CHAPTER III
RESEARCH METHOD

This chapter is divided into three sections. The first section presents the research design used in this study. The second section outlines the procedures and steps of the research at each phase and also presents the stages of instrument development tailored to the problem formulation. The third section explains the techniques for collecting research data.

A. Research Design

This research aims to develop a STEM-LCE learning program to enhance critical thinking skills, creativity, collaboration skills, communication skills, and sustainability consciousness among prospective teacher students. This research uses a mixed method with an exploratory design in accordance with the sequential steps and stages in the collection of both qualitative and quantitative data (Creswell & Clark, 2007). The research process is conducted through several stages of activities, including the first stage, which is a preliminary study to identify the form of intervention (treatment) needed in STEM-LCE learning program for learning activities qualitatively. The second stage is STEM-LCE learning program development stage using the ADDIE development model (analysis, design, develop, implementation, evaluation), which includes the design and preparation of interventions, expert validation stage, and the trial implementation stage of the treatment (the developed intervention) to the non-subject students, followed by evaluation. The third stage is the implementation of the STEM-LCE learning program that has undergone trials and validation to the subject, as well as quantitative data collection. The fourth stage is the qualitative interpretation of the data.

The researcher used this mixed method design because it is very suitable for the learning program development activities conducted in this study. The researcher developed and implemented the learning program quantitatively based on qualitative findings sequentially. In this design, the researchers first explored the

research topic qualitatively related to the perspectives of students and teachers on the Low-carbon education concept and STEM in learning by using questionnaires with several participants. Here is also the qualitative data analysis related to SETS learning for environmental issues at the university and literature studies related to low-carbon education, STEM, 4C, and sustainability consciousness. The qualitative findings then guide the development of the STEM-LCE curriculum program along with its components, namely the semester learning plan, e-modules, and instrument items to quantitatively assess 4C skills and sustainability consciousness. In the next phase of data collection, the researchers quantitatively applied and validated the learning program and instruments. Then the data were collected quantitatively with pretests and posttests, along with some supporting qualitative data. Then, the qualitative and quantitative data were interpreted with a greater emphasis on the quantitative data. In this design, qualitative and quantitative methods are linked through the development of STEM-LCE learning programs and instruments. Researchers who use this design often emphasize the quantitative aspects of the study (Mak & Marshall, 2004). The description of the research stages that have been conducted in this research can be described in **Figure 3.1** below. This research used mixed method by exploratory research design.

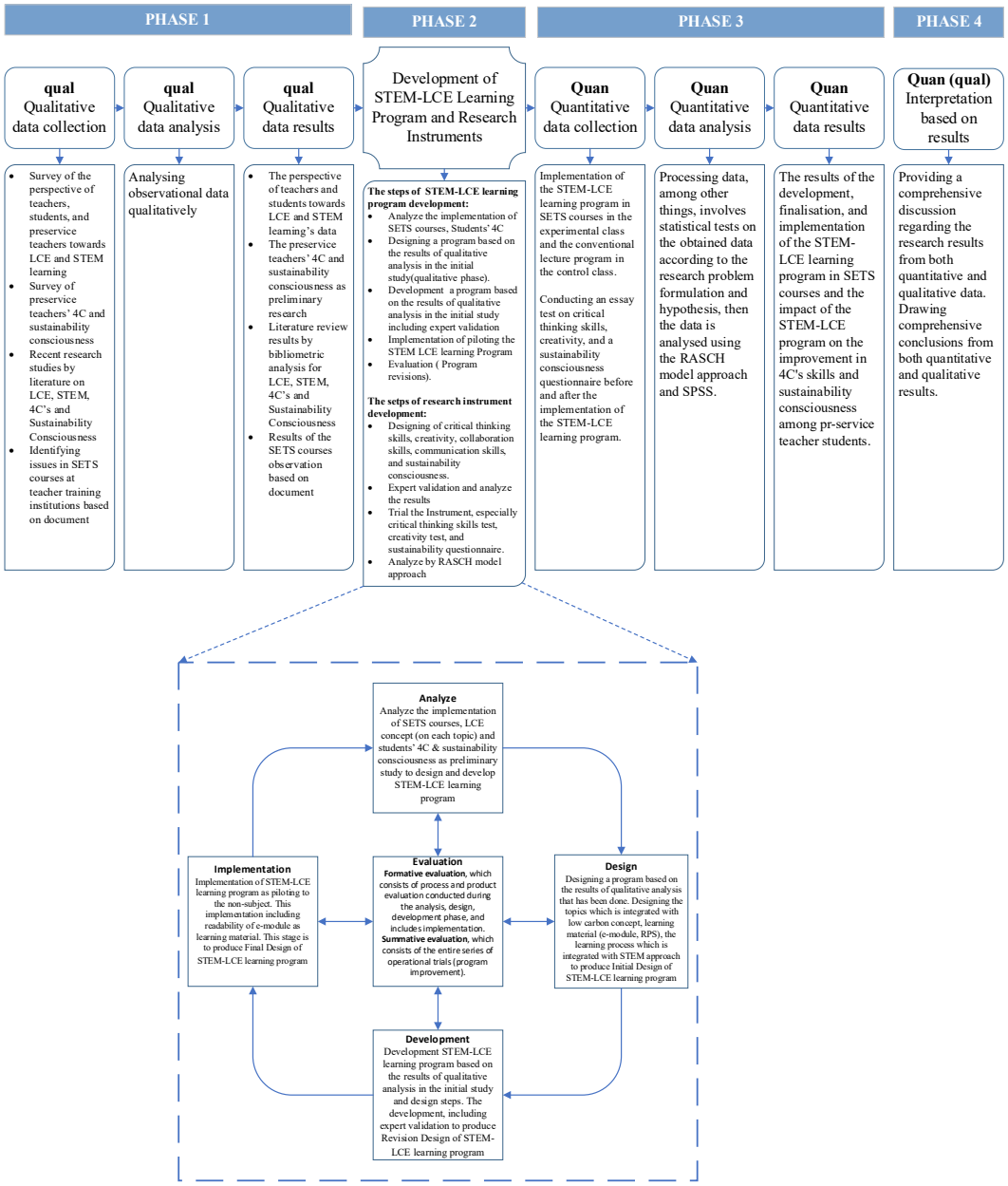

Figure 3.1. Procedures and Design of Exploratory Research

B. Research Procedure

This research uses mixed methods exploratory design research. The implementation of the mixed methods exploratory design research is divided into 4 main stages: 1) the qualitative stage before the intervention, in this stage a preliminary study is conducted through literature review and field study by collecting and analyzing data; 2) Developing the program along with its

instruments. The development of this STEM-LCE learning program are conducted by ADDIE model of program development; 3) The quantitative stage involves implementing the developed STEM-LCE learning program by examining the dependent variables related to the program; 4) Interpreting quantitative and qualitative data. The four stages are detailed into several activities as follows:

1. Qualitative stage before the intervention

The qualitative stages before intervention consisting of collecting qualitative data, analyze qualitative data, and results of the qualitative data for need analysis of this research. The collection of qualitative information before the intervention was conducted by distributing questionnaires or forms containing information about the understanding and presence of low carbon education and the implementation of STEM learning in the field, especially in schools, to various stakeholders (teachers, lecturers, principals, and students) along with the implementation of environmental-based learning that has been carried out at their institution in Java from elementary school, middle school, high school, and university. In addition, there are interviews regarding the understanding, awareness, and attitudes of teachers or lecturers and students towards the environment, particularly the essence of low-carbon education. Observation and study of learning document such as semester lesson plan (RPS) or syllabus from some of the University in Java and outer Java which has environmental education courses and also study of SETS courses implementation documents and learning activities in one of the private universities in Bogor. The literature study also has been done by bibliometric analysis pertaining low-carbon education research and STEM learning in the world, especially in Indonesia. Additionally, preliminary study of preservice teachers' critical thinking skills, creativity, collaboration skills, communication skills, and sustainability consciousness through survey or previous study.

Those qualitative data have been obtained and published with the results that described most of teachers at school has misunderstanding pertaining the implementation of STEM learning at the classroom which only science and mathematics teacher who could conduct that learning approach (Nurramadhani et al., 2024c). While, actually students and teachers has already done the concept

pertaining low-carbon education (LCE) at school and also in university, but implicitly. They think that low carbon only studies the smoke from motor vehicles and factories in the air, air pollution, and air contamination, whereas LCE is related to daily lifestyles on how we can reduce carbon emission footprints (Nurramadhani et al., 2022, 2024c). This is also supported by the analysis of learning documents (RPS) related to environmental education at universities, which have not yet explicitly stated the concept of low-carbon education. Similarly, the results of the bibliometric analysis of previous research documents on low-carbon education indicate that low-carbon education research is on the rise, with many researchers worldwide concerned about LCE, particularly in countries like China, the USA, the United Kingdom, Brazil, and others. Meanwhile, in Asia, there are countries like Malaysia and Japan that have conducted extensive research related to LCE. Indonesia itself already has several researchers studying LCE, but there are not many and there has not yet been any real implementation of the low carbon concept in the field of education (Nurramadhani et al., 2024b). The results of these analyses can serve as a strong foundation for conducting research on the development of a curriculum program that explicitly incorporates the concept of low-carbon education and is contextualized with a STEM learning approach.

Thus, based on the qualitative data obtained, the STEM-LCE learning program along with its teaching materials was developed. Like the semester learning plan (RPS) and e-module that were developed based on document studies related to SETS learning materials, which still implicitly convey the low-carbon concept, the materials or topics prepared are those that explicitly include the low-carbon-education concept. For example, this includes calculations of carbon emissions footprint. The selection of topics or materials is also adjusted to address actual and real environmental issues in daily life and can be viewed from an interdisciplinary perspective. The preparation of learning materials is also aligned with the approach used in the developed STEM-LCE learning program, namely the STEM approach. Additionally, the e-module and semester learning plan (RPS) construct the 4C skills and sustainability consciousness of preservice teacher. Then, instruments were also developed to collect quantitative data during the

implementation of the STEM-LCE learning program. In the next phase of data collection, the researchers quantitatively applied and validated the learning program and instruments. Then the data were collected quantitatively with pretests and posttests, along with some supporting qualitative data.

2. Development Stage of the STEM-LCE Learning Program and Research Instruments

At this stage, the development of the STEM-LCE learning program along with its learning material and research instruments is being prepared. For development of STEM-LCE learning program is uses ADDIE learning model development adapted from Robert Maribe Branch which is the most widely used systematic framework in learning development (Allen, 2006; Mesra, 2023). The steps to develop this learning program, initially identify and analysis the needs assessment, the reason to develop STEM-LCE learning program. Then, design and develop the STEM-LCE learning program that suitable with SETS courses and research objective. After that implementation the STEM-LCE learning program that has been developed by implement the piloting it to non-subject students. Finally evaluate the piloting results in order to make the feasible STEM-LCE learning program to be implementing in research subject. In detail, the stages are explained in the following explanation below.

a. Analysis or Needs Assessment

This steps, it needs assessment to identify the existing of low-carbon education concept that has been implemented in learning, especially in Indonesia. Based on the entire description of courses related to environmental education in science education study program in public and private LPTK in Indonesia, there is no explicit low carbon concept. This is corroborated by data on understanding the concept of low carbon in students and teachers who do not know what low carbon is. The teacher did not realize they already knew about the low carbon education (LCE) concept. Low carbon education is a type of environmental education that covers topics such as the greenhouse effect, energy conservation, renewable energy, and so on. These subjects and activities have previously been included in

Indonesian education curricula. Those that have already been implemented in teaching and learning at all levels of education, from elementary school to higher education, but implicitly (Nurramadhani et al., 2022).

It is strengthened by the observation study that was conducted at a private university in Bogor, which also implemented environmental education under the name of SETS course. SETS courses are taken by students of all study programs within the Faculty of Teacher Training and Education including science education with 2 credits in semester 1 and 2. The material of this course has applied related to how to protect the environment from global warming based on local wisdom with the role of technology in it for the community. For example, analyzing local wisdom in Greater Bogor; analyzing Bogor as the city of million *angkot*; analyzing food potential in Greater Bogor, analyzing Bogor the city of rain. These materials are implemented with project-based learning. All the topic has not been explicitly described pertaining low-carbon education concept. In addition to the document analysis related to the existence of the low-carbon education concept, the analysis also includes the 21st-century skills of students who have undergone observations of previous SETS courses. Learning in the SETS courses that have been completed, students have been trained in collaboration skills, communication, critical thinking skills, and creativity. However, the results show that students' 4cs' is still not optimal. Their sustainability consciousness also not optimal.

Therefore, there is a need for learning that can enhance students' creativity, especially originality. The STEM learning approach can help optimize these skills, as STEM education can train students to become problem solvers related to real and contextual issues. The LCE concept is a real and contextual concept that can train students' 21st-century skills and sustainability consciousness. Thus, topics can be developed and organized in SETS courses that describe the low-carbon education (LCE) concept and outline learning steps with a STEM approach to train 4C's skills and sustainability consciousness. The evaluation in this analysis stage is when analyzing, not forgetting to analyze previous learning activities, so that it is clear to see which parts can be integrated with STEM learning and the concept of low-carbon education. And the analysis is extended to other similar courses like SETS,

which is implemented in universities with characteristics close to the low-carbon education concept.

b. Design

After the need assessment or analysis is described, the STEM-LCE learning program begins to be designed by organizing the topics to be studied with a low-carbon education (LCE) concept. The topics are climate change and destruction, low-carbon food, and circular economic waste. These topics are structured by contextually integrating the concept of low-carbon education based on real-life problems and local wisdom.

Designing the steps of the STEM-LCE learning program as an initial design, including brainstorming (problem identification), discover a solution (design and make a project), reveal a solution to the problem (project communication and evaluation). The learning process also considering using the scientific inquiry and engineering design process (EDP) framework. The learning material that is designed is e-module and semester lesson plan (RPS) which based on low-carbon education concept and STEM approach which can train 4C skills and sustainability consciousness.

In addition to the design materials for the STEM-LCE learning program and teaching materials for learning, instruments were also constructed for research to collect data on 21st-century thinking skills (critical thinking skills, creativity, collaboration skills, communication skills) and sustainability consciousness. The form of instruments is creativity test, critical thinking skills test, sustainability questionnaire, collaboration rubric, and oral communication rubric also developed in these stages.

Evaluations at the design stage include, there should be focused in description of the activity flow per topic. The design should explain how each topic is integrated into the learning and project stages. Not all topics in the SETS course can be integrated with the low-carbon education concept, so a topic was chosen that is highly relevant to real life and the low-carbon education concept, which emphasizes carbon emission footprints. Topics, learning materials, and learning

processes should emphasize to train students' 4C skills and sustainability consciousness.

c. Development

The STEM-LCE learning program, its learning material, and the instrument of research should be validated by the expert in these stages. STEM-LCE learning program has validated by 5 experts, 2 experts in low-carbon education and 3 experts in STEM learning. The criteria for a validator are someone with expertise in STEM and low-carbon education, who implements this in their *tridharma* activities, and can provide feedback to improve the STEM-LCE learning program. Someone who has education qualification minimum doctoral degreee.s They provided feedback on the learning program along with its teaching materials. Likewise, this research instrument. The experts gave the feedback in the learning program, there is a suggestion to add an Introduction at the brainstorming stage, resulting in a revision design. For the learning material, e-module, there is feedback to add “challenge” in students’ worksheets for each topic. Thus, the limited STEM-LCE design that will be piloted is the design that has been revised from initial design. Designing the steps of the STEM-LCE learning program as revised design, including brainstorming (introduction and problem identification), discover a solution (design and make a project), reveal a solution to the problem (project communication and evaluation).

The evaluation at the development stage includes the validator assessing the instrument grid as clear enough, making it easier to evaluate the suitability of the test items. The validator also provided input to build a better STEM-LCE learning program that aligns with the research objectives. The selection of validators was appropriate, based on their expertise and the research needs. The program structure follows the scientific inquiry framework and the Engineering Design Process (EDP), facilitating the implementation of problem-based and project-based learning. The integration of low-carbon education with real-world topics (climate change and destruction (low-carbon energy), low-carbon food, circular economy waste) was considered relevant by the validator.

d. Implementation

This stage is the implementation of piloting for STEM-LCE learning program. This piloting has been done for one semester in small group. There are 3 topics related to low carbon education, i.e. climate change and destruction, low-carbon food, and circular economic waste, then the final result of which is a project solution to the problems presented by each topic. A limited trial was conducted with non-subject pre-service teacher. After obtaining the results of the limited trial, revisions were made to the learning program as final design and research instruments. The final design described the STEM-LCE learning program as follow several steps brainstorming (introduction and problem identification), discover a solution (design and make a project), reveal a solution to the problem (project communication and evaluation). The differences between revised design with this final design, it has characteristic in learning process, one of them is home-based activity for identification of the problem and classroom-based activity for other steps. Final design of STEM-LCE learning program will be implemented in quantitative stage with the subject of this research.

In these stages, beside construct the learning program design, it also has been done the readably test for e-module to ensure that the e-module suitable, understood, and comprehended by students, so they will find it easy to learn new concepts explicitly, namely the low-carbon education concept. The research instruments for 4c skills, especially critical thinking and creativity skills, and sustainability consciousness were also piloted with non-subject students. This is done to see whether the questions and questionnaires are valid and reliable for implementation on the research subjects. Thus, the data collected are optimal results.

The evaluation at this implementation stage, with program and instrument revisions after piloting, demonstrates the application of formative evaluation principles. The evaluation of the implementation includes, among other things, the conduct of a small group trial for one semester, which allows for in-depth observation of the effectiveness of the learning design before full-scale implementation. It's better to have more students so it's more realistic to see the first

trial. Dividing activities between home-based (problem identification) and classroom-based (solution design and presentation) enhances the connection between field experience and classroom learning. Peer assessment can be used to assist with evaluation during home-based learning activities.

e. Evaluation

At this stage, is an overall program evaluation. This evaluation can be called summative evaluation. The evaluation of the program is based on the learning observation sheets. The observation sheet given to the piloted students is to see how the implementation of learning with the STEM-LCE learning program and its impact on students' motivation and ease of understanding the low carbon education concept. The evaluation results have been described. The implementation of the STEM-LCE learning program took slightly more meeting time than usual. Topic 1 took more time than the midterm test, totaling 9 meetings, which required the meetings for the other two topics to be compressed. Thus, the learning process is divided into home-based activities and classroom-based activities for managing the time and meeting. Students are asked to conduct problem identification through home-based activities, and in the next meeting, they are required to present the results of their group's identification before moving on to the design stage. The other evaluation results which should be considered in the next research implementation, is also related to students' understanding of calculating carbon emission footprints. The students are not only learnt from the e-module, but also they need to be reinforced in the introduction stage by the lecturer for how to calculate carbon emissions footprint.

3. Quantitative Stage

Quantitative stage is the implementation of STEM-LCE learning program research to the subject as explained in phase 3 on **Figure 3.1**. In these stages, the implementation is done by the quantitative method by giving pretest and posttest to the subject. Quantitative data during the intervention were obtained by administering tests on critical thinking skills, creativity, and a questionnaire related to sustainability consciousness, conducted before (pretest) and after (posttest) the

intervention in both of classes. The STEM-LCE learning program in SETS courses is conducted over a full semester. The implementation is conducted in two classes. The first class used project-based learning model with STEM-LCE learning program as experimental class, while control class used project-based learning model with SETS approach as common learning. The critical thinking skills, creativity, and sustainability consciousness are analyzed by the stacking analysis with RASCH model approach from the logit value of pretest and posttest.

During this research, the others skills such as collaboration skills and communications skills, and also the assessment of the products produced from each topic in STEM-LCE learning are assessed. Collaboration skills and communication skills, the results are analyzed through the stacking scores with RASCH model approach analysis from the meetings on topic 1, topic 2, and topic 3 (**Figure 3.2**). Similarly, the analysis of project creativity results. In addition, the administration of questionnaires to gather student responses to the STEM-LCE learning process and conducting semi-structured interviews to understand the perspectives of pre-service teachers on the STEM-LCE based learning process. The learning observation also conducted during the research by the two observer and they also filled the implementation form of the STEM-LCE learning program. The criteria of the observer are someone who have the qualification in education, have already teaching in the classroom either school or university, and has a knowledge pertaining STEM approach and environmental learning.

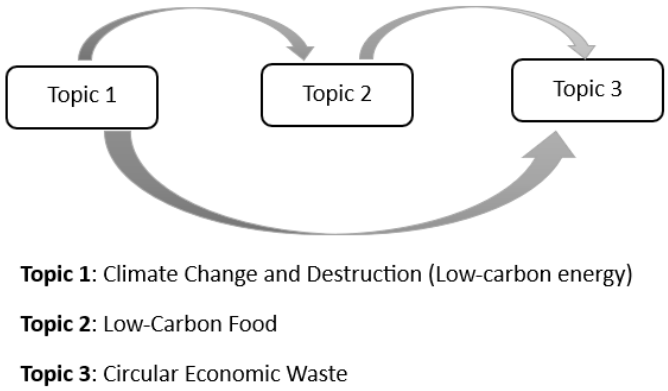

Figure. 3.2. The Steps of Collaboration skills, Communication skills, and Product Creativity of Groups Analysis.

4. Interpretation Stage

At this stage, the data interpretation is emphasized to quantitative data. quantitative data is analyzed using statistical analysis by using RASCH model approach, and qualitative data is used to reinforce the results of the quantitative data analysis by describing the research subjects. The interpretation of both data can provide information regarding the progress and process of the STEM-LCE learning program development activity. Including the strength and weaknesses of this program and also its characteristics to differ with others learning program that has been implemented in educations. In this stage also describe the impacts of STEM-LCE learning program implementation to the improvement of critical thinking skills, creativity, collaboration skills, communication skills, and sustainability consciousness among pre-service teacher. In addition, at this stage also the conclusions, recommendations, strengths, and weaknesses of the implemented STEM-LCE learning program are also outlined. The description of the research stages that have been conducted in this research can be described in **Figure 3.1**. This research used mixed method by exploratory research design.

C. Research Subject

This research was conducted in the Elementary School Teacher Education Study Program (PGSD) at one of the private universities in Bogor, West Java. This location was chosen based on the main consideration of having integrated faculty courses related to the environmental learning, SETS (Science Environment Technology and Society) courses. Another consideration is the ease of conducting research, as well as the time and cost efficiency required during the research process. Before conducting research on the subjects, a piloting of the STEM-LCE learning program was carried out on 15 non-subject students of the 2022/2023 science education study program in SETS courses. The empirical validation was conducted by involving 63 non-subject pre-service teacher who already taken SETS courses for critical thinking skills and creativity test instrument, while for sustainability consciousness questionnaire involving 81 non-subject pre-service

teacher who already taken SETS courses including the 15 students who involved as a subject in a piloting learning program.

The subjects of this research are pre-service elementary school teacher, students' class of 2023/2024 (freshman) within the Faculty of Teacher Training and Education at one of the private universities in Bogor City, who are enrolled in the SETS (Science Environment Technology and Society) course, which is a faculty course, totaling 57 students. The sampling in this study is based on purposive sampling, as the samples taken are specifically targeted for this research in a particular course, SETS course in particular semester (1st semester) as faculty courses and multidisciplinary. The subject is the students who enrolled in STES course. The number of students was divided into two classes, namely 29 students in the experimental class and 28 students in the control class. The demographic of subject is described in **Table 3.1** which elaborate the educational background and gender of students.

Research variables can be grouped into two categories, namely independent variables and dependent variables. The independent variable in this study is the STEM-LCE (Low Carbon Education) learning program. The dependent variable is one or more variables that are bound to the independent variable (R. B. Johnson & Christensen, 2008). There are five dependent variables in this study, namely critical thinking skills, creativity, collaboration skills, communication skills, and sustainability consciousness.

Table 3.1. The Students' Demographic

Students Demographic on Piloted STEM-LCE Learning Program		**Students Demographic on Empirical validation of Instrument**	
Aspect	**Number of persons**	**Aspect**	**Number of persons**
Gender		**Gender**	
Male	2	Male	11 (questionnaire), 8 (test)
Female	13	Female	70 (questionnaire), 55 (test)
Educational Background		**Educational Background**	
Science	15	Science/Biology	52 (questionnaire), 39 (test)
		Language	29 (questionnaire), 24 (test)

Students Demographic on Piloted STEM-LCE Learning Program		Students Demographic on Empirical validation of Instrument	
Students Demographic on STEM-LCE Learning Program Research			
Control Class		**Experimental Class**	
Aspect	**Number of persons**	**Aspect**	**Number of persons**
Gender		**Gender**	
Male	2	Male	3
Female	26	Female	26
Educational Background		**Educational Background**	
Science	12	Science	14
Social study	8	Social study	9
Broadcasting and Multimedia	1	Broadcasting and Multimedia	2
Office administration	3	Office administration	1
Beauty vocational study	1	Tourism	1
Classical music study	1	Religious study	1
Linguistic	2	Nursing	1

D. Research Instrument

This research uses a mixed methods approach that combines qualitative and quantitative data. In qualitative research, the main instrument in the study is the researcher themselves, commonly referred to as the human instrument (Creswell & Clark, 2007). The researcher plays a very significant role in determining the focus of the study, selecting informants as data sources, collecting data, analyzing data, interpreting data, and drawing conclusions based on the findings. Researchers also use several types of instruments to assist them in obtaining data. There are several types of instruments that have been developed, namely instruments in the form of tests, attitude scales, questionnaires, observation sheets, and assessment sheets presented in **Table 3.2**.

In order to obtain a valid instrument, instrument validation was conducted, which included content validation and empirical validation. Content validation is conducted by involving five expert lecturers in the fields of STEM and LCE, so that valid instruments and learning material can be obtained based on rational analysis from the experts. Empirical validation was conducted by involving 63 non-subject pre-service teacher who already taken SETS courses for critical thinking skills and

creativity test instrument, while for sustainability consciousness questionnaire involving 81 non-subject pre-service teacher who already taken SETS courses.

Table 3.2. Research Instruments

NO	Research Questions	Instruments	Data
1.	How is the characteristic of STEM-LCE learning program that has been developed?	- STEM-LCE learning Program Implementation Observation Sheet (**Attachment B.7**.) - Rubric of Validation expert (**Attachment B.9**.) - Student Response Questionnaire on STEM-LCE Learning **Attachment B.8**.)	- The results of learning observation during learning implementation as a result of learning activity. - The results of expert validation pertaining the STEM-LCE learning program (E-module and RPS) - The results of student's responses toward STEM-LCE learning program
2	How is STEM-LCE learning program is able to improves pre-service teacher's critical thinking skills?	- Essay test of critical thinking (Heard, et.al., 2020) (**Attachment B.1**.)	- Results of students' answers to critical thinking questions. - The results of the student project presentation assessment as a communication skill
3	How is STEM-LCE learning program is able to improves pre-service teacher's creativity?	- Creative thinking (Hu & Adey, 2002) (**Attachment B.1**.) - Product creativity rubric (**Attachment B.6**.)	- Results of students' answers to creative thinking questions. - The results of the product evaluation from the student project.
4	How is STEM-LCE learning program is able to improves pre-service teacher's collaboration skills?	- Collaboration skills rubric – Social Domain (Griffin, 2014). (**Attachment B.3**.)	- Results of the student collaboration in social domain.
5	How is STEM-LCE learning program is able to improves pre-service teacher's communication skills?	- Communication skills rubric (oral) (Baltimore University) (**Attachment B.4**.)	- The results of the student project presentation assessment as a communication skill.
6	How is STEM-LCE learning program is able to improves pre-service	- Sustainability Consciousness for Low carbon education	- The results of the student questionnaire regarding Sustainability

NO	Research Questions	Instruments	Data
	teacher's sustainability consciousness?	questionnaire (Gericke, et.al., 2019) (**Attachment B.5**.)	Consciousness for Low Carbon Education

1. Implementation Form of STEM-LCE Learning Program

The observation sheet instrument for the implementation of the STEM-LCE learning program is given to observers, who then fill out whether the STEM-LCE learning program is implemented well or not. In this instrument, there are a total of 21 statements divided into 6 sections. The sections include: 1) Implementation (Brainstorm/Introduction), which consists of 5 statements; 2) Implementation (Brainstorm/Problem Identification), which consists of 4 statements; 3) Implementation (Discover a Solution/Designing), which consists of 3 statements; 4) Implementation (Discover a Solution/Project Creation), which consists of 3 statements; 5) Implementation (Reveal a solution to the problem/Project Presentation and Evaluation), which consists of 3 statements; 6) Time management; 7) Classroom atmosphere, which consists of 2 statements. From each statement item, the available options are "yes" or "no" for each topic (topic 1, topic 2, and topic 3).

This instrument is to see whether the implementation of the STEM-LCE learning program at each stage is running well or needs improvement. Based on the results of this instrument, the strengths and weaknesses of the program's implementation can also be seen, which can serve as suggestions and inputs for the future development of the program.

2. Critical Thinking Skills and Creative Thinking Skills Test

This instrument is designed to measure how students' critical thinking and creative thinking skills change before and after learning. Especially in the experimental class that implements the STEM-LCE learning program. This instrument helps to determine how the improvement in these skills occurs after students take the STES course for one semester using the STEM-LCE learning program. This instrument consists of 9 essay test questions with three discourses related to each topic, including climate change and destructions, low-carbon food,

and circular economic waste based on the low-carbon education concept. Of the 9 essay test questions, they are divided into 5 essay test questions on critical thinking skills and 4 essay test questions on creative thinking skills. The aspects of critical and creative thinking skills in the essay test instrument given to students are outlined in **Table 3.3**. Beside the creative thinking skills essay test, there is also rubrics of creativity products to assess the product as a result of each groups project in each topic. The rubrics also use the aspect of creativity, such as fluency, flexibility, and originality. In addition to the three aspects of creativity, the timeliness of project completion and the conformity to design, neatness, and beauty, as well as the functionality of the product, whether the product can function well or not, are also evaluated.

Table 3.3. The Aspects of Critical Thinking Skills and Creative Thinking Skills on Test

Critical Thinking Skills	Creative Thinking Skills
Discourse 1	
Evaluating Reasoning	Fluency
	Originality
Discourse 2	
Knowledge Construction	Originality
Decision Making	
Discourse 3	
Knowledge Construction	Flexibility
Decision Making	

3. Collaboration Skills Rubrics

The collaboration skills instrument is in the form of a rubric adapted from Griffin (2015). The instrument consists of a social strand with three domains and eight aspects. This instrument is designed to assess how student collaboration within their groups, both collectively and individually, is evaluated from a social perspective. The assessment of this instrument consists of a scale from 1 to 4, with 1 being the lowest score and 4 being the highest. If students perform well in each aspect, they will receive the highest score, and vice versa. The following are the domains and aspects used in this instrument as outlined in **Table 3.4**.

Table 3.4. The Social Skills Domain in Collaboration Skills Rubrics

Social Skills Domain	Aspect
Participation	*Action*
	Interaction
	Task Completion
Perspective-taking	Adaptive responsiveness
	Audience Awareness (mutual modeling)
Social Regulation	Negotiation
	Self-Evaluation (metamemory) and Transactive memory
	Responsibility initiative

4. Communication Skills Rubrics

The communication skills instrument is in the form of a rubric adapted from Baltimore University. This instrument focuses on oral communication skills. The instrument consists of three domains and six aspects. This instrument is designed to assess how students' oral communication skills are when they present their project results in front of their friends and professors. Students are individually assessed on their oral communication skills. The assessment of this instrument consists of a scale from 1 to 4, with 1 being the lowest score and 4 being the highest. If students perform well in each aspect, they will receive the highest score, and vice versa. The following are the domains and aspects used in this instrument, as outlined in **Table 3.5**.

Table 3.5. The Domain and Aspect in Communication Skills Rubrics

Domain	Aspect
Knowledge (Opinion)	*Organization*
	Delivery
	Conclusion
Attitude (Gesture)	*Eye Contact*

Domain	Aspect
	Responsiveness
Competency (Technology skills)	*Multimedia Support*

5. Sustainability Consciousness for STEM LCE Questionnaire

The sustainability consciousness instrument is in the form of a questionnaire adapted from Gericke (2019). This instrument focuses on students' sustainability awareness based on low-carbon aspects. The instrument consists of three domains, namely sustainability knowingness (SK), sustainability attitude (SA), and sustainability behavior. In each domain, there are three aspects: Environment, social, and economy. In each aspect, there are three statements that students must answer using a likert scale. The scale consists of strongly agree, agree, disagree, and strongly disagree. The value of the scale depends on the statement; if the statement is positive, then strongly agree gets a score of 4, while strongly disagree gets a score of 1. Conversely, for negative statements, the opposite applies. The total number of statements in this questionnaire is 27, consisting of 21 positive statements and 6 negative statements evenly distributed across each domain. This instrument was created to see how students' sustainability awareness towards the environment before and after they receive learning with the STEM-LCE learning program for the experimental class and the common lecture program for the control class.

E. Data Analysis

The data analysis techniques used in the research begin with needs analysis, instrument validation, and continue through the analysis of data resulting from the implementation of the research. The data analysis is obtained by various technique and analysis. This is done to obtain a comprehensive overview of the results from various perspectives that align with the type of data, qualitatively or quantitatively.

1. Need analysis

Before developing the STEM-LCE learning program, preliminary research was conducted to analyze needs as a basis for developing the program. The most important thing is to understand the perspectives of students and teachers regarding the concepts of low-carbon education, environmental learning, and STEM learning, both in schools and universities. A questionnaire related to these components was given to teachers and students at the school. Simple data processing is used, based on the percentage results of those answers. Statements are answered with the options "yes" or "no". The value “yes” is 1 and “no” is 0. After that, semi-structured interviews were conducted with several teachers regarding the concepts of low-carbon education and STEM learning in schools.

After that, a document study was conducted to determine whether the concept of low-carbon education was included in the 2013 Science curriculum for Junior High School and the P5 Program (Pancasila Student Profile Strengthening Project) of the Merdeka curriculum. This analysis was conducted on several materials and concluded that some low-carbon education concepts are already present in several materials within the 2013 Junior High School Science curriculum, but they are still implicit. This was followed by a document study of semester learning plans (RPS) for courses related to environmental learning at one state university in Central Java, Makassar, and a private university in Bogor City. This analysis concludes that the concepts of low-carbon education are still implicit. No one has explicitly stated the concept of low-carbon education yet. Similarly, the implementation of learning that has not yet used the STEM approach.

In addition to the studies mentioned above, an analysis was also conducted regarding the low-carbon education concept and the implementation of the STEM approach in learning, particularly environmental learning related to sustainability. This analysis uses a bibliometric method based on relevant article data collected from Scopus. Then the data was sorted based on the required components, by year (the last 10 years), open access journals, keywords, and English. The data was then downloaded in RIS format and processed using the VOSviewer application for data visualization. With the results, in Indonesia, there is still little research related to

low-carbon in the field of education, and low-carbon education, which is included in sustainable education, can be implemented using the STEM approach to increase students' sustainability consciousness and construct their 4C skills. Based on these analysis results, the STEM-LCE learning program and its research instruments can be developed.

2. Validation of Instruments

The validation of the instruments used in this study is content validation and empirical validation. Content validation requires a rational analysis from someone who is an expert in the field related to the developed instrument, this is referred to as expert judgment. The assessment results conducted by experts are then analyzed using qualitative and quantitative data analysis techniques. Qualitative data analysis is conducted by summarizing and coding the experts' inputs, reducing the data, and concluding the experts' inputs, which will subsequently be used as a basis for revising the instrument. Quantitative data analysis is conducted using the Content Validity Ratio (CVR). CVR is an approach to content validity to determine the appropriateness of items with the measured domain based on expert judgment and CVI (Content Validity Index). CVI measures the proportion of agreement among experts regarding the relevance of an item or the entire instrument. The feasibility of teaching materials for the STEM-LCE learning program, evaluated by experts, particularly the learning modules, was analyzed using a percentage feasibility calculation. While, the empirical validation of the instruments, are analyze by RASCH model approaches to see whether the instruments are reliable and valid or not, also the instruments are fit or not for the item and the person.

a. Criteria and Category for Evaluating Validator Responses

The validator provides feedback on the instrument, especially essay test instrument that has been created, and the criteria are then scored according to the following provisions “yes” with score 1 and ‘No.” with score 0. Scoring the item responses using CVR (content validity ratio). The scores given by expert evaluators are then processed. Calculating the CVI score (content validity index) After

identifying the sub-questions in the instrument using CVR, the CVI for the total number of sub-questions is then calculated. The result of the CVR and CVI calculations is in the form of a ratio between -1 until +1. Whether a validated unit is appropriate or not depends on achieving the critical CVR value. Here is the table of Lawshe's cited in Wilson et al., (2012) regarding critical CVR values for different numbers of experts are described in **Table 3.6**.

Table 3.6 Category of CVR Calculation from the Number of Experts

Amount of Expert	CVR Minimum Score
5	0.736
6	0.672
7	0.622
8	0.582
9	0.548
10	0.520
11	0.496
12	0.475
13	0.456
14	0.440
15	0.425
20	0.368
25	0.329
30	0.300
35	0.278
40	0.260

(Wilson, F.R. Pan, W. & Schumsky, 2012)

The result of the CVI calculation is in the form of a ratio between 0-1. The number can be categorized as follows in **Table 3.7**. While the feasibility of learning material, such as module by the expert, it could be analyzed by CVR and CVI analysis and/or the percentages by the category of the feasibility score is described in the **Table 3.8**. adapted from Sugiyono (2015) for the feasibility of learning material by the experts.

Table 3.7. CVI Results Category

Range	Category
0 – 0,33	Not relevant
0,34 – 0,67	Relevant
0,68 – 1	Very relevant

(Wilson, F.R. Pan, W. & Schumsky, 2012)

Table 3.8. Feasibility Percentages Category of Learning Material

Range (%)	Category
0 - 25	Very not feasible
26 - 50	Not feasible
51 - 75	Feasible
76 - 100	Very feasible

(Wilson, F.R. Pan, W. & Schumsky, 2012)

After calculations, here are the results of the analysis of the CVR and CVI values of the STEM-LCE learning materials (**Table 3.9**), critical and creative thinking skills test questions (**Table 3.10**), and the sustainability consciousness questionnaire (**Table 3.11**).

Table 3.9. Feasibility of Learning Material (E-Module) from Expert

Item	n_e	CVR	CVR Feasibility	I-CVI	I-CVI Feasibility
Scope of the Material	5	1.0	Essential	1.0	Very relevant
Contextual Update	5	1.0	Essential	1.0	Very relevant
Graphics and Presentation	5	1.0	Essential	1.0	Very relevant
Language and Readability	5	1.0	Essential	1.0	Very relevant

Table 3.10. Feasibility of Critical and Creative Thinking Skills Test Questions from Expert

Item	n_e	CVR	CVR Feasibility	I-CVI	I-CVI Feasibility
1.	4	0.6	Essential (Need revision)	0.8	Very relevant
2.	4	0.6	Essential	0.8	Very relevant
3.	4	0.6	Essential	0.8	Very relevant
4.	5	1	Essential	1	Very relevant
5.	5	1	Essential	1	Very relevant
6.	5	1	Essential	1	Very relevant
7.	5	1	Essential	1	Very relevant
8.	5	1	Essential	1	Very relevant
9.	5	1	Essential	1	Very relevant

Table 3.11. Feasibility of Sustainability Questionnaire by The Expert

Item	n_e	CVR	Feasibility of CVR	I-CVI	Feasibility of I-CVI
1.	5.00	1.00	Essensial	1.0	Very relevant
2.	5.00	1.00	Essensial	1.0	Very relevant
3.	5.00	1.00	Essensial	1.0	Very relevant
4.	5.00	1.00	Essensial	1.0	Very relevant
5.	5.00	1.00	Essensial	1.0	Very relevant
6.	5.00	1.00	Essensial	1.0	Very relevant
7.	5.00	1.00	Essensial	1.0	Very relevant
8.	5.00	1.00	Essensial	1.0	Very relevant

Item	n_e	CVR	Feasibility of CVR	I-CVI	Feasibility of I-CVI
9.	5.00	1.00	Essensial	1.0	Very relevant
10.	5.00	1.00	Essensial	1.0	Very relevant
11.	5.00	1.00	Essensial	1.0	Very relevant
12.	5.00	1.00	Essensial	1.0	Very relevant
13.	5.00	1.00	Essensial	1.0	Very relevant
14.	5.00	1.00	Essensial	1.0	Very relevant
15.	5.00	1.00	Essensial	1.0	Very relevant
16.	5.00	1.00	Essensial	1.0	Very relevant
17.	5.00	1.00	Essensial	1.0	Very relevant
18.	5.00	1.00	Essensial	1.0	Very relevant
19.	5.00	1.00	Essensial	1.0	Very relevant
20.	5.00	1.00	Essensial	1.0	Very relevant
21.	5.00	1.00	Essensial	1.0	Very relevant
22.	5.00	1.00	Essensial	1,0	Very relevant
23.	5.00	1.00	Essensial	1.0	Very relevant
24.	5.00	1.00	Essensial	1.0	Very relevant
25.	5.00	1.00	Essensial	1.0	Very relevant
26.	5.00	1.00	Essensial	1.0	Very relevant
27.	5.00	1.00	Essensial	1.0	Very relevant

b. Empirical Validation of the Instruments

Empirical validation was conducted on several instruments that were directly given to students. For example, there are essay test questions on critical and creative thinking skills, as well as a sustainability consciousness questionnaire. After passing the content validation stage by experts, the instrument was then tested on non-subject students. The data collected are polytomous data in the form of a Likert scale and a rubric scale. Therefore, the data can be analyzed using the RASCH model approach. The criteria used to determine whether the instrument is valid and reliable are by examining the logit values of MNSQ (meansquare) infit and outfit, ZSTD (Z-standard) infit and outfit, PTMEA CORR (Point measure correlation), and Cronbach alpha (Sumintono & Widhiarso, 2015).

Infit measures the fit of an item (question in the test) with the model, focusing on items that respondents are expected to answer correctly (responses expected according to the model). Outfit measures the overall fit of an item, including unexpected responses (responses that deviate from the model). A fit item will make a good contribution in defining a common construct (Rahayu et al.,

2021). MNSQ is the mean square of the difference between the expected response and the actual response. ZSTD measures how far MNSQ deviates from the expected value (1). PTMEA CORR is used to measure the correlation between the item score and the total score of the respondents. Indicates how well the item distinguishes between respondents with different levels of ability. A high positive correlation indicates that the item is good at distinguishing respondents (Andrich & Marais, 2019).

Validation of item level. An item is declared acceptable if it meets three criteria or at least two criteria. However, if it only meets one criterion or does not meet any criteria at all, the item is rejected. The criteria for the acceptance of an item are:

1). The Infit-outfit mean square (MNSQ) value is at 1 (ideal). or within the range of 0.5 to 1.5.

2) The Infit-outfit Z-standard (ZSTD) value is at 0 (ideal) or within the range of -2 to 2.

3) The Point Measure Correlation (PTMEA CORR) value is at positive (ideal) values between 0.4 and 0.85.

Meanwhile, an item is said to be reliable by looking at the reliability of the Cronbach alpha value. The ideal value is more than 0.6 (Andrich & Marais, 2019; Bond & Fox, 2015; Wright & Linacre, 1994).

The data below are the results of the validity and reliability of critical thinking and creative thinking test instruments. Analysis of the validity and reliability of the test instrument of critical thinking skills and creative thinking skills using the RASCH model approach. Based on the results (**Table 3.12**), it can be said that the instruments of critical thinking skills and creative thinking skills are valid and reliable. The overall criteria are met for the validity and reliability of the instrument items. The MNSQ infit and outfit statistical values in were used to measure the suitability of individual items in critical thinking skills and creative thinking skills item test (Andrich & Marais, 2019). A fit item will make a good contribution in defining a common construct (Rahayu et al., 2021). Even the item test number 4 for critical thinking MNSQ and ZSTD outfit values slightly exceed

the standard, but are still within the acceptance range. PT-Measure Corr. value of the critical thinking skills and creative thinking skills value moved in a positive direction from 0.41 to 0.67, as shown in **Table 3.12**. This means that the value shows the suitability of all items against the agreed latent variables (Andrich & Marais, 2019).

Table 3.12. Validity (Fit Item) and Reliability of Critical Thinking and Creative Thinking Research Instrument

No	Item	Infit		Outfit		PT Measure Corr	Cronbach alpha (kr-20)	Conclusion
		MNSQ	ZSTD	MNSQ	ZSTD			
1	4-critical	1.2	1.06	1.56	2.03	0.3	0.68	Valid
2	1-creative	1.28	1.64	1.28	1.44	0.46		Valid
3	3-creative	1.05	0.39	0.98	-0.04	0.53		Valid
4	2-critical	0.98	-0.13	0.92	-0.44	0.54		Valid
5	6-critical	0.98	-0.07	0.95	-0.25	0.52		Valid
6	9-creative	0.91	-0.39	0.97	-0.09	0.54		Valid
7	7-critical	0.95	-0.24	0.91	-0.32	0.48		Valid
8	8-critical	0.84	-0.96	0.79	-1.17	0.54		Valid
9	5-creative	0.8	-1.32	0.69	-1.4	0.63		Valid

Besides calculating the validity and reliability of the critical thinking and creative thinking skills test instruments, this also measures the suitability of the sustainability consciousness questionnaire instrument. This trial test was given to 81 preservice elementary school science teacher students non subject that has already received SETS learning for filling the 27 items based on 3 main domains, i.e. sustainability knowingness (SK), sustainability attitude (SA), sustainability behaviour (SB). The result shows that all item are valid and reliable, although in ZSTD value there are some values are exceeded because this respondent is less than 200, so it is not stable (Azizan et al., 2020). Nevertheless, that value could be ignored and can be categorized as valid items and can be used. This questionnaire is feasible to be given to the students. Here the table of feasible results of sustainability consciousness instrument (**Table 3.13**).

Table 3.13. The Validation (Item Fit) and Reliability of Sustainability Consciousness in Low Carbon Education Questionnaire Results

No	Item	Infit		Outfit		PT Meassure Corr	Cronbach alpha (kr-20)	Conclusion
		MNSQ	ZSTD	MNSQ	ZSTD			
1	SK9	1.89	5.01	2.03	5.57	A .06	0.80	Valid
2	SB4	1.61	3.54	1.64	3.64	B .17		Valid
3	SA5	1.58	3.66	1.59	3.71	C .07		Valid
4	SB8	1.43	2.84	1.50	3.17	D .20		Valid
5	SA1	1.46	2.60	1.46	2.62	E .43		Valid
6	SK1	1.44	2.68	1.45	2.79	F .38		Valid
7	SK4	1.26	1.53	1.26	1.56	G .43		Valid
8	SB9	1.20	1.18	1.19	1.16	H .47		Valid
9	SA8	1.09	.58	1.12	.77	I .42		Valid
10	SA6	1.08	.57	1.07	.50	J .65		Valid
11	SB7	1.02	.19	1.08	.55	K .23		Valid
12	SK3	.95	-.34	.97	-.19	L .46		Valid
13	SK2	.90	-.68	.90	-.68	M .46		Valid
14	SK6	.88	-.91	.83	-1.19	N .57		Valid
15	SA7	.82	-1.30	.81	-1.41	m .56		Valid
16	SA2	.81	-1.40	.81	-1.43	l .63		Valid
17	SB1	.74	-1.69	.75	-1.62	k .44		Valid
18	SA4	.74	-2.01	.74	-2.01	j .52		Valid
19	SB6	.71	-2.28	.71	-2.23	i .59		Valid
20	SK7	.70	-2.36	.69	-2.44	h .51		Valid
21	SB5	.70	-2.34	.70	-2.35	g .63		Valid
22	SA9	.69	-2.31	.69	-2.34	f .47		Valid
23	SK5	.63	-2.61	.65	-2.54	e .46		Valid
24	SK8	.60	-3.34	.64	-2.88	d .57		Valid
25	SA3	.64	-2.92	.63	-2.95	c .68		Valid
26	SB2	.61	-2.71	.61	-2.71	b .52		Valid
27	SB3	.52	-3.56	.53	-3.50	a .46		Valid

3. Data Analysis of Critical Thinking, Creativity, and Sustainability Consciousness

Data were obtained from the results of the pretest and post-test of students. Critical and creative thinking were assessed using essay test questions, while sustainability consciousness was measured using a questionnaire. The purpose of conducting pretests and post-tests is to determine whether there is an improvement in critical thinking, creativity, and sustainability consciousness among students

after participating in the STEM-LCE learning program. The calculation uses the RASCH model with stacking analysis technique by Winstep application. Stacking analysis is the calculation of the difference in logit values between the pre-test and post-test. Stacking analysis in Rasch modeling is a longitudinal analysis technique used to compare the abilities of individuals (students) before and after an intervention or specific event in the context of learning (Laliyo, 2021).

Analysis using the RASCH model was used to see the improvement in ability not only for the group, but also for each individual. Therefore, the researcher still used RASCH model analysis despite the small sample size. Because the sample data is counted twice the number of students. This is because the researchers used the stacking technique, where the pretest data calculation process was combined with the posttest data in a single calculation cycle (not calculated separately) to overcome the small sample size and obtain sufficient confidence levels (Nuraeni & Karlimah, 2023; Sukarelawan et al., 2024). The minimum confidence level for polytomous data is 50. Meanwhile, when the class data in this study is calculated, for example, the experimental class using the STEM-LCE learning program has 28 students. Using the stacking calculation as presented, the number of data points becomes 56, which exceeds the minimum threshold for a 99% confidence level (Linacre, 1994). However, decision-making and conclusions based on data analysis must be extremely careful, and additional data is needed to strengthen the analysis results.

However, before proceeding to the stacking analysis, the validity of the items in the data test must first be examined to ensure that the data is suitable for the RASCH model analysis. Validation of persons and items as a whole. This validation aims to determine whether the respondent data and item data can be analyzed using the Rasch Model. The criteria are (Andrich & Marais, 2019; Bond & Fox, 2015; Wright & Linacre, 1994):

1) The Infit-Outfit mean square (MNSQ) value is at 1 (ideal) or within the range of 0.5 to 1.5.
2) The Infit-outfit Z-standard (ZSTD) value is at 0 (ideal) or within the range of -2 to 2.

After the overall stacking values for each skill are determined, stacking values are also calculated for each aspect within each skill. Thus, it can be determined in detail which parts have a high logit value (above 0), indicating that the students' skills in that aspect or overall are good. And which parts have a low logit value (below 0), indicating that the students' abilities in that aspect or overall are not good or still need an improvement. Besides the logit value, what category does the RASCH model show for that value? Because the items on critical and creative thinking skills are essay questions, the evaluation results are in the form of polytomous data. The assessment rubric is categorized into three parts, from the lowest to the highest, namely beginning, developing, and demonstrating. The division of the assessment boundaries is explained in **Table 3.14** as LVP (Logit Value Person). With a critical thinking score in experimental class SD = 2,49, M = -0,14, while in control class, SD = 1,32, M = -0,93. The creativity score in experimental class SD = 1,33, M = -0,68, while in control class, SD = 1,02, M = -0,98.

Table 3.14. The Category of Critical Thinking Skills and Creativity of Students based on RACH Model Analysis

Range	Category
>M+SD	Demonstrating
M – SD < x < M+SD	Developing
<M-SD	Beginning

After obtaining the logit values for each student in both the pretest and posttest, a t-test was conducted, starting with prerequisite tests for Homogeneity and Normality. The test was conducted using the SPSS 27 application. The normality test is used to examine whether the data being analyzed follows a normal distribution pattern. The assumption of normally distributed data is the basis for many parametric statistical tests to provide valid results. If the data is not normal, parametric statistical tests may not be accurate (Sari et al., 2012). The normality test in this study uses the Kolmogorov-Smirnov test. The homogeneity test is a statistical test used to ensure that the variance or variation among the compared data groups is the same. The assumption of homogeneous variance is important in parametric statistical analysis, especially when comparing means between groups.

If the variances are not homogeneous, the results of the statistical test may not be valid. The homogeneity test in this study uses Levene's Test (Sari et al., 2012).

After the prerequisite tests are met, a difference test is conducted using the t-test. Assuming that the data is normally distributed and homogeneous. The t-test is a statistical testing method used to compare the means of two data groups. This test is often used in hypothesis testing to determine whether the difference between the two groups is statistically significant or merely coincidental. The t-test helps determine whether the means of the two data groups are significantly different (Sari et al., 2012). The t-test can be used to determine whether a treatment or intervention has a significant effect on a variable. The t-test used in this study is the two-sample (independent) t-test, which is used to compare the means of two independent (unrelated) samples. The t-test is also used to test the null hypothesis (which states that there is no difference) and the alternative hypothesis (which states that there is a difference). If the t-test result is less than alpha (0.05), then the null hypothesis is rejected, and vice versa. Here is the hypothesis for critical thinking skills and creativity of students. After performing a significance test between the control and experimental groups using logit data, the effect size of the difference test results was also examined by looking at the Cohen's d value **Table 3.15**.

H_0 = There is no difference in the critical thinking skills of preservice teacher after the implementation of learning in the experimental class and the control class.

Ha = There is a difference in the critical thinking skills of preservice teacher after the implementation of learning in the experimental class and the control class.

H_0 = There is no difference in the creativity of preservice teacher after the implementation of learning in the experimental class and the control class.

Ha = There is a difference in the creativity of preservice teacher after the implementation of learning in the experimental class and the control class.

Creativity is also assessed based on the project creativity created by each group. The average score for project creativity is calculated for each topic. Then, it was examined whether there was an improvement in students' creativity based on

their artwork from topic 1 to topic 2, then from topic 2 to topic 3, and from topic 1 to topic 3. To see more details, a difference test was conducted on the project creativity results using repeated ANOVA if the data was normally distributed (>0.05). If the data was not normally distributed (<0.05), the test was performed using a non-parametric test, namely the Friedman test. Because the Friedman test only shows whether there is an overall significant difference, a further test, the Wilcoxon signed-rank test, was used to see the improvement differences in each topic.

Table 3.15 Effect Size Group Category

Category	Interval
Ignored	<0.20
Small	0.20 – 0.40
Medium	0.41 – 0.60
Large	0.61 – 0.80
Very Large	>0.80

(Sere & Manaf, 2023)

In addition to critical thinking skills and creativity, sustainability consciousness data was also collected before and after the implementation of the learning process. The form of the sustainability consciousness instrument is a questionnaire with a 1-4 Likert scale. Thus, the data obtained is polytomous data. Similarly, like the essay test instrument for critical and creative thinking skills, the questionnaire data is also analyzed using stacking analysis from the RASCH model. The steps for stacking analysis and prerequisite testing are also carried out in the same way as analyzing essay questions for critical and creative thinking skills tests.

After the overall stacking values are determined, stacking values are also calculated for each aspect. Thus, it can be determined in detail which parts have a high logit value (above 0), indicating that the students' skills in that aspect or overall are good. And which parts have a low logit value (below 0), indicating that the students' abilities in that aspect or overall are not good. Besides the logit value, what category does the RASCH model show for that value? The categorization in the sustainability consciousness questionnaire differs from the essay test questions. The questionnaire is categorized into four parts, from the lowest to the highest, namely beginning, emerging, developing, and demonstrating. The division of the

assessment boundaries is explained in **Table 3.16** as LVP (Logit Value Person). With the score in experimental class SD = 0,94, M = 1,80, 2SD = 1,88, while in control class, SD = 0,63, M = 1,48, 2SD = 1,26.

Table 3.16. The Category of Sustainability Consciousness of Students based on RACH Model Analysis

Range	Category
>M+SD	Demonstrating
M – SD < x < M+SD	Developing
M-2SD< x < M-SD	Emerging
<M-2SD	Beginning

After obtaining the logit values for each student in both the pretest and posttest, a t-test was conducted, starting with prerequisite tests for homogeneity and normality. After the prerequisite tests are met, a difference test is conducted using the t-test. Assuming that the data is normally distributed and homogeneous. The t-test is a statistical testing method used to compare the means of two data groups. This test is often used in hypothesis testing to determine whether the difference between the two groups is statistically significant or merely coincidental. The t-test used in this study is the two-sample (independent) t-test, which is used to compare the means of two independent (unrelated) samples. The t-test is also used to test the null hypothesis (which states that there is no difference) and the alternative hypothesis (which states that there is a difference). If the t-test result is less than alpha (0.05), then the null hypothesis is rejected, and vice versa. Here is the hypothesis for sustainability consciousness of students.

H_0 = There is no difference in the sustainability consciousness of preservice teacher after the implementation of learning in the experimental class and the control class.

Ha = There is a difference in the sustainability consciousness of preservice teacher students after the implementation of learning in the experimental class and the control class.

4. Data Analysis of Collaboration Skills and Communication Skills

Analysis data of collaboration skills and communications skills are quite different with those three skills, critical thinking skills, creativity, and sustainability consciousness. Those three data are taken from students directly, means students

do the test and fill the questionnaire. While both collaboration and communication data were taken by the observer based on students' activity. The activity was taken by the recorder and camera, then the researcher analyzes students' collaboration and communication skills by make a score based on the rubric (1-4). After make a score, then both collaboration skills and communication skills data are analyzed by stacking analysis with RASCH model using winstep applications. This data was taken only in experimental classes, focuses to how the development of students' collaboration skills and communications skills during the implementation of STEM-LCE learning program. The stacking is not done by calculate the pretest and posttest data, but the data from topic 1, topic 2, and topic 3 like time series. It would be figure out the development of those skills gradually.

However, before proceeding to the stacking analysis, the validity of the items in the data test must first be examined to ensure that the data is suitable for the RASCH model analysis. Validation of persons and items as a whole. This validation aims to determine whether the respondent data and item data can be analyzed using the Rasch Model. The criteria are (Andrich & Marais, 2019; Bond & Fox, 2015; Wright & Linacre, 1994):

1) The Infit-Outfit mean square (MNSQ) value is at 1 (ideal) or within the range of 0.5 to 1.5.
2) The Infit-outfit Z-standard (ZSTD) value is at 0 (ideal) or within the range of -2 to 2.

After the overall stacking values for each skill are determined, stacking values are also calculated for each aspect within each skill. Thus, it can be determined in detail which parts have a high logit value (above 0), indicating that the students' skills in that aspect or overall are good. And which parts have a low logit value (below 0), indicating that the students' abilities in that aspect or overall are not good. Besides the logit value, what category does the RASCH model show for that value? the results are in the form of polytomous data with scale 1-4. So that, it is categorized into four parts, from the lowest to the highest, namely beginning, emerging, developing, and demonstrating. The division of the assessment boundaries is explained in **Table 3.17** as LVP (Logit Value Person). With a

collaboration skills score is SD = 3,20, M = 6,48, 2SD = 6,40. The communication skills score is SD = 2,41, M = 2,41, 2SD = 4,28.

Table 3.17. The Category of Collaboration Skills and Communication Skills of Students based on RACH Model Analysis

Range	Category
>M	Demonstrating
M – SD < x < M	Developing
M-2SD< x < M-SD	Emerging
<M-2SD	Beginning

5. Analysis data of learning implementation

The analysis of the program implementation data was conducted descriptively. Data were obtained from the observation of STEM-LCE learning program implementation by filling out qualitative answers of "yes" and "no," as well as field notes by the observer in each topic. The method for determining the level of implementation of learning is done by calculating the percentage of activities that were carried out at each stage of learning. To interpret the percentage of learning implementation obtained from the calculations, categories are used as shown in **Table 3.18**:

Table 3.18. Category of Program Implementation

Percentages of Implementation (%)	Category
0 - 35	Not Executed Well
36 -70	Needs Improvement
71 - 100	Well Implemented

Additionally, data was also collected qualitatively during the implementation of learning through observation by observers and learning recording results. The data from the observations were then collected and analyzed to be used as supporting data for the calculation results. Similarly, the learning recording data also serves as reinforcement for the results.

6. Students' Responses toward STEM-LCE Learning Program in Learning Process

The analysis of the students' responses toward STEM-LCE learning program data was conducted descriptively. Data were obtained by a questionnaire consisting of 13 statements. Statements based on each step of the STEM-LCE

learning program implementation. They were asked to respond qualitatively to one of the scale options for each statement. The scale consists of 4 agreement scales, namely SS (strongly agree), S (agree), TS (disagree), STS (strongly disagree). Then it was analyzed using a simple percentage calculation. To interpret the percentage of students' responses toward STEM-LCE learning program obtained from the calculations, categories are used as shown in **Table 3.19**:

Table 3.19. Category of Students' Responses

Percentages of Implementation (%)	Category
0 - 25	Not Good
26 -50	Fair
51 - 75	Good
76-100	Excellent