CHAPTER III
RESEARCH METHODOLOGY

A. Type of Research Methodology

This research is aimed to develop a STEM-based module as an instructional material in STEM learning process in a way to enhance STEM literacies. Accordingly, Design and Development Research (DDR) method is used to fulfill the aim of this research in a way to produce a new product based on need-analysis, test the effectiveness and validation, as well as development and evaluation process. Additionally, Richey dan Klien (2007) defined DDR as the systematic study of design, development and evaluation processes with the aim of establishing an empirical basis for the creation of instructional products and tools a new or enhanced models that govern their development.

Richey dan Klein (2007) classified *Design and Development Research* as two categories namely (a) *product and tool research*, and (b) *model research*. Generally, there are six procedures to develop STEM-based module which based on Peffers et al. (2007) as follow:

1. Identify the problem
2. Describe the objectives
3. Design and develop product
4. Test the product
5. Evaluate testing result
6. Communicate testing result

The detail explanation of design and development research process is shown by this following diagram based on (Peffers, et al., 2007).

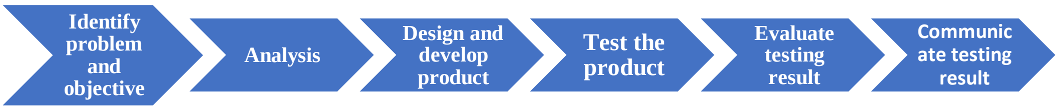


Figure 3.1 Design and Development Research Process (Peffers, et al., 2007).

B. Research Object

The research object of this research is the instructional materials in a form of STEM-based module that consist materials, learning guidelines, clues, rules as well as question sets and science activity about earth's structure and its dynamics topic.

C. Research Population and Sample

The location of this research is in one secondary high school in Bandung which used revised 2013 Curriculum. The instruction in classes is mainly conducted in Bahasa.

The population of the research is the 7th grade students who is studying earth's structure and its dynamics topic which is delivered with STEM approach. Meanwhile, the samples are the Junior high school students from one class. The subject of this research is defined under purposed of the responsible science teacher who implement STEM-based teaching and learning activity at class.

D. Operational Definition

In order to conduct the research in accordance with the expected aims and avoid misunderstanding, therefore an operational definition need to be elaborated as follows:

1. The development of STEM-based module on this research is a process of constructing new product as instructional materials on earth's structure and its dynamics topic, evaluate, and revise the module become an instructional product that can be used in learning process. The effectiveness of STEM based module is tested through N-gain <g> calculation, repeated testing, revising and observation. The structure of STEM-based module referred to learning goals from basic competence, module requirements, and STEM literacy goals and practices for secondary level. It refers to NGSS n NRC (2010), OECD (2016), NAEP (2014) and *Kurikulum* 2013.
2. Students' STEM literacies is defined as the ability to identify, implement, and integrate concepts and contexts of Science, Technology, Engineering, and Mathematics (STEM) to understand and solve problems that cannot be solved using one scientific discipline but through innovative products. In this research,

STEM Literacy is measured on knowledge aspect and student's profile on STEM process.

a. The context aspect has indicators of personal, social, and global which includes the ability of integrating Science, Technology, Mathematics and Engineering knowledge as a whole. Student's understanding and confidence in explaining STEM topic as a whole to another student is captured
b. Indicators of knowledge aspect are presenting facts, concepts, and laws; as well as presenting theoretical hypotheses and models, asking students to remember and analyzing knowledge or information. Knowledge aspect is measured through paper and pencil test on STEM-based module in the form of multiple choice and short answer questions which were given as a pre-test and post-test.
c. Indicators of student's profile on STEM process is measured by the ability of students to solve the problem through essay questions (written) as well as skills on integrating technology and engineering aspect to solve science daily life problem which is given in the form of science activity worksheet.
d. Attitude aspect is interest in the STEM field, supporting inquiry, responsibility for resources and environment. Attitude aspect would be captured by filling the questionnaire.

3. Student's perception towards STEM is captured through questionnaire which is given after teaching and learning process to gain information about how students think STEM based learning is.

E. Research Instrument

In this research, instrument is necessary to be used to obtain data. It is in line with Arikunto (2006) who stated that instrument has functions to gain data and to be compared to certain standard to cope with the necessity. Research instrument is constructed based on research objective to characterize STEM based module, to analyze the effectiveness of STEM based module to enhance student's STEM literacy as well as to gain information of students' perception of STEM. In short, research instruments which are used in this research are captured on the Table 3.1.

Table 3.1 Research Instrument

No	Data	Instrument	Description
1.	Module development	a. Validation sheet of content, layout and language aspects. b. Readability test	The instruments are given to experts, teachers and students after reading season before research implementation.
2.	STEM literacy on knowledge aspect	20 multiple choice questions were given to students, which are constructed of these three components: - Science literacy - Mathematics literacy - Technology-Engineering literacy	The instrument is given in a form of pretest and posttest, before and after teaching and learning practices.
	Attitude towards STEM	Questionnaire (student's STEM interest and student's attitude towards environmental concern)	The instrument is given before and after teaching and learning practices.
	Profile on STEM Process	Observational sheet and rubric	The instrument is given during research implementation.
3.	Student's perception towards STEM	Questionnaire (Likert skale about student's STEM perception)	The instrument is given after teaching and learning practices.

a. STEM-based Module Development Instrument

The STEM based module was developed based on the newest Indonesia curriculum (*Kurikulum 2013*). STEM-based module was developed in earth's structure and its dynamics topic for 7th grader students. Science sections are about earth's structure, earthquake, tsunami, volcanic eruption and flood. Additionally, technology engineering section mostly talk about how seismograph works and challenge students to conduct STEM activity based on engineering design process. Finally, mathematics sections are calculating earthquake's magnitude, time and distance. STEM-based module contains a series of quizzes, science content, and students' activity worksheet. The content of STEM based module can be seen at a glance in Figure 3.2.

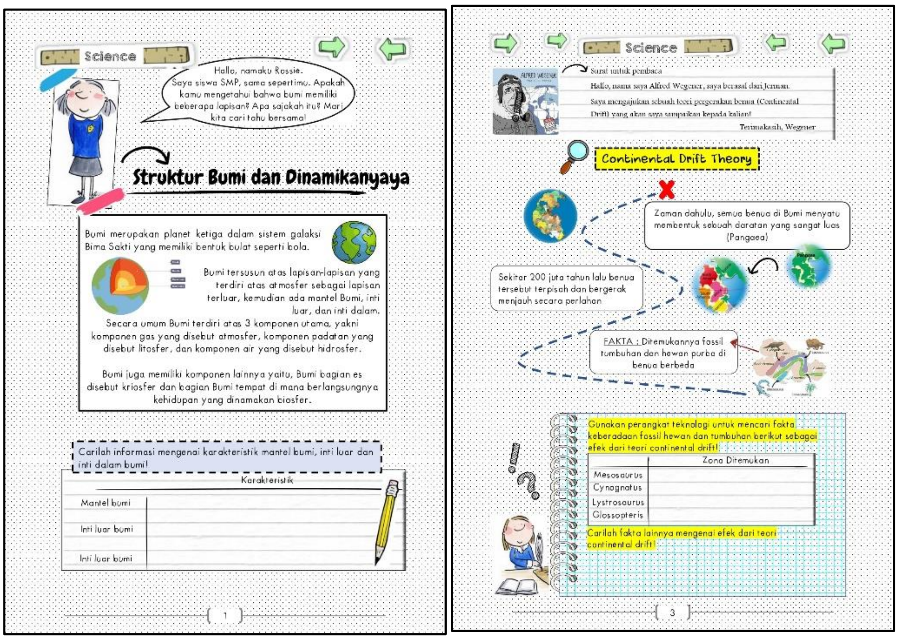


Figure 3.2 The Content of STEM based Module

To examine the validation of STEM based module, validation sheet was delivered to experts to examine the content, layout and language aspects (attached in appendix). Meanwhile readability test was delivered to four students and four teachers to examine the clarity and difficulty level of each page of STEM based module which was filled after reading session. Readability test measures layout, content and utility aspects of STEM based module to be used in 7th grade of junior high school classroom setting (attached in appendix).

b. STEM Literacy on Knowledge aspect

One aspect of STEM literacy is knowledge, in this research knowledge aspect measures student's understanding on earth's structure and its dynamics topic before and after the implementation of STEM based module. There are 20 multiple choice questions delivered which covers three components of STEM literacy on knowledge aspect namely science literacy, technology engineering literacy and mathematics literacy (questions are attached in appendix). Below is the grid of STEM literacy questions on knowledge aspect.

Table 3.2 The Grid of STEM Literacy Questions

STEM Literacy Component	Aspect	Indicator	Question Number	Total
Science Literacy	Science Literacy Competency Aspect			
	Content Knowledge	- Recognize range of natural phenomena	9, 18, 19	3
			12, 13, 17	3

STEM Literacy Component	Aspect	Indicator	Question Number	Total
	- Explain phenomena scientifically	- Offer and evaluate explanations for a range of natural phenomena		
	Procedural Knowledge - Interpret data and evidence scientifically	Analyze and evaluate data	1, 2, 3, 4, 5	5
			Total	11
Mathematics Literacy	Mathematical Processes			
	Formulating situations mathematically	- Simplifying a situation or problem in order to make it amenable to mathematical analysis	6, 7, 8	3
		- Representing a situation mathematically, using appropriate variables, symbols, diagrams and standard models	14, 20	2
			Total	5
Technology Engineering Literacy	Practical Aspect of Technology Engineering			
	Understanding Technological Principles	Make use of knowledge about technology.	11, 15, 16	3
	Developing solution and achieving goals	Systematical use of technological knowledge, tools, and skills to solve problems and achieve goals.	10	1
			Total	4

c. Attitude towards STEM

Attitude towards STEM is measured through questionnaire which is adapted from OECD (2016). Attitudes toward STEM are measured based on two aspects. First, interest in science and technology indicates student's interest about STEM issues and career choice as well as lifelong learning. Secondly, attitude toward environmental awareness is developed and adapted based on PISA questions which includes student's awareness about environmental problems, perception towards complex environmental issues, and environmental optimism. Table 3.3 presents the distributions of STEM literacy on attitude aspect.

Table 3.3 Distribution of Attitude towards STEM

Attitude Aspect	Indicator	Type of Questions		Total
		Positive	Negative	
Interest in science and technology	Demonstrate curiosity towards STEM issues	2	1	3
	Career choice relates to STEM	2	1	3
Environmental awareness	Awareness about environmental problems	1	2	3
	Perception towards complex environmental issues	2	1	3
	Environmental optimism	2	1	3
Total		**9**	**6**	**15**

Scoring criteria of student's interest towards STEM and environmental awareness is given in form of statement in a questionnaire which consist of both positive and negative statements followed by Likert scale of strongly agree, agree, disagree and strongly disagree options.

d. Student's Profile on STEM Process

Scoring system of STEM literacy on skill aspect is focused on product design activity by assessing student's activity and worksheet. The indicators used refer to the TEL indicator in NAEP which is described in several assessment indicators as described in Table 3.4.

Table 3.4 Indicator of TEL on Skill Aspect

No	Indicator	Page on module
1	Proposed solution (designing)	24-25
2	Analyze tools and materials requirements	27
3	Product design	26
4	Identify and solve tool malfunction problems	29
5	Conduct a trial	28
6	Product production	31

Student's skill aspect is measured in a group by assessing student's worksheet, production process, and science product based on scoring rubric. Worksheet, observation sheet and scoring rubric are attached in appendix.

e. Student's Perception towards STEM

Questionnaire is delivered to capture student's perception of STEM after using STEM based module in learning process. The questionnaire consists of several positive and negative statements about student's interest towards science education, the benefit of integrating technology and mathematics in learning science, clarity in giving task, the benefit of science activity, and group work activity. The questionnaire is followed by Likert scale of strongly agree, agree, disagree and strongly disagree options (attached in appendix). Table 3.5 presents the grid of student's perception towards STEM learning.

Table 3.5 The Grid of Student's Perception towards STEM Learning

Aspect	Question Number		Total
	Positive	Negative	
Student's interest towards learning science	1	4	5
Integrating technology and mathematics in learning science	3	2	5
Clarity in giving task	1	2	3
Benefit of science activity	3	1	4
Group work activity.	2	1	3
Total	10	10	20

F. Instrument Analysis

a. Content Validity

Validity is the ability of an instrument to measure what is designed to measure (Kumar, 2005). Anderson (Arikunto, 2010 : 65) revealed that a test is valid if it measures what it is purposed to measure and interpret data of research exactly. Validity has been defined as referring to the appropriateness, correctness, meaningfulness and usefulness of the specific inferences base on the data that have been collected. Additionally, validation is the process of collecting and analyzing the data and evidence to support such inferences (Fraenkel, Wallen and Hyun, 2007).

Kaplan and Saccuzzo (2012) describe that validity can be defined as the agreement between a test score and the quality to be measured. The maximum validity coefficient (r_{12max}) between two variables is equal to the square root of the product of their reliabilities, or

$$r_{12max} = \sqrt{r_{11} r_{22}}$$

Where:
r_{11} and r_{22} are the reliabilities for the two variables

(Kaplan and Saccuzzo, 2012)

The result of instrument validity indicates that the collected data is not deviating from the idea of the validity itself. Table 3.6 presents the classification and interpretation of validity score (Arikunto, 2010).

Table 3.6 Classification of Validity Coefficient

Value r_{xy}	Interpretation
$0,90 \leq r_{xy} \leq 1,00$	Very high
$0,70 \leq r_{xy} \leq 0,90$	High
$0,40 \leq r_{xy} \leq 0,70$	Medium
$0,20 \leq r_{xy} \leq 0,40$	Low
$0,00 \leq r_{xy} \leq 0,20$	Very low
$r_{xy} < 0,00$	Invalid / NAN

b. Reliability

Measurement error is common especially in science. The test items that are relatively free of measurement error are considered to be reliable and test items that contain relatively large measurement error are considered to be unreliable (Kaplan and Saccuzzo, 2012).

Reliability refers to the consistency of the item tests on scoring, how consistent item tests from one question to another (Fraenkel, Wallen and Hyun, 2007). According to Carmines and Zeller (1979), reliability shows the tendency toward consistency found in repeated measurements of the same path.

Kaplan and Saccuzzo (2012) describe that the reliability coefficient is the ratio of the variance of the true scores on a test to the variance of the observed scores:

$$r = \frac{\sigma^2 T}{\sigma^2 x}$$

Where:

r	The theoretical reliability of the test
$\sigma^2 T$	The variance of the true scores
$\sigma^2 x$	The variance of the observed scores

(Kaplan and Saccuzzo, 2012)

The reliability interpretation is represented on Table 3.7.

Table 3.7 Reliability Interpretation

Correlation Coefficient	Reliability Criteria
$0,00 < r \leq 0,20$	Very low
$0,20 < r \leq 0,40$	Low
$0,40 < r \leq 0,60$	Satisfactory
$0,60 < r \leq 0,80$	High
$0,80 < r \leq 1,00$	Very high

(Arikunto, 2013)

c. Difficulty Index

Item difficulty is defined by the number of people who achieve a particular correct test items especially for a test that measures achievement, ability or skill.

The optimal difficulty level for test item is usually about halfway between 100% of the respondents who got the correct answer (Kaplan and Saccuzzo, 2012). Difficulty index, also called facility index or P value. Difficulty index is one of the key parameters or measurements of test item analysis. Difficulty index describes the percentage of the students who correctly answer a given test item. Difficulty index ranges from 0 to 100% or 0 to 1. Easy test item has a higher difficulty index (Abdulghani et al., 2015).

Yuan et al. (2013) describes that the difficulty level of a test item is understood as the proportion of the respondents who correctly answer the test item. Difficulty index is calculated by the number of respondents who answer the questions correctly and the result is divided by the total number of the respondents who answer the questions. This proportion is indicated by the letter *p*, which indicates the difficulty level of the test item. The formula of difficulty level as follow:

$$P_i = \frac{A_i}{N_i}$$

Where:

P_i = Difficulty index of item *i*

A_i = Number of correct answers to item *i*

N_i = Number of correct answers plus number of incorrect answers of item *i*

(Yuan et al., 2013)

Additionally, Tomak and Bek (2014) state that for a particular item, the difficulty index can be defined as the ratio of those who provide correct answers. Abdulghani et al. (2015) state that base on the value of the difficulty index which base on the calculation of above formula, the difficulty index of an item tests can be categorized as shown on Table 3.8.

Table 3.8 Difficulty Level Interpretation

Difficulty Index	Interpretation
< 0.20	Very difficult
$0.21 < P_i \leq 0.69$	Moderately difficult
$0.70 < P_i \leq 0.90$	Easy
> 0.90	Very easy

(Abdulghani et al., 2015)

d. Discriminating Power

According to Ferrando (2012) the term "discriminating power" refers to the effectiveness of the score to distinguish between high level and low level achiever of the respondents who answer the questions. In a broad sense, discriminating power refers to the degree to which a high level varies with lower level. Yuan et al. (2013) state that good item shall discriminate between those who achieve high score and those who achieve low score. Discrimination index and discrimination coefficient are two ways of determining power of test items. The formula that is used in determining the discriminating power is described below:

$$D = \frac{P_H - P_L}{100}$$

Where:

D = Discrimination

P_H = Average score for the 27% of those with highest test scores

P_L = Average score for the 27% of those with lowest test scores

(Yuan et al., 2013)

Yuan et al. (2013) interpret the discrimination power and categorize them base on the result of above formula. If the number of D>0.39 it means that the quality of the exam paper is excellent. When D is in the 0.30-0.39 range, the exam paper is qualified. If 0.20<D<0.29, it indicates that the quality of the exam paper is passable and need to be improved. The exam paper should be discarded if D is less than 0.20. Table 3.9 concludes the interpretation of D value.

Table 3.9 Discrimination Power of Answers According to D Value

D =	Quality	Recommendations
> 0.39	Excellent	Retain
0.30< D ≤ 0.39	Good	Possibilities for improvement
0.20 < D ≤ 0.29	Satisfactory	Need to check/review
0.00 < D ≤ 0.20	Poor	Discard or review in depth
< -0.01	Worst	Definitely discard

(Yuan et al., 2013)

Furthermore, according to Long et al. (2012) a negative value means that participants got a low score in the test and tended to select the correct options more than a higher scoring participants. Conversely, a positive value for D index means that higher scoring respondents were more likely to select the response more.

G. Research Procedure

In order to have a good sequence and systematically research, the research procedure is arranged in three stages. Those of three stages are preparation stage, implementation stage, and analysis and conclusion stage which will be explained as follows:

a. Preparation Stage

In this stage, researcher focused on all of the preparation to conduct and support the research. The activity in the preparation stage is focusing on arranging and designing the instruments and lesson plan based on revised 2013 Curriculum with STEM approach, STEM-based science instruction, STEM-based modules, and STEM literacies. The preparation stage is stated below which is differentiated into three different steps:

STEP 1

1. Analysis of KI, KD, and Indicators from revised 2013 Curriculum.
2. Analysis of STEM-based module characteristics.
3. Analysis of STEM-based learning and STEM literacies.

STEP II

1. Arranging research proposal.

STEP III

1. Constructing outline model of modules with the concept.
2. Developing instrument for measuring students' STEM literacies.
3. Do the expert judgement.
4. Developing module with STEM content.
5. Expert judgement (content, display, graph, language)
6. Readability test (Gap and interview)

b. Implementation Stage

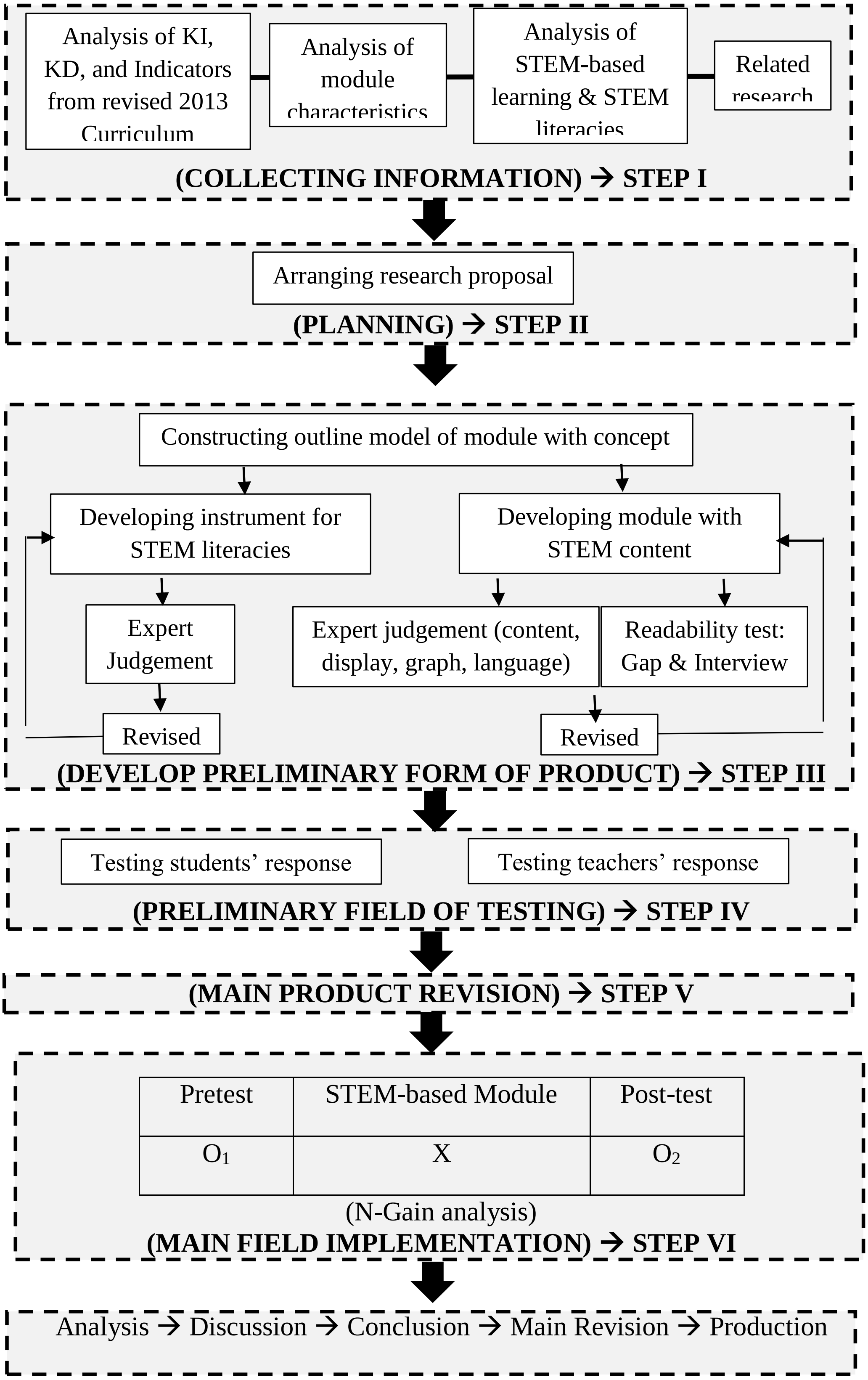
In this stage, it is a chance for the researcher to implement STEM-based module in STEM-based learning process on electricity and magnetism topic to take some data, and evaluate data gained using validated instrument. Teacher's and student's responses are being captured to revise the module.

Moreover, in this stage the pre-test is delivered to capture students' understanding of STEM subjects and STEM literacy before implementing STEM-based module and at the end, the post-test is delivered to measure student's learning improvement.

c. Analysis and Conclusion Stage

This is the final stage of research design, in this stage the observer analyzes and processes all the data gained from the implementation process. After the entire data are being captured and processed, the whole research will lead to the conclusion.

H. Research Scheme



(OPERATIONAL PRODUCT REVISION) → STEP VII

Figure 3.3 Diagram of Reseach Plot

I. Data Analysis of Research Results

Data processing was carried out on the three aspects of STEM literacy namely aspects of knowledge, attitudes and skills as well as processing of students' responses to the learning done.

1. Data collection of STEM based module validation and readability

a. Data collection of validation analysis is processed and validated by three lecturers. Those validators evaluate the accuracy of concept explanation, also suitability of content indicators and STEM indicators. Validation sheet examines the content, layout and language aspects of STEM based module. Revisions are done to revise the missed content so STEM based module is valid to be used in learning practice.

b. Data collection of readability analysis done through questionnaire given to four students and four teachers to examine the clarity and difficulty level of each page of STEM based module which was filled after reading session. Readability test measures layout, content and utility aspects of STEM based module to be used in 7th grade of junior high school classroom setting. The result of questionnaire is calculated by this formula:

$$readability\ result = \frac{raw\ score}{maximum\ score}\ x\ 100$$

2. Data collection of STEM literacy on knowledge aspect

The instrument for measuring students' knowledge understanding is by giving an objective test in a form of 20 questions. The instrument should be tested in terms of validity, reliability, discriminating power, and difficulty level which were analyzed by Anates V4 software. The test was given to 27 students of 9th grade class which have learned about the chapter that will be learned for the research. According to the result, 17 questions are significant while 3 other questions are concluded as very significant, which means that those questions are valid. The recapitulation of questions analysis is presented in Table 3.10.

Test Item Statistical Result

Mean	: 13,56	Correlation XY	: 0,51
Standard Deviation	: 4,09	Reliability Test	: 0,68

Table 3.10 Recapitulation of Questions Analysis

No	Discriminant Power	Difficulty Level	Correlation Value	Correlation Significancy
1.	-28,57	Satisfactory	-0,229	NAN
2.	42,86	Easy	0,399	Significant
3.	57,14	Easy	0,419	Significant
4.	71,43	Satisfactory	0,470	Significant
5.	57,14	Satisfactory	0,509	Very Significant
6.	57,14	Easy	0,470	Significant
7.	-14,29	Satisfactory	-0,006	NAN
8.	57,14	Hard	0,487	Significant
9.	57,14	Hard	0,552	Very Significant
10.	42,86	Hard	0,433	Significant
11.	57,14	Easy	0,474	Significant
12.	57,14	Satisfactory	0,453	Significant
13.	71,43	Satisfactory	0,477	Significant
14.	57,14	Satisfactory	0,411	Significant
15.	-14,29	Satisfactory	0,031	NAN
16.	42,86	Satisfactory	0,412	Significant
17.	0,00	Satisfactory	0,011	NAN
18.	71,43	Hard	0,592	Very Significant
19.	57,14	Satisfactory	0,440	Significant
20.	71,43	Satisfactory	0,431	Significant
21.	0,00	Satisfactory	0,077	NAN
22.	42,86	Hard	0,459	Significant
23.	42,86	Easy	0,385	Significant
24.	57,12	Satisfactory	0,431	Significant
25.	57,14	Hard	0,403	Significant

Description *NAN = invalid

Analysis of pretest and posttest data is calculated to see the enhancement of student's knowledge aspect in STEM literacy before and after teaching and learning activity. The steps are as follows:

a. Calculate the raw score of each pretest and posttest answer

b. Turning raw scores using this formula:

$$pretest/postest\ score = \frac{\sum raw\ score}{\sum maximum\ score}\ x\ 100$$

c. Calculate mean score using this formula:

$$mean\ score = \frac{\sum total\ score}{\sum number\ of\ students}$$

d. Determine the enhancement of student's STEM literacy on knowledge aspect by calculating the means of normalized gain score. The difference in pretest and posttest score is assumed as the effect of treatment. Normalized gain calculations are intended to determine the categories of student's achievement improvement. According to Hake (1999) gain is calculated by this formula:

$$G = S_f - S_i$$

Description:
G = Gain
S_f = Post-test score
S_i = Pretest score

The effectiveness of STEM-based module in improving students' STEM literacy on knowledge aspect will be seen from the result of the normalized gain that achieved by students during the learning process. For the calculation of the normalized gain <g> value and its classification will use equations (Hake, 1999) as follows:

$$< g >= \frac{\% G}{\% Gmax} = \frac{(\%S_f - \%S_i)}{(100 - \% S_i)}$$

Description:
<g> = Normalized gain
G = Actual gain
G_{max} = Maximum gain possible
S_f = Post-test score
S_i = Pretest score

Average normalized gain (<g>) which is formulated using this formula:

$$< g >= \frac{\%<G>}{\%<G>max} = \frac{(\%<S_f> - \%<S_i>)}{(100 - \% <S_i>)}$$

Description:
<g> = Normalized gain
<G> = Actual gain
$<G>_{max}$ = Maximum gain possible
$<S_f>$ = Average of post-test score
$<S_i>$ = Average of pretest score

e. Interpret normalized gain score based on determined criteria on Table 3.11.

Table 3.11 Normalized Gain Score Criteria

Score <g>	Classification
g ≥ 0,7	High
0,7 > g ≥ 0,3	Satisfactory
g < 0,3	Low

(Hake, 1998)

f. Determine effect size of student's STEM literacy on knowledge aspect by calculating the means of normalized effect size. The difference in pretest and posttest score is assumed as the effect of treatment and is divided by the result of standard deviation. The calculation of effect size is intended to determine the effect of student's improvement on knowledge aspect. According to Cohen (2007) effect size for single group is calculated by this formula:

$$Effect\ Size = \frac{average\ posttest\ score - average\ pretest\ score}{Standard\ Deviation}$$

g. Interpret effect size score based on determined criteria on Table 3.12.

Table 3.12 Effect Size Criteria

Size	Classification
$0 < EF \leq 0,20$	Weak effect
$0,20 < EF \leq 0,50$	Modest effect
$0,50 < EF \leq 1,00$	Moderate effect
$> 1,00$	Strong effect

(Cohen, 2007)

3. Data Collection of STEM Literacy on Attitude Aspect

Data of student's STEM literacy on attitude aspect includes student's interest in STEM studies, student's environmental concern, and student's attitudes toward STEM which is calculated in a quantitative descriptive manner using this formula:

$$attitude\ score = \frac{raw\ score}{maximum\ score}\ x\ 100$$

4. Data Collection of STEM Literacy on Skill Aspect

The analysis of student's STEM literacy on skill aspect was carried out on the data from observation sheet performance appraisal (group assessment) which has been assessed by four observers in class. The calculation steps were carried by using this formula:

$$Skill\ score = \frac{raw\ score}{maximum\ score}\ x\ 100$$