

CHAPTER 3

RESEARCH METHOD

A. Operational Definition

To avoid confusion on understanding the content of this paper, operational definitions of variables in this study are presented as follow.

1. *Interdisciplinary thinking skill* is a score of students in answering questions of biology and mathematics understandings and students' ability to explain and argue the answers in essay tests on Plant Reproduction.
2. *Argumentation Analysis* is analyzing of students' answers at essay forms using Toulmin Modified Analysis. Students' answer will be categorized based on the level of their argument on Plant Reproduction topic.
3. STEM-based instruction is an instruction which involve science (biology), mathematics, technology and designing process in a learning process in order to solve a problem and creating a product.

B. Data Source

This research was conducted at Darul Hikam International School, it is located on Jalan Maribaya No. 89 Lembang, Kabupaten Bandung Barat. Population in this research is all students grade X natural science program of Darul Hikam International School. Sample in this research are two classes of X natural science program which are studying materials of Plant Reproduction. Sample taking is conducted by two classes which is using total sampling technic because Darul Hikam International School is a small school which are in a cohort just compose of two classes.

Table 3.1 *One group Pretest-Posttest Design*

Class		One Group Design	
Secondary 4	Pretest	application of STEM-based instruction on plant reproduction topic	Posttest

(Source: Fraenkel & Wallen, 2011)

C. Research Design

Research method used in this study is quasi-experiment. Based on Fraenkel *et al.*, (2011) quasi experimental designs are not include the use of random assignment. Reseachers who employ these design rely instead on other techniques to control or to least reduce threats to internal validity. Like in Table 3.1, this research applied one-group pretest posttest design, a single group is measured or observed not only after being exposed to a treatment of some sort, but also before. This design is better than the one-shot case study (the reseacher at least knows whether any change occured), but it is still weak. Nine-uncontrolled-for threats to internal validity exist that might also explain the results on the posttest. They are history, maturation, instrument decay, data collector characteristics, data collector bias, testing, statistical regression, attitude of subjects, and implementation. Any or all of these may influence the outcome of the study (Fraenkel and Wallen, 2011).

To both classes applied the same strategy which is STEM-based instruction. Measuring interdisciplinary thinking skill and students' argumentation are done through pretest and posttest. The research design showed at the Diagram 3.1.

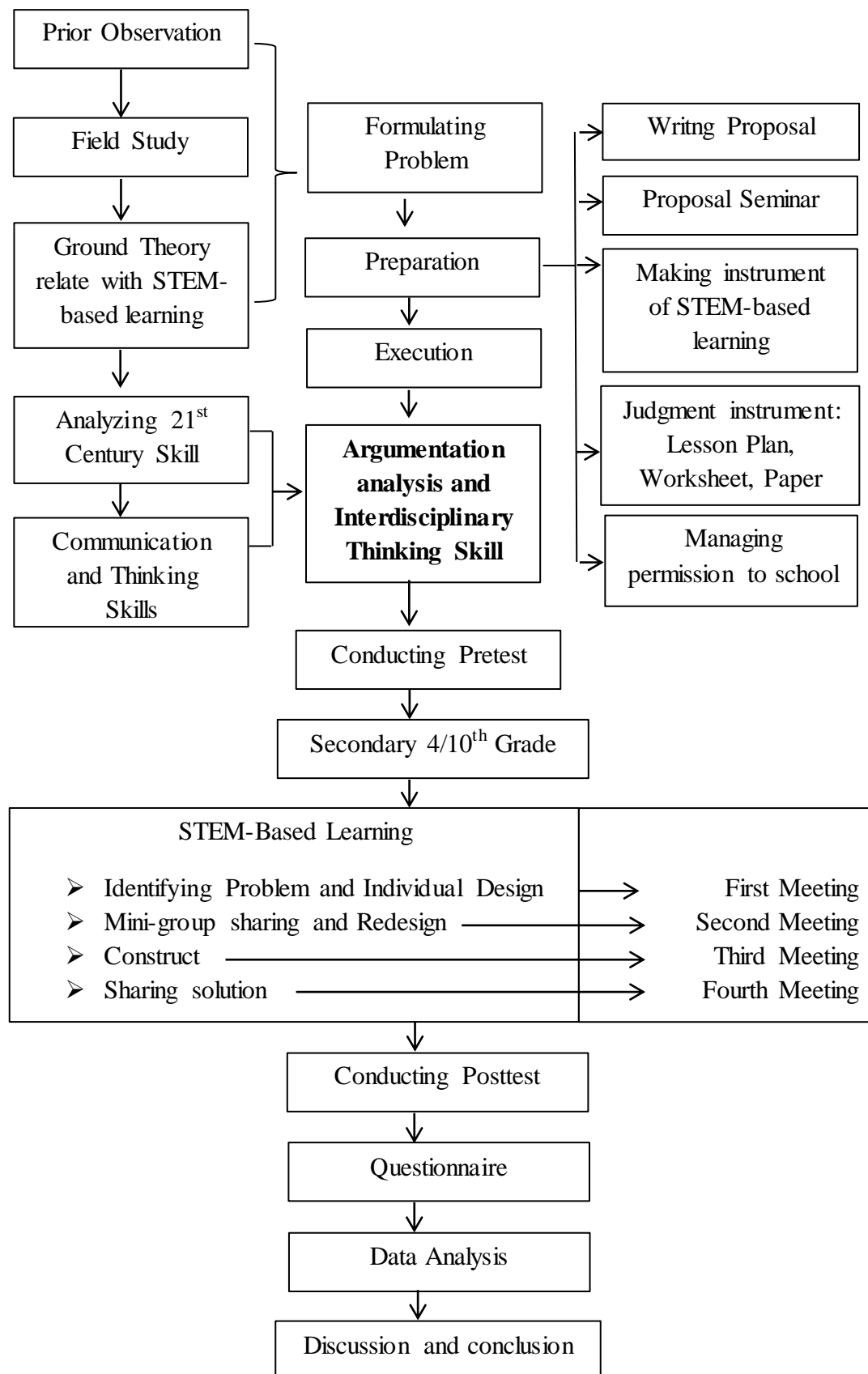


Figure 3.1 Research Design

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INTERDISCIPLINARY THINKING SKILL OF UPPER SECONDARY STUDENTS' THROUGH ARGUMENTATION ANALYSIS IN STEM-BASED INSTRUCTION ON PLANT REPRODUCTION

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D. Developing Instruments

The primary instruments that used in this research are *three-tier diagnostic test* (3TDT) and worksheet. The researcher developed the three-tier instrument on this material. The procedure outlined by Caleon and Subramaniam (2010). Below are presented the steps to develop 3TDT instrument administered in this study.

1. Defining the Content Boundaries of the Study

The propositional statement that define the content boundaries of the study were drafted by referring to two standard biology textbooks and biology syllabus for grade 10. This study focused on the flowering plant and asexual plant propagation.

2. Exploratory Phase

The researcher did the interview to thirteen students of grade 12 who already learnt about plant kingdom and plant cells. From these interviews and studies of the literature in the context of plant reproduction, the two-tier questions was developed. The response of each item were categorized in order to determine the alternatives of the multiple-tier test. Then, for the third tier was added the confidence level or credibility (sure and not sure).

3. Content Validation and Revision

The 3TDT instrument was evaluated by four biology educational experts from Indonesia University of Education and two biology secondary teachers (with at least 4 years of teaching experience). In general, the judges found the materials reviewed to be in good order, accurate and relevant to upper secondary plant reproduction. There are almost 5 options of the reason in each item and a blank space was provided for the students to write their own reason, in case they could not find a suitable explanation for their answer among the choices.

4. Piloting

After judgment session the instrument were administered in a pilot testing session to test its' criterion validity. The 3TDT pilot test was administered to 26 students (61.5% males and 39.5% females) who already learnt about plant reproduction. They are upper secondary grade 11 of one of private international school at Lembang, Bandung Barat. The time allocated for the test was 120

minutes. They were told that the test is a diagnostic test and not an achievement test. Further, they were informed that the results of the test will not affect their school grade, but would be used by their teachers in planning their *clinic class*.

5. Factor Analysis

After pilot testing, the instruments were analyzed using a test item analysis. The test item analysis using *ANATES version 4.0.7 9* and *IBM SPSS V.20* and the analysis itself encompassed these aspects: validity, reliability, difficulty index, and item discrimination.

6. Research Instruments

There are some instruments used in this research. The instruments along with their data source and the aim of its incorporation in the study showed in the Table 3.2.

Table 3.2 Instruments of the Study

Instruments	Data Source (Data type)	Aim
Three-tier Diagnostic Test	Students	Measure students' disciplinary grounding
Essay Test	Students	Measure argumentation and critical awareness of students
Worksheet	Students	Measure students' problem solving and designing skill
Questionnaire	Students	Catch students' opinion about STEM-based learning
Interview	Students	Catch students' argumentation orally
STEM-Observation Protocol	Observation record	Cover information uncovered by other instruments

The instruments is developed by using Marzano's framework which is dimension of learning. The third dimension is ***Extending and Refining Knowledge*** that comprises of indicators: *comparing, classifying, abstracting, inductive reasoning, deductive reasoning, constructing support, analyzing error, and analyzing perspectives* an information or knowledge. While the fourth dimension is ***Using Knowledge Meaningfully*** that comprises of *decision making*,

problem solving, invention, investigation, experiment, and systems analysis (Marzano, 1992). The instrument blue print is shown in Table 3.3.

Table 3.3 Instrument Blue Print

Component of Interdisciplinary Thinking Skill	Dimensions of Learning (Marzano)	Reasoning Indicator	Question No	Total Question
¹ Disciplinary Grounding (Three-tier test)	³ Extending and Refining Knowledge	Comparing	1,2	2
		Abstracting	3,4	2
		Classifying	5,6	2
		Inductive Reasoning	7,8	2
		Deductive Reasoning	9,10	2
		Analyzing Errors	11,12	2
		Constructing Support	13,14	2
		Analyzing Perspectives	15,16	2
	⁴ Using Knowledge Meaningfully	Decision Making	17,18	2
		Experimental Inquiry	19,20	2
		Investigation	21,22	2
		System analysis	23,24	2
		Problem solving*	25,26,27,28	4
Advancement through integration ² and Critical awareness ³ (Essay Test)	3rd and 4th dimensions	Describing	1	1
		Comparing	2	1
		Analyzing perspectives	3, 4,5	3

a. Three-tier Diagnostic Test

TTDT is an instrument designed to asses student's disciplinary grounding in biology (science) and mathematics. This instruments consists of 24 items (See Appendix B). Each of items was made based on learning objectives by Marzano (1992) in the third and fourth dimensions of learning which are extend and refine knowledge and use knowledge meaningfully.

b. Essay Test

ET is an instrument designed to assess student's argumentation and critical awareness. This instrument consists of six items (See **Appendix B**). For ET, the reliability index was high ($\alpha=0,70$). All of the ET items are valid. It has medium and difficult levels degree of test item. Each of items was made based on learning objectives by Marzano (1992).

c. Worksheet

Worksheet made is for students to cultivate students' designing skill and argumentation of their design of a product in order to create a company that produce propagation system through cutting methods. There are two designs assessed which are from individual and small group design. The worksheet made is based on Vee-diagram certainty (see Appendix B).

d. Questionnaire

Questionnaire made is questionnaire for students to know students' opinion about STEM-based learning and their involvement in learning process on Plant Reproduction Topic. This questionnaire was given to students after learning process finished. These questionnaire made use Likert scale and require students to choose response of a statement in certain category from strongly disagree until strongly agree. According to Bertram (2004), questionnaire with psychometric response used to acquire preferences or agreement level of a statement or set of a statement. The blue print of questionnaire is showed in Table 3.4.

Table 3.4 The Questionnaire Blue Print

Indicator	Total Statement	Kinds of Statement	
		Possitive	Negative
Students' innovation abilities and responsibility	6	3	3
Knowledge understanding	3	2	1
Designing skill	4	2	2
Problem solving skill	4	2	2
Worksheet implementation	4	2	2
Total	21	11	10

e. Interview

Interview is conducted to the students after attending learning process which aims to describe students' impression about learning and difficulties in learning. Besides, this interview purposed to show the relevancy of students' argumentation from paper test which are essay questions and their answer orally. The questions asked is same with the paper-based questions.

f. STEM-Observation Protocol

This observation format was made to observe STEM-based instruction during the research. This format made as a modification from classroom observational protocol of the North Carolina Race to the top STEM Initiative (2012). There are six points that assessed which are: 1) mathematics and science content; 2) student cognitive engagement in meaningful instruction; 3) inquiry learning: project and problem-based learning; 4) common instructional framework; 5) student engagement; and 6) use of technology. The observers are three secondary teachers who teach chemistry, bahasa indonesia and a counselor. All observer were told about each point of observation before did the observation.

g. Result of Factor Analysis

The factor analysis of Thee-tier Diagnostic Test (TTDT) showed that TTDT have limited applicability ($\alpha = 0.67$). It could also be reported that majority of test items are valid, some of the item were revised based on Judgment. While for Essay Test (ET), the reliability index was adequate ($\alpha = 0.70$). The validity analysis showed that a half of TTDT were having a low significance and; on the contrary all of the ET items are significance. Some of the items ($r_{cal} > r_{table}$) were used in this study, some of them were revised based on judgment ($0 < r_{cal} < r_{table}$). The result of factor analysis for three-tier diagnostic test is showed in Table 3.5.

Table 3.5 Result of Factor Analysis for the Three-tier Diagnostic Test

Previous No.	New No.	Index of Discrimination	Degree of Difficulty	Correlation	Validity	Information
1	1	0.00	Medium	-0.010	-	IR
2	2	0.00	Medium	-0.069	-	IR
3	3	14.29	Medium	0.116	Very Low	IR
4	4	42.86	Medium	0.338	Low	IU
5	5	42.86	Medium	0.313	Low	IR
6	6	57.14	Medium	0.562	Very significant	IU
7	7	42.86	Difficult	0.499	Very significant	IR
8	8	0.00	Medium	-0.037	-	IR
9	9	57.14	Medium	0.418	Significant	IU
10	10	57.14	Medium	0.344	Low	IR
11	11	28.57	Difficult	0.389	Significant	IU
12	12	57.14	Medium	0.529	Very significant	IU
13	13	71.43	Medium	0.588	Very significant	IU
14	14	14.29	Difficult	0.150	Very low	IR
15	15	28.57	Medium	0.126	Very low	IU
16	16	42.86	Medium	0.316	Low	IR
17	17	42.86	Medium	0.296	Low	IU
18	18	28.57	Medium	0.404	Significant	IU
19	19	14.29	Difficult	0.244	Low	IU
20	20	14.29	Difficult	0.226	Low	IU
21	21	14.19	Easy	0.154	Very low	IU
22	22	57.14	Medium	0.402	Significant	IU
23	23	42.86	Medium	0.271	Low	IR
24	24	42.86	Medium	0.473	Very significant	IU
25	25	28.57	Medium	0.237	Low	IU
28	28	57.14	Very Easy	0.417	Significant	IU
27	27	57.14	Medium	0.539	Very significant	IU
28	28	0.00	Difficult	0.057	Very low	IR

Note: Reliability = 0,67

IR = Item Revised (39,3%)

IU = Item Used (60,7%)

The result of piloting test is analyzed using ANATES software to give the information about the aspect validity, reliability, difficulty index, and determination index. The result of factor analysis for the essay question show in Table 3.6.

Table 3.6 Result of Factor Analysis for the Essay Questions

Previous No.	New No.	Index of Discrimination	Degree of Difficulty	Correlation	Validity	Information
1	1	50.00	Difficult	0.762	Very significant	IU
2	2	67.86	Medium	0.806	Very significant	IU
3	3	42.86	Medium	0.527	Significant	IU
4	4	37.14	Difficult	0.628	Significant	IU
5	5	48.57	Medium	0.646	Significant	IU
6	-	14.29	Very Easy	0.360	Sufficient	INU

Note: Reliability: 0.70 IU = Item Used (83,3%) INU= Item Not Use (16,7%)

E. Data Processing

1. Three-tier Diagnostic Test

TTDT were scored using a scoring guide generated by author. The score of each questions was two point for each correct answer and it was transformed became value. Because of this is not a conventional multiple-choice, but it has the reason beside the the option and also the level of confidence which is called as three-tier questions. So, each of students' answer categorized into the criteria below (see Table 3.7).

Table 3.7 Categorization of Students' Answer on Three-tier Diagnostic Test

Option	Reason	Level of Confidence	Category	Scoring
True	True	Sure	Whole understanding	2
True	True	Not sure	Partial understanding	1
False	True	Sure		
False	True	Not sure	Misconception	0
True	False	Sure		
False	False	Sure	Don't know or chop off the answer	0
True	False	Not sure		
False	False	Not sure		

Score two (2) for the category 'whole understanding', score one (1) for category 'partial understanding', while zero (0) for both category 'misconception' and 'don't know or chop off the answer'. The total score of 28 questions were

summarized in converted to the value, and the maximum score for the test is 100. This process implemented separately for each question of both pretest and posttest data. Normalized-gain value were used to know how much improvement after learning process. Based on Hake (2002), categorization of normalized gain value can be seen based on the Table 3.8. Normalized-gain is counted by using the formulation:

$$n\text{-gain} = \frac{T2 - T1}{Is - T1}$$

Explanation: T1 = Score *pretest*
 T2 = Score *posttest*
 Is = Score maximum

Table 3.8 Value Category Normalized-gain

N-gain	Category
$g \geq 0,7$	High
$0,3 \leq g < 0,7$	Medium
$g < 0,3$	Low

2. Essay Test

The essay question were scored using rubric (see **Appendix A**), which made by author. Essay question requires students to convey their argumentation. So, this argumentation was categorized into six levels based on Toulmin Modified Analysis (Lee *et al.*, 2013). The data must first transformed into interval scale before furtherly analyzes. The maximum score for this test is 100. This process implemented separately for each question of both posttest and pretest data. The rubric of essay test assessment is showed in Table 3.9.

Table 3.9 Rubrics of Essay Test

Question No	Score	Description
1 and 3	6	Students could answer the questions with the correct and complete explanation in all three terms
	5	Students could answer the questions with the correct explanation in almost three terms
	4	Students could answer the questions with the correct and complete explanation in two terms
	3	Students could answer the questions with the correct explanation in almost two terms
	2	Students could answer the questions with the correct explanation in only one term
	1	Students could answer the questions with the correct explanation in almost one term
	0	Students could not answer the question correctly or do not answer the question
2	4	Students could describe four correct reasons about the advantages of asexual propagation
	3	Students could describe three correct reasons about the advantages of asexual propagation
	2	Students could describe two correct reasons about the advantages of asexual propagation
	1	Students could describe one correct reason about the advantages of asexual propagation
	0	Students could not answer the question correctly or do not answer the question
4 and 5	5	Students could answer the correct questions with the valid all five aspects (claim, data, warrant, backing, and rebuttal)
	4	Students could answer the correct questions with the valid four aspects (claim, data, warrant, backing or rebuttal)
	3	Students could answer the correct questions with the valid all three aspects (claim, data, warrant)
	2	Students could answer the correct questions with the valid all two aspects (claim and data)
	1	Students could answer the correct questions with the valid all one aspect (claim)
	0	Students could not answer the question correctly or do not answer the question

3. Questionnaire

This questionnaire that consists of ordinal scales (4-scales) which are strongly disagree, disagree, agree, and strongly agree. There are 21 statements belong to positive and negative statements in this questionnaire and it comprises of five

general categories. Then, the students' opinion counted and it percentaged based on the scale in every category and got the average percentage of its aspect.

F. Data Analysis

Analysis of the data (Three-tier and Essay Tests) was conducted mainly using the IBM *Statistical Package Software for Social Sciences (SPSS) version 20.0*. The analysis was conducted using descriptive statistics. The assumptions test of two important properties of data distribution were also conducted to determine what type of inferential statistics test that should be conducted. The two basic assumption were: normality (using: *Kolmogorov-Smirnov Test*) and homogeneity using (*Levenes Statistics*). After the assumptions tests, researcher used statistics test to examine the proposed hypotheses. Detailed result of each test were included in the **Appendix C**.

One-sample t-test or Z-test was incorporated in this study if the data distribution was normal. On the contrary, if the data distribution non-normal, then the data were transformed for got the normal data, but if non-normal consistent, so the data were analyzed using non-parametric test (*Kolmogorov Smirov*).

To specifically adress the first until three research question, normalized gain between pretest and posttest were also calculated (See **Appendix C** for the detailed result). The derived acquired scores of the n-gain could the be used to show the effectiveness of the given instruction. The normalized-gain was then categorized based on standards appointed by Hake (2002). After completing the data analysis, crosscheck to the literature review was also conducted to explain important findings.

G. Procedure of the Research

Research procedure covers all the things done starting from the beginning step of problem determination until the final step of making conclusion. The procedure of this research consists of four stages, which are **preparation, planning, execution and writing report**.

1. Preparation: in the preparation step, the researcher did:

a. Literature Review

The researcher studied some articles related to interdisciplinary thinking skill and STEM education in order to develop research variables. Besides, the researcher studied the material of Plant Reproduction and developed learning strategy to acquire the learning system in STEM school. In this stage, the researcher did the consultancies with the advisor and STEM-expert and also followed STEM training to acquire the representation of STEM based learning.

b. Field Observation

In this stage, the researcher did the observation to the school which implemented STEM-based instruction. In this activity, the researcher was as an observer noted and observed the learning process in Darul Hikam International School, did the interview with the STEM-teacher and also analyzed the lesson plan. From this field observation acquired the ground theories related with the implementation of STEM-based learning (Wulandari, 2016).

2. Planning: this stage is comprises of some activities related to the research design, those are:

a. Design the Lesson Plan

Stages of STEM-based instruction chose based on the local culture and school characteristics. According to field observation result, STEM-based instruction contain the integration among Science, Technology, Engineering, and Mathematics. So it is similar with the integrated approach that invite the other subject in a learning process. The researcher was determined the integrated model from Fogarty (1991) which connect technology, science, and mathematics in a learning of plant reproduction. In this research, the designing process was an intersection among science, technology and mathematics. The learning design show in the Figure 3.2.

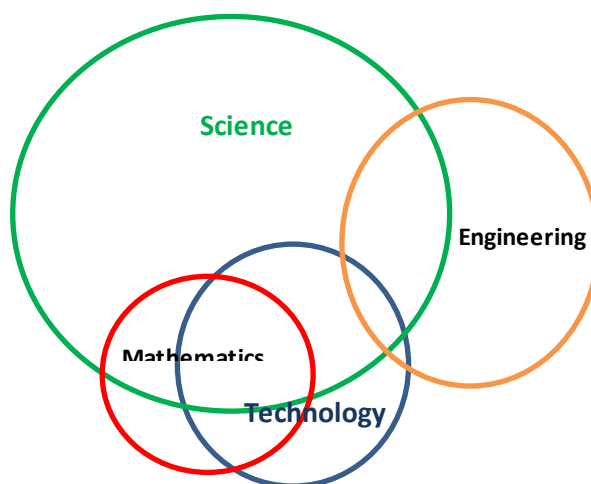


Figure 3.2 Model of STEM-based Instruction

Source: Fogarty, 1991

In this research, students stimulated to produce a technology that used in plant propagation, in the criteria of keep the humidity to make the cutting system possible to growth the new tissue. Engineering applies math and science to create technology. Engineering is a professional occupation, so one of the goal of this research is to make students aware to this profession. Engineering is about the design and making of structures, products, processes, models, devices, and systems. The engineers solve problems in engineering by design process which comprises of 7-step technological process: 1) identify the problem, need, or preference; 2) information gathering to develop possible solutions; 3) selection of the best possible solution; 4) design and making; 5) testing to see if it works; 6) modifications and improvement; and 7) assessment (Reeve, 2015).

STEM education is a teaching and learning approach in which science, technology, engineering, and mathematics are purposely integrated. Regarding the stages of STEM learning, the instruction will be held in fourth meetings, that comprises of seven stages which are: 1) identifying problem; 2) sharing ideas or brainstorming; 3) design; 4) construct; 5) test or evaluation; 6) sharing solution; and 7) redesign. It was not including pretest and posttest. The description of each stage show in the Table 3.10.

Table 3.10 Description of STEM-Based Instruction

STEM Stages	Materials	Students' Activities
Identifying Problem¹ and Design²	<ol style="list-style-type: none"> 1. Asexual Reproduction in Plants: Natural and Artificial Ways 2. Artificial: cutting, grafting, oculation, layering 3. Factors that influence the success of cutting method 	<ol style="list-style-type: none"> 1. Questions and Answer 2. Observation to Rizal Florist 3. Teacher's presentation 4. (Minds-on activity) 5. Individual design to be students' assignment
Sharing Ideas³ and Redesign⁴	<ol style="list-style-type: none"> 1. Make a group design model of a cutting methods experiment to growth certain plant with consider some factors that influence its successness 2. Determine the medium culture; kinds of plants; and regulating hormone; and the cutting system design 	Group Discussion: each group consists of 3-4 students
Construct⁵	<ol style="list-style-type: none"> 1. Create a model of cutting technic system 2. Growth and development of plants 	<ol style="list-style-type: none"> 1. Hands-on activity 2. Do the observation every day in two weeks
Sharing Solution and Evaluation⁶	The result of students' project of plant reproduction	Presentation and discussion
Connection of STEM Component	Science	Technology
	<ol style="list-style-type: none"> 1. Factors that influence the successness of cutting methods 2. Characteristics of plant cell and tissue 3. Abiotic factors in plant growth: transpiration, humidity, hormone, minerals, and light intensity 4. Investigate the role of mitosis and differentiation in producing a complex plant 5. Determine the variables 	<ol style="list-style-type: none"> 1) Students' innovation that involves the generation of knowledge and processes to develop a project which is plant propagation. 2) Specific device: computer and equipments to make mini-green house
	Mathematics	Engineering
	<ol style="list-style-type: none"> 1. Calculate the concentration of a solution (fertilizer or hormone) 2. Design the place for plant growing with some mathematical consideration (width and volume) 3. Calculate the amount of root and shoot systems which growth up 4. Compare the rate of plants growth based on the different treatments 5. Make a table of observation result 	<ol style="list-style-type: none"> 1. Identify the problem, need, and preference 2. Information gathering to develop possible solutions 3. Selection of the best possible solution 4. Design and making 5. Testing to see if it works 6. Modifications and improvement

b. Developing the Instruments

In this stages, the researcher determined the kinds and form of instrument to collect the data. Instrument design was made then make judgment to the plant expert and also to the education expert. Then, the instrument test to the students who already learn about material of plant reproduction. The trial test involve 26 students of Secondary 5 or Grade 11th.

c. Make the Data Analysis Design

Data analysis design formulated based on the research design which is experimental research. There are two kinds of data acquired in this research which are interval data (students' score) and nominal data (level of argumentation) in pretest and posttest that analyzed statistically.

3. Execution: this step is begun by:

- a. Giving pretest
- b. Conducting activity in two classes using STEM-based learning which consists of minds-on and hand-on activities as follow:
 - 1) Identifying problems
 - 2) Design
 - 3) Brainstorming
 - 4) Redesign
 - 5) Construct
 - 6) Evaluation and Sharing solution
- c. Conducting posttest and giving questionnaire to get students' opinion about STEM-based learning.
- d. In order to completing the data, in this research also conducting interview to students about plant propagation. This interview purposed to compare students' answer on paper and oral test.
- e. In the last meeting, *posttest* is done and questionnaire is collected to catch students' opinion about teaching process that have been done. Summary of all procedures of this research is presented in the Picture 3.3.

4. Writing Report

This step covered analyzing data. However, before analyzing data, there are some steps as follow: doing data classification suit to the need, making conclusion and suggestion. After the data gained are interpreted and inclination to final result is gained, writing report of final result of this research is done. Writing report of the research is in the form of thesis writing as final task. The picture 3.3 show the summary of the research procedure.

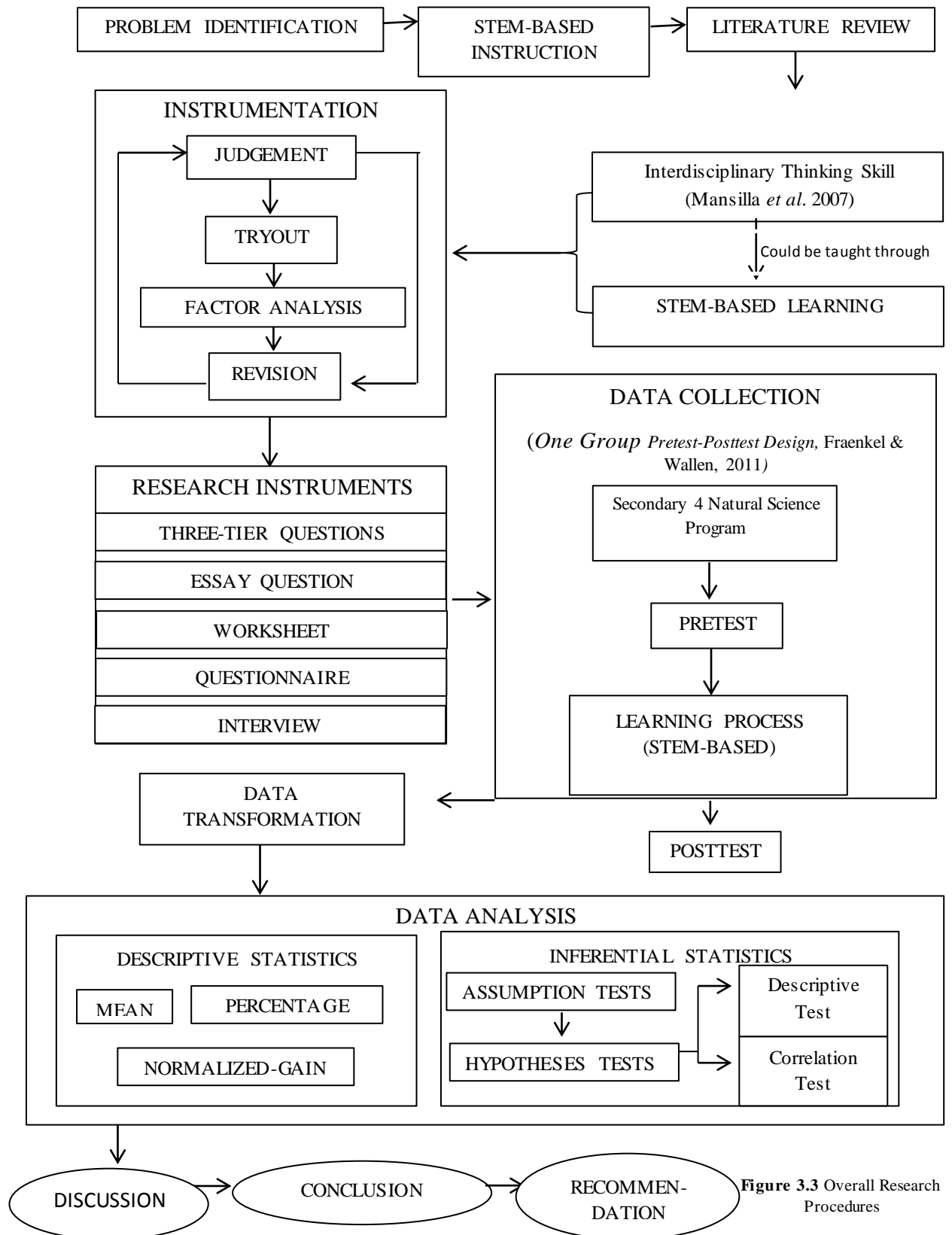


Figure 3.3 Overall Research Procedures