CHAPTER I

INTRODUCTION

1.1 Background

Chemistry is a study of structures, compositions, changes and its energies of a substance (Liliasari, 1996). Structures and compositions of a substance describe micro particles such as atoms, ions, and molecules combined to form substances. Substances with a specific composition can be described by approved chemical symbols. Based on those characteristics, chemist explains chemistry phenomena through three chemical representations: macroscopic, submicroscopic and symbolic which are known as multiple representations of chemistry (Treagust, 2002).

Multiple representations convey much information. Through representation students are able to explain and predict both the physical and chemical properties of a material (Cooper *et al*., 2010). Representational competence is students' capabilities to associate multiple representations through meaningful technique and to apply them on solving problems or explaining a phenomenon (Grove *et al*, 2012; Stieff, 2011). Therefore, multiple representations are known as a language of chemical science that can be used to communicate and develop thinking skills, process skills or scientific methods of students. Connecting multiple representations is highly recommended in chemistry learning process in order to enhance students' knowledge of chemical content as well as the development of students' thinking skills.

Previous empiric studies showed that students' chemical representation skills were low. They only focused on recognizing and understanding chemical phenomena on a macroscopic level. Meanwhile, submicroscopic and symbolic representations are the most difficult representations for many students. Most of students in several educational levels find the difficulties of this subject competence. Students who are lack of in proficiency level to visualize the structure and the process of the chemical phenomena, they merely focus on memorizing submicroscopic and symbolic representation. As the consequences they are not able to imagine the process and structures of the phenomena well (Adadan, 2014; Adesoji & Omilani, 2012; Barke *et al*, 2009; Chandrasegaran *et al*., 2007; Chittleborough & Treagust, 2007; Gilbert, 2005; Hand & Choi, 2010; Hinton & Nakhleh, 1999; Linenberger & Bretz, 2012; Luxford & Bretz, 2014; Madden *et al*, 2011; Nahum *et al*, 2007; Ramnarain & Joseph, 2012; Stojanovska *et al*, 2017; Treagust, 2002).

Many researchers and practitioners of chemistry education conducted the study on how to teach chemistry by connecting the multiple representations. They were: 1) designed chemistry learning based on multiple representations using technology (Al-Balushi & Al-Hajri, 2014; Blonder, 2010; Dori & Kaberman, 2012; O'Keefe *et al*., 2014; Warfa *et al*., 2014; Wu *et al*., 2001; Yakmaci-Guzel & Adadan, 2013) and 2) learned chemistry based on multiple representation integrated with hands on laboratory activities (Demirbag & Gunel, 2014; Dori & Sasson, 2008; Milenković *et al*., 2014). The results of those studies showed submicroscopic and symbolic representations are presented with model of chemical structures that are easily recognized by the students. The model of chemical structures help the students to visualize submicroscopic phenomena, therefore the students can easily connect one another representation.

Model of chemical structure is known as a simplification of chemical phenomena or processes that focus on specific aspects or components of a system such as ideas, concepts, objects, events, processes, compositions, and molecular structures that represented both in physical and computational form (Coll *et al*., 2005; Dori & Kaberman, 2012; Fretz *et al*., 2002). The model of chemical structure can help students to imagine and visualize molecular structures and to develop their cognitive skills (Barke & Engida, 2001; Dori & Kaberman, 2012; Harrison & Treagust, 2000) and the activities on the model of chemical structure itself are known as modeling skills.

Modeling skill is the skills to connect analog and target. In chemistry, analog is a symbolic representation that explains the targets of macroscopic and submicroscopic phenomena. Scientific model of chemical structure helps students to develop science knowledge as well as a bridge between the conception of scientists and students. Through modeling activities, students are able to comprehend the phenomena in the real world and the phenomenon of science as well as without any separations (Carey & Gougis, 2017; Liu *et al*., 2017). Regarding this view, model and modeling cannot be separated in chemistry learning process.

Experts use models of chemical structure to describe very specific aspects in their learning process. Using a model of chemical structure expect students to comprehend all the aspects of science that are initially unfamiliar for them. Consequently, the simplification of the model of chemical structure is less precise represent the real aspect (Coll *et al*., 2005). To overcome those limitations, during modeling activities, the students must be able to explain, interpret, analyze, evaluate, and predict the aspect contained in the model of chemical structure. The activities of explaining, interpreting, analyzing, evaluating, and predicting are categorized as critical thinking (CT) skills (Facione, 1990). CT skills in certain content knowledge are define as domain-specific CT skills because of learning and applying a CT in certain context such as chemistry, physics, and computer science require a domain-specific knowledge (Tiruneh *et al*., 2016). Therefore, it is known that model and modeling activities in chemistry learning are be able to develop students' science knowledge but also improve CT skills.

Learning in a certain context such as science or chemistry context needs specific domain-knowledge to enhance CT skills. Proficiency in CT skills involves certain knowledge because of thinking is always linked to a specific domain-subject. For example, interpreting varies with the context, and this difference is connected with a different kind of knowledge. Based on this view, CT skills cannot be separated from the content-knowledge. The Assumption of each domain-knowledge or scientific knowledge interventions targets inherently on the development of domain-specific CT skills.

Solid state chemistry (SSC) is chosen as a topic of this study. The characteristic of its concept is abstract with real phenomena context that could be found in human daily life and in an advanced technology. It allows students to make connections between science and human daily life application. In order to enhance students' comprehension relations of property structure, basic concepts such as chemical structure and chemical bonding (metallic, ionic and covalent bonding) should be introduced. However, these concepts are abstract; students usually find them difficult and struggle to understand them and it causes misconceptions (Bergqvist & Chang Rundgren, 2017; Bergqvist *et al*., 2016; Bergqvist *et al*., 2013; Croft & de Berg, 2014; Dhindsa & Treagust, 2014; Nimmermark *et al*., 2016; Sen & Yilmaz, 2017). In line with the results of preliminary research, showed that students' understanding of SSC concept mostly (41%) is in the low category, while the category of modeling skills are 51% students not able to connect the model with macroscopic and submicroscopic phenomena (Nursa'adah *et al*, 2016). Applying model and modeling activities in SSC learning process make students able to focus on relating structure and properties of matter. Students find the application of concept in human daily life and technology easily. The most important thing is they do not assume that science or chemistry in the school is different from human daily life.

Integrating domain-specific CT skills in learning of SSC may promote students' conceptual understanding and change students conception to the scientific conception. Develop in-depth understanding involves CT skills such as interpreting, analyzing, evaluating data, making inferences, constructing explanations, and applying knowledge to different situations. Structure-property knowledge leads students to make a prediction about future material applications. Making a prediction needs inference of data. Based on the view, learning SSC necessitates students to think critically, and it would be useful to develop modeling skills and domain-specific CT. Therefore, designing a learning that covered at the instance of learning demand is an urgency.

Model of educational reconstruction (MER) is a German didactic tradition developed as a framework for teaching and learning a concept or scientific knowledge (Duit *et al*., 2012). MER has a good way of bringing 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 (Duit *et al*., 2012; Niebert & Gropengiesser, 2013; Sam, 2017). It is important to consider students conception in designing learning sequence because students should not enter the class without any knowledge or blank mind: they have observed the scientific process over many years and developed their own alternative conception (Barke *et al*., 2009). This case should became a concern for teachers or lecturers in considering instructional design in order to change the pre-conception to the scientific conception.

Previous researchers used MER as a base of their learning design. They showed that teaching sequences based on MER could promote the development of conceptual knowledge and the students' knowledge to be significant and remained stable on a high in some subject knowledge such as chemistry, physics, geography, and science computer content (Grillenberger *et al*., 2016; Reinfried *et al*., 2015; Saarelainen *et al*., 2009; Sam *et al*., 2016; Sam *et al*., 2015). Yet, little is known about whether MER could promote domain-specific CT skills, modeling skills and NOST aspect in chemistry learning process.

Comprehending SSC content into learning process that focus on relating structure and properties needs modeling skills and domain-specific CT skills. Furthermore, a learning design based on MER, worksheets, design of laboratory activities, and multimedia are designed to support the SSC learning in order to enhance those skills. They are required to analyze the context of the phenomenon, to infer data, and to make a conclusion. Students practice a blend of their prior knowledge and newly acquired scientific information through explanations and discussions. They evaluate the theory to predict complex application to enrich their knowledge. All these interventions require thinking critically.

Using an advance technology as a modern context in the learning process is expected to change students' views on nature of science and technology (NOST) aspects. Develop an adequate conception of the NOST is one of the goals of science education (Temel *et al*., 2017). A good conception of NOST is related to how can students understand and perceive science concept. To identify students' views on NOST, there are five NOST aspects developed in the study (Tairab, 2001). Through MER, it is expected to enhance not only the domain knowledge, modeling skills, and domain-specific CT skills but also the students' view of NOST.

Concerning on the importance of modeling skills, domain-specific CT skills and NOST aspects in SSC learning and the benefits of interventions based on MER, the analysis of the use of MER in developing modeling skills, domain-specific CT skills and the view of NOST aspects is an urgency.

1.2 Problem Statement and Research Questions

1.2.1 Problem Statement

Based on the background stated, it can be concluded that statement of the problem elements is : Enhancing students' modeling skills, domain-specific CT skills and view of NOST on SSC learning process based on MER.

1.2.1 Research Questions

Research questions are formulated as follow:

1. How reconstruction of instructional materials are applied in SSC learning process based on MER?
2. Does the implementation of an intervention based on MER promote students' conceptual knowledge?
3. Does the implementation of an intervention based on MER promote students' modeling skills?
4. Does the implementation of an intervention based on MER promote students' domain-specific CT skills?
5. Does the implementation of interventions based on MER promote students' view of NOST aspects?
6. Is there a relationship among students' conceptual knowledge, modeling skills and domain-specific CT skills?

1.3 Purpose of the Research

Based on the research questions, the purpose of this study is to examine the use of MER to enhance modeling skills, domain specific CT, and NOST aspects in SSC.

1.4 Contribution of Research

Research contributions are described as follows:

1. Learning design based on MER in SSC topics is designed to enhance modeling skills, domain-specific CT as well as domain-knowledge.
2. Domain-specific CT skills are base to develop domain-general CT. The CT is a necessary skill in the 21^{st} century. This research is expected to support the government's efforts to provide the necessary skills to face the 21^{st} century.
3. Context phenomena and modern are used in learning in order to enhance students' view of NOST aspects.
4. Intervention is designed based on daily life context and students' prior conceptions, it enable students to connect content knowledge with their daily life phenomena. Modern context is chosen as an abstraction in order to make students' content knowledge stable.
5. Interventions are not only integrated with a *software* that represent/visualize the structure of solid state chemistry, properties, and the applications but also supported by hands-on activities to develop modeling skills and domain-specific CT skills.
6. The development of worksheets on SSC topic can be used to improve students' modeling skills and domain-specific CT skills.

1.5 Explanation of the Terms

Definitions of some terms used in this study are as follows:

1. The Model of Educational Reconstruction (MER) is a Germany didactic tradition developed as a framework for teaching and learning a concept or scientific knowledge (Duit *et al*., 2012). Reconstruction is focused on the design of learning that make science content simpler and easier to accept students for meaningful learning (Viiri & Savinainen, 2008).

2. The modern context referred to in this study is the modernization of learning content is done by combining content and context that is closely related to advanced technology and current (Bell & Lederman, 2002)
3. Modeling skills are the ability to think spatial about molecular structure and transfer it through molecular representation and level of chemical understanding. This ability is required by the learner (Barke & Engida, 2001; Barke *et al*, 2009; Dori & Kaberman, 2012).
4. Domain-specific CT skills is a CT skill on a certain domain-knowledge (McPack, 1990; Tiruneh *et al*, 2016).
5. Domain-general CT skills are about reasoning and reflective thinking that focuses on determining what is believed and what should be done in daily life (Ennis, 1985; Tiruneh *et al*, 2016).
6. SSC is one of the topics studied in inorganic chemistry. This topic consists of metallic, ionic, molecular, and covalent networks crystals. The characteristics of this concept are abstract with concrete examples in daily life. Abstract criteria require modeling to explain it, and the concrete example criteria make it easy for learners to find solid state chemistry concepts in their daily lives (Kauffman, 2000).
7. Scientists' conception are scientists' conception about :1) which is scientific theory and conception, 2) which is the function and meaning of the scientific conception, 3) which scientific term are being used, 4) which scientific and epistemological position are implied, 5) which ethical and social implications are associated with the scientific concept, and 6) which field of application are affected (Duit *et al*., 2012; Viiri & Savinainen, 2008; Duit *et al*., 1997; Kattmann *et al*., 1996)
8. Students' conception are students' conception about: 1) how are the scientific concept represented in student perspectives, 2) which conception are used by students, 3) which perspective do student have about science itself, 4) how do alternatives framework and conceptions of students correspond with scientific theories (Duit *et al*., 2012; Viiri & Savinainen, 2008; Duit *et al*., 1997; Kattmann *et al*., 1996)

1.6 Dissertation Structure

To understand this dissertation easily, dissertation structure is made as follows:

Chapter 1 is an introduction of dissertation, consisting of research background, problem statement and research questions, research purposes, research significance, and dissertation structure.The research background contains the problems which is the reason for the researcher to conduct research on the field, and the urgency of the research.

Chapter 2 contains literature review of modeling skills, domain-specific CT skills, NOST aspects on SSC concept based on MER. This chapter consists of six parts.The first part describes the characteristics of chemistry concepts and its' learning. The second part describes the analysis of SSC concepts and their characters. The third section describes previous studies of SSC learning process. Section Four presents the theoretical framework underlying research. The fifth section describes the results of previous research related to the research undertaken, and part six describes the conceptual framework about learning design based on MER which provides the necessary skills in the SSC learning.

Chapter 3 contain research method. 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.

Chapter 4 This chapter is intended to describe the research findings and discussion about SSC learning based on MER which develops domain-knowledge in SSC, modeling skills, domain-specific CT skills and view of NOST aspects. The details of the data analysis, research finding and discussion are presented in accordance with the sequence of the research questions that had been formulated in chapter 1. This chapter is divided into three parts, they are : a) Preliminary research, b) Pilot study, and c) Implementation of SSC learning based on MER to enhance modeling skills and domain-specific CT skills, and view of NOST pre-service chemistry teachers.

Chapter 5 contains conclusions and recommendations. The conclusion is derived from findings to answer research questions. Some possible recommendations for conducting further related studies are provide in this chapter.