CHAPTER III
RESEARCH METHODOLOGY

A. Type of Research Methodology

The research has purpose to develop a STEM-based workbook as an instructional material, the methodology that being used in this research is Research and Development. This research methodology is used to produce a new product based on need-analysis and test the effectiveness of the product (Sugiyono, 2012). Borg and Gall (1989) gives limitation about the research methodology to be used in educational field it is done as an effort only to develop and validate some products that will be used in educational field.

In the application for Research and Development, there are some models that can be applied they are; descriptive, evaluative, and experimental model. Descriptive model will be used in the beginning of the research to collect some data about current condition. Evaluative model will be used to evaluate trial process about the product and the last model is experiment, where the researcher will implement the product in real situation, in this research the researcher wants to test the STEM competencies through the workbook to check the effectiveness.

As known that research and development methodology takes several times to finish the whole research, therefore the researcher limits the procedure to develop the STEM-based workbook based on Borg and Gall (1989) as follows;

1. Research information collecting,
2. Develop preliminary form of product,
3. Preliminary field testing (validation, readability, sample testing),
4. Main product revision,
5. Main field implementation, and
6. Operational product revision (final).

The model that is used for this R & D method is a descriptive model where it can portrays and describe each steps in achieving research purpose and the influences in each stages more actual (Gati & Asher, 2001). The detail explanation of research and development process is shown by the following diagram:

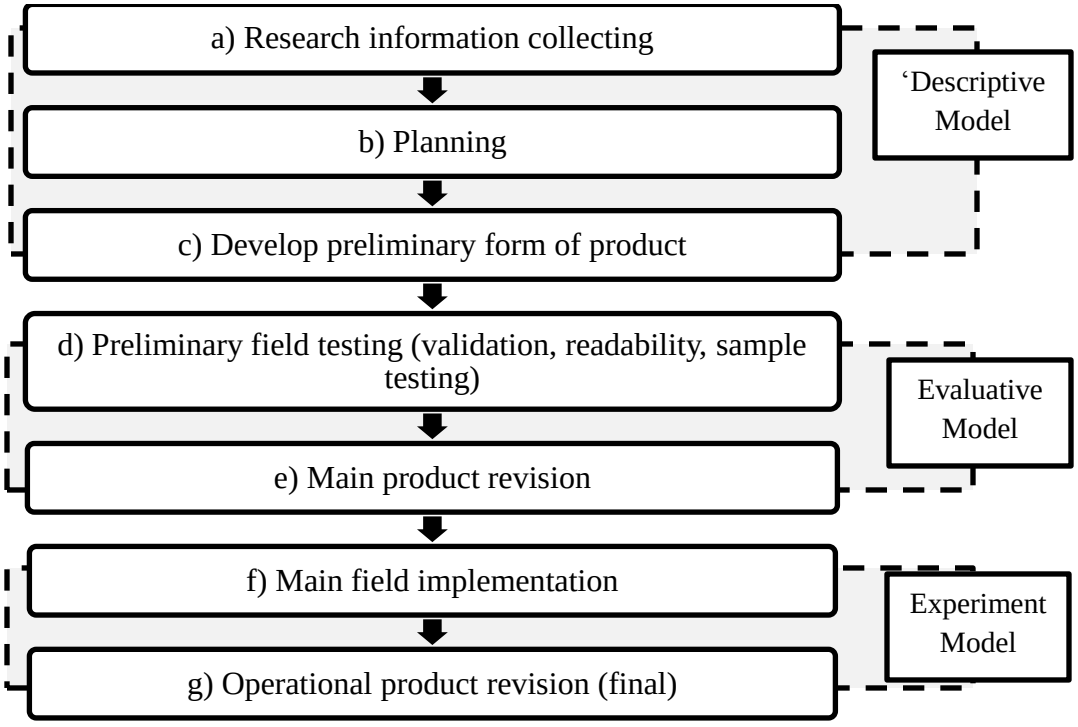

Figure 3.1. Research and Development Process

B. Research Object

The research object of this research is the instructional materials in a form of STEM-based workbook that consist materials, learning guidelines, clues, and rules as well as question sets about lever system in human body, specifically about lever system.

C. Research Subject

The research subject for this research is one class classrooms in grade secondary two with total 26 students with 13 students in each class, the entire

students have not learnt about lever system in human body, but they have already learnt about lever system. The research was conducted in one of Private International School in Bandung which applied Combined Curriculum in the learning process. The data collection was done in February up to May 2016.

D. Research Procedure

There are three stages of procedure that is conducted in this research, it is including preparation stage, implementation stage, and analysis and conclusion stage. Those three stages will be explained as follows:

a. Preparation stage

In this stage, the activity is focusing on arranging and designing the instruments and lesson plan by considering the curriculum, STEM-based science instruction, STEM-based workbook, and STEM competencies as shown in Figure 3.2 it is done from STEP I until STEP III.

b. Implementation Stage

This stage is the chance for researcher to implement STEM-based workbook to take some data, and evaluate the data gained using validated instrument, in this stage also test student and teacher response, then being revised and finally implemented to the students (Figure 3.2, STEP IV - VI).

c. Analysis and Conclusion Stage

This is the final stage of research design, in this stage the observer will analyze and process all the data gained from the implementation. After all data (both quantitative and qualitative) are being processed the whole research will be conclude as shown in STEP VII in Figure 3.2.

E. Research Plot

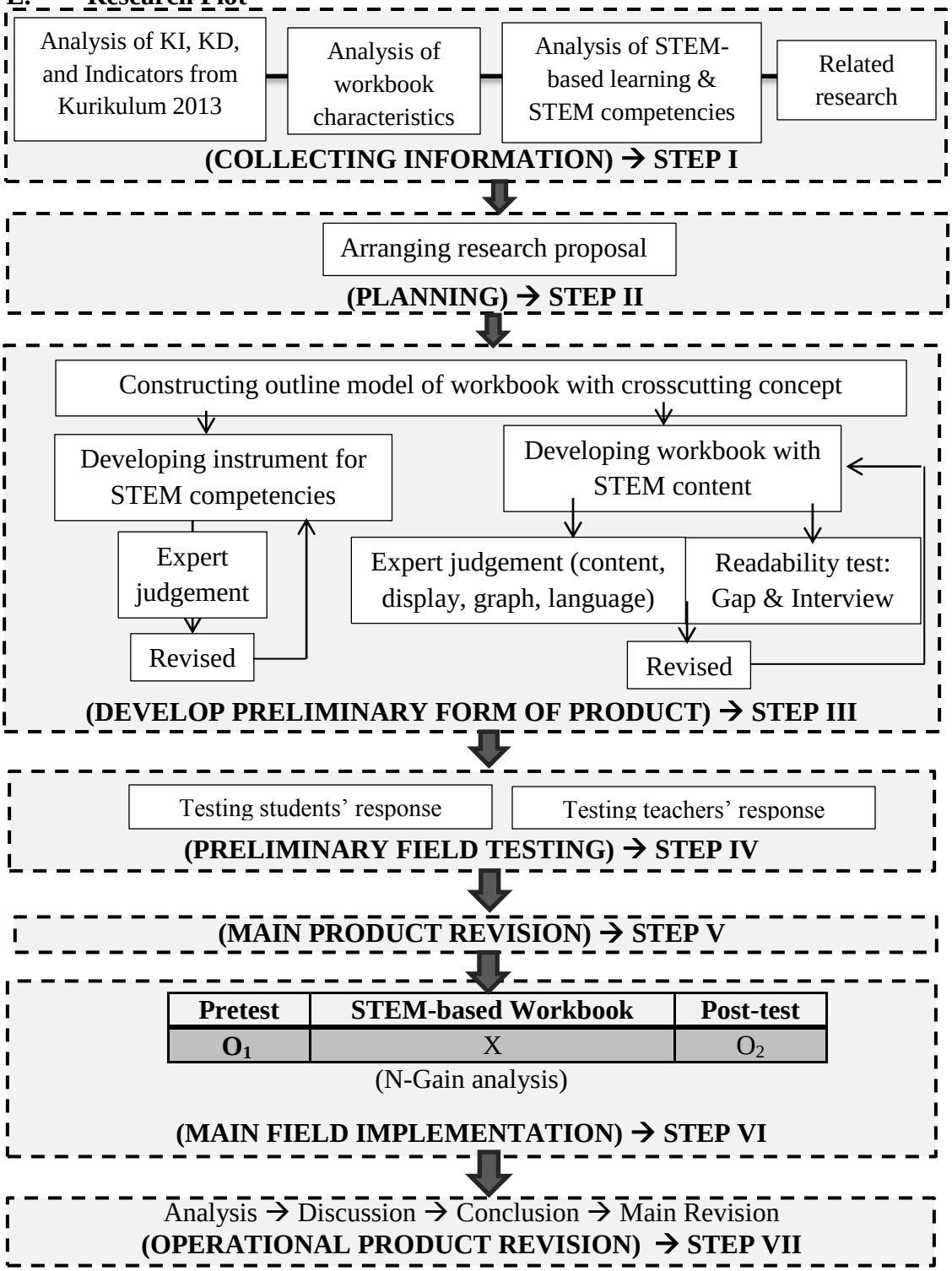

Figure 3.2 Diagram of Research Plot

F. Research Instrument

Instrument has function to gain data needed and being compared to certain standard to cope with the necessity (Arikunto, 2006). The research instrument which is used to collect the data in this research divided into workbook development and workbook effectiveness, and it consists of:

Workbook development includes:

1. Literature study in a form of outline table (Appendix D.1).
2. Validation sheet of indicators suitability between lever system in human body concept and STEM education (Appendix B.1).
3. Readability test (Appendix C.3 & C.4).

Workbook effectiveness covers:

1. Objective test in a form of pretest and posttest (Appendix B.2 & B.3).
2. Performance test and rubrics for innovative abilities, responsibility value, and students' designing skill (Appendix B.5 – B.8)
3. Questionnaire for analyzing students' perception of STEM (Appendix B.9).
4. Field notes during the research implementation (Appendix B.10).

G. Instrument Development

The process of instrument development explore about the explanation of each instruments, it begins with analysis of the applicable curriculum at the involved school. The instrument needs to be validated (judgment) by the concerned lecturer and some experts in related fields. After being judged, the instrument which is not appropriate enough should be revised. After the instrument revised, it should be tried out on another class which has the same level of research sample. Below are the development of each instruments.

Workbook development:

1. Literature study, to gain information about the criteria of STEM education and workbook requirements so that the characteristics of STEM-based workbook can be known. The result of literature study would be shown as a STEM-based workbook outline (Appendix D.1)
2. Validation sheet of indicators suitability and lever system in human body concept with STEM education, this insturment is being used to check the suitability of curriculum and STEM-based workbook that will be implemented.
3. Readability test, this test is will be used to analyze the STEM-based workbook. Readability has two common meanings, one applying to document design, the other to language. Readability as it is applied to document design is concerned with such matters as line length, leading, white space, font type and the like (Marnell, 2009). It is conducted to know how the readability level is by using a Gap Test (Appendix C.3) and Interview Test (Appendix C.4).

Workbook effectiveness:

1. Objective test in a form of pretest and posttest, with closed and open ended test. This test is used to measure students' STEM competencies for knowledge understanding and problem solving skills through STEM-based workbook on lever system in human body. The tests used to gain students' knowledge understanding in this research are writing tests consist of 14 multiple choice questions and two essay questions to obtain problem solving skill as part of STEM competencies (Appendix B.1 and B.2). Based on the test results, the instrument questions will be analyzed with ANATES software, with the following explanation:

a. Validity

Validity is the ability of an instrument to measure what it is designed to measure (Kumar, 2005) Anderson (Arikunto, 2010 : 65) revealed that "A test is valid if it measure what it purpose to measure". An instrument categorized as valid if it can measure something that will be measured and interpret data from variable of research exactly. The result of instrument validity indicates that the collected data is not deviating from the idea of the validity itself. The classification of interpretation about r_{xy} will be divided into different categories based on Guilford (Arikunto,2010).

Table 3.1 Classification validity coefficient

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

b. Reliability

Anderson (Arikunto, 2010) state that validity and reliability are important, "A reliable measure in one that provides consistent and stable indication of the characteristic being investigated". The concept of reliability related with research instrument means if a research instrument is consistent and stable, and, hence, predictable and accurate, it is said to be reliable. The greater the degree of consistency and stability in a research instrument, the greater its reliability. Reliability of an evaluation instrument is intended as a tool that gives the same results if the measurement is given on the same subject although done by different people, at different times, and different places (Arikunto, 2006). The classification of reliability value is shown in Table 3.2

Table 3.2 Classification of Reliability Coefficient

Value	Interpretation
$0,90 \leq r_{11} \leq 1,00$	Very high reliability degree
$0,70 \leq r_{11} < 0,90$	High reliability degree
$0,40 \leq r_{11} < 0,70$	Medium reliability degree
$0,20 \leq r_{11} < 0,40$	Low reliability degree
$r_{11} < 0,20$	Very low reliability degree

c. Discriminating Power

Another important procedure in item analysis is calculating the item discrimination power (DP) which can be defined as the degree to which an item test discriminates between students with high and low achiever. Discriminating power of test item is the ability of test item to distinguish between a high achiever and low achiever student (Arikunto, 2006). So, to obtain the discrimination power of the items, the following formula has been used:

$$DP = \frac{RU - RL}{\frac{1}{2} T}$$

…….(3.1)

Explanation:

DP = Discriminatory power.

RU = The number of tests in the upper group who got the item right.

RL = The number of tests in the lower group who got the item right.

T = The total of tests included in item analysis.

Classification of discriminating power interpretation used is (Arikunto,2006):

Table 3.3 Discriminating Power Classification

Value DP	Interpretation
$\boldsymbol{DP \leq 0,00}$	Very poor
$\boldsymbol{0,00 < DP \leq 0,20}$	Poor
$\boldsymbol{0,20 < DP \leq 0,40}$	Fair
$\boldsymbol{0,40 < DP \leq 0,70}$	Good
$\boldsymbol{0,70 < DP \leq 1,00}$	Very good

d. Difficulty Level

After scoring the test papers, the researcher has arranged the scored test in order of scores, from the highest to the lowest score. The researcher, then, separated two subgroups of test papers; an upper group consisting of the top (27%) of the total group who received the highest scores, and a lower group including an equal number of papers (27%) who received the lowest scores. The researcher also counted the number of times each response to each item is chosen correctly on the papers of the upper group and does the same separately for the papers of the lower group. In doing so, she intended to calculate the difficulty level (henceforth DL) or (facility value) of each item. It means as Gronlund (1976:211) remarks "the percentage of students who got the item right"; so, in order to find out the level of difficulty for each item in the test, the following formula has been used:

$$DL = \frac{HC + LC}{\text{Total Number of the Sample}}$$

…… (3.2)

Where:

DL = Difficulty level

HC = High correct

LC = Low correct

(Madsen, 1983)

Classification of difficulty level in each test item that used is based on Arikunto,2010:

Table 3.4 Coefficient classification of difficulty level

Value DL	Interpretation
IK = 0,00	Very difficult
0,00 < IK ≤ 0,30	Difficult
0,30< IK ≤0,70	Medium
0,70< IK <1,00	Easy
IK = 1,00	Very easy

\

2. Performance test and rubrics, these instrument are needed for assessing the students' STEM competencies for abilities (innovation) and work values (responsibility) as well as students' designing skill. (Appendix B.4, B.5, and B.6)
3. Questionnaire, to analyze students' perception on STEM-based workbook implementation on lever system in human body. (Appendix B.8)
4. Field notes, to be used for analyzing the whole students' activity and teacher activity during the learning process. (Appendix B.9)

H. Data Collection Technique

In this research, there are six different data which is collected, those data has different instrument to measure. The data collection techniques are explained as follow:

1. Data collection of validation analysis of concept indicators and STEM indicators

The validation process is validated by five STEM experts consist of three lecturers and two teachers. Those validators evaluate the accuracy of concept explanation, also suitability of content indicators and STEM indicators.

2. Data collection of readability analysis

Readability test was done through Gap Test to five experts and also interview to high, middle, and lower students. The gap test result being analyzed based on its suitability between picture and text, while the closed interview being analyzed whether the text is understandable or not and also checking their understanding to some instructions in the STEM-based workbook.

3. Data collection for analysis of knowledge understanding instrument

The instrument for measuring students' knowledge understanding is by giving an objective test in a form of 14 questions. The instrument should be tested in terms of validity, reliability, discriminating power, and difficulty level as explained before. The test was given to 30 students which have learned about the chapter that will be learned for the research. The recapitulation of test item analysis is shown in the following table.

Test item statistical result:

- Mean = 13.30
- Standard Deviation = 3.24
- Correlation XY= 0.65
- Reliability Test= 0.79

Table 3.5 Test Item of Knowledge Understanding Result

Test Item	Discriminating Power (%)	Difficulty Level	Correlation	Sign. Correlation	Status
1	0.00	Very Easy	NAN*	NAN*	REJECTED
2	0.00	Medium	NAN*	NAN*	REJECTED
3	25.00	Medium	0.133	-	REJECTED
4	37.50	Medium	0.230	-	REVISED
5	12.50	Medium	0.185	-	REJECTED
6	37.50	Very Easy	0.485	Significant	USED
7	25.00	Very Easy	0.529	Significant	USED
8	75.00	Easy	0.794	Very Significant	USED
9	35.00	Very Easy	0.613	Very Significant	USED
10	25.00	Very Easy	0.499	Significant	USED
11	50.00	Very Easy	0.653	Very Significant	USED
12	25.00	Easy	0.351	-	USED
13	75.00	Easy	0.794	Very Significant	USED
14	100.00	Easy	0.885	Very Significant	USED
15	75.00	Easy	0.671	Very Significant	USED
16	50.00	Medium	0.366	-	REVISED
17	37.50	Easy	0.483	Significant	USED
18	75.00	Medium	0.466	Significant	USED

*) NAN = Invalid

4. Data collection for analysis of problem solving skill instrument

The instrument for measuring students' problem solving skill is by giving an essay test in a form of two questions. The instrument should be tested in terms of validity, reliability, discriminating power, difficulty level, and readability as explained before. The test was given to 30 students which have learned about the chapter that will be learned for the research. The recapitulation of test item analysis is shown in the following table.

Essay test statistical result:

- Mean = 19.57
- Deviation Standard= 3.86
- Correlation XY= 0.73
- Reliability Test= 0.84

Table 3.6 Test Item of Problem Solving Skill Result

Test Item	Discriminating Power (%)	Difficulty Level	Correlation	Sign. Correlation	Status
1	31.67	Medium	0.927	Very Significant	USED
2	30.00	Medium	0.933	Very Significant	USED

5. Data collection of rubrics analysis of innovative abilities, responsibility value, and designing skill

The rubrics will be used to observe the final result of students' innovative abilities, responsibility, and students' designing skill. The assessment is gained through observation during learning process and analysis on students' STEM-based workbook. The rubrics made by the observer after being judged with certain scale to measure the result, the rubrics will be fulfilled by the researcher as well as the observer.

6. Data collection of questionnaire analysis

Unstructured questionnaire is used to know the response of the students towards the implementation of STEM-based workbook on lever system in human body during the lesson. This data obtained from students' answer from 22 questions given in the end of the lesson.

I. Data Analysis Technique

Data obtained from both quantitative data and qualitative. Quantitative data obtained from the pretest and data of students' knowledge understanding (post-test) and students' problem solving skill, while the qualitative data obtained from the rubrics and questionnaire. Exploration of data processing techniques are obtained as follows:

1. Data of Students' Knowledge Understanding

The students' knowledge understanding is the first competencies of STEM competencies. This data will be collected through objective test in form of multiple choice consist of 14 questions. Students' knowledge understanding that will be measured is only about lever system in human body. The result will be collected then analyzed using the normalized gain formula as shown in Table 3.7.

Table 3.7 Test Item Specification of Knowledge Understanding

Basic Competencies	STEM Indicators	Question Number				
		C1	C2	C3	C4	C5
To understand the concept of work, simple machine, and its application in our daily life as well as its correlation with the work of muscle on human skeletal muscle system and presenting investigation result about the use of simple machine in our daily life.	Student can obtain, evaluating, and communicating information	2		1		
	Student can engage in argument from evidence		7, 3			
	Student can apply mathematical and computational thinking			4, 5		
	Student can plan an investigation			11	6	
	Student can develop concept using models		8			
	Student can construct explanation on science concept	9	12			
	Student can analyze and interpret data				14	10
	Student can define problem		13			
TOTAL		2	5	3	2	1

In this research, the data of test scores is used to measure the improvement of students' knowledge understanding and problem solving skill. The data processing carried out in by calculating gain and normalized gain, gain score (actual gain) was obtained from the difference of pretest score and post-test score. The difference in pretest scores and the post-test is assumed as the effect of the treatment. Normalized gain calculations are intended to determine the categories of students' achievement improvement. According to Hake (1999) gain is calculated by using Equation 3.3:

$$G = S_f - S_i$$

…… (3.3)

Description :

G = Gain

S_f = Post-test score

S_i = Pretest score

The effectiveness of STEM-based workbook in improving students' STEM competencies on lever system in human body, it 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 value and its classification will use equations (Hake, 1999) as follows:

Normalized gain of each student <g> defined as following formula:

$$\langle g \rangle = \frac{\%G}{\%G \text{ max}} = \frac{(\%Sf - \%Si)}{(100 - \%Si)}$$

…… (3.4)

Description:

$\langle g \rangle$ = Normalized gain

G = Actual gain

G_{max} = Maximum gain possible

S_f = Post-test score

S_i = Pretest score

Average of normalized gain (<g>) which is formulated as:

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

…… (3.5)

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

The value of normalized gain <*g*> which is already gained is interpreted with the classification of Table 3.8

Table 3.8 Interpretation of Normalized Gain Value

Value ⟨g⟩	Classification
⟨g⟩≥ 0,7	High
0,7 >⟨g⟩≥ 0,3	Medium
⟨g⟩< 0,3	Low

(Hake, 1999)

Next, a normality test of N-gain on students' knowledge understanding result is done by *Shapiro-Wilk* or *Kolmogorov-Smirnova* by software *IBM SPSS Statistics 22* if the result showed more than α= 0.05, then the data are normally distributed. Then, a single sample of T-test, it is used to compare the result of the data with students minimum achievement / *kriteria ketuntasan minimal* (KKM) from Indonesian government as much as 65 after the implementation of STEM-based workbook of lever system in human body. If the score of $t_{calculation}$ is greater than $t_{table,}$ it means that there is a significant improvement compare to national standard on students' knowledge understanding.

2. Data of Students' Problem Solving Skill

The second skill from STEM competencies is the result of students' problem solving skill. The problem solving skill result will be gained from two essay questions. The answer of students in the test will be analyzed in specific rubrics. The result will be collected then analyzed using the normalized gain formula.

Table 3.9 Essay Test Item Specification

No	Learning Objective	Question Number				
		Identify	Explore	Look Alter-native	Select best	Implement
1	Understand the working principle of lever in making human easier to do work	1a 2a				1e 2e
2	Create a lever product based on basic principle of muscular system in human body		1b 2b	1c 2c	1d 2d	
Total		2	2	2	2	2

The data that has been gained from research instrument, further it is analyzed by giving certain score for problem solving skill. The score given is already determined in specific rubrics. It is shown in Table 3.10 below.

Table 3.10 Scoring Guidance of Problem Solving Skill

Problem Solving Process	Rating = 1	Rating = 2	Rating = 3
Identifying the problem	Student does not clearly identify the problem.	Student defines the problem but not too detail	Student states the problem clearly and identifies underlying issues.
Exploring the problem	Student cannot even mention the cause as well as the effect of the problem.	Student catches up symptoms or effect of a problem but not get down to the real cause.	Student should analyze the problem to see what the root case is and state the effect of the problem clearly.

Problem Solving Process	Rating = 1	Rating = 2	Rating = 3
Look at Alternative	Student does not develop a coherent plan to solve the problem.	Student develops an adequate plan, but does not follow it to conclusion.	Student can clarify the direction to take into solving a problem, gives them definite to focus on, follows the plan.
Select the best solution	Student cannot collect inadequate information and cannot give any solution.	Student collects adequate information and performs basic analyses and gives at least 2 alternative solutions.	Student collects information from multiple sources and analyzes the information in-depth and gives at least 3 alternative solutions.
Implement	Student does not interpret the findings or reach a conclusion, students do not make any improvement from the product	Student provides an adequate interpretation of the findings and solves the problem, but fails to choose the best solution. There is some improvement on the design but fails to meet the requirements.	Student provides a logical interpretation of findings and clearly solves the problem, offering alternatives solutions, and chooses one best solution based on several reasons. Give a design of improvement and meets the requirements.

Adapted from Kelley (2006)

3. Data of Innovative Abilities Rubrics

The third STEM competencies that should be mastered by students is innovative abilities, it can be gained after learning implementation and finishing the STEM-based workbook, and it is necessary to be assessed. The assessment for the product will be measured by a rubric with specific criteria. The scoring guidance for innovative abilities assessment is gained through observation and product result after implementing STEM-Based Workbook Page 4, 9, 10, 11 has shown below:

Table 3.11 Innovative Abilities Observation Rubrics

INNOVATIVE ABILITIES	Rating 1	Rating 2	Rating 3
Functioning product	Student can create the product but cannot be functioning.	The product that is created by students can be functioning well but they cannot explain how it works.	The product that is created by students can be functioning well and they can explain how it works
Improving product	Student can create new product/ design but there is no improvement	Student can create new product/ design but only perform a little changes	Student can create new product/design with large scales of improvement
Collaborative skill	Student work alone by himself	Student work in a team but only become a supporter	Student work in a team and give contribution to the final product

Adapted from: (Bement, Jr. et. al, 2015)

4. Data of Responsibility Value Rubrics

The forth STEM competencies that would be observed is responsibility value, it can be observed during learning implementation and finishing the STEM-based workbook, and it is necessary to be assessed. The observation process will be guided by a rubric with specific criteria as shown below:

Table 3.12 Responsibility Value Observation Rubrics

Responsible Behavior	Description	Always	Most of the time	Rare
Self-control	Student does no harm to others verbally or physically; includes/works well with others; resolves conflicts peacefully if they emerge	3	2	1
Effort	Student tries hard to master every task and focuses on improvement	3	2	1

Responsible Behavior	Description	Always	Most of the time	Rare
Self-Direction	Student will stay on task without direct instruction or supervision whether working alone or with others; does not seem to follow bad examples or peer pressure	3	2	1

Adapted from: Wright (2009)

The data that has been gained from research instrument, further it is analyzed by giving certain criteria for responsibility value interpretation. The score given is already determined in specific rubrics. The rubric for analyzing students' responsibility criteria that adapted from national curriculum rubrics as shown in table 3.13 below.

Table 3.13 Categorization of Responsibility Value Rubrics

Grade	Description	Total Score
Very good	Students always realize what they supposed to do, trusted, never deviate the tasks given, and always feel confidence in finishing their tasks	9-8
Good	In general, these students can be trusted, and able to finish their tasks without any guidance	7-6
Fair	With some guidance, these students can finish the tasks given and in normal situation these students can be trusted	5-4
Poor	Students do not want to finish the tasks given, cannot be trusted in finishing the tasks, and do not realize their role.	3-0

5. Data of Designing Skill Rubrics

The development of students' designing skill and it will be observed through the whole learning process and the STEM-based workbook fulfillment the data gained through observation and development of students' design after implementing STEM-Based Workbook Page 5, 6, 7, 8, 10, 11 and obtained through rubrics with several criteria as follows:

Table 3.14 Designing Skill Observation Rubrics

Designing Skill	Rating 1	Rating 2	Rating 3
Define	Student cannot formulate a problem based on the case given	Student can formulate a problem but not related with the case given	Student can reframe needs and insight into an actionable problem statement
Ideate	Student can only design an idea to solve the problem but cannot explain how it works	Student can design an idea to solve the problem and explain the stages but fail to explain how it works	Student can design an idea to solve the problem, explain the stages and able to explain how it works completely
Prototype	Student cannot visualize possible solution for finishing the problem	Student can visualize possible solution but still incomplete	Student can visualize possible solution by creating a model in detail

Adapted from: (Stanford University: Taking Design Thinking to Schools, 2011)

6. Data of Questionnaire

Non-test data collection through questionnaire was used to determine the perception of the students towards students' learning in lever system in human body using STEM-based workbook. The data obtained from the questionnaire is a secondary instrument, and it is processed by a percentage calculation. The blue print of students' response questionnaire is shown in table 3.15:

Table 3.15 Table of Specification Students' Response Questionnaire

Indicators	Category and Statement Number
Students' perspective on improvement of their knowledge understanding	Positive statement: 7, 8
	Negative statement: 9, 10
Students' perspective on improvement of their problem solving skill	Positive statement: 11, 13
	Negative statement: 12, 14
Students' perspective on improvement of their innovative abilities and become more responsible	Positive statement: 1, 3, 5
	Negative statement: 2, 4, 6
Students' perspective on stimulating their designing skill	Positive statement: 15, 17
	Negative statement: 16, 18
Students' perspective about the effectiveness of implementing STEM-based workbook	Positive statement: 19, 21
	Negative statement: 20, 22

The qualitative analysis will describe the real situation of the research result and also the result of students' perception in learning lever system in human body using STEM-based workbook. Processing is done by calculating Likert scale will be calculated into score and then converted into percentage, the percentage of answers observer to then be evaluated for the next lesson. The scoring guideline will be shown in the following table:

Table 3.16 Scoring Guideline of Students' Response

	Strongly Disagree	Disagree	Not sure	Agree	Strongly Agree
Positive Statement	5	4	3	2	1
Negative Statement	1	2	3	4	5

The percentage data will be gained by calculating through the following formula:

$$\mathbf{P = \frac{f}{n} x\ 100\%}$$

..... (3.6)

Explanation :

P : Percentage

f : score from frequency of the answer

n : score from total response

The result then will be recapped for each indicators, for those that results more than 50% means that the responses are positive or agree with the statements of questionnaire.