use any digital tools or components, and it does not help solve the solid waste problem.	The design is somewhat structured but still unclear, with limited information on materials, measurements, and functions. It uses technology, but does not effectively address the solid waste problem.	The design is mostly clear and includes materials, size, and function (with a few unclear parts). It uses digital tools or components and helps address the solid waste problem.	The design is complete, includes detailed information on materials, size, and function. It uses technology to create a strong solution to the solid waste problem.

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
	Students are able to create the prototype based on the design they've made.	The prototype does not created.	The final prototype is only materialized by a simple product that includes some technological components but is incomplete and there is no similarity to the design.	The final prototype is materialized by a simple product that includes some technological components and mostly follows their design.	The final prototype is materialized by a technology prototype that is aligned with the design resulting in a tool that is able to overcome solid waste problems.
	Students can test their prototypes in terms of efficiency, profits, and benefits.	Only 1 of 4 things (detection accuracy, speed, sorting correctness, consistency) works well: sensors are often wrong, slow, or do not sort waste correctly.	2 of 4 things (detection accuracy, speed, sorting correctness, consistency) work well: sensors sometimes work, but are still slow or not sorting correctly.	3 of 4 things (detection accuracy, speed, sorting correctness, consistency) work well: sensors are mostly fast and correct, but still need a bit of improvement.	All 4 things (detection accuracy, speed, sorting correctness, consistency) work well: sensors are fast, accurate, sort correctly, and work smoothly.
		The production cost of prototype is high and leads to a loss.	The production cost of prototype is balanced with the result, but it	The production cost of prototype is balanced with the result and	The production cost of prototype is well planned and gives a high profit

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
			makes no profit.	gives a small profit (1–20%).	(more than 20%).
		The explanation is unclear or shows that the idea may give no clear benefit.	The prototype has some benefits, but the explanation is not clear, or the benefits are very limited.	The prototype helps reduce waste or improve the environment, and students explain how it helps the community, though not in detail.	The prototype clearly helps reduce waste and brings clear benefits to the environment and community, explained with good reasoning or comparison (e.g. faster than manual sorting, less pollution, etc).
Presentation and Reporting	Students are able to present about their engineering design processes and final results.	The explanation is unclear. The steps are missing or confusing. No pictures or examples. The prototype doesn't match the problem.	Some steps are explained, but not clearly. Some examples or pictures are shown, but they don't help much. The prototype doesn't clearly solve the problem.	Most steps are explained well. Some pictures or examples are used. The prototype is related to the problem, but the explanation could be stronger.	The explanation is clear and complete, step by step. Strong pictures or examples are included. The prototype clearly matches and helps solve the solid waste problem.

Step	Indicator	Scale			
		Poor 1	Marginal 2	Satisfactory 3	Excellent 4
Design Process Management	Students are able to complete the prototype with the final design within the allotted time by controlling the design process through activities that involve working in teams.	Students do not make changes or any improvements in completing the final result of their prototype.	Students refine their prototype without considering anything.	Students refine their prototype but only consider one of the results of the trial or feedback they got.	Students refine their prototype based on the trial test results as well as feedback relevant to the subject matter.

According to this criterion, each score represents the degree of students' engineering design skills in ESD-STEM learning.

3.5.1.1. Engineering Design Skill Instrument Analysis

Before being used to assess students' engineering skills in the classroom, the instrument underwent an expert judgment stage first. The expert provided feedback in the form of qualitative comments for each phase of the engineering design process in the assessment rubric. Table 3.4 shows the recapitulation of comments from the four validators.

Table 3. 4 Recapitulation of Experts' Feedback for EDS

Phase of EDP	Experts' Feedback			
	Expert A	Expert B	Expert C	Expert D
Problem	-	Use terms that are more measurable and objective. Need indicators that can be measured consistently by all validators.	There is an inconsistency between indicator verbs and description. Need consistency in terms.	Indicators are too long, need to be simplified without losing the essence. The rating scale should use measurable and consistent phrases for all levels and use present tense.
Solution	Avoid using the word "efficient" as the context is not appropriate. The indicator is not coherent with the description of the sensor function. Suggested changing the term to better fit the design context.	Some terms need to be clarified. It is recommended to make the scale quantitative and have a logical basis for assessment. The correspondence between indicators and description needs to be strengthened, as well as simplifying score descriptions for easy understanding.	Some terms are relative and ambiguous. Need a more detailed description so as not to cause multiple interpretations.	Indicators need to be simplified to make them easier to understand. Use concrete terms, improve language consistency, use present tense. Some terms need to be changed to align with description. The rating scale should be aligned with the indicators.
Implementation	The term "technology" is too general, needs to be	Description are not yet aligned with indicators.	-	Indicators need to be simplified for clarity, using

Phase of EDP	Experts' Feedback			
	Expert A	Expert B	Expert C	Expert D
	clarified. Avoid excessive focus on profit as it is not always quantitative. It is suggested to assess the extent to which the prototype functions and how students understand and explain its performance and the assessment should focus on the learning process.	Some terms are subjective and need to be replaced with quantitative measures. The score scale also needs a clear and measurable definition.		consistent terms. Some terms like should be replaced to make it easier to understand. Use present tense consistently.
Proces managem ent	-	It should be considered if the product does not require revision after the pilot test. The assessment should consider the context of the initial functionality.	-	Use present tense in all scales.

After getting feedback from the experts, the rubric was revised according to the feedback provided so that it could be used effectively to assess students' engineering skills. Overall, the experts provided feedback related to clarity of indicators, consistency of terms, suitability between indicators and descriptions, and the use of appropriate language in the rating scale.

3.5.2. Sustainability Action Questionnaire

The sustainability actions of the students were assessed through the development of the Environmental Citizenship Questionnaire (ECQ). For the purpose of evaluating the environmental citizenship of secondary school pupils, the Environmental Citizenship Questionnaire (ECQ) is a validated assessment tool. The use of this instrument contributes to a better understanding of environmental citizenship among secondary school students, which is an important area for the study of sustainability because students as current and future citizens have a significant role to play in the accomplishment of sustainability and sustainable development goals (SDGs).

Indicators of responsible consumption and production are past and present actions, competences, and future actions. Past, present, and future actions are about everything that students have been done in the past, are being done now, and will be done in the future to overcome the environmental issues, especially in solid waste problems inside and outside the school. Competencies are about their knowledge, conceptions, and attitudes for dealing with the environmental issue and to overcome it.

The questionnaire consists of 52 items, with 27 items for past, present, future actions and 25 items for the competencies. The score used is a 4-point Likert scale with a maximum point is 4 and a minimum point is 1. Students choosed the options that reflect their daily habits related to the environment and the level to which they feel capable of taking sustainable action. For the past and present action indicator, the 4 options are never, rarely, often, and always, while for future action, the options are will not do, hesitate to do, try to do, and sure will do. For competence, the options consist of very incapable, incapable, capable, and very capable.

The questionnaire was distributed to the students at the beginning of learning (pre-test) and at the end of learning (post-test) for both experiment and control class. Students' sustainability action scores on the pretest and posttest demonstrate the impact of ESD-STEM learning as determined by statistical calculations. The results of the pretest represents the initial actions taken by students before the learning activites and posttest represents the actions taken after the learning activities. The

explanation begins with the meaning of statistically processed data, followed by the results of ESD-STEM learning during product development. It then presents an analysis from SPSS of students' sustainability actions, with each indicator explained in detail. Both quantitative and qualitative data were systematically analyzed with normality and homogeneity tests. The detailed instrument for sustainability action is attached in Appendix 2. Table below shows the blueprint of the sustainability action instruments before validation.

Table 3. 5 Blueprint of sustainability action questionnaire (before validation)

Indicator	Number of questions				Total number
	Lifestyle	Production and consumption	Environmental and social impacts	Promote sustainable practices	
Past, present, future action	1,2,3,4,5, 6,7,8	9,10,11,12, 13,14,15	16,17,18,19, 20,21,22	23,25,25,26 ,27,28,29,30	30
Competencies	1,2,3,4,5, 6	7,8,9,10,11, 12	13,14,15,16, 17,18,19	20,21,22,23 24,25	25

Source: Hadjichambis & Paraskeva-Hadjichambi (2020)

3.5.2.1. Sustainability Action Instrument Analysis

Sustainability action instrument was first validated by experts' judgment. The form is attached in Appendix 3. Each expert provided feedback in the form of qualitative comments on each indicator. The table 3.6 is a recapitulation of comments from the three experts.

Table 3. 6 Recapitulation of Experts' Feedback for Sustainability Action Instrument

Indicator	Experts' Feedback		
	Expert A	Expert B	Expert C
Past, present, future action	Some terms and phrases need to be adjusted to make them easier for students to understand. In addition, some sentences need to be grammatically simplified to make them more communicative and appropriate for the age level of the respondents.	Some words should be removed or replaced because they are too general or vague. Some items should also be revised to be more contextual and specific.	Some statements are considered to overlap with behavioral aspects and do not reflect socio-emotional aspects. It is recommended to add an element of emotion to better fit the social-emotional domain.
Competencies	Some items were considered too general or similar to other items. It is recommended to use more specific and contextual sentences, such as mentioning concrete behaviors. Some terms also need to be replaced to make them more relevant and easier to understand.	Some sentences were suggested to be restructured to make them clearer and more natural in language. Some items were considered similar to other statements and were suggested to be revised. There were also suggestions to make the statements more active and realistic.	The behaviors in the statement are considered not to reflect sustainable practices, so they need to be replaced with behaviors or choices that are more relevant to sustainability principles.

The instrument was revised based on the judgment result and distributed to secondary school students to be tested. Then the result data of the test was analyzed

by using IBM SPSS to see the validity and reliability. In research, validity means how accurately a study measures what it is meant to measure and the reliability refers to the consistency of a measure. Table below shows the interpretation of the validity and reliability score.

Table 3. 7 Validity and Reliability Interpretation

Validity		Reliability	
Sig. (2-tailed) Value	Interpretation	Cronbach's Alpha Value	Interpretation
>0.05	Valid	>0.60	Reliable
<0.05	Not valid	<0.60	Not Reliable

The results of the validation study of the sustainability action questionnaire from the past, present, and future action indicator showed in table below.

Table 3. 8 Validity score of sustainability action questionnaire past, present, and future indicator

Item Num ber	First trial			Valid	Second trial			Conclus ion
	Validity				Validity			
	Past	Present	Future		Past	Present	Future	
1	0.034	0.001	0.788	Not Valid	0.006	0.001	0.027	Accepted
2	0.147.	0.001	0.004	Not Valid	0.001	0.001	0.001	Accepted
3	0.008	0.100	0.001	Not Valid	0.002	0.001	0.001	Accepted
4	0.457	0.344	0.216	Not Valid	0.003	0.001	0.001	Accepted
5	0.001	0.001	0.001	Valid				Accepted
6	0.273	0.124	0.024	Not Valid	0.013	0.008	0.001	Accepted
7	0.811	0.124	0.034	Not Valid	0.005	0.001	0.043	Accepted
8	0.180	0.048	0.087	Not Valid	0.020	0.186	0.001	Not Accepted
9	0.001	0.001	0.001	Valid	0.001	0.001	0.001	Accepted

Item Num ber	First trial			Valid	Second trial			Conclus ion
	Validity				Validity			
	Past	Present	Future		Past	Present	Future	
10	0.007	0.001	0.004	Valid	0.007	0.001	0.004	Accepted
11	0.001	0.001	0.039	Valid	0.001	0.001	0.039	Accepted
12	0.001	0.013	0.033	Valid	0.001	0.013	0.033	Accepted
13	0.001	0.001	0.002	Valid				Accepted
14	0.044	0.001	0.096	Not Valid	0.004	0.007	0.05	Accepted
15	0.043	0.169	0.160	Not Valid	0.001	0.001	0.019	Accepted
16	0.001	0.001	0.060	Not Valid	0.001	0.001	0.006	Accepted
17	0.001	0.001	0.130	Not Valid	0.001	0.001	0.035	Accepted
18	0.239	0.001	0.446	Not Valid	0.189	0.680	0.032	Not Accepted
19	0.091	0.008	0.010	Not Valid	0.012	0.027	0.012	Accepted
20	0.004	0.001	0.889	Not Valid	0.004	0.001	0.012	Accepted
21	0.029	0.003	0.001	Valid	0.029	0.003	0.001	Accepted
22	0.025	0.001	0.001	Valid				Accepted
23	0.001	0.001	0.046	Valid	0.001	0.001	0.046	Accepted
24	0.001	0.001	0.072	Not Valid	0.001	0.001	0.001	Accepted
25	0.001	0.001	0.005	Valid	0.001	0.001	0.005	Accepted
26	0.019	0.001	0.001	Valid	0.019	0.001	0.001	Accepted
27	0.001	0.001	0.029	Valid	0.001	0.001	0.029	Accepted
28	0.001	0.001	0.001	Valid	0.001	0.001	0.001	Accepted
29	0.040	0.020	0.001	Valid				Accepted
30	0.943	0.460	0.001	Not Valid	0.943	0.460	0.001	Not Accepted

Table 3. 9 Reliability score of sustainability action questionnaire for action indicator

First trial	Second trial	Reliability	Conclusion
0.705	0.800	Reliable	Accepted

The result of the first trial showed that 14 out of 30 questions were invalid and all the valid statement didn't enough to represent all sub-topics so the second trial was conducted. After the second trial, it was found that 3 out of 30 questions were still invalid, but because the all valid statements were already represented all sub-topics, the 3 invalid statements were just not be used. Thus, the final number of the instrument used to measure students' sustainability action of responsible consumption and production was 27 numbers. For the result of the validation analysis of competencies indicator of sustainability action questionnaire is shown in table below.

Table 3. 10 Validity score of sustainability action questionnaire for competencies indicator

Number of items	First trial	Valid	Second trial	Conclusion
1	0.001	Valid		Accepted
2	0.001	Valid		Accepted
3	0.001	Valid		Accepted
4	0.037	Valid		Accepted
5	0.047	Valid		Accepted
6	0.040	Valid		Accepted
7	0.001	Valid		Accepted
8	0.001	Valid		Accepted
9	0.001	Valid		Accepted
10	0.001	Valid		Accepted
11	0.264	Valid	0.001	Accepted
12	0.620	Valid	0.001	Accepted
13	0.001	Valid		Accepted
14	0.001	Valid		Accepted
15	0.034	Valid		Accepted
16	0.002	Valid		Accepted
17	0.001	Valid		Accepted
18	0.001	Valid		Accepted
19	0.001	Valid		Accepted
20	0.001	Valid		Accepted
21	0.001	Valid		Accepted
22	0.001	Valid		Accepted

Number of items	First trial	Valid	Second trial	Conclusion
23	0.001	Valid		Accepted
24	0.222	Valid	0.001	Accepted
25	0.001	Valid		Accepted

Table 3. 11 Reliability score of sustainability action questionnaire competencies indicator

First trial	Second trial	Reliability	Conclusion
0.837	0.790	Reliable	Accepted

The first step in the process of developing an instrument is to have an understanding of each indicator that has been developed (Hadjichambis & Paraskeva-Hadjichambi, 2020). After that, 55 items were created to match the topic of solid waste in science learning. These 55 items were reviewed through the experts' judgment for wording, relevance of indicators and concepts to junior high school level. After the experts' judgment, revisions were made based on feedback and judgment. The items that was already revised, tested on 60 students and the data were analyzed using IBM SPSS.

In this process, the researcher did twice for the trial until all the items covered all sub-topics. At the first trial, all the items for competencies indicator were valid but the second trial needed because the past, present, and future action indicator that didn't covered the sub-topics. The final results showed 52 out of 55 items were valid. This trial test checked for validity, reliability, to determine whether the questions are clear and can be understood by students as well as to see the time taken to complete the questionnaire. The final and complete instrument is attached in Appendix 4.

Table 3. 12 Blueprint of sustainability action questionnaire (after validation)

Indicator	Number of questions				Total number
	Lifestyle	Production and consumption	Environmental and social impacts	Promote sustainable practices	
Past, present, and future action	1,2,3,4,5,6,7	8,9,10,11,12,13,14	15,16,17,18,19,20	21,22,23,24,25,26,27	27
Competencies	1,2,3,4,5,6	7,8,9,10,11,12	13,14,15,16,17,18,19	20,21,22,23,24,25	25
Total	13	13	13	13	52

The statements in this questionnaire have been adapted to activities that are close to the lives of junior high school students with the use of simple words. For the example of statements can be seen in the table below.

Table 3. 13 Sample statement of responsible consumption and production instrument

Indicator	Statement
Past, present, and future action	<i>Saya menyumbangkan pakaian lama yang tidak terpakai</i>
Competencies	<i>Saya mengikuti kegiatan kerja bakti di lingkungan rumah atau sekolah</i>

3.6. Research Procedures

3.6.1. Preparation Stage

In this stage, the researcher made several preparations to carry out the research. Starting from identifying some global national and ideal issue then formulating the problem to find the variables to be measured and the topics to be discussed related to sustainability issues. The researcher did a literature study and began to design the proposal outline and compile it. After that, researcher also developed rubrics, questionnaires, lesson plans, worksheets, and observation sheets

that would be used to analyze predetermined variables, which were then evaluated through judgment by the expert, statistical calculation, and carried out revisions based on the results of the evaluation conducted.

3.6.2. Implementation Stage

The implementation stage consists of several steps as follows:

1) Giving the pre-test to students

At the beginning, before the ESD-STEM learning for solid waste management begins, both experimental and control classes will be given a pre-test to determine the students' initial knowledge and ability for sustainability action. The pre-test was given to students using Google Forms.

2) Implementation of a solid waste management project on the topic of environmental pollution

After conducting the pre-test, the experimental class conducted ESD-STEM learning through a solid waste management project with the STEM stages from Widodo, A. (2021), whereas the control class learned through teacher's regular model using with the stages of inquiry-based learning from Pedaste et al. (2015). Because of the different model used, the time taken was quite different. The experimental class took about six meetings, with two meetings at home, while the control class took only 4 days without any tasks at home. Teaching materials, the worksheet, and observation sheet can be seen in Appendix 5. The table 3.14 shows the differences between the experiment class and control class in learning activity.

Table 3. 14 Experiment Class and Control Class Differences in Learning Activities

Meet-ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
At home	1) The teacher assigns students to conduct group observations outside of school	Problem Formulation	-	-

Meet -ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	regarding environmental problems caused by the accumulation of waste 2) The teacher distributes LKPD through Google Classroom 3) Students conduct group observations outside of school hours 4) Students record their findings into worksheet by answering the questions on LKPD pages 1-3. 5) The teacher ensures that all students make environmental observations.			
1	1) The teacher and students pray before learning begins 2) The teacher checks student attendance. 3) Students divided into 5 groups. 4) Students bring the own worksheet. 5) The teacher directs students to read about the objectives of sustainable development on the worksheet. 6) Students carry out a group discussion to answer the	Think	Orientation	1) The teacher and students pray before learning begins. 2) The teacher checks student attendance 3) The teacher shows a picture of a neighborhood filled with waste and invites students to observe and ask what is happening in the picture.

Meet-ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	questions in the worksheet. 7) The teacher shows a video of an example of existing technology that is able to overcome solid waste problems that happened due to lack of public awareness. 8) Students watch the video and fill the worksheet about the advantages and disadvantages of the technology. 9) Students carry out group discussions to propose 3 technology solutions that can overcome solid waste problems. 10) Students analyze the relationship of the designed technological solution with economic, social, and environmental aspects.			4) Students divided into 5 groups. 5) The teacher shows a video about solid waste problems that occur in Indonesia, West Java, and Bandung city. 6) Students watch the video about solid waste problems. 7) Students note important things from the video. 8) Students answer the questions in the worksheet.
			Conceptualization	9) Students discuss to formulate some questions based on the information in the video. 10) Students discuss making hypotheses about solutions that can answer their questions.
			Investigation	11) The teacher directs students to search for information to answer the

Meet-ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
				questions and test their hypotheses. 12) Students search for information through the internet to analyze the questions and hypotheses that have been made. 13) Students write down one main idea that answers their question. 14) Students continue the group discussion to answer the questions on the worksheet.
2	1) Students in a group make the details of the technology product to be made from the size, shape, materials, work methods, and also the cost. 2) Students choose one solution that can be implemented based on the ir discussion results. 3) The teacher guides students during the discussion.	Think	Investigation	1) The teacher shows a video of an example of existing technology that is able to overcome solid waste problems that happened due to lack of public awareness. 2) Students analyze the advantages and disadvantages

Meet-ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	4) The teacher directs students to make product designs in groups. 5) Students determine the tools and materials they will use. 6) Students in groups create a design for a technology product that has been selected.	Design		of the products in the video and propose another innovation as their product solution. 3) Students analyze the economic, social, environmental impacts of their solutions 4) Students design the product starting from the size, shape, material, how it works, cost. 5) Students continue the discussion to answer questions in the worksheet related to the product. 6) Students create product designs. 7) Teacher guides the students during the planning of the product design.
3	1) The teacher directs the students to prepare the tools and materials and	Create	Investigation	1) The teacher directs students to make products.

Meet -ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	then start making the product. 2) Students prepare the tools and materials they have brought. 3) Students start making technology products according to the design that has been designed. 4) The teacher guides students during the making of the technology product. 5) Students take documentation of the creating technology products process.			2) Students make the product based on the design that has been made. 3) Students write the tools & materials as well as the creating steps carried out into the worksheet 4) Students take documentation of the creating process.
			Investigation	1) The teacher directs students to test their products by doing a presentation. 2) Students test their products. 3) Students record the results of their product test by answering the questions in the worksheet.
4	4) The teacher directs students to continue making technology products.	Create	Conclusion	1) The teacher directs the students to make conclusions about the

Meet -ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	5) Students make technology products in groups. 6) Students take a documentation of the process. 7) The teacher guides students during product creating. 8) Students fill in the worksheet about the process of making the product.			effectiveness of the products that have been made. 2) Students conclude whether their products are effective enough to solve solid waste problems based on the records of the trial results. 3) The teacher directs students to evaluate the results of their products. 4) Students compare the product test results with their initial hypothesis.
5	1) The teacher directs students to test the products that have been made by doing a presertation. 2) Students explain the creating process, show the documentation, and then show how the product works. 3) The teacher and other students give a question or the feedback for the	Test	-	-

Meet -ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	product that is being tested. 4) Students in groups answer the questions on the lkpd to evaluate the product's efficiency, profiy, andbenefits obtained based on the test results. 5) The teacher guides students during the testing process.			
6	1) Students carry out the discussion to 2) The teacher directs students to do the redesign. 3) Students make product improvements according to previous notes. 4) The teacher guides students in carrying out the redesign. 5) Students continue to fill in the worksheet in groups to record the results of their redesign.	Redesign	-	-
At home	1) The teacher directs students to socialize their technology products. 2) Students in a group design a strategy to socialize their products and design.	Socialize	-	-

Meet -ing	Experiment Class	Learning Stages		Control Class
		STEM Model	Teacher's regular model	
	3) Students socialize their products through their social media.			

4) Giving the post-test to students

The post-test was given at the end of the activity when all meetings had been conducted. The post-test was conducted during at school in the for the experimental class while the control class was conducted online. The students were given a sustainability action instrument using Google Forms. The post-test of students' engineering skills was conducted by the researcher to assess students' engineering skills during learning.

3.6.3. Completion Stage

The data collected on students' sustainability actions and engineering design skills is analyzed and addressed in the final stage. It involves an in-depth examination of the gathered data using statistical approaches. Therefore, the conclusion will be formed.

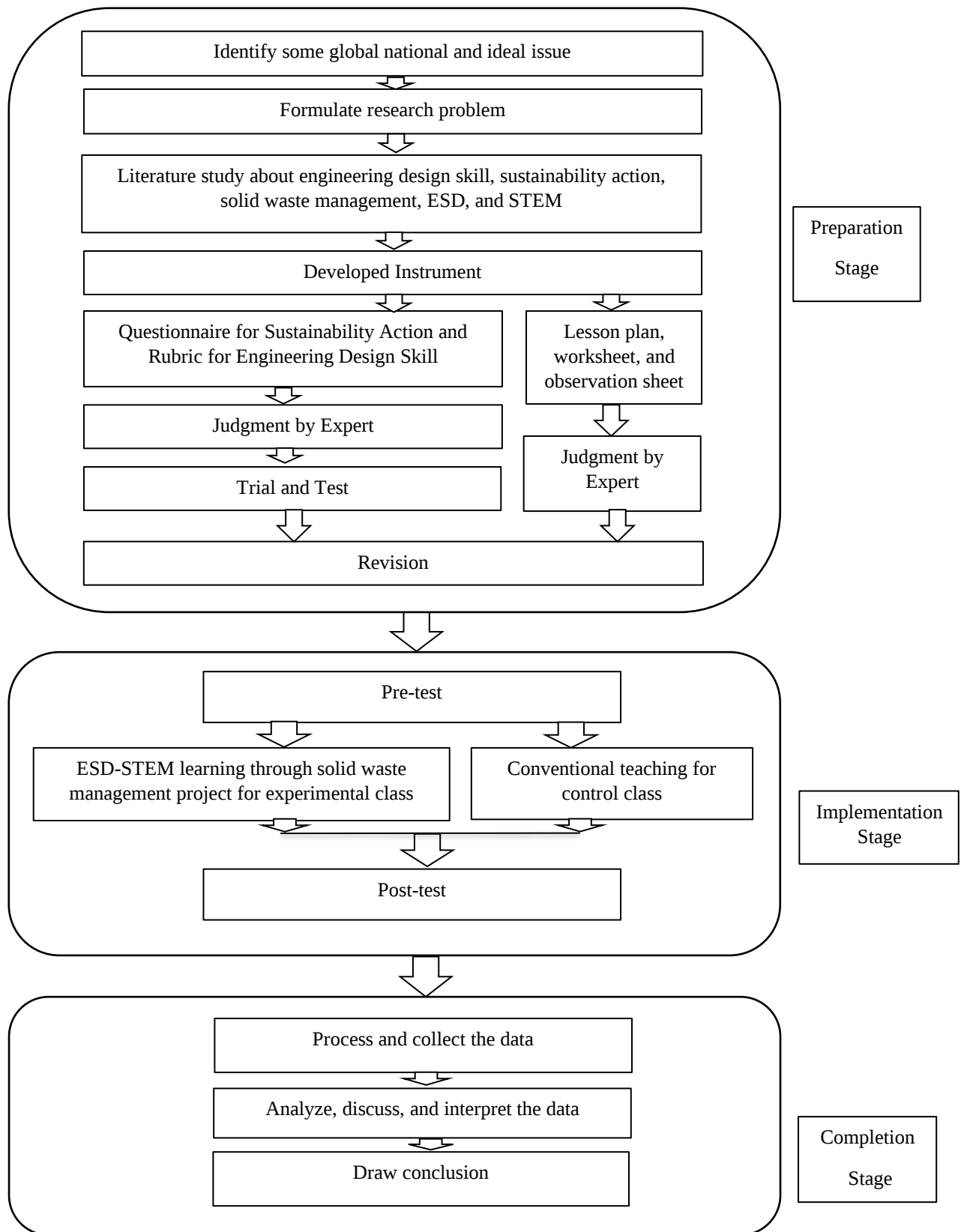


Figure 3.1: Research Procedure Flowchat

3.7 Data Analysis of Result

The data collected from students were analyzed qualitatively and quantitatively. The analysis used to compare the result of experimental and control class. The procedures are explained below:

3.7.1. Engineering Design Skill

Qualitative data for students' engineering design skill were collected through observation during classroom learning. The classroom learning process was observed by the researcher and the observers and notes were taken. The results of observations from researchers and observers were combined to be analyzed descriptively which included student involvement, activeness, and engineering design skills during the project. In addition, an interview was also conducted to support the analysis.

Quantitative data on students' engineering design skills were collected from a performance-based evaluation rubric, which ranged from a highest score of 4 to a lowest score of 1. The data analysis began by calculating the average (mean) of the experimental class to determine the distribution of engineering design skill scores within the experimental class. The results of the group's average aim to show how good students' engineering design skills are in the experimental class, which is categorized based on the categorization from (Purwanto, 2008), including four categories as shown in Table:

Table 3. 15 Categorization of Engineering Design Skills

Category	Score (%)
Very good	86-100
Good	76-85
Fair	60-75
Poor	55-49
Very poor	<54

Source: Purwanto (2008)

No statistical test was carried out because students' engineering design skills were only measured at the end of the study without a pretest.

3.7.2. Sustainability Action

Qualitative data for students' sustainability action were collected through the interviews with selected students. The interview was about some questions to know the affect of the learning to students' sustainability action in their daily life and then the answers will analyzed descriptively the students' experiences and actions.

For the quantitative data for students' sustainability action were collected from questionnaire given to students at the beginning and at the end of the learning activity. The pre-test and post-test were in the form of statements related to students' actions in daily life that were converted into numbers to facilitate analysis and interpretation. There were 2 types of statements in the questionnaire, namely positive and negative, which have an inverse score. With a score on the statement that is 1 for the lowest and 4 for the highest and then the data were analyzed using non-parametric tests because one of the data was not normally distributed.

The data analysis began with normality and homogeneity tests to facilitate for further analysis and then the average pre-test and post-test scores of students' sustainability actions were compared between the experimental and control groups. Additionally, gain scores were determined by subtracting pre-test scores from post-test scores. An N-Gain test was subsequently administered to assess the level of improvement: low, medium, or high.

3.7.2.1. Normality Test

The normality test is used to verify whether the data obtained is from normally distributed populations or not. In this study, the results of the pretest and post-test were tested using the Shapiro-Wilk test because there were only 36 samples for each class. To determine whether the data follows a normal distribution with the criteria if the significance value is <0.05 , it means the data is not normally distributed while if the value is >0.05 , it means the data is normally distributed.

For the experimental class, the results of the normality test using SPSS showed 0.014 for the pre-test and 0.001 for the post-test. As for the control class,

the normality test results showed 0.549 for the pre-test and 0.094 for the post-test. This shows that one of the data was found to be not normally distributed.

3.7.2.2. Homogeneity Test

A homogeneity test was performed to determine whether or not samples from the control and experimental classes originated from uniform populations with the criteria, if the significance value is <0.05 , then the data is not homogeneous and if the significance value is >0.05 , then the data is homogeneous. The result of analysis shows 0.374 for the pre-test and 0.054 for the post-test which indicates the data of the pre-test and post-test are homogeneous that were tested by using the Laveine test.

3.7.2.3. Hypothesis Test

Hypothesis test was conducted to determine the influence of ESD-STEM learning projects on sustainability action of secondary school students using non-parametric tests using Mann-Whitney U test. With a criteria if a significance of <0.05 , it indicates that there is an influence. The result of the analysis shows 0.029, indicating H_1 is accepted which means there is a significant difference in students' sustainability action before and after the learning activity.