CHAPTER III

RESEARCH METHOD

The research method will be discussed in this chapter. It is divided into six sub-sections as follows: 1) research paradigm, 2) research design, 3) participants and research setting, and 4) research instrument, and 5) data analysis.

3.1 Research Paradigm

This research is intended to provide modeling skills, domain-specific CT skills, and NOST aspects in solid state chemistry learning based on MER. Figure 3.1 shows the research paradigm.

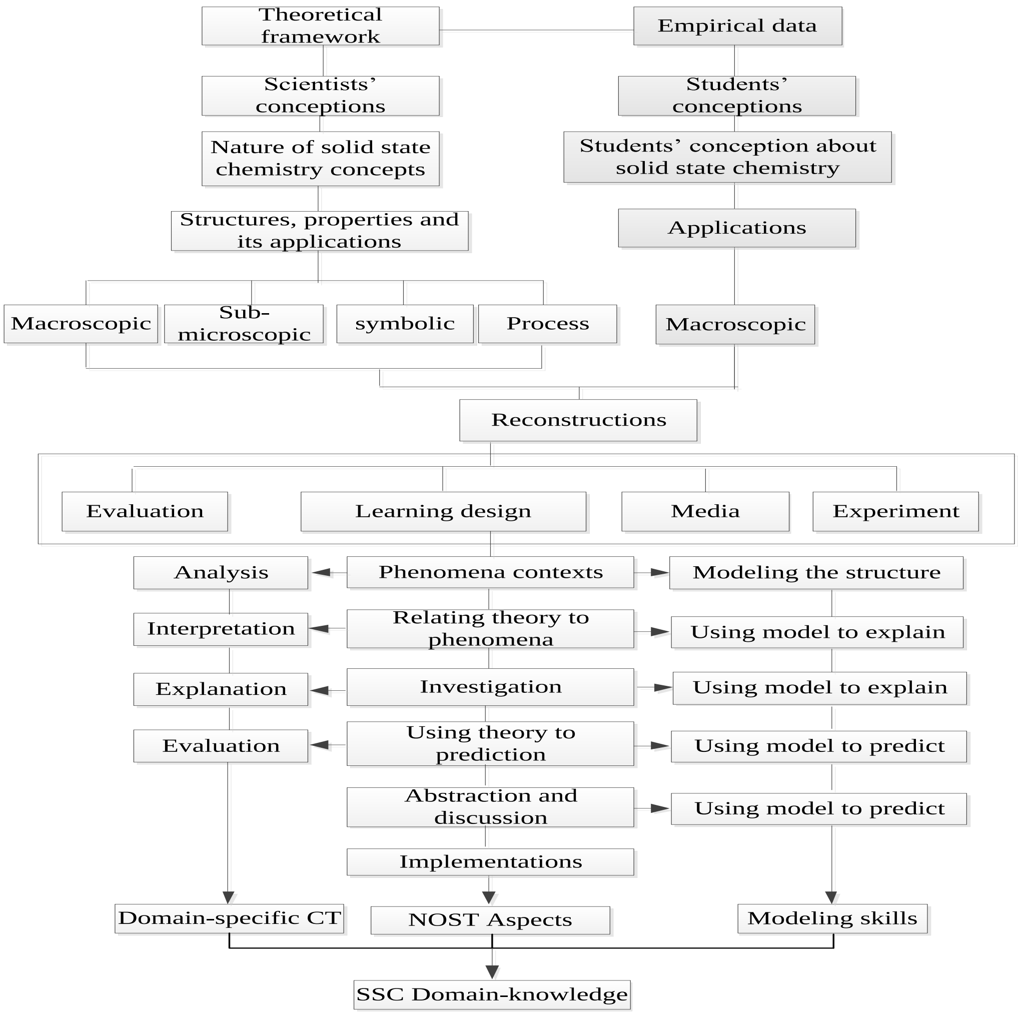


Figure 3.1 Research Paradigm

Figure 3.1 show that reconstruction of learning materials are done by researchers to bring students' conception closer to scientists' through three relevant phases: 1) analysis of science content, 2) investigation in students' conception, and 3) development of learning sequences.

Scientist easily think about science in macroscopic, sub-microscopic, symbolic, and process level, meanwhile most of students think at macroscopic level. In this study, SSC learning focus on connecting structure, properties, and application. According to the focus, students need to think in macroscopic, sub-microscopic, symbolic, and process level to comprehend SSC.

Context phenomena are used to motivate students. They asked to analyze contexts; infer data in make a conclusions; integrate previous knowledge with new knowledge through discussions and scientific explanations; evaluate the theories that are previously studied to predict the properties and application of concepts in more complex context in order to enrich their knowledge. The modern context is used in this research to make students connecting content with the application easily, meaningful, and change students' view of NOST aspects. Those activity need modeling activity and domain-specific CT skills. Using an advance technology as a modern context in the learning process is aimed to make leaning meaningful, students are able to connect between concept and its application, and change students' views about NOST aspects. Media, worksheet, and laboratory activities are provide to help students during learning process.

3.2 Research Design

This research used mixed method with the embedded experimental model (Figure 3.2) (Creswell & Clark, 2007). Figure 3.2 show that quantitative and qualitative analysis before interventions are done by analyzing students' and scientists' conceptions on SSC domain knowledge. Both data as a basic to reconstruction learning materials. Through constructions, learning design to enhance modeling skills, domain-specific CT skills, and NOST aspects on SSC is produced.

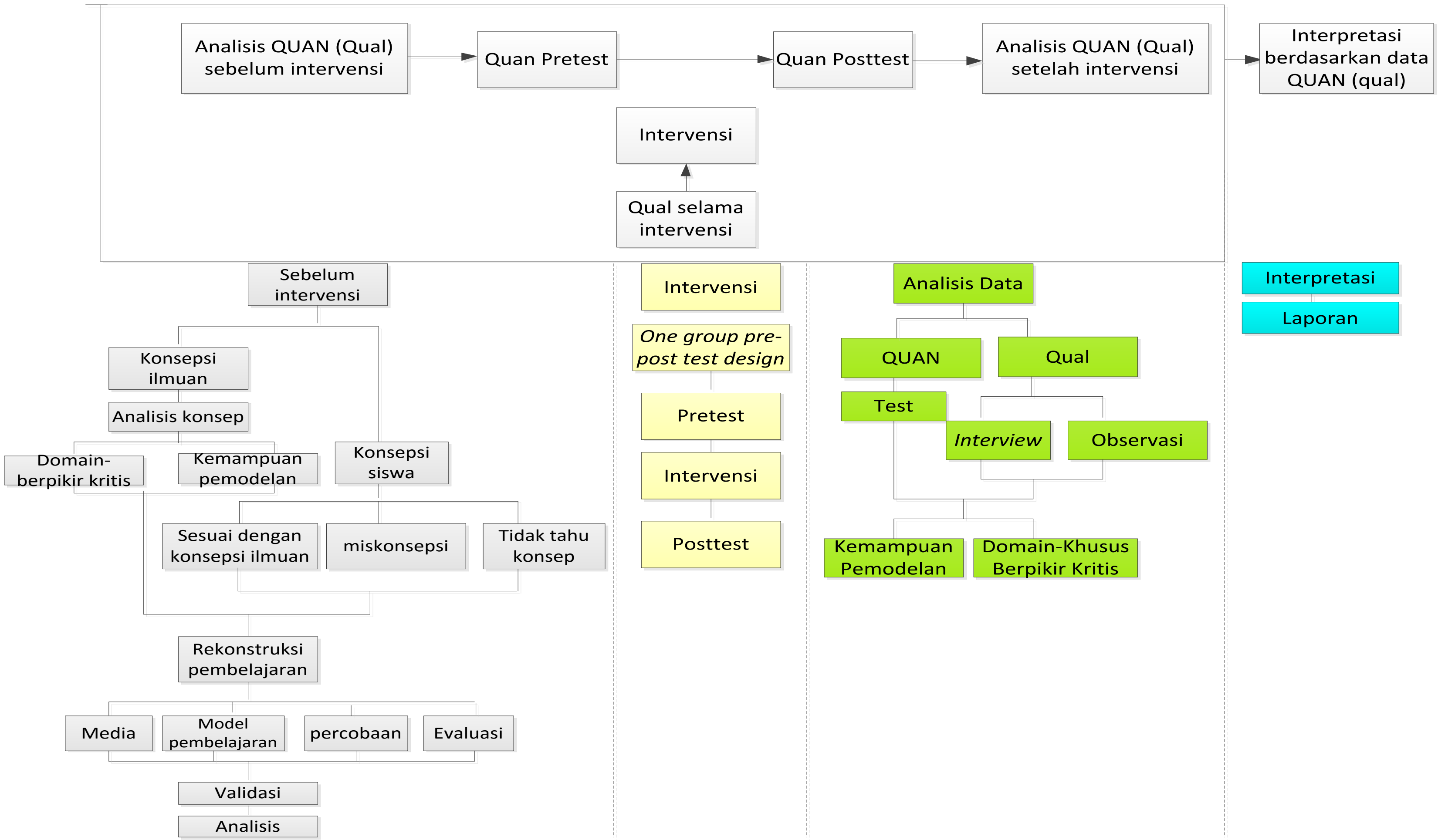


Figure 3.2 Research Design Adopted from Creswell & Clark (2007)

Multimedia, worksheet and laboratory activities are designed to support learning design. Questions and questionnaire are design to measure conceptual knowledge, modeling skills, Domain-specific CT skills, and view of NOST aspects.

Learning design, multimedia, worksheets, laboratory activities, and questions are validated by chemical education experts and apply the in the pilot study. Reliability test are performed in questions that measure modeling skills, domain-specific CT skills. Results of validity and reliability are analyzed to get better instruments. Setting one group pretest and post-test design is used in the learning interventions. Qualitative and quantitative data during interventions are analyzed and reported.

3.3 Participants and Research Setting

Research design mixed method with the embedded experimental model has three general phases. They are quantitative and qualitative study before analysis, pilot study and intervention. Each phase has different participants.

The participants in the preliminary research were 22 pre-service chemistry teachers who were enrolled in the inorganic chemistry courses at one of Teachers Education College in Bandung-Indonesia. Preliminary research was conducted to analyze students' conceptions (22 students), scientists' conceptions (Barke *et al.*, 2009; Housecroft & Sharpe 2012; Miessler *et al.*, 2014) and literature study (Bergqvist *et al.*, 2013; Bergqvist & Rundgren, 2017; Bergqvist *et al.*, 2016; Croft & de Berg, 2014; Dhindsa & Treagust, 2014; Nimmermark *et al.*, 2016; Pérez *et al.*, 2017; Sen & Yilmaz, 2017). They were used as the basis data to potray a learning design, media, worksheets, laboratory activities and assessment tests.

The participants in reliability test were 63 pre-service chemistry teachers at two Teachers Education College in Bandung and Serang, Indonesia. The participants in the pilot study were 23 pre-service chemistry teachers at one of Teachers Education College in Bandung who were enrolled in the inorganic chemistry course. The pilot study is one of the process of validation of the instruction. The framework validation is conducted through empirical research in order to propose and test a suitable method to empirical investigation and validation of the main working steps our framework (Diethelm *et al*., 2012).

The participants who involved in the implementation of the interventions were 33 pre-service chemistry teachers who were enrolled in the inorganic chemistry course at one of Teachers Education College in Serang Banten-Indonesia. The research setting used one group pre-test and post-test embedded experimental design.

3.4 Research Instruments (Test and Questionnaire)

The instruments in this study consist of pre-test and post-test that measure domain knowledge, modeling skills and domain-specific CT and questionnaires to measure students' view of NOST aspects. Each instrument is clearly described below.

3.4.1 Questions that Measure Domains-Knowledge

This instrument consists of 24 structured essays based on SSC. There are five domains of knowledge that construct SSC as follows: 1) metallic crystals, 2) alloy, 3) covalent crystals, 4) semiconductors, and 5) ionic crystals. Each domain-knowledge is represented by some questions (Table 3.1). Those question is used to measured students' conceptual knowledge as mentioned in research question number 2.

Table 3.1
Criteria of Domain-Knowledge Questions

No	Concepts	Domain-knowledge	Question number	Score
1	metallic bonding related to the melting point	metallic crystal	1Aa	0-3
2	metallic bonding model		1Ab	0-3
3	metallic structure related to % occupancy		1B	0-3
4	metallic structure related to density		1C	0-2
5	metallic structure related to ductility		1D	0-2
6	Material conductive and band theory		2B	0-2

Table 3.1
Criteria of Domain-Knowledge Questions (Cont..)

No	Conc		on er	Score
			Total	13
7	Alloy criteria	Alloy	1Fb	0-2
8	Type Alloy structure		1Eb	0-1
9	Type of an alloy		1Ea, 1Fa	0-3
			Total	6
10	Conductivity of material	Covalent crystal	2Aa	0-3
11	Material conductive		2Ab	0-4
12	Covalent network structure		4A	0-2
13	Covalent network properties		4B	0-3
14	Polymer conductive		5A	0-2
15	Polymer conductive structure		5B	0-2
			Total	16
16	Type of a semiconductor	Semiconduc tor	2Ca, 2Cc	0-4
17	The conductivity of extrinsic semiconductor model		2Cb	0-2
18	Conductivity process in semiconductor		2Da	0-1
19	Semiconductor bonding model		2Db	0-1
			Total	8
20	Ionic structure	Ionic crystal	3A	0-2
21	Character covalent bonding in ionic bonding		3Ba	0-3
22	Ionic crystal properties		3Bb	0-1
23	Ionic versus metallic crystal properties		3C	0-2
24	Ionic crystal defect properties		3D	0-2
			Total	**10**

All the questions and rubric developed in this study were validated by five chemistry education experts. They were asked to: 1) review the suitability of indicators, question items, score as well as key answers, and 2) check the accuracy of the data presented on each question, word/sentence or paragraph on each item question. Experts' advices are considered to correct each item.

Validity is analyzed by experts and Content Validity Ratio (CVR). CVR value was 0.99 (acceptable (Wilson *et al.*, 2012)) as mention in formula 3.1 below:

$$CVR = \frac{ne - N/2}{N/2}$$

n_e = number of experts who agreed

N= number total of experts

CVR value for five experts judge is ≥ 0.736 (Wilson *et al.*, 2012)

Results of CVR analysis are described in Appendix G. All items are tested to 63 pre-service chemistry teachers who have received an inorganic chemistry course on solid state chemistry topic to measure the reliability. Cronbach alpha coefficient is calculated to measure the reliability of the instrument test. The results show that the value of $\alpha = 0.77$ (accepted). Cronbach alpha value between 0.70 and 0.80 is reliable criteria (Cohen *et al.*, 2007). Results of reliability test is described in Appendix H.

3.4.2 Question that Measure Domains-Specific Critical Thinking

There are four domain-specific CT: explanation, inference, interpretation, and analysis. Each domain-specific CT is represented by several questions (Table 3.2). Those question is used to measured students' domain-specific CT skills as mentioned in research question number 2.

Table 3.2
Criteria of Domain-Specific CT questions

Question Items	Conceptual-Knowledge	Domain-Specific CT skills	Scores of Domain Knowledge	Scores of Domain-Specific CT skills
2	Metallic crystal	Inference	0-3	0-1
4	Metallic crystal		0-2	0-1
8	Metallic crystal and covalent network		0-3	0-1
10	Metallic crystal and covalent network		0-2	0-1
11	Semiconductor		0-2	0-1
12	Semiconductor		0-2	0-1
14	Semiconductor		0-1	0-1
18	Ionic crystal		0-2	0-1

Table 3.2
Criteria of Domain-Specific CT questions (Cont..)

Question Items	Conceptual-Knowledge	Domain-Specific CT skills	Scores of Domain Knowledge	Scores of Domain-Specific CT skills
22				0-1
9	Semiconductor and covalent network	Analysis	[illegible]	0-3
15	Ionic crystal		0-2	0-3
16	Ionic crystal		0-4	0-3
17	Ionic crystal		0-2	0-3
19	Covalent network		0-2	0-3
20	Covalent network		0-3	0-3
3	Metallic crystal	Interpretation	0-3	0-3
5	Metallic crystal		0-2	0-3
7	Alloy		0-4	0-3
13	Semiconductor		0-1	0-3
1	Metallic crystal	Explanation	0-3	0-2
6	Alloy		0-3	0-2
21	Covalent network		0-2	0-2

All the questions and rubric developed in this study were validated by five chemistry education experts. They were asked to: 1) review the suitability of indicators, question items, score as well as key answers, and 2) check the accuracy of the data presented on each question, word/sentence or paragraph on each item question. Experts' advices are considered to correct each item.

Validity is analyzed by experts and Content Validity Ratio (CVR). CVR value was 0.99 (acceptable (Wilson *et al.*, 2012)) as mentioned before. Based on CVR analysis, it is known that items of 13, 19, and 20 are rejected. Furthermore, 22 question item are analysis. A confirmatory factor analysis (CFA) also performed to test accurately and consistently conceived indicators and what indicators act as the constructs studied. The results showed a strong significance for Bartlett test (Chi-Square = 505.493 and $p < 0.001$). In addition Kaiser-Meyer-Olkin (KMO) was measured to be 0.667. Based on the data, distribution of domain-specific CT skills question items is presented in Table 3.3.

Table 3.3
Distribution of Question Items Based on CFA

Domain-Specific CT Skills	Items	Accept/Reject/Revise
Inference	Items 2, 4, 8, 10, 11, 12, 14, 18, 22	Item 4 and 14 recommended to revise or reject
Interpretation	Items 3, 5, 7, and 13	Item 7 recommended to revise or reject
Explanation	Items 1, 6, and 21	-
Analysis	Items 9, 15, 16, 17, 19, and 20	Item 20 recommended to revise or reject

All items are tested to 63 pre-service chemistry teachers who have received an inorganic chemistry course on solid state chemistry topic to measure the reliability. Cronbach alpha coefficient is calculated to measure the reliability of the instrument test. The results show that the value of $\alpha = 0.815$ (accepted). Cronbach alpha value between 0.70 and 0.80 is reliable criteria (Cohen *et al.*, 2007). Results of reliability test is described in Appendix H.

3.4.3 Question that Measure Modeling Skills

Three modeling skills indicators are: 1) modeling the structure, 2) using models to explain the properties of the compound, 3) using models to evaluate or predict the properties of compounds (Table 3.4). Those question is used to measured students' modeling skills as mentioned in research question number 3.

Table 3.4
Criteria of modeling skills questions

Table 3.4
Criteria of modeling skills questions (Cont..)

No	Domain knowledge	Modeling skills	Question number	Score
1	Alloy	Made structure model	1Eb	0-1
2	Semiconductor		2Ca, 2Db	0-2
4	Ionic structure		3A	0-1
			Total	**4**
5	Metallic crystal	Using the model to	1A	0-2
6	Metallic crystal		1B	0-2
7	Metal		[illegible]	0-2
8	Metal		[illegible]	0-2
9	Semic[illegible]		[illegible]	0-2
10	Ionic crystal		3C	0-2
11	Ionic crystal		3D	0-2
12	Covalent network		4	0-2
			Total	**16**
13	Covalent network	Using the model to make prediction	2A	0-2
14	metallic crystal		2B	0-2
15	Covalent network		5	0-2
			Total	**6**

All the questions and rubric developed in this study were validated by five chemistry education experts. They were asked to: 1) review the suitability of indicators, question items, score as well as key answers, and 2) check the accuracy of the data presented on each question, word/sentence or paragraph on each item question. Experts' advices are considered to correct each item.

Validity is analyzed by experts and Content Validity Ratio (CVR). CVR value was 0.99 (acceptable (Wilson *et al*, 2012)) as mentioned before. All items are tested to 63 pre-service chemistry teachers who have received an inorganic chemistry course on solid state chemistry topic to measure the reliability. Cronbach alpha coefficient is calculated to measure the reliability of the instrument test. The results show that the value of $\alpha = 0.77$ (accepted). Cronbach alpha value between 0.70 and 0.80 is reliable criteria (Cohen *et al*., 2007). Results of reliability test is described in Appendix H.

Table 3.5 shows the sample question item, item objective, key answers, and scoring guide for domains-knowledge, domain-specific CT skill, and modeling skills.

Table 3.5
Sample of domain-specific CT (analysis) and modeling skills (Sub-modeling 2) question

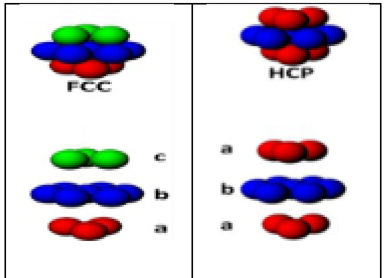
Question	Key answer (domain-knowledge)	Score	Domain-specific CT	Score	Modeling skills	Score
Magnesium and copper metallic crystal both adopt a closed packing structure. Magnesium crystal adopts a hexagonal closed packing structure whereas copper crystal adopts a cubic closed packing structure. The close packing structures of the two metals are modeled as follows:  Cubic Closed Packing / Hexagonal Closed Packing	In the case of the cubic closed structured metallic crystal, there are glide planes within the atomic layers in all directions, thus the mechanical attack can be repelled from many directions through the movement between atomic layers. The elementary cube itself allows the movement of smooth triangular layers in four directions, i.e. perpendicular to the four diagonal spaces.	0-1	Categorizing closed packing structure into cubic and hexagonal closed packing	0-1	Analysis a model	0-1
Both metals have the same "Hardness" properties that when we cut off must use sharp scissors (hard). In other cases, copper metal can be made sheets, while magnesium	In comparison, the hexagonally closed structured metal crystal has only one direction of the triangular layer in the hexagonal unit cell. These metals are not very ductile and crumble to dust	0-1	Clarifying meaning of glide plane in cubic and hexagonal closed packing Decoding	0-1	Using the model to explain phenomena	0-1

Table 3.5
Sample of domain-specific CT (analysis) and modeling skills (Sub-modeling 2) question (Cont…)

Question	Key answer (domain-knowledge)	Score	Domain-specific CT	Score	Modeling skills	Score
metal tends to crumble when the sheets are made as shown in Fig.   Magnesium Metal | Copper metal Analyze the two metal structures; explain why there are differences in properties on both metals?	when force is applied		significance for magnesium and copper metal structure	0-1		

3.4.4 Questionnaire

This questionnaire was aimed to analyze students' views of nature of science and technology (VNOST) before and after int erventions based on MERon the topic of solid state chemistry. There are five aspects of NOST developed that consist of 1) characteristics of science and technology, 2) science objective and scientific research, 3) characteristics of scientific knowledge and scientific theory, 4) ways of acquiring scientific knowledge and scientific theory, and 5) the relationship of science and technology. These five aspects are implied in 9 multiple choice questions.

Each option on the multiple choices describes the view of the NOST aspects. Each option on multiple choice ends with 3 (three) equal options. 9 (nine) multiple choice consists of 1) definition of science 1, 2) definition of science 2, 3) objective of science, 4) objective of research, 5) scientific knowledge, 6) scientific theory, 7) technology, 8) science and technology, and 9) scientific finding. The instrument is presented in Appendix F

To discuss students' views of NOST, each statement in multiple choices was presented in each questionnaire. It was grouped according to the three categories defined by Ruba (1996) as follows: realist (R), has merit (HM), and naive (N). Those question is used to measured students’ views of NOST aspect before and after interventions as mentioned in research question number 7.

3.5 Data Analysis

Data collection is conducted according to the steps of research.

Table 3.6
Data Collection Techniques and Analysis

No.	Data	Techniques	Activities	Analysis
1	Learning conditions	Observations, Interviews	Learning activities	Descriptions
	Students’ conceptions	Concept map and interview	Preliminary research	Description and percentage
	Scientists’ conceptions	Book analysis	Preliminary research	Descriptions

Table 3.6
Data Collection Techniques and Analysis(Cont..)

No.				
2	Domain knowledge	Test (pretest-post-test)	Before and after interventions	Paired sample t-test & n-gain
3	Modeling skills	Test (pretest-post-test)	Before and after interventions	Paired sample t-test & n-gain
4	Domain-specific CT	Test (pretest-post-test)	Before and after interventions	Paired sample t-test & n-gain
5	VNOST	Questionnaire	Before and after interventions	Percentage and categorize
6	Modeling and CT activities	Students tasks	During learning activities	Description
		Worksheet	During learning activities	Description

Here are the steps of analyzing pretest and post-test data for domain-knowledge, modeling skills, domain-specific CT skills, and NOST aspects.

1. Students' answers in each domain-knowledge question are scored as described in Table 3.7.

Table 3.7
Scoring guide for domain knowledge

Categories	**Score**	**Criteria**
Complete	Full Score	Students who completely answered correctly
Incomplete	Accordance to the complexity of the answers	Students who answer partially
Misconception	No score	Students who answered in misconceptions
Wrong Answer	No score	Students who answered incorrectly
No Answer	No score	Students who did not answer

2. The number of students in each category is presented before and after the intervention and analysis of the pattern.

3. Students' answers on domain-specific CT questions are scored as described in Table 3.8.

Table 3.8
Scoring Guide for Domain-Specific CT skills

Question Items	Conceptual-Knowledge	DS-CT skills	Criteria	Scores of DS-CT skills
2	Metallic crystal	Inference skill	Providing the evidence of the differences metallic bonding model among sodium, magnesium, and aluminum	0-1
4	Metallic crystal		Providing the evidence of copper metal will sink compared to sodium	0-1
8	Metallic crystal and covalent network		Providing the conductivity of graphite and polymer compare to metal	0-1
10	Metallic crystal and covalent network		Providing the evidence that beryllium has high conductivity using band theory	0-1
11	Semiconductor		Providing the evidence why model in type a is p type semiconductor and model in type b is n type semiconductor.	0-1
12	Semiconductor		Providing the evidence about the conductivity process in p and n types semiconductor	0-1
14	Semiconductor		Providing the evidence about the silicon structure produce free electrons to conduct electricity	0-1
18	Ionic crystal		Providing the evidence about the conductivity crystal defect	0-1
22	Covalent network		Providing the evidence about the conductivity crystal defect	0-1
9	Semiconductor and covalent network	Analysis skill	a) Checking idea about how to make a better graphite and polymer conductivity b) Analysis graphite and polymer structure c) Identifying the way to make a better graphite and polymer	0-3
15	Ionic crystal		a) Checking idea about NaCl structure b) Analysis the parameter structure in NaCl c) Identifying Na_2Cl_2 structure	0-3
16	Ionic crystal		a) Checking idea about character covalent in ionic bonding b) Analysis ionic compound with greatest character covalent bonding c) Identifying properties of ionc compound with covalent character	0-3
17	Ionic crystal		a) Checking idea about metallic and ionic bonding b) Analysis the parameter structure metallic and ionic crystal	0-3

Table 3.8
Scoring Guide for Domain-Specific CT skills(Cont..)

Question Item	Conceptual-	DS-CT skills	Criteria	Scores of DS-CT skills
			c) Identifying the fragility of ionic crystal	
19	Covalent network		a) Checking idea about orbital hybrid in diamond and graphite b) Analysis difference orbital hybrid in diamond and graphite c) Identifying structure of diamond and graphite	0-3
20	Covalent network		a) Checking idea about difference between diamond and graphite properties b) Analysis the structure of diamond and graphite c) Identifying the properties of diamond and graphite	0-3
3	Metallic crystal	Interpretation skill	a) Categorizing calculating a density in sodium and copper metals b) Clarifying meaning of percent occupancy in sodium and copper metal structure c) Decoding significance for sodium and copper metal structure	0-3
5	Metallic crystal		a) Categorizing closed packing structure into cubic and hexagonal closed packing b) Clarifying meaning of glide plane in cubic and hexagonal closed packing c) Decoding significance for magnesium and copper metal structure	0-3
7	Alloy		a) Categorizing types of alloy b) Clarifying criteria of alloy c) Decoding significance for interstitial and substitutional alloys	0-3
13	Semiconductor		a) Categorizing type of bonding in silicon semiconductor b) Clarifying the total electron valence in 50 gram silicon c) Decoding significance the number of broken bonds needed	0-3
1	Metallic crystal	Explanation skill	a) Present arguments why melting and boiling point of several metals increase from sodium to aluminum metal b) Declaring the results that the strength metallic bonding cause the high melting point	0-2
6	Alloy		a) Present argument about the alloy criteria b) Declaring the results of determine alloy type	0-2
21	Covalent network		c) Present argument about process of converting the electrical conductivity of organic polymers d) Declaring the results conductive	0-2

Question Items	Conceptual-Knowledge	DS-CT skills	Criteria	Scores of DS-CT skills
		polymer		

4. Students' answers to modeling skills questions are scored as described in Table 3.9.

Table 3.9
Scoring Guide for Modeling Skills

Modeling Skills	Score	Criteria
Sub-modeling skill 1	1	Students create the structure model
Sub-modeling skill 2	2	Students create and analyze the model and use the model to explain the scientific phenomena and daily life
	1	Student only conducted one steps from above
Sub-modeling skill 3	2	Students create and analyze the model and use the model to predict phenomena or properties
	1	Student only conducted one steps from above

5. Paired sample t-test is used to analyze the differences between domain-knowledge, domain-specific CT, and modeling skills pre-test and post-test. A hypothesis test with the p-value < .05 was considered significant.

6. To investigate the relationship among domain-knowledge, domain- specific-CT and modeling skills, Pearson's correlation coefficient is used to determine correlation between domain knowledge and domain-specific CT skills, domain-knowledge and modeling skills, and domain-specific CT skills and modeling skills. Multiple regression is used to determine correlation modeling skills and domain-specific CT skills to domain-knowledge.

7. Increased domain-knowledge, modeling skills and domain-specific CT skills of students on each indicator is also measured by n-gain (normalized gain). Measuring n-gain is aimed at eliminating the impact of guessing and the effect

of the highest value (ceiling effect), thus avoiding biased conclusions (Hake, 1998). The equation: n-gain = interpretation of improvement using Table 3.10.

Table 3.10
n-gain interpretation based on Hake (1998)

n-gain (<g>)	Interpretation
(<g>) ≥ 0,7	High
0,7 > (<g>) ≥ 0,3	Middle
(<g>) < 0,3	low

8. Questionnaires of students' views of NOST are analyzed and categorized into three categorizes (Rubba & Harkness, 1996) as follows; 1) Realist is a group of statements that show the actual conditions and in accordance with the general view, concepts and theories of science; 2) Has merit is a group of statements that show conditions that are not entirely true but there is a part of the statement that is still in accordance with the general view, concepts and theories of science; 3) Naïve is a view that is totally unrelated to the concepts and theories of science or students do not have enough knowledge to make choices.
9. Qualitative data analysis is done by percentage and matrix analysis of qualitative data correlation.