Science and Mathematics Education Centre

Curriculum Evaluation and Predict-Observe-Explain Implementation: A Case Study on Developing Chemistry Pre-service Teachers' Understanding of Particulate Nature of Matter in Indonesia

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DECLARATION

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.
To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

Signature:

ABSTRACT

The main purpose of this research study was to evaluate the existing program of developing pre-service teachers' content knowledge of the particulate nature of matter (PNM) using a framework for curriculum evaluation and to study the effectiveness of the Predict-Observe-Explain (POE) strategy in enhancing pre-service teachers' knowledge of PNM. This research focus on the PNM topic was because it covers fundamental concepts which are essential for further understanding about chemistry.

Using a case study design, this research explored pre-service teachers' content knowledge development in one teacher education institution in Indonesia. The theoretical basis was a framework for curriculum evaluation that included the vision and intention of the curriculum as mentioned in the curriculum documents (intended curriculum), the users' interpretations and perceptions about the curriculum (perceived curriculum), the actual process of curriculum implementation (implemented curriculum), and the outcomes of the curriculum (achieved curriculum). Through this research the coherence among those aspects was examined.

This case study involved three stages: The first stage included analysing government and institution documents to gather information of the expected outcomes and the designed program, as well as conducting a pilot study. The second stage consists of the observation of the teaching and learning process in the unit that was specifically intended to develop pre-service teachers' understanding about basic concepts of chemistry. The second stage also included the interviews with the lecturers as well as the pre-service teachers which sought to reveal their perceptions of the program, administering the Particulate Theory Diagnostic Instrument (PTDI) to gather information about pre-service teachers' achievements in understanding the PNM, and interviewing pre-service teachers to gather more explanation about their responses to PTDI. The third stage of the research included the implementation of a POE strategy followed by interviews with pre-service teachers to gather further explanation about their understanding after the POE implementation.

Regarding the POE strategy, conducted at the end of the semester, this study developed four POE activities which represent three conceptual categories of the PNM topic that research has shown are not well understood: (1) intermolecular spacing in matter, (2) diffusion in liquids and gases, (3) influence of intermolecular forces in phase changes. The comparison between the results of PTDI on pre and post-test, supported by individual interviews as well as reports

from students' journals during the lesson were used to examine the effectiveness of POE strategies in strengthening pre-service teachers' understanding about the PNM.

The results of the study about the intended chemistry education curriculum illustrated the importance of teacher comprehension of content knowledge to support their teaching practice in the classroom. In response to this, the Chemistry Education Department has provided a unit which specifically elaborates the chemistry concepts for lower secondary school entitled Teaching and Learning of Chemistry for Lower Secondary School (LS-Chem) which covers the topics of the PNM. In accordance to this, the lecturers and the pre-service teachers perceived the need to strengthen the pre-service teachers' understanding of basic concept in chemistry in order to be able to teach chemistry effectively to lower secondary students. However, in the implementation of the LS-Chem unit, it was recorded that there were more discussions about teaching strategies than basic concept development where discussions about chemistry concepts often only involved explaining the series of terminologies and definitions. These learning processes appear to be insufficient to strengthen pre-service teachers' understanding about the concepts related to the PNM. This is confirmed by achievement shown on the result of PTDI test which indicated pre-service teachers' limited or fragmented understanding even in several basic concepts such as volume, density, influence of heat on intermolecular forces, the role of intermolecular forces in the states of matter, and the movement of particles within three different phases.

Regarding the implementation of the POE strategy, this study also has shown the advantages of the POE strategy as an alternative strategy to strengthening PSTs' conceptual understanding about basic concepts in chemistry with a better understanding of density, volume, space between molecules, particle movements, and variables relating to the gas system. The POE strategy facilitated the pre-service teachers to reflect the quality of their previous understandings, which then challenged them to restructure their own conceptual understanding

This study has made distinctive contributions to improve the program of chemistry teacher education. The framework of curriculum evaluation could be a valuable model to evaluate pre-service teacher education program in Indonesia. Moreover, the study of the implementation of POE strategy also provided information about the usefulness of that strategy in reinforcing pre-service teachers' content knowledge in the teacher education process.

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INTRODUCTION TO THE THESIS

1.1 Introduction

The purpose of this chapter is to provide an introduction to this thesis which consisted of seven chapters. Section 1.2 discusses the rationale for the study describing the reason why the study was undertaken to evaluate the program of chemistry pre-service teachers' curriculum at a Teacher Education Institution in Indonesia. Section 1.3 introduces the conceptual framework for curriculum representations which focuses on the *intended*, *perceived*, *implemented*, and *achieved* curriculum. Section 1.4 presents the general and specific purposes of this research while Section 1.5 delineates the research questions which were established within the framework of each curriculum representation. Section 1.6 communicates and gives supporting evidence for the significance of the study. Section 1.7 presents the research design which was developed to answer the research questions. Section 1.8 describes the definitions and terminologies used in this thesis and Section 1.9 presents an overview of the thesis. Finally, Section 1.10 presents a brief summary of this chapter.

1.2 Rationale for the study

Chemistry as a branch of science is known as one of the hardest subjects to learn. Many people dislike chemistry and have a low motivation to learn this subject because they feel it is hard to have a good understanding about the content. The difficulties might emerge due to the unique characteristics of chemistry which has many abstract concepts and requires molecular spatial thinking skills to understand the meaning of many of the concepts (Carlisle, Tyson, & Nieswandt, 2015; Wu & Shah, 2004). These difficulties are not only experienced by the students who learn chemistry in the lower and upper secondary school but also by students in tertiary education including those in pre-service teacher education.

One of the essential factors for successful learning of chemistry is understanding the basic concept, known as the Particulate Nature of Matter (PNM). The PNM deals with the concept about the structure and the composition of matter and the interaction between the components of matter.

Chemistry is a subject with an enormous number of concepts to learn. Teachers will never have enough time to teach all the content to the students. Thus, what is necessary to be mastered by the students is not only the content, but also the way to learn and the way to maintain the spirit of learning. This means that the teacher's role is not only to transfer the knowledge to the student but also to transfer the skill of how to gain the knowledge and create a learning environment that can motivate students to keep enquiring and questioning.

In order to improve the practice of chemistry education, one aspect that become the focus of this study is the development of chemistry teachers in their teacher education program. According to De Jong, Veal, and Van Driel (2002) and Yezierski and Herrington (2011), teachers' understanding of concepts will strongly influence the way they organise a lesson. Further, De Jong et al. (2002) emphasized that teachers' deep understanding about a certain concept will assist the teacher to know the possibilities of students' prior conceptions, which will later help them determine the strategy that they use in the classroom. Although Shulman (1986) has introduced Pedagogical Content Knowledge (PCK) as teachers' essential knowledge, he also emphasized that content knowledge (CK) is a prerequisite for developing teachers' PCK. This idea was also supported by many scholars (Carlsen, 1999; De Jong et al., 2002; Gess-Newsome, 1999b; Magnusson, Krajcik, & Borko, 1999; Morine-Dershimer & Kent, 1999; van Driel, Verloop, & de Vos, 1998). Besides, there are also many research studies concerning students' difficulties in science learning that have concluded with the need for improving teachers' pedagogical content knowledge, as well as teachers' content knowledge (De Jong et al., 2002; Gustafson, Shanahan, & Gentilini, 2010).

Some research studies have shown that pre-service teachers (PST) still possessed limited or fragmented understanding of content knowledge when they graduate from university (Çalik & Ayas, 2005; Cheung, 2009; Gess-Newsome & Lederman, 1999; Haidar, 1997; Niess & Scholz, 1999). Gabel, Samuel, and Hunn (1987) have also warned that pre-service teachers' lack of understanding about concepts in chemistry, especially about the PNM, has serious impact in chemistry education. Thus teacher education and professional development should pay more attention to improve the content knowledge of primary and secondary teachers as has been suggested by De Jong (2002).

In fact, there are several research studies focusing students' understanding of concepts in chemistry (Andersson, 1990; Boz, 2006; Naah & Sanger, 2013; Rahayu & Kita, 2010). There are also multiple research studies about the development and implementation of teaching and learning strategies and their positive impact on students' alternative conceptions (Adadan, Irving, & Trundle, 2009; Akaygun & Jones, 2013; Kibirige, Osodo, & Tlala, 2014; Treagust, Mthembu, & Chandrasegaran, 2014). These research studies are considered important because students' understanding in specific concepts will influence their achievement of other relevant concepts. Moreover, understanding those concepts also will influence their comprehension in applying the concepts in daily life.

However, there is a lack of research dealing with teacher development programs, especially those focusing on the pre-service teachers' content knowledge development. As mentioned by De Jong (2002), research about teacher professional development seems like a 'blank space'.

> *The weakest focus has been on research into the professional development of university-level teachers of chemistry. This area emerges as a 'blank space' in teacher education. (De Jong, 2002, pg. 366)*

A study by Teo, Goh, and Yeo (2014) analysed the trend of research in chemistry education from 2004-2013. One of the results presented the fact that there were few research articles which study about pre-service teacher education. From 650 research articles from 6 different journals about chemistry education, only 31 papers (4.8%) were classified as being related to chemistry teacher education, and only 54 papers involved pre-service teachers in the studies reviewed. This fact is consistent with De Jong's quote that there are still limited studies concerned about teacher professional development.

Hereafter, this study tries to examine the process of a teacher professional development program especially content knowledge development in one of the teacher education institutions in Indonesia. There is a challenging task for Teacher Education Institutions (TEI) to develop programs that effectively strengthen PST's CK, to support the development of their PCK, and improving their quality of teaching. Regarding the challenges faced by TEI to develop PST's CK, this study is intended to evaluate the existing program. This evaluative study is anticipated to reveal the strength of current situation which can be a basis for improving the strategy to overcome the challenges.

1.3 Conceptual framework

In order to depict the existing program of the development of pre-service teachers' content knowledge in one teacher education institution in Indonesia, this study utilised the framework of curriculum evaluation (Treagust, 1987) that has been modified from Goodlad, Klein, and Tye (1979). This framework consists of *the intended curriculum*, *the perceived curriculum*, *the implemented curriculum*, and *the achieved curriculum*. The intended curriculum presents the objectives and the goals of the program as stated in the curriculum document. The perceived curriculum describes the interpretation of the curriculum by the teachers or lecturers and the students as the persons who are involved in the program. The implemented curriculum describes the actual process of the delivery of the curriculum. The achieved curriculum presented the students' achievement as a result of the curriculum being implemented. Through this study, the thesis examined whether or not there was any coherence among those aspects.

1.4 Purpose of the study

The general purpose of this study was to evaluate the curriculum of the teacher education program to obtain a depiction about the development of chemistry pre-service teachers' content knowledge in one teacher education institution in Indonesia. The scope of the chemistry content focused on the topic about the Particulate Nature of Matter (PNM).

Regarding the theoretical framework used in this study, this general purpose can be further specified into five specific purposes.

- The first purpose was to study the design of teacher education program in developing pre-service teachers' understanding about the PNM. This study was conducted by analysing objectives and the goals of the program as stated in the guideline document from the government as well as curriculum documents from the teacher education program.
- The second purpose was to identify the perceptions of chemistry teacher educators and also the chemistry pre-service teachers' perceptions about the program.

- The third purpose was to analyse the activities used to develop pre-service teachers' understanding about the PNM through the implementation of the program.
- The fourth purpose was to analyse the PSTs' understanding about the PNM after they enrolled in the unit of Teaching and Learning of Chemistry for Lower Secondary School (LS-Chem) that was designed to strengthen their knowledge about basic concepts in chemistry.
- The last purpose was to analyse the impact of the POE (Predict-Observe-Explain) strategy in improving PSTs' understanding of the PNM.

1.5 Research questions

Consequently, six research questions were addressed in this study.

1. What is the designed program to develop pre-service teachers' understanding of the particulate nature of matter in the Chemistry Education Program?
2. How is the pre-service chemistry teachers' understanding of the particulate nature of matter developed through the unit of *Teaching and Learning of Chemistry for Lower Secondary School*?
3. What are the chemistry teacher educators' perceptions about the chemistry education curriculum in terms of enhancing pre-service teachers' understanding of the particulate nature of matter?
4. What are the pre-service teachers' perceptions about the chemistry education curriculum in terms of enhancing their understanding of the particulate nature of matter?
5. What are the pre-service chemistry teachers' understandings of the particulate nature of matter after enrolling in the unit of *Teaching and Learning of Chemistry for Lower Secondary School*?
6. How does the POE strategy effect pre-service teachers' understanding of PNM?

These first five research questions represent the four aspects of framework of the curriculum evaluation by Treagust (1987). Research Question 1 is related to the intended curriculum and Research Question 2 is related to the implemented curriculum; the results of these two Research Questions are presented in Chapter 5. Research Question 3 and 4 are associated to the perceived curriculum and Research Question 5 is related to the achieved curriculum. The results of Research Question 3, 4, and 5 are presented in Chapter 6. While Research Question 6 is related to the study of the implementation of the POE strategy and the result is presented in Chapter 7.

1.6 Significance of the study

Owing to the intention to improve the quality of the programs in Indonesian teacher education institutions, evaluation of the existing programs is needed to identify the base condition for further development. Using the framework of curriculum inquiry by Treagust (1987), which was modified from Goodlad et al. (1979), this study has the potential to evaluate the actual program from different aspects. The aspects consist of the curriculum documents, the lecturers' and pre-service teachers' perceptions about the curriculum, the actual implementation of the curriculum, and also the pre-service teachers' achievements as an outcome of this curriculum. Further, this study will examine the coherence among those aspects. This framework has the potential for program evaluation at the institution level within an education system, because it places greater focus on the practical situations rather than the theoretical aspects.

The study of curriculum evaluation allows us to reveal the strengths and the weaknesses of the existing program and enables us to find out the opportunities and the threats if we want to develop a new program. Thus, we can assume the strengths and opportunities as a potentiality that could and should be optimized. At the same time, we also have to consider the weaknesses and threats as a challenge that have to be resolved in the future development of the program. This kind of study can be beneficial if conducted in Chemistry Education Department as well as in other Departments of Teacher Education in Indonesia because each Department has autonomous rights to develop, implement, and evaluate its programs.

Meanwhile, the study about the implementation of the POE strategy attempts to explore the impact of the POE strategy in improving pre-service teachers' conceptual understanding. Many research studies have reported the benefits of POE strategy in enhancing students' understanding of chemistry concepts (Chang et al., 2013; Kala, Yaman, & Ayas, 2013; Kearney, Treagust, Yeo, & Zadnik, 2001; Sesen, 2013; Treagust et al., 2014). One of the essential factors of the POE strategy is the involvement of students' prior knowledge at the beginning of the learning process.

Considering this, the POE is expected to be an effective strategy in strengthening pre-service teachers' understanding.

1.7 Research design

In an attempt to answer the research questions, this study is conducted in three stages as shown in Figure 1.1.

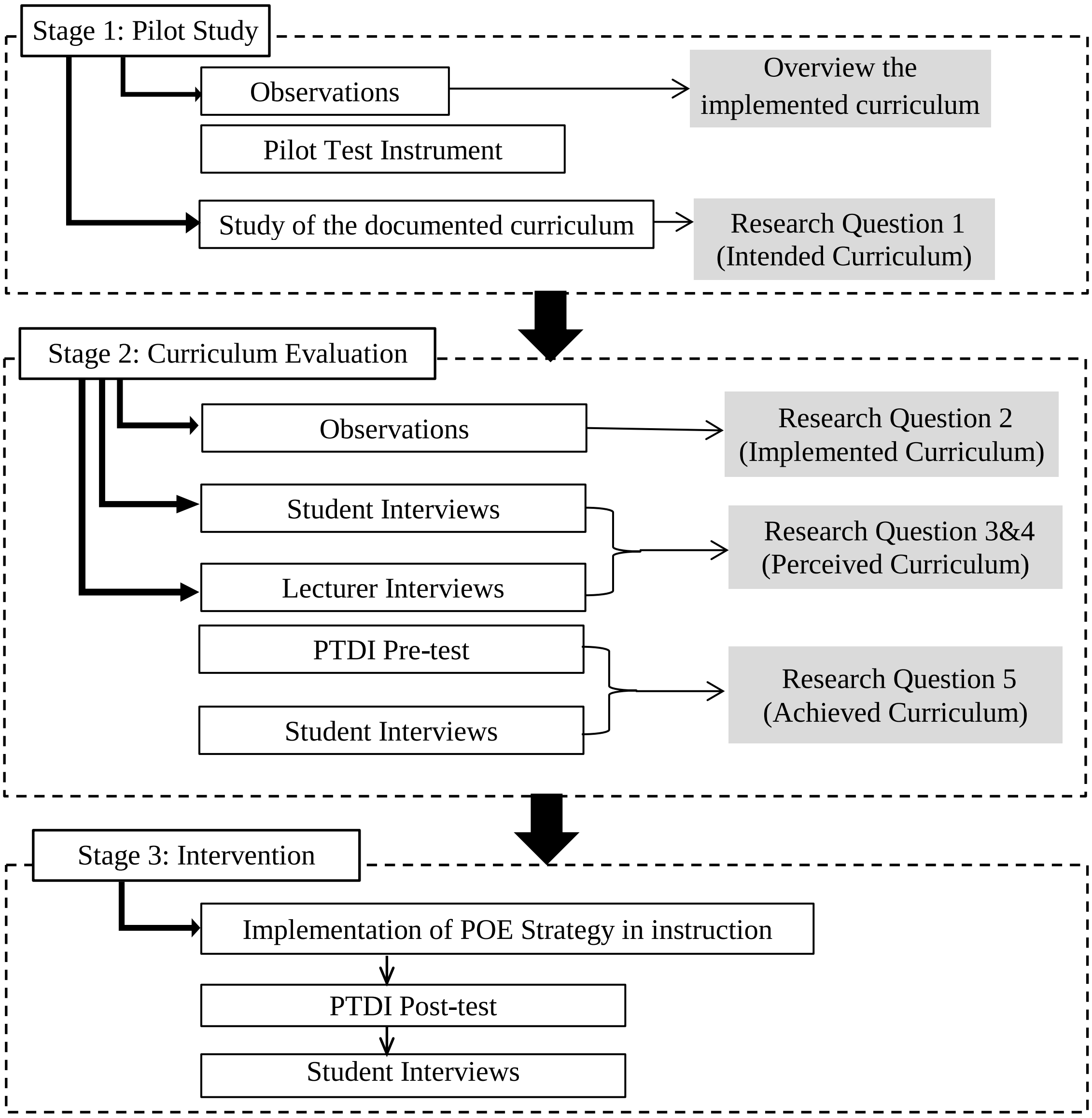


Figure 1.1. Three stages of the research

The first stage of this research is the pilot study which consists of classroom observations and a pilot test of the instruments. The observations within this first stage were conducted in the condensed semester (an additional semester between two academic years which was conducted in only 9-10 weeks) and provided an overview of how the program is implemented.

The second stage is the curriculum evaluation that consists of four main activities corresponding to the curriculum inquiry framework, such as: 1) A study of the documented curriculum to address the research question about the intended curriculum; 2) Interview the lecturers and the pre-service teachers to find out information about the perceived curriculum; 3) Observe the teaching and learning process in the LS-Chem unit in a regular semester to see the actual practice of pre-service teachers' content knowledge development as an implemented curriculum; 4) Administer the PTDI (Particulate Theory Diagnostic Instrument) test, a two-tier diagnostic test developed by Treagust et al. (2010). The test was then followed by interviews with the pre-service teachers to examine their achievement at the end of the semester.

The third stage is the implementation of POE strategy that consists of three different topics: 1) Intermolecular spacing in matter, 2) diffusion, 3) influence of heat in the phase changes. The implementation of these POE strategies was followed by the interview with the pre-service teachers to gather further explanation about their understanding after POE implementation.

All of the stages above were conducted using a case study design (Creswell, 2012; Yin, 2009) that attempted to explore the actual case about pre-service teacher preparation in a teacher education program in a university in Indonesia. Those stages also clearly shows that this research combined qualitative and quantitative methods of data collection and interpretation (Erickson, 1986). The data collected consisted of document analysis, classroom observation, interviews, students journal and the Particulate Theory Diagnostic Instrument (PTDI), a two-tier diagnostic instrument adopted from Treagust et al. (2010).

1.8 Definitions and terminology

1.8.1 Key terms used in this thesis

Achieved Curriculum – the information obtained from teacher records of students' progress (Treagust, 1987).

Content Knowledge – the amount and organization of knowledge in teachers' mind (Shulman, 1986)

Ideal Curriculum – The original vision underlying a curriculum (basic philosophy, rationale or mission) (van den Akker, 1998).

Implemented Curriculum – The actual process of teaching and learning (van den Akker, 2003), based on qualitative and quantitative data from classroom observations (Treagust, 1987).

Intended Curriculum – The syllabus, the text books, teaching foci and the nature of the academic work described by the teachers (Treagust, 1987).

Particulate Nature of Matter – Basic concepts in chemistry which include the kinetic molecular theory and becomes the basis of explanations of atomic structure, bonding, molecules, much of solution chemistry and chemical reactions, equilibrium and chemical energetics (Harrison & Treagust, 2003)

Pedagogical Content Knowledge – A special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding (Shulman, 1987).

Perceived Curriculum – The curriculum as interpreted by its users (van den Akker, 1998).

Predict-Observe-Explain – The teaching strategy that probes understanding required by learners to make a prediction of an event, record and justify their prediction, describe their observation, and reconcile the discrepancies between prediction and observation (White & Gunstone, 1992).

Two-tier Diagnostic Test – Multiple choice test item consist of two tiers. The first tier of the items consists of a content question, while the second tier elicits a reasoning response (Chandrasegaran, Treagust, & Mocerino, 2008).

Written Curriculum – The specified intention in curriculum documents (van den Akker, 2003).

1.8.2 Abbreviation used in this thesis

PST – Pre-service Teacher (the term PST in this thesis refers to pre-service chemistry teachers)

PNM – Particulate Nature of Matter

CK – Content Knowledge

PCK – Pedagogical Content Knowledge

LS-Chem – Teaching and Learning Chemistry for Lower Secondary School

POE – Predict-Observe-Explain

PTDI – Particulate Theory Diagnostic Instrument

1.9 Overview of the thesis

This thesis is organized into seven chapters. Chapter 1 provides a background of the study and delineated the research questions that are intended to be answered through this study. The first chapter also describes the conceptual framework, followed by the purpose and the significance of the study.

Chapter 2 elaborates the literature review about science teacher education including the factors influencing the quality of teachers as well as the essential role of teachers' content knowledge development in teacher institutions and some related issues. This chapter also presents the program of teacher education in Indonesia. In particular, this chapter also describes the curriculum inquiry as the framework of evaluation for a teacher preparation program, the two-tier diagnostic test as the instrument used in this study, and also the POE strategy as an alternative strategy presented to improve pre-service teachers' understanding of basic concepts in chemistry.

Chapter 3 elaborates the literature review about the PNM that became the main focus of chemistry concepts studied in this research. The discussion consists of the essentials of the PNM in chemistry learning and some related research studies about the problem of students' learning about the particulate nature of matter. This chapter also describes Indonesian students' understanding of the PNM based on the results of TIMSS (*Trends in International Mathematics and Science Study)* which assesses students' knowledge about science and mathematics all around the world. Moreover, some research studies that focused on teachers' and pre-service teachers' experience with the PNM are also elaborated in this chapter.

Chapter 4 describes the research methods used in this study and includes the theoretical framework, the research stages and the participants' selection. This chapter also presents some data sources used in this study, as well as the data analysis procedure.

Chapter 5 elaborates the results of the study about curriculum evaluation in terms of the intended and implemented curriculum. The discussion covers research questions 1 to 5 which are organised into four sub-sections representing the aspects of curriculum inquiry. The intended curriculum presents the expectation of the curriculum about teacher content knowledge development especially in their knowledge about the basic concepts of chemistry. The implemented curriculum describes the actual process of teaching and learning in a specific unit that focused the discussion of basic chemistry concepts.

Chapter 6 presents the result of curriculum evaluation specified in the perceived and achieved curriculum. The perceived curriculum describes the lecturers' and pre-service teachers' perceptions about the current program. While the achieved curriculum presents the pre-service teachers' achievement as an outcome of the current program that has been evaluated.

Chapter 7 presents the teaching and learning activities and the result of Research Question 6 about the implementation of POE strategy as an alternative strategy to improve pre-service teachers' understanding of the concepts related to the particulate nature of matter. This chapter is organized based on the conceptual categories of the PNM: (1) Intermolecular spacing in matter; (2) diffusion; (3) influence of heat in the phase change.

Chapter 8 presents the discussion, conclusions, and implication of this study. This chapter compiles the major findings of curriculum evaluation as well as the outcomes from the intervention using the POE strategy. This chapter also summarises the conclusions and presents the limitations of the study. Besides, this chapter also outlines the implications for future research especially in the study about teacher education in chemistry.

1.10 Summary of the chapter

This first chapter has introduced the main framework of this study which consists of two main stages: the curriculum evaluation and the POE strategy implementation in chemistry teacher education. The focus of this study is the development of pre-service teachers' content knowledge, specifically in the concepts related to the particulate nature of matter. Thus, this study was conducted in the unit that mainly discusses the content about chemistry for lower secondary school because the concepts of the PNM are mostly covered in the curriculum of chemistry for lower secondary school. The study about curriculum evaluation has the potential to explore the strengths and challenges of the current teacher education practice. The findings from this study may have implications for future development of teacher preparation programs. Meanwhile, the current study reveals the advantages of the POE strategy in strengthening pre-service teachers' conceptual understanding.

Besides describing the framework and the objective of this study, this chapter also presented an overview of every chapter. It provides a general idea of the study that was further elaborated in this thesis. Following this chapter, Chapter 2 provides a literature review associated with the essential role of teacher quality to attain the goals of education.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Introduction

Following the previous chapter about the background of this study, this chapter discusses a review of the literature related to the study. The scope of this chapter is about pre-service teachers' knowledge and their professional development programs. Besides, this chapter also introduces curriculum evaluation as the theoretical framework of this study to evaluate the existing program of pre-service teachers' knowledge development. Overall, this chapter consists of seven sections. Section 2.2 provides an elaboration about the factors that contribute to teacher quality, emphasising the essentials of content knowledge development in teacher education and some issues in teacher education programs related to teachers' knowledge development. Section 2.3 describes the background of pre-service teachers' preparation programs in higher education institutions in Indonesia. Section 2.4 explains the framework of curriculum inquiry as a means to evaluate the curriculum for pre-service teachers' education. Section 2.5 provides a brief description about two-tier diagnostic tests as a tool for data collection in this research while Section 2.6 describes the strategy of POE as an approach to improve pre-service teachers' achievement. Lastly, a summary of the chapter is provided in Section 2.7.

2.2 Science teacher education

Teacher education institutions have an essential role to develop the basic teaching skills of their prospective teachers. Although the literature states that a major influence of teacher professional development is the training during teachers' practice in the classroom, in addition to this, the process of the development of fundamental teaching skills of pre-service teachers in teacher education institutions is also important. Teacher education institutions need to develop appropriate programs that provide opportunities for students to transform themselves to be capable teachers. The programs should be able to produce teachers who will be confident in their roles as proficient facilitators of learning.

2.2.1 Factors influencing the quality of teachers

Teachers play an important role in the process of achieving the goals of science education. As has been well-recognized, it is essential that teachers in general need to have good qualifications. This thought leads to further questions: "Who is a qualified teacher?", and "What criteria does a person need to fulfill to be considered as a qualified teacher?" There are many research studies that suggest criteria of teachers that are needed for better education of children. In general, there are three aspects that will contribute to the personal quality of a teacher such as her/his learning experience, self-efficacy, and knowledge as shown in Figure 2.1. Knowledge is further elaborated as four aspects arranged as a Transformative Model of Teacher Cognition postulated by Gess-Newsome and Lederman (1999). These aspects need to be considered when developing programs in teacher education institutions involved in educating pre-service teachers.

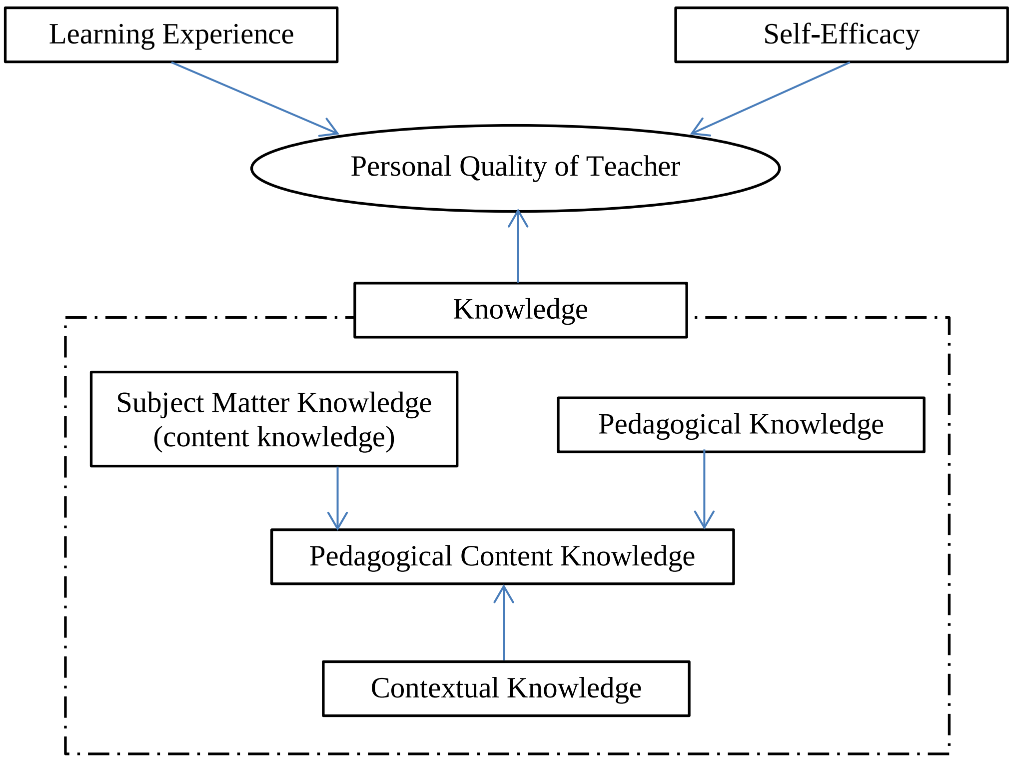


Figure 2.1 Factors influencing the quality of teachers (modified from Gess-Newsome and Lederman (1999))

2.2.1.1 Learning experience

Teacher education institutions should be concerned with providing pre-service teachers with meaningful learning experiences because teachers will teach the way they were taught (Sarason, 1990; Tamir, 1988; Yezierski & Herrington, 2011). These experiences, either in school or university learning, are likely be reflected in the way they conduct teaching and learning in their classrooms, in terms of the strategies they use and the approaches they choose (Sarason, 1990). A research study by Koballa, Gräber, Coleman, and Kemp (2000) has shown that there is a correlation between prospective chemistry teachers' perspectives about learning (based on their experiences) and the way they perform their teaching in the classroom. Just as with Koballa et al. (2000), De Jong et al. (2002) also stated that chemistry teachers' beliefs about teaching and learning may influence the way they simplify a concept into a more plausible one that can be understood by their students. Moreover, previous learning experiences possibly become an inspiration and motivation for pre-service teachers to actualize themselves as teachers (Rahmawati, 2012).

Pre-service teachers' prior knowledge and school experiences are resources as well as challenges for teacher education programs (Ell, Hill, & Grudnoff, 2012). Pre-service teachers enrolled in teacher education institutions would have just graduated from school with different learning experiences. Teacher education institutions cannot change these pre-service teachers' school experiences but can provide meaningful learning experiences during their study by developing their teaching skills (Tamir, 1988). It is also important to develop programs that challenge pre-service teachers' prior experiences in order to influence their practice of teaching and the need to facilitate their consideration and adoption of other ways of teaching (Corrigan, 2009). Further, Tamir (1988) recommended that programs need to develop pre-service teachers' content knowledge as well as to enrich their experiences of learning through various strategies. These programs should take into account the variety of students' previous experiences of learning (Jeanpierre, Oberhauser, & Freeman, 2005). Pre-service teachers could then be expected to apply the knowledge gained in their teaching practices at school (Jeanpierre et al., 2005; Tamir, 1988).

2.2.1.2 Self-efficacy

Bandura (1977) introduced the concept of self-efficacy as a belief that makes someone recognize his or her capacity to ensure his or her ability to reach a particular goal. This theory was initiated in psychology and has been continuously developed in different areas of knowledge. In the context of teacher professional development, teacher self-efficacy is related to teachers' beliefs about their potential to engage their students in the lessons and be able to understand the subject that they are teaching (Guo, Connor, Yang, Roehrig, & Morrison, 2012).

Many research studies have indicated that teachers' self-efficacy may influence students' performance. Ross (1992) has shown that seventh and eighth grade students' achievements in social studies were influenced by their teachers' self-efficacy. Similar results have also been found which demonstrated that literacy skills of preschool students (Guo, Piasta, Justice, & Kaderavek, 2010) and fifth grade students (Guo et al., 2012) were related to their teachers' self-efficacy. These results suggest that developing pre-service teachers' self-efficacy supports the improvement of the quality of education.

One way to help pre-service teachers develop their self-efficacy is through the development of their content knowledge. Although no significant correlation has been shown to exist between teachers' level of conceptual understanding and their level of self-efficacy, it has been found that teachers with fewer alternative conceptions in science tend to possess higher self-efficacy in teaching science, and vice versa (Schoon & Boone, 1998; Tekkaya, Cakiroglu, & Ozkan, 2004). Responding to this result, Tekkaya et al. (2004) argued that the pre-service science teachers need opportunities to explore, alter, or even reconstruct their previous conceptions to achieve better understanding of scientific concepts. Moreover, teacher education should develop effective programs for strengthening pre-service teachers' conceptual understanding. The number of science units in the university is not the main issue, it is more about the units that provide an opportunity for pre-service teachers to develop a deep understanding of science concepts that can help them improve their efficacy to be science teachers.

2.2.1.3 Knowledge

Another aspect that is essential to be developed in teacher education institutions is the prospective teachers' knowledge. Teacher education institutions have a responsibility to develop teachers' fundamental knowledge that might be further elaborated by them during their teaching activities in the classroom. Teachers' basic knowledge, initially suggested by Shulman (1986), is divided into three sub-categories: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Subsequently, in 1987, Shulman extended the categories into seven categories of teachers' knowledge: (1) content knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) pedagogical content knowledge, (5) knowledge of learners and their characteristics, (6) knowledge of the educational context, and (7) knowledge of educational ends, purposes, and values, and their philosophical and historical grounds. Following this, Morine-Dershimer and Kent (1999) included additional knowledge about assessment and evaluation as well as knowledge about specific contexts. The distinct relationship among these categories is shown in Figure 2.2.

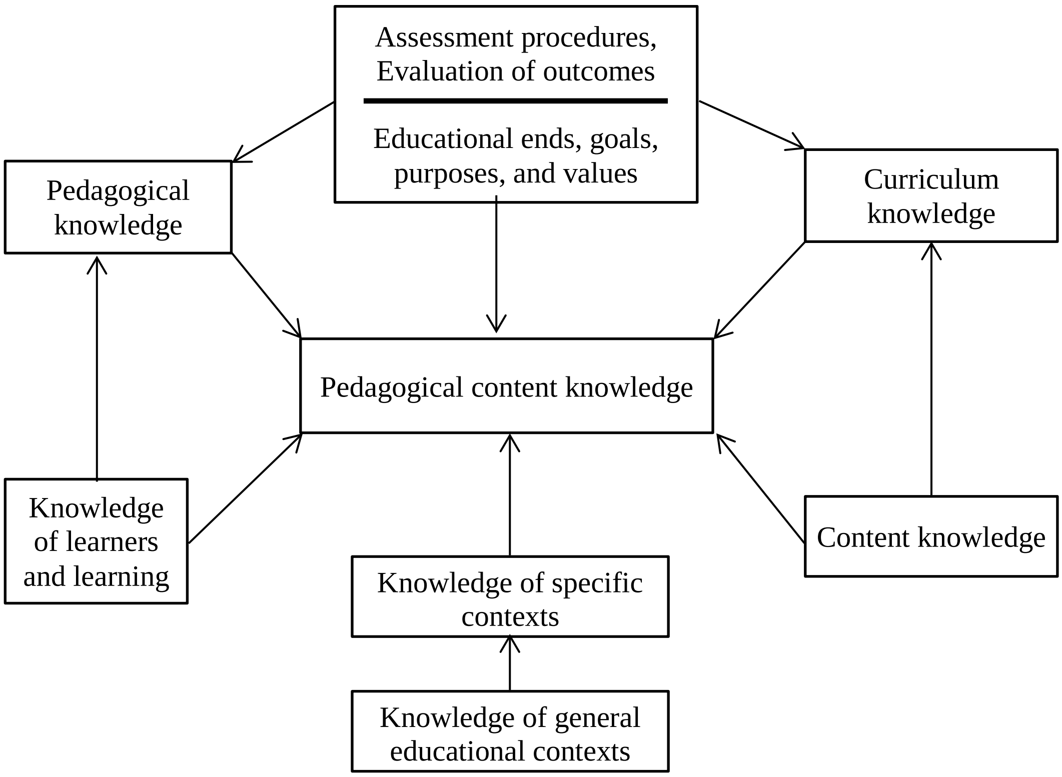


Figure 2.2 The relationship among categories of teachers' basic knowledge (Adopted from Categories contributing to Pedagogical Content Knowledge by (Morine-Dershimer & Kent, 1999))

All components mentioned by Shulman (1987) are related to pedagogical content knowledge as shown in Figure 2.2. These components are broader than teachers' basic knowledge proposed by Gess-Newsome and Lederman (1999) which consists of three main aspects, i.e., subject matter knowledge or content knowledge, pedagogical knowledge, and contextual knowledge that are embodied as pedagogical content knowledge as seen in Figure 2.1. However, the aspects of basic knowledge of the teacher that are further discussed in this chapter are only content knowledge, pedagogical knowledge, and pedagogical content knowledge.

a. Content knowledge

The first category of knowledge to be mastered by someone who intends to be a teacher is content knowledge which also is a requirement for the development of the other categories of teachers' knowledge (Shulman, 1986). The term content knowledge refers to subject matter knowledge (Shulman, 1986; Tamir, 1988) which involves hierarchical in-depth knowledge about concepts. For teacher education programs, this means that teachers' knowledge should cover the dimensions of what is the meaning of the concept, what are the reasons beyond that concept, what are the conditions that are suitable for that concept, what is the correlation between the concept and other concepts and how is this concept applied in the everyday life.

Teacher education institutions face a great challenge to develop pre-service teachers' mastery of the content knowledge because this comprehension about content is essential to the quality of teaching performance (Johnston & Ahtee, 2006). Some literatures argue that chemistry teachers' understanding of a certain concept will strongly influence the way they organise a lesson about that concept, including the way they prepare the lesson and also the way they perform (De Jong et al., 2002; Kosnik & Beck, 2009; Yezierski & Herrington, 2011). The mastery of content knowledge is also important to build connection among several subjects to build an integrated conceptual understanding as a fundamental aspect for meaningful teaching (Kosnik & Beck, 2009). Moreover, Shulman (1986) has stated that the role of content knowledge exceeds the importance of pedagogical knowledge. Shulman's statement does not necessarily mean that content knowledge is superior to the other categories of knowledge. It is just to emphasize that content knowledge is a prerequisite for developing other categories of knowledge (Shulman, 1986; van Driel et al., 1998).

It is widely known that teachers' professional knowledge is not only developed during pre-service teacher education, but also during practice as a teacher during in-service teacher professional development programs. Teachers certainly are provided with training to improve their knowledge about teaching strategies; however, they rarely have such opportunities to improve or rectify their content knowledge. This is the reason why the development of pre-service teachers' content knowledge in teacher education institutions needs attention as suggested in education curriculum materials proposed by Davis and Krajcik (2005).

b. Pedagogical knowledge

The teaching process is not about transferring teachers' knowledge to the student. According to the constructivist view, the teaching process involves providing guidance, support, and opportunity for the students to invent and construct ideas (Clements & Battista, 1990). During the process of teaching, teachers should offer appropriate tasks and create opportunities for dialogue that indirectly create learning moments for the students (Bruner, 1986). This means that the constructivist teacher has to have an appropriate strategy to help students reorganize or construct their knowledge. Based on this task, only having good content knowledge is not enough for the teacher to help students learn effectively. Teachers need some strategies to teach effectively in terms of dealing with different concepts, contexts, situations, even different students (Groundwater-Smith, 2007). In this case, the teacher needs some knowledge related to pedagogical aspects that is known as pedagogical knowledge. In chemistry education, according to Yezierski and Herrington (2011), pedagogical knowledge is one of the factors that influence chemistry teachers' decisions in the classroom. This factor will combine with content knowledge to produce effective teaching and learning process.

According to Morine-Dershimer and Kent (1999), pedagogical knowledge involves three aspects, namely, classroom management and organization, instructional models and strategies, and classroom communication and discourse. Further, Morine-Dershimer and Kent (1999) explain that pedagogical knowledge is developed through the process of reflection. This reflection stage involves the process of broadening the pedagogical knowledge from personal beliefs and experiences. Besides, the stage of reflection also comprises the process of contextualizing or applying pedagogical knowledge from research and scholarly literature. Figure 2.3 shows the facets of pedagogical knowledge as explained by Morine-Dershimer and Kent (1999) which consists of two main parts: the scope of pedagogical knowledge and the source of pedagogical knowledge.

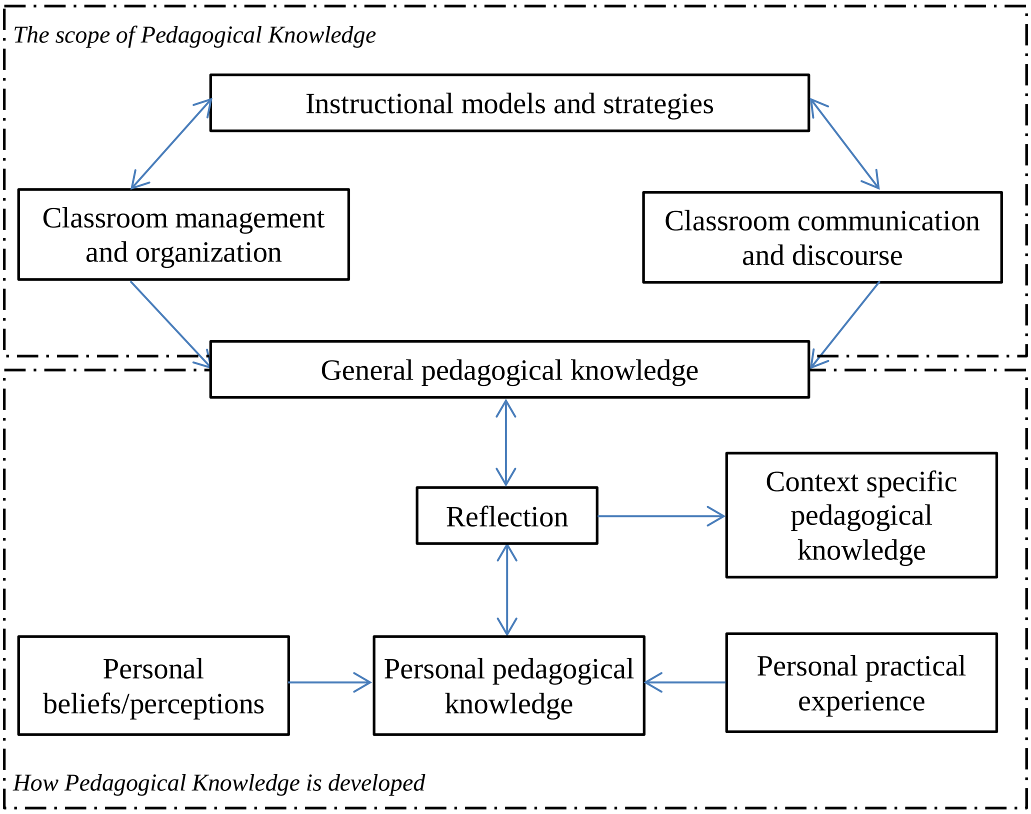


Figure 2.3 Facets of pedagogical knowledge (adopted from Morine-Dershimer and Kent (1999)

c. **Pedagogical content knowledge**

The third category of knowledge that is important to be developed in teacher education institutions is Pedagogical Content Knowledge (PCK). This knowledge was initially introduced by Shulman as a knowledge that "*goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching*" (Shulman, 1986, p. 9). This knowledge consists of the several ways to reduce the complexity of the subject matter to be taught in the classroom. PCK includes the knowledge about models, representations, analogies, media, experiments, and illustrations of a particular concept that help students learn the concept (Shulman, 1986; van Driel et al., 1998).

According to Morine-Dershimer and Kent (1999), six out of the seven basic knowledge categories of teaching mentioned by Shulman (1987) contribute to the pedagogical content knowledge as shown in Figure 2.2. However, many scholars emphasize that the mastery of content knowledge is a prerequisite for PCK in science education (Carlsen, 1999; De Jong et al., 2002; Gess-Newsome, 1999b; Morine-Dershimer & Kent, 1999; Shulman, 1986; van Driel et al., 1998). Further, in classroom practice, teachers should recognize the emerging conceptions in their students' understanding as well as their students' difficulties in learning. Harrison and Treagust (2000) have similarly emphasized, in the context of the use of analogy in the chemistry classroom, that teacher's analogy should be aware of students' responses to determine their subsequent steps to provide optimum opportunities for students' learning. In doing so, teachers will spontaneously use their knowledge about content, that had been mastered previously, to combine with other knowledge in their teaching practice in the classroom.

Pedagogical content knowledge will continuously improve during the teachers' activities. According to Magnusson et al. (1999) teacher education is expected to help pre-service teachers build a relationship between the content knowledge and pedagogical content knowledge. Another way to develop teachers' PCK, as suggested by van Driel et al. (1998), is through workshops that consist of activities to review students' school textbooks, planning and doing experiments, and also analysing students' alternative conceptions and students' possible responses to questions. However, in these activities, teachers need to involve their knowledge about content.

2.2.2 The essential role of teachers' content knowledge development in teacher education institutions

All factors that have been mentioned in Section 2.2.1 are essential for teachers' qualifications, but this study is only focused on the content knowledge domain. As stated in Chapter 1, a reason for placing more attention on content knowledge is because many issues were found during the process of teacher education, culminating in a lack of content knowledge understanding of pre-service teachers. Besides, there are also many research studies concerning students' difficulties in chemistry learning that have concluded with the need for improving teachers' pedagogical content knowledge, as well as teachers' content knowledge (De Jong et al., 2002; Gustafson et al., 2010). These issues show how teachers' content knowledge needs extra preparation in teacher education institutions.

The value of mastery of content knowledge has been clearly argued by Shulman (1986) before he proposed the notion of Pedagogical Content Knowledge one year later. His argument was in response to the statement by George Bernard Shaw, who mentioned that “Those who can do, those who cannot teach”. In his article, Shulman emphasized that demonstration of sufficient knowledge is a must to be a teacher.

> *The person who presumes to teach subject matter to children must demonstrate knowledge of that subject matter as a prerequisite to teaching. Although knowledge of the theories and methods of teaching is important, it plays a decidedly secondary role in the qualification of a teacher.* (Shulman, 1986, p. 5)

Later when he introduced Pedagogical Content Knowledge as knowledge that is underlying to the quality of teachers’ practice, Shulman (1987) pointed out that content knowledge becomes one of seven basic knowledge categories of teachers. In accordance with Shulman’s view, most of the scholars who are concerned about Pedagogical Content Knowledge consider content knowledge as fundamental knowledge. Teachers’ deep understanding about a certain concept will assist them to know the possibilities of students’ prior conceptions, which will later help determine strategies that they use in the classroom (De Jong et al., 2002). This view becomes an example of the relationship between Content Knowledge and Pedagogical Content Knowledge which also underlies the importance of teachers’ content knowledge development.

Thus, several questions emerge regarding when content knowledge should be part of in teachers’ professional development. Could content knowledge be developed during teaching practice as in-service teachers? Will training sessions or workshops in professional development for in-service teachers, especially designed to discuss the content of the subject matter, help them revise their misconceptions? Will discussions during teacher association meetings involve subject matter? These questions are reflections and critical thoughts about the teacher professional development programs. In fact, the program for in-service teachers mainly discusses the strategies of teaching and learning or about the curriculum and its implementation in the classroom. These professional development programs for in-service teachers rarely pay attention to the development of content knowledge. Consequently, the development of content knowledge must be optimized during pre-service teacher education.

Moreover, Lederman and Gess-Newsome (1999) have also found that the development of well-structured subject matter understanding during pre-service teacher programs is not as easy as developing conceptions and skills about pedagogy. The development of pedagogy would be feasible when pre-service teachers are provided with opportunities to reflect on their experiences of instruction with exposure to teaching excellence through direct classroom or video-taped observations, and classroom teaching practice (Corrigan, 2009; Lederman & Gess-Newsome, 1999). Meanwhile, in the process of constructing subject matter, pre-service teachers use a variety of their content understanding that they possess from previous learning experience. In this case, teacher education institutions have a significant challenge to facilitate pre-service teachers to re-develop or reconstruct their content knowledge from their previous understandings. Thus, they will graduate as pre-service teachers with comprehensive knowledge about subject matter that is integrated with pedagogical knowledge.

In other perspectives, there is also the relationship between the way pre-service teachers learn in teacher education institutions and students' achievement. Diez (2010) shows the flow of the impact of teacher education programs to students' learning as displayed in Figure 2.4.

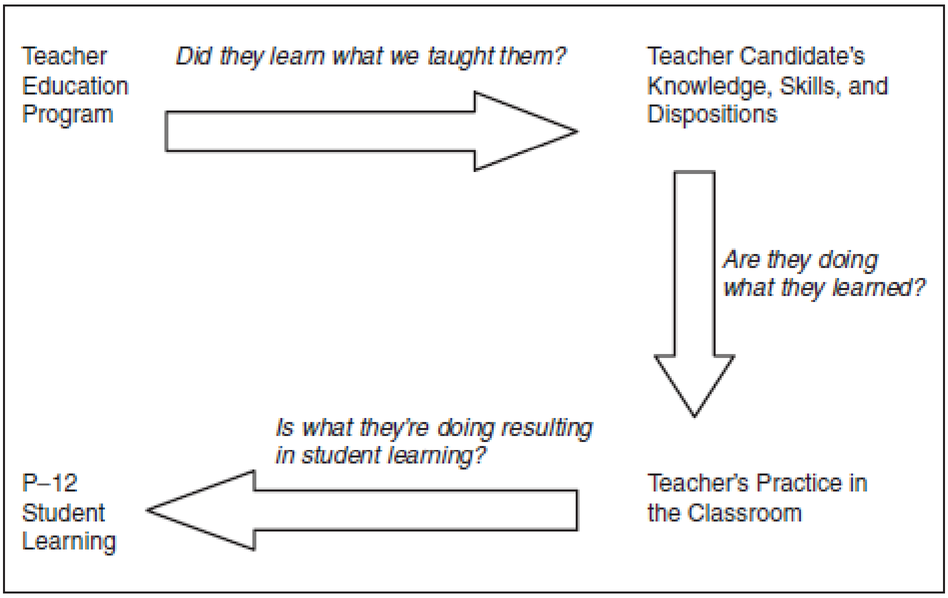


Figure 2.4 The flow of the impact of teacher education programs on students' learning (Adopted from Diez (2010))

Figure 2.4 clearly shows that the quality of pre-service teachers (teacher candidates) will depend on the program of teacher education. It is not only about what is taught in the program, but also how the program is conducted. Later on, this quality of the teacher candidate will be represented in their teaching practice in the classroom, which certainly is reflected in the process of students' learning. This simple and logical figure gives a vivid illustration of how improving the quality of teacher education programs can directly improve students' achievement.

2.2.3. Chemistry teacher education programs and some related issues

The initial process of teacher professional development occurs in teacher education programs. This stage of professional development plays a vital role. During the teacher preparation program, the learning experiences of pre-service teachers are important aspects.

"*from students to teachers, from a state of expertise as learners through a novitiate as teachers exposes and highlights the complex bodies of knowledge and skill needed to function effectively as a teacher*" (Shulman, 1987, p. 4).

Considering the important role of teacher education programs, there are two main issues related to teacher preparation, summarized from the literature. First, when pre-service teachers graduate from the university, they still have limited or fragmented understanding of content knowledge (Cheung, 2009; Gess-Newsome & Lederman, 1999; Haidar, 1997; Niess & Scholz, 1999). They also have limited knowledge about context issues that they need to relate to their teaching (Gess-Newsome & Lederman, 1999). In the case of chemistry education, it is noted that teachers still have a problem in understanding basic chemistry concepts (De Jong, 2002) especially in understanding the conservation of particles and the orderliness of particles (Gabel et al., 1987). Second, when graduating from university, pre-service teachers have limited tools to integrate their understanding about content knowledge, pedagogical knowledge and contextual issues and to translate them into instructional strategies (Gess-Newsome & Lederman, 1999; Sanford, 1988). These issues are still a problem for teacher education programs.

Fortunately, many studies in the literature that have concerns about the quality of teacher education give some suggestions to overcome the issues that have been mentioned previously. Regarding the issue about teachers' understanding, De Jong (2002) argues that preparing chemistry teachers with many chemistry content units is not merely to help them develop a good understanding about basic chemistry concepts. The program that is assumed to be more suitable for teaching careers is the one that prepares an integrated content generalist rather than a content specialist for a specific profession such as a chemist (Gess-Newsome & Lederman, 1999). Besides, Lin, Cheng, and Lawrenz (2000) also have suggested that teachers, either pre-service or in-service, need some opportunities to clarify their conceptual understandings. Thus, the units that are intended to develop pre-service teachers' conceptual understandings should facilitate them to challenge, evaluate and re-construct their own understandings, and also help them to rectify and organize the structure of those concepts to develop integrated knowledge (Haidar, 1997; Magnusson et al., 1999; Treagust & Chandrasegaran, 2007).

In order to enrich pre-service teachers with tools to transform their knowledge of teaching, De Jong (2002) suggested that teacher education and professional development should pay more attention to improving the subject matter knowledge of primary and secondary teachers. Besides, he also suggested developing teacher education programs aimed at PCK at the university level. More specifically, Magnusson et al. (1999) emphasized the need for teacher education programs to introduce the relationship between content knowledge and pedagogical content knowledge to pre-service teachers. The programs should also provide numerous opportunities for practice, so pre-service teachers will then become science teachers who have confidence to facilitate their students learning (Jeanpierre et al., 2005). Hence, teacher education programs should be concerned with improving the quality of their graduate pre-service teachers.

A key point in the effort to improve the quality of teacher education programs as mentioned by Diez (2010) is "*What we do as teacher educators is much more powerful than what we say to our students*" (p. 448). This means that teacher educators should do what they expect their pre-service teachers do in the class. This point is similar to the principle of "*How a teacher educator teaches is the message*" proposed by Russell

(1997, p. 46). Instead of giving an account to pre-service teachers about many teaching strategies, it would be better if teacher educators apply those teaching strategies when they teach their students. This approach is also an effective way to introduce various assessment strategies. Using various ways in assessing and evaluating pre-service teachers' achievement will be more effective in teaching about assessment rather than giving them an explanation.

Another key point is the provision of a learning environment that could empower pre-service teachers to be aware of their own learning (Haidar, 1997). Pre-service teachers need to realize their responsibilities in learning and its impact on their future profession. Hopefully, this self-awareness will raise their motivation so that their learning process becomes more effective.

2.3. Teacher education programs in Indonesia

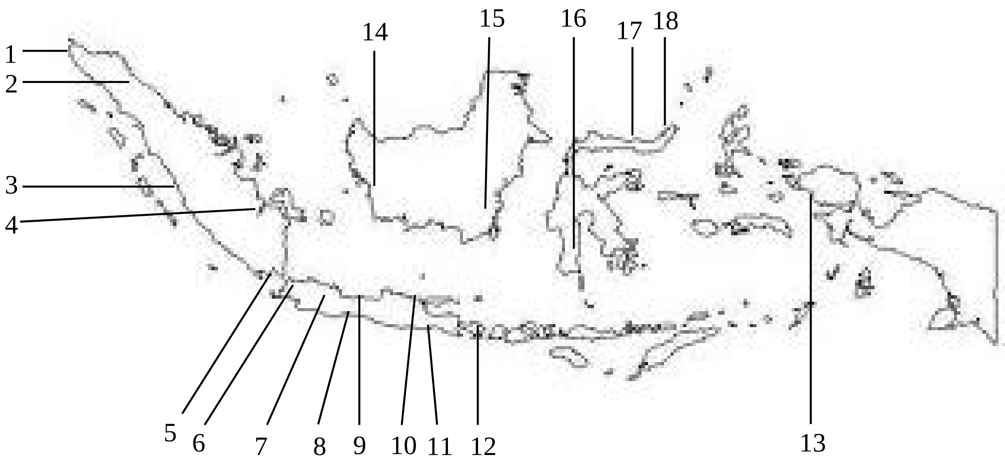
Following the elaboration about science teacher education and some important aspects that need to be considered, this section presents a description of teacher education programs in Indonesia. Since this research deals with pre-service chemistry teachers, the scope of the description is more about teacher preparation programs in chemistry education departments. However, this description begins with a historical chronology of the development of teacher preparation in Indonesia and how the programs have evolved. This chronology implies a major impact on recent teacher education initiatives.

2.3.1 A historical background of teacher education programs in Indonesia

Indonesia is a developing country which was colonized by the Netherlands for more than three centuries and obtained its independence in 1945. After achieving independence, the Indonesian government began to develop the country in every aspect, including education. To support national development after independence, the Indonesian government realized the demand for teacher preparation programs to fulfill the needs of teachers in terms of quality and quantity. In order to produce teachers with good qualifications, the government introduced several courses to prepare teachers in various subjects for every level of education. This initiative was conducted in the 1950s, including the program called B-I to prepare lower secondary school teachers and the B-II program to prepare secondary school teachers. In 1954, the Ministry of

Education and Culture published a regulation referred to as 382/Kab of 1954 for the establishment of PTPG (*Perguruan Tingi Pendidikan Guru*), a college for teacher education, in four different cities: Bandung, Malang, Batusangkar and Manado. Later, at the end of the 1950s, through the Decree of the Ministry of Education and Culture number 6-7 of 196, these B-I, B-II, and also PTPG programs were embedded in local universities in a faculty of education (FKIP – *Fakultas Keguruan dan Ilmu Pendidikan*). Hereinafter, in 1963 teacher education institutions emerged, namely IPG (*Institusi Pendidikan Guru*) in many places. This emergence of various programs of teacher education that spread to all regions was mainly intended to prepare and improve the quality of teacher education in Indonesia.

However, with the intention to standardize the quality of teachers as well as make the management of teacher education more efficient, the FKIP and IPG were integrated to become IKIP (*Institut Keguruan dan Ilmu Pendidikan*) (Institute of Education and Teachers' Training) in 1963 by Presidential Decree No. 1. IKIP became the only institution for teacher preparation that spread all over the nation, for example, Medan, Padang, Jakarta, Bandung, Semarang, Yogyakarta, Surabaya, Malang, Singaraja, Manado, Makassar, and Gorontalo.



1. Banda Aceh	7. Bandung	13. Jayapura
2. Medan	8. Yogyakarta	14. Palangkaraya
3. Padang	9. Semarang	15. Banjarmasin
4. Palembang	10. Surabaya	16. Makassar
5. Lampung	11. Malang	17. Manado
6. Jakarta	12. Singaraja (Bali)	18. Gorontalo

Figure 2.5 The location of teacher education centres in Indonesia in the 1980s

Moreover, considered as an outstanding institution, IKIP Bandung then had the duty to develop branches in four different cities such as Banda Aceh, Palembang, Palangkaraya and Banjarmasin. IKIP Jakarta also developed branches in Tanjung Karang and Lampung. These branches then merged with local universities and existed as a Faculty of Education, based on the policy released by the Education and Culture Department in 1970s-1980s. As can be seen in Figure 2.5, teacher education centres spread nation-wide. This distribution was expected to fulfil the demand for teachers in Indonesia.

With the intention to widen the scope of the mandate of teacher education institutions, six IKIPs were then converted to universities based on Presidential Decree Number 093 on 4th of August 1999. These six IKIPs are IKIP Padang that converted to be *Universitas Negeri Padang* (UNP), IKIP Jakarta converted to be *Universitas Negeri Jakarta* (UNJ), IKIP Yogyakarta became *Universitas Negeri Yogyakarta* (UNY), IKIP Surabaya became *Universitas Negeri Surabaya* (Unesa), IKIP Malang became *Universitas Negeri Malang* (UNM), and IKIP Makassar became *Universitas Negeri Makassar* (UNM). On 7th October 1999 another Presidential Decree number 124 was released which converted three IKIPs to be universities, namely IKIP Medan became *Universitas Negeri Medan* (UNM), IKIP Bandung became *Universitas Pendidikan Indonesia* (UPI) and IKIP Semarang was converted to be *Universitas Negeri Semarang* (Unnes). In the following years some other IKIPs also converted to universities, namely IKIP Manado became *Universitas Negeri Manado* (Unima) in the year 2000, IKIP Gorontalo became *Universitas Negeri Gorontalo* (UNG) in 2004, while IKIP Singaraja became *Universitas Pendidikan Ganesha* (Undiksha) in 2006. Converted to universities, these institutions received the mandate to conduct academic education courses, as well as professional education programs in various subject areas. These institutions also have a mandate to develop education, teaching and learning, and to educate academic and professional staff in the field of education.

2.3.2 Issues in teacher education programs in indonesia

A massive recruitment of teachers in Indonesia began in the 1970s. The Indonesian government through presidential instruction started a program to build an extensive number of primary schools in all districts (Raihani & Sumintono, 2010). To fulfil the need for teachers for this enormous new primary school initiative, recruitment was opened to everyone. Many people were interested to be a teacher because they could become government employees who will earn regular income and will be provided with a pension fund when they retired. Hence, the demand for teachers was fulfilled in terms of quantity, but not necessarily in quality.

Since then, the quality of teachers has become a major issue in Indonesian education. As the government has to pay a large number of teachers, a teacher's salary in Indonesia is very low. It is only one third compared to that in Malaysia and the Philipines, and only ½ compared to Thailand (Chang et al., 2014). The low salaries of teachers make this profession unpopular for the best students in high school who rarely choose teaching as their future profession. Most of higher achieving secondary school graduates choose other professions and pursue further studies in various fields except education. This situation relates to a statement by George Bernard Shaw who stated that "*He who can, does. He who cannot, teaches*" (Shulman, 1986, p. 1). Besides, many of those who already were teachers found other part-time jobs to augment their income, thus affecting their professionalism of being a teacher.

Regarding this issue, the Indonesian government then passed a new rule in 2003 that was followed by the Law for Teachers and Lecturers in 2005. According to this law, teachers and lecturers are required to be certified and those who are certified are eligible for extra incentives. This certification program is intended to increase the wealth as well as the quality of teachers. Thereafter, the certification program reported not only improved quality of teachers, it also raised the popularity of the profession among those who aspire to become teachers (Chang et al., 2014).

2.3.3 Chemistry teacher preparation programs in an Indonesian teacher education institution

In the Chemistry Education Department, where the author works, chemistry teachers are prepared through a 4-year Bachelor of Education program. Different from the system in several countries which conduct the training of pedagogy after the teacher candidates have achieved a certain level of content knowledge base, this teacher education institution in Indonesia introduces a concurrent curriculum that develops pedagogical knowledge and subject matter knowledge concurrently. So during eight semesters, the students will learn about the content of subjects and the pedagogy in teaching the subjects in each semester. There are also some units that are intended to develop pre-service teachers' pedagogical content knowledge.

According to the Decree of Academic Senator number 002/SenatAkd./UPI-SK/VIII/2010 on 2 August 2010, 144-150 credits are to be taken by pre-service teachers during their 4-year study as a standard number of credits for bachelor degree in all nations. These credits are distributed over eight semesters with the average credits in each semester being 18 credits representing 8-9 units. These credits are also covered in many units in the curriculum structure as shown in Figure 2.6.

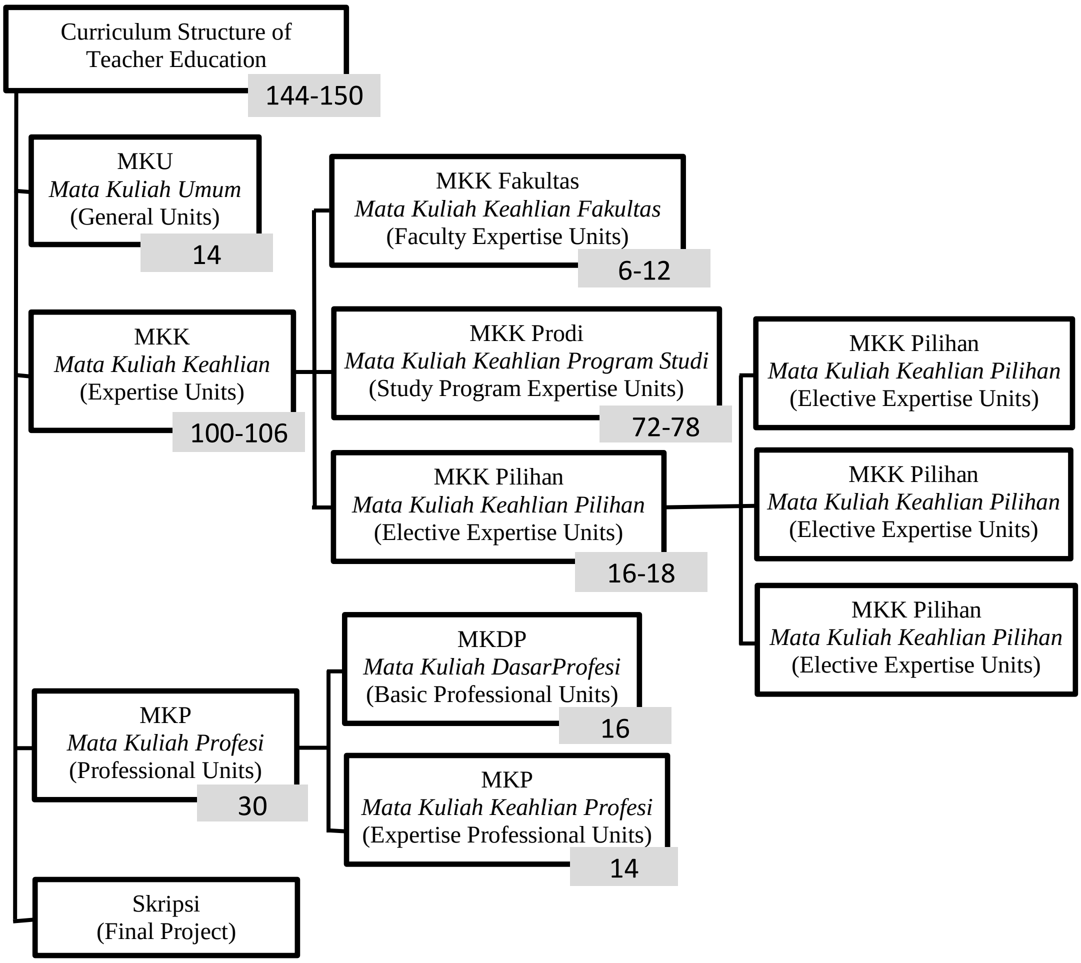


Figure 2.6. Curriculum structure for pre-service teachers education in one of Indonesian Teacher Education Institution

There are three main categories of units that have a specific aim. The first category is General Units (MKU – *Mata Kuliah Umum*) that are intended to develop pre-service teachers' personality as an individual within society. The second category is Expertise

Unit (MKK – *Mata Kuliah Keahlian*) which consist of faculty expertise units, study program expertise units, and elective units. The Expertise Units are mainly aimed to strengthen pre-service teachers' understanding about the subject matter or content knowledge. The third category is Professional Units (MKP – *Mata Kuliah Profesi*) that are deliberately intended to develop pre-service teachers' pedagogical knowledge and teaching skills.

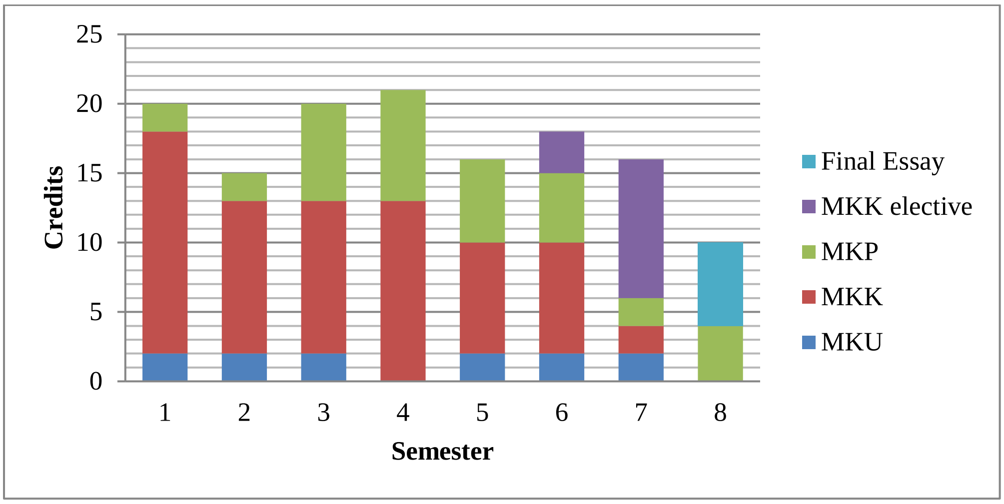


Figure 2.7. Unit distribution in each semester of 4-year bachelor program of teacher education

Note: MKU (General Units)
MKK (Expertise Units)
MKP (Professional Units)
MKK elective (Elective Expertise Unit)

Unit distribution for the 4-year program of teacher education is provided in Figure 2.7 which shows that, in each semester, some units are related to pedagogical knowledge and some units related to subject matter knowledge. In general, the graph shows that the proportion for the credits for content knowledge development (MKK) during the first six semesters exceeds the portion for pedagogical knowledge development (MKP). This fact indicates that the institution considers the importance of developing PST's conceptual understanding. This graph also show that in Semester 1 and 2, the portion of content knowledge (MKK) development is much larger than pedagogical knowledge (MKP). This pattern represents the consideration about the need of fundamental content understanding to support the development of pedagogical skills.

2.4 Curriculum evaluation framework for evaluating teacher preparation programs

Due to the intention to improve the quality of the programs in Indonesian teacher education institutions, evaluation of the existing programs is needed to identify the base condition for further development. Curriculum evaluation framework by Goodlad et al. (1979), which places greater focus on the practical situations rather than the theoretical aspects, is a potential framework for program evaluation purposes at the institution level of the education system.

The curriculum evaluation framework by Goodlad et al. (1979) was adopted by van den Akker (1998, p. 2) for "*analysing the roots and fruits of numerous curriculum efforts in science education.*" He believed that there were three main activities that were closely related to curriculum that exist in a cycle as shown in Figure 2.8(a).

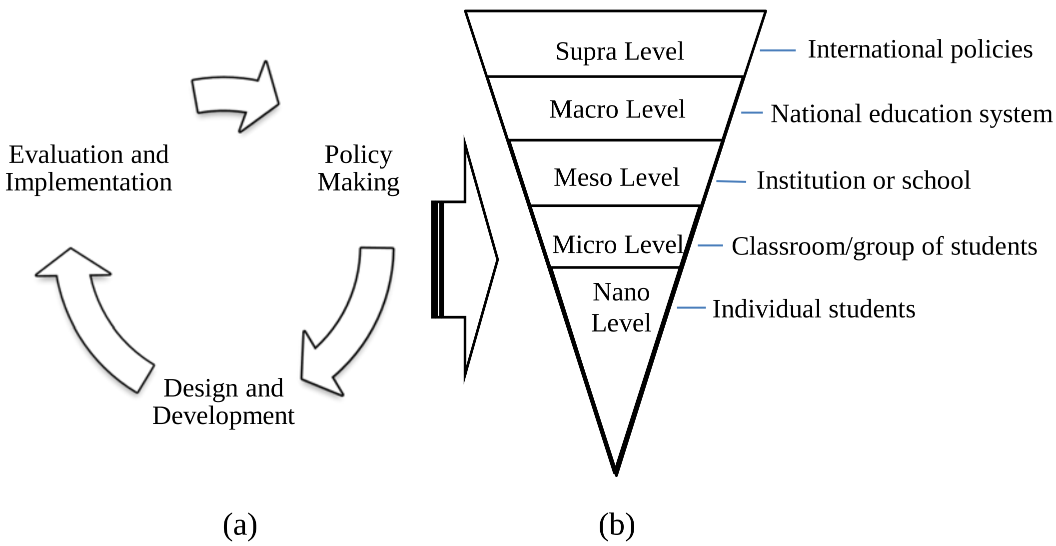


Figure 2.8 (a) The cycle of curriculum activities and (b) different levels of education organization (Interpreted from van den Akker (1998))

These activities are policy making, design and development, and also evaluation and implementation, which are applied in five different levels of an educational organization (supra, macro, meso, micro, and nano) (Leyendecker, Ottevanger, & van den Akker, 2007; van den Akker, 2003). The supra level is related to international policies of education, while the macro level means curriculum activities in the societal system at the level of the national government and the educational system. The scope of meso is associated with curricular activities at the level of the institutional or school, while the micro level is associated with curricular activities in the classrooms and groups of students. Lastly, the narrowest level (nano level) is related to the activities of individual students.

As mentioned earlier in a previous paragraph, the cycle (Figure 2.8a) can be conducted in five different levels of units (Figure 2.8b). Those units have their own policies that have been designed and developed as their programs. The implementation of the programs can be evaluated to find out the achievement of the aims that have been pursued by the policies. The result from the evaluation stage also provides information of the effectiveness of the programs that have been designed and developed. Further, the result of the first cycle generates considerations for the revision the previous program or the development of new program to be conducted in the next cycle to improve the achievement.

According to the diagram shown in Figure 2.8, this study involves the stage of the evaluation of the implementation of teacher preparation program at the meso level – the teacher education institution. In this study, the framework of curriculum inquiry is applied to analyse the policies that held by the institution and how these policies are embodied in their teacher education program. Through this framework, this study tries to evaluate the existing program in order to expose the potentials and the challenges as deliberation for the next cycle.

The curriculum evaluation framework involves five domains, namely the ideal curriculum, formal curriculum, perceived curriculum, operational curriculum, and experiential curriculum (Goodlad et al., 1979). The ideal curriculum is related to curricula which are determined by the government, while the formal curriculum is a school curriculum that comes from the ideal curriculum interpreted by teachers or educators. Besides a pre-designed curriculum, this framework also involves a domain of teachers' perceptions about that curriculum, i.e., the perceived curriculum. In regards to the focus on practical situations, this framework also involves the actual implementation or the operational curriculum as well as students' experiences as reflected by the experiential curriculum.

This five domains by Goodlad et al. (1979) is elaborated by van den Akker (1998) resulting in six domains with an additional domain about students' achievement (attained curriculum). These six domains are categorized in three levels in the following typology as shown in Table 2.1. These domains are expected to give a comprehensive analysis in evaluating any curriculum. Thus, if students' outcomes are not as expected, the explanation of this failure can be generated from the different domains involved in the curriculum inquiry framework rather than only criticizing the stakeholders as curriculum designers.

Table 2.1 van den Akker's typology of curriculum representation

INTENDED	*Ideal*	Vision (rationale or basic philosophy underlying a curriculum)
	Formal/Written	Intentions as specified in curriculum documents and/or materials
IMPLEMENTED	*Perceived*	Curriculum as interpreted by its users
	Operational	Actual perocess of teaching and learning
ATTAINED	*Experential*	Learning experiences as perceived by learners
	Learned	Resulting learning outcomes of learners

(Adopted from van den Akker (2003))

The curriculum evaluation framework by Goodlad et al. (1979) has also been adopted in some research studies. Treagust (1987) modified the framework to become four main domains: the intended curriculum, the implemented curriculum, the perceived curriculum and the achieved curriculum, with the perceived curriculum also including the perceptions of students. Friedel and Treagust (2005) also applied the revised version of the framework to investigate nursing students' perceptions of a bioscience course in nursing education. Moreover, the framework of curriculum evaluation was also used to evaluate the development of industrial chemistry learning materials in Israel (Hofstein & Kesner, 2006) and the implementation of context-based chemistry education in the United States (Schwartz, 2006). Recently, Severiens, Wolff, and van Herpen (2013) used the framework to find out the relevance between the intended curriculum and the implemented curriculum of teacher training colleges in The Netherlands.

2.5 Two-tier diagnostic tests

Since the scope of this study also covered the achieved curriculum, a two-tier diagnostic test was utilized as a tool to reveal pre-service teachers understanding about the Particulate Nature of Matter. The two-tier diagnostic test, which was initially developed by Tamir (1971) and expanded by Treagust (1986), is a diagnostic test that consists of choices of answers in the first tier and also options of reasons for the first tier answers in the second tier. This diagnostic test is not only easy to administer, but also provides an opportunity for the students to articulate their thoughts about the reason for their answer (Tamir, 1971). With this design of the item, the two-tier diagnostic test enabled teachers to identify students' alternative conceptions about a particular concept (Treagust, 1988).

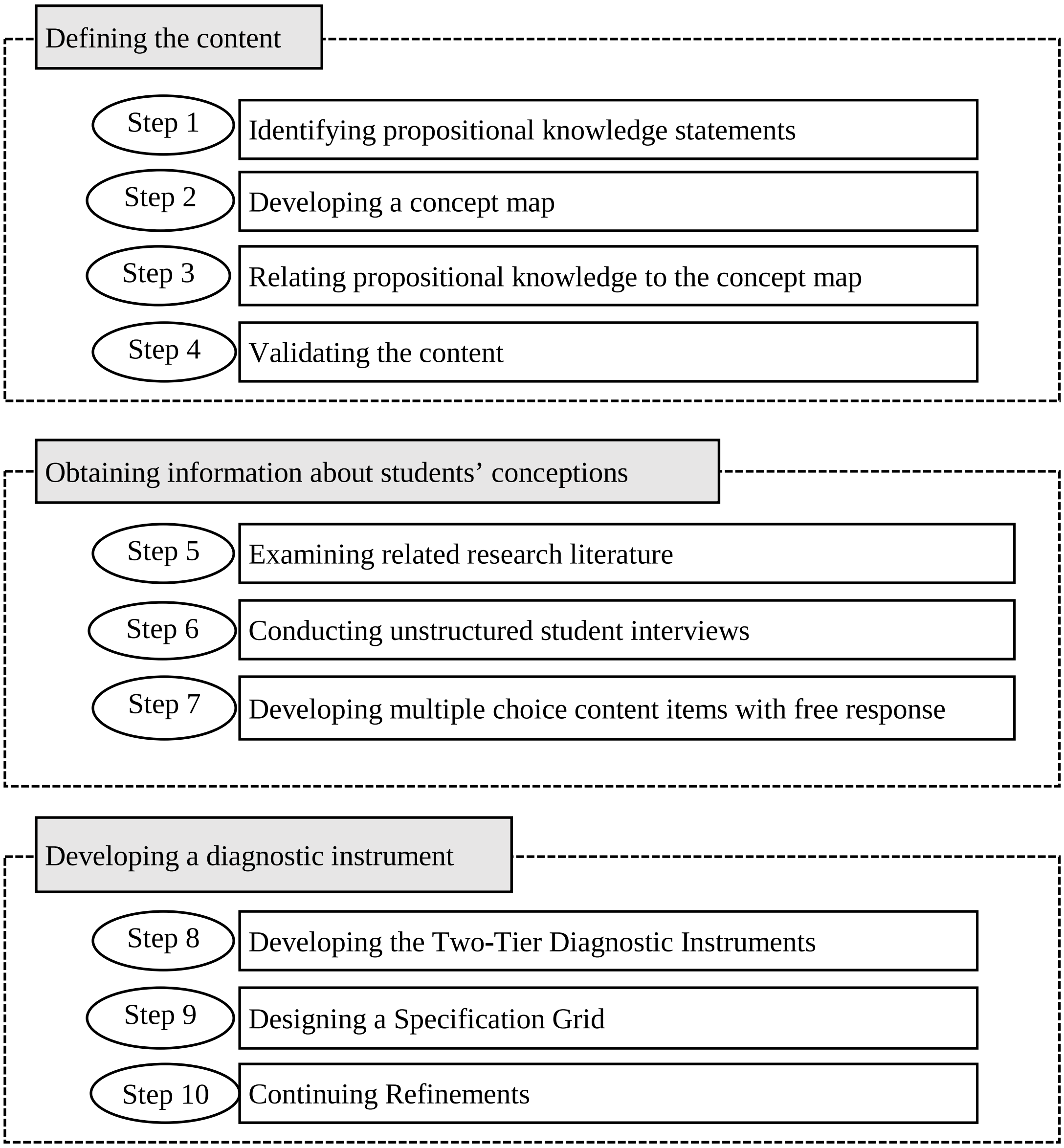


Figure 2.9 The development steps of two-tier diagnostic instruments (Treagust, 1988)

The development of the two-tier diagnostic instrument consists of ten steps (see Treagust, 1988) that are categorized into three main parts as shown in Figure 2.9. Based on those steps of the item development, the options of the answer are derived from students' conceptions. Some of the options also represent the common misconceptions among students. This is the reason why this instrument is useful to reveal students' understanding about a certain concept.

There are many other advantages of using the two-tier diagnostic test. First of all, this instrument is convenient to administer and quick to mark (Treagust & Chandrasegaran, 2007). This convenience is similar to the common multiple choice test, but this instrument is superior in terms of its potential to reveal students' thinking about the reasons for their answers. This instrument is also useful in helping teachers as well as students to achieve the expected learning outcomes (Treagust & Chandrasegaran, 2007). Moreover, this instrument has the advantage of helping the teacher in understanding how students consider a concept during their process of learning (Chiu, 2007).

2.6 The strategy of Predict-Observe-Explain (POE)

Abbreviated to POE, Predict-Observe-Explain is a strategy that was developed by Gunstone and White (1981) as a revised version of the Demonstrate-Observe-Explain (DOE) strategy proposed by Champagne, Klopfer, and Anderson (1980). Initially, POE and DOE were the strategies for testing students' understanding that consist of three stages. The first stage of prediction requires students to make a prediction of some events that is followed by the explanation of their prediction. Although this stage is not clearly stated in DOE, the prediction stage also was involved in several items. The second stage is observation that requires the students to observe the phenomena and write down the results of their observations. In the third stage, the students explain their results, especially by reconciling any discrepancy between what they have predicted and observed. The process of the explanation stage is usually conducted in a classroom discussion.

Based on the processes involved in this approach, the POE has the potential to support the process of learning in several ways. Firstly, the POE is assumed to be a tool to reveal students' understanding in a more direct way. The POE strategy can be helpful for the teacher to recognise students' logic and previous experiences about the concept that can be revealed during the learning process. Especially at the prediction stage, students try to involve their prior understanding and experiences to make their prediction and give a reason behind their thoughts. Based on the principle of constructivism, it is essential for teachers to recognise students' prior conceptions, beliefs, and knowledge to facilitate the development of students' understanding about a particular concept (Andersson, 1990; De Jong et al., 2002; Treagust & Chittleborough, 2001). Regards this point, the POE strategy has the potential to support the teacher to identify students' prior knowledge that is the starting point for providing an effective learning process to their students. In addition to this, the prediction stage also provides opportunities for the students to explicitly recognize their prior knowledge which is important as a starting point for conceptual change (Coştu, Ayas, & Niaz, 2010; Johnston & Scott, 1991).

Secondly, the process of observation and explanation illustrates the way students understand the concept (White & Gunstone, 1992) which would also assist teachers to develop their students' understanding. During the process of observation, students experience the phenomenon that often differs from their expectations. At this stage, students experience cognitive conflict that may lead them to the process of conceptual change. While the students try to assimilate their observations with their knowledge, the teacher can ask some guiding questions that lead the students to the expected understanding (Coştu et al., 2010). This teaching and learning process makes the POE strategy useful for the teacher to help students develop their understanding.

Thirdly, the stage of explanation in this strategy provides the opportunity for students to clarify their ideas in the discussion process; by reasoning, students have the opportunity to share and exchange ideas among them. The discussion is also important to help students recognize their own quality of understanding. It would then be easier for them to change their understanding if their previous understanding is not acceptable (Coştu et al., 2010; Garnett, Garnett, & Hackling, 1995).

Those activities involved in POE strategy clearly show that this teaching strategy is based on constructivist principles. The POE strategy has advantages to provide students with opportunities to reconstruct/restructure their conceptions based on demonstrations, experiencing cognitive conflict situations through discussions and by reflecting on their understandings.

Based on this advantage, POE is widely used as an alternative way to assess students' learning achievement. Shwartz, Dori, and Treagust (2013) suggested the use of POE as an assessment tool to evaluate students' achievement of learning objectives. Meanwhile, Sesen (2013) utilized POEs to assess Turkish pre-service teachers' understanding during the process of learning about surface tension, cohesion and adhesion. Besides, there are also many research studies that have used POEs to probe students' understanding about particle concepts (Chang et al., 2013; Kala et al., 2013; Kearney et al., 2001).

POE not only has potential as an assessment tool, but also has been widely used as a constructivist teaching and learning strategy in the science learning process. A research study about students' difficulty in science understanding involved applying the POE strategy in science learning. In a study by Boz (2006) involving students' misconceptions about the particulate nature of matter, he suggested the use of the POE strategy in developing basic chemistry understanding. This strategy was expected to provide an opportunity for students to construct their understanding or revise their previous understanding by observing phenomena that would contradict their initial ideas. The effectiveness of the POE as a strategy to enhance students' understanding had been shown by Treagust et al. (2014) to promote students' understanding about redox reactions. Not only for students, the POE also has been reported as an effective strategy in fostering pre-service teachers' understanding of basic chemistry concepts such as evaporation and solubility (Coştu et al., 2010; İpek, Kala, Yaman, & Ayas, 2010). The use of materials from everyday life in conducting POE experiments as well as emerging phenomena from daily life are the reasons for the use of POE to help students recognize the connection between science and real life (Treagust & Chittleborough, 2001). Furthermore, the POE strategy is also useful in fostering students' critical thinking and reasoning, and in improving their self-confidence and communication skills (Chang et al., 2013; Kearney, 2004; Treagust & Chittleborough, 2001). Considering the potentials of POE, Kibirige et al. (2014) even suggested the need to emphasize the use of POE in the curriculum.

However, there are several issues that must be considered in the implementation of POE (White & Gunstone, 1992).

(1) It is important to ensure that all students have written their prediction and their reasons before conducting the experiments and making observations. It is necessary to let the students commit to one decision and give them the opportunity to apply their knowledge in developing their reasoning. It is also important to teach the students to be confident with their own ideas.

(2) It is necessary to ensure that all students have written down their observations before the discussion in order to ascertain their actual thinking and to teach the students about honesty.

(3) When reconciling the discrepancy between their prediction and observation, students are often not confident with their own results. They often assume that either their prediction or the observation that they made was wrong. In this stage, the teacher needs to encourage the students to consider any possibilities that they can think of.

(4) In choosing the POE experiments, it is necessary to consider the situation that enables the students to make a prediction and provide the explanation based on their personal experience.

(5) It is important to use material that is familiar to the students.

(6) Although the teacher or researcher can provide several choices of prediction in students' worksheet, an open-ended format of the worksheet is better because it can accommodate a variety of responses from the students.

2.7 Summary of the chapter

In this chapter, it has been argued that the quality of teachers is essential to attain the goals of education. Among several factors that influence the quality of teachers, mastery of content knowledge plays a significant role in the process of teaching and learning. However, there were still several issues due to the lack of teachers' content knowledge. Research studies show that graduated teachers still have a lack of comprehensive content knowledge. Whereas, pre-service teacher education provides the greatest opportunity to develop the comprehensive content knowledge, most of the in-service teacher education focuses on the development of teachers' teaching skill. Thus, teacher education institutions have to design a 4-year program that can effectively develop comprehensive knowledge of content and teaching skills.

Besides elaborating on the importance of content knowledge development in teacher education institution, this chapter also described the framework of curriculum inquiry that was used in this study as an approach to evaluate the existing curriculum of the development of teachers' content knowledge in a teacher education institution in Indonesia. Using this framework, the research analysed how the program has been designed, how it is implemented, how it is perceived by the lecturers and the pre-service teachers, and what results were achieved.

Moreover, this chapter also presented a brief explanation about two-tier diagnostic test that was used as a tool in the evaluation stage about pre-service teachers' achievement. Items in the two-tier diagnostic instrument require pre-service teachers to provide explanations following their answer. Thus, this instrument could reveal pre-service teachers' misconceptions.

In response to overcome pre-service teachers' misconceptions found in the curriculum evaluation stage, this research is followed by an experimental stage, i.e. the implementation of predict-observe-explain (POE) strategy as an effort to enhance teacher's content knowledge. This chapter also describes the stages in POE and the advantage of POE that has the potential to help pre-service teachers develop better understanding of their conceptual knowledge.

CHAPTER 3
PARTICULATE NATURE OF MATTER

3.1 Introduction

Following the previous chapter that reviewed research about teacher knowledge and teacher education as an area of interest of this study, this chapter discusses the particulate nature of matter as the focus of the content in this study. This chapter, begins with the elaboration of concepts related to the Particulate Nature of Matter (PNM) (Section 3.2), presents an explanation why it is essential to have knowledge about the PNM when learning chemistry (Section 3.3), and explains how the PNM is supposed to be taught to the students (Section 3.4). This chapter ends with a brief description about Indonesian students' achievements of PNM (Section 3.5) followed by a summary of the chapter (Section 3.6).

3.2 Concepts related to particulate nature of matter

The PNM, which also is called the kinetic particle theory, covers several fundamental concepts in chemistry (Harrison & Treagust, 2003). Basically, the ideas of the PNM are related to descriptions about matter and its properties at its submicroscopic level. Harrison and Treagust (2003, p. 190) mentioned the important notion of the theory of the PNM is that "*all matter is composed of discrete, energetic particles that are separated by space*". The coverage of the subject particulate nature of matter, adopted from Othman, Treagust, and Chandrasegaran (2008), is shown by a concept map presented on Figure 3.1. Based on this concept map, the topic of PNM is divided into three main ideas as follows:

1. The three states of matter, the properties, and how they differ from each other (shaded in blue)
2. Different processes of physical change and how they differ from chemical reactions (shaded in red)
3. Components and properties of matter and how they differ in different compositions (shaded in green)

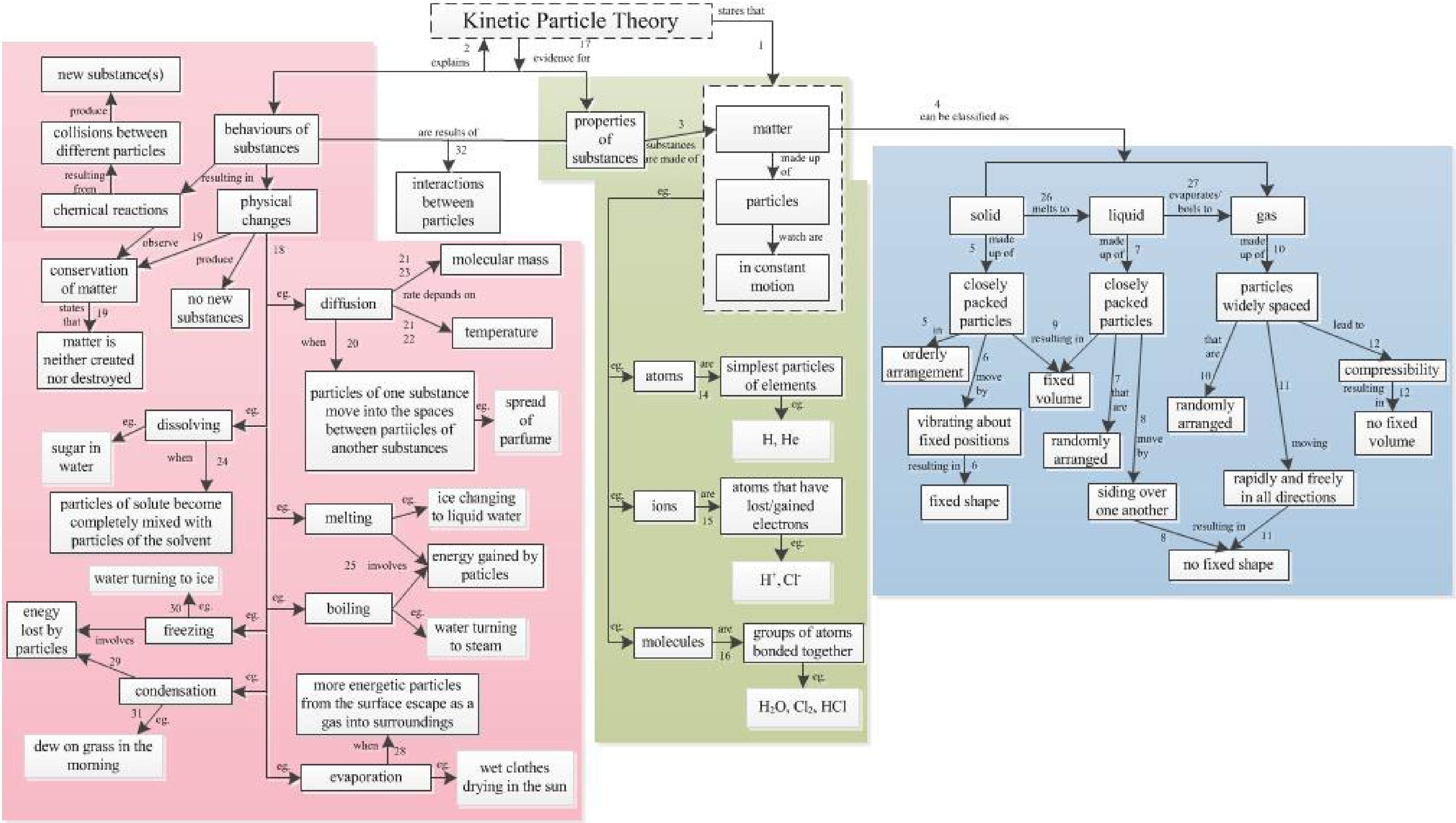


Figure 3.1 Concept map of PNM (adopted from Othman et al. (2008))

3.3 Essentials of the particulate nature of matter in chemistry learning

Presenting the explanation about matter including the types of matter, properties of matter, and changes of state, the PNM encapsulates the fundamental concepts in understanding chemistry. In other words, because chemistry is a branch of science that encompasses matter, having a good understanding of PNM is a prerequisite to develop further understanding of advanced concepts in chemistry (Nakhleh, 1994). Hence, appropriate learning about the PNM is essential to help students gain a strong basic knowledge of matter and its properties, which makes them ready to learn more advanced concepts in chemistry. Besides, a study of the PNM also helps students develop their ability to think about abstract ideas.

3.3.1 Learning about the particulate nature of matter to prepare basic knowledge in chemistry

Ausubel's theory about meaningful learning (Ausubel, 1968) and the constructivist paradigm of learning state that students' prior experience influences the quality of students' learning. In chemistry education, this principle underlines the need to develop a strong fundamental understanding about the PNM in order to prepare students for further learning about chemistry (Gabel, 1993; Garnett et al., 1995; Griffiths & Preston, 1992). Being the core of nearly all chemistry topics, the PNM is considered as a fundamental concept in chemistry (Treagust, 2002; Williamson & Abraham, 1995). For example, the theory about dissolving will be useful in learning stoichiometry, acids and bases, solubility and colligative properties. The concepts about states of matter and their changes are needed to help students develop a sound understanding of intermolecular forces, chemical equilibria, reaction kinetics, colligative properties and also help students to easily understand the properties of hydrocarbon compounds. Moreover, the concept of a gas becomes a fundamental study of thermodynamics while the concept of solid is basic for further study about material science. These examples show how the PNM becomes a foundation for students to learn chemistry.

Many research studies have illustrated the essentials of the PNM to comprehend other chemistry concepts. One study by Othman et al. (2008) examined the relationship between students' understanding about chemical bonding and the understanding of the

PNM. The results showed that to have a better understanding about chemical bonding students need to acquire a well-developed understanding of the PNM. Another study reported by Chiu (2007) diagnosed Taiwanese students’ conceptions of several concepts in chemistry including oxidation/reduction, acids and bases, chemical equilibrium, materials and organic compounds. The results showed that students’ knowledge was still underdeveloped, unstructured and incomplete. Further, Becker et al. (2013) demonstrated the influence of students’ understanding of the particulate nature of matter on their argumentation in learning about thermodynamics. In summary, the argument regarding the main reason for students’ lack of conceptual understanding in these chemistry concepts was students’ insufficient understanding about the basic concepts of chemistry which are related to the concepts of particles.

For chemistry pre-service teachers, a well-developed understanding about the particulate nature of matter is essential as a fundamental knowledge for further learning of advanced concepts in chemistry. Also, this knowledge is important for pre-service teachers’ practice which further influences their students’ conceptual understanding (Canpolat, Pinarbasi, & Sözbilir, 2006; Tan, 2005; Tan & Taber, 2009; Tekkaya et al., 2004). As has been described previously in section 2.2.1.3, teachers’ conceptual understanding affect the way they organize the lesson (De Jong et al., 2002; Kosnik & Beck, 2009; Yezierski & Herrington, 2011) and inappropriate teaching methods and material may result in school-made misconceptions (Barke, 2009). In short, to avoid students’ misconceptions, pre-service teachers need to be assisted to develop a comprehensive understanding of basic knowledge in chemistry.

3.3.2 Learning the particulate nature of matter stimulates and develops students’ spatial intellegence

Another aspect that makes the PNM essential in chemistry learning is the potencial to help students stimulate their ability in thinking at sub-microscopic level. A study by Abraham, Williamson, and Westbrook (1994) inferred that the lack of students’ understanding about the PNM led to their difficulty in building a visualization of the chemical phenomena of particulate behaviour. In turn, this brought the students into further difficulties in their learning process. It means that having a well-developed understanding of PNM is important to stimulate students to imagine and make visualizations of the matter in a submicroscopic manner.

The ability to think about chemistry concepts at the submicroscopic level may be related to the notion of spatial intelligence introduced by Gardner (1983) in his theory about multiple intelligence. Spatial intelligence is defined as an ability to perceive visual information and to transform information and recreate visual images from memory (Ferk, Vrtacnik, Blejec, & Gril, 2003). This definition explicitly states that spatial intelligence is very important to help students digest abstract ideas. Besides, it is also important to make sub-microscopic representation as one of the triplet representations in chemistry. Regarding its role in redeveloping visualisation from someone's memory, spatial intelligence is also important for the science teacher. With good spatial intelligence, teachers may be able to develop clear explanations about abstract concepts in a feasible manner for their students.

On the other hand, to be able to understand chemistry comprehensively, students need a deep understanding of three representations of chemistry, namely, the macroscopic, submicroscopic, and symbolic (Johnstone, 1993). Besides, it is important to understand the relationships between them (Gilbert & Treagust, 2009). Regarding different chemical representations, giving reinforcement to teaching about the PNM can trigger students to learn chemistry using the three dimensions of representations, thus promoting their achievement in chemistry learning (Gabel, 1993). For instance, when the topics of PNM are basically related to daily life phenomena, students can observe the phenomena at the macroscopic level. Further, use of symbols in explaining the phenomena also can develop students' ability to translate scientific symbolic language to everyday language. Moreover, since the explanations about the phenomena involved abstract concepts, imagination is used to create a depiction about the process of the phenomena in a submicroscopic manner. This process of learning shows how spatial intelligence can be stimulated and developed through learning about the PNM.

3.4 Research studies related to chemistry learning about the particulate nature of matter

Many research studies try to examine and elaborate students' experiences in learning about the particulate nature of matter. The interest to conduct research about PNM is based on a consideration that the particulate nature of matter is an important topic in chemistry learning. Besides, it is also driven by the fact that, although chemistry courses include the PNM to some degrees during instruction, existing courses have been shown to be insufficient to bring students to a high level of understanding (Gabel et al., 1987).

Continuous-discontinuous

In an investigation of 8th-grade students' understanding about several concepts of the PNM, Novick and Nussbaum (1978) found that students have difficulties in changing their perception from continuous to discontinuous properties of matter. Many research studies have shown that students often subscribe properties of matter at the macro level to the particles at the submicro level (Abraham et al., 1994; Andersson, 1990; Gabel et al., 1987; Othman et al., 2008; Özalp & Kahveci, 2015; Treagust & Chittleborough, 2001), and that students are more confident providing explanations at the macroscopic level of representation (Treagust & Chittleborough, 2001). This condition shows that students are confused about where the properties belong. They also have difficulties in applying their knowledge about the composition of materials in explaining the properties of matter (Nakhleh, Samarapungavan, & Saglam, 2005). These findings indicate that students do not have a clear understanding, or hold fragmented understanding, about how the properties are derived. Regarding continuous versus discontinuous matter, research has shown that it is difficult for students to believe the existence of empty space in matter. This aspect was demonstrated by Novick and Nussbaum (1981) with a range of participants from elementary school, junior high school, senior high school and university.

Another issue about the PNM is students' understanding about the states of matter. A study by Shepherd and Renner (1982) indicated that most of the 10^{th} and 12^{th}-grade students' explanations about the states of matter held partial understanding. A similar result also was found by Nakhleh and Samarapungavan (1999) who discovered the fact that elementary students experienced difficulties in providing an explanation about the states of matter. Students were confused with the macro and submicro properties of the states of matter because most of them tended to perceive matter as continuous.

Transformation process of matter

The next problem to investigate is the transformation process from one state to another. Several research studies found that students have difficulty developing their understanding about the processes of boiling, evaporation, condensation, and melting (Boz, 2006; Nakhleh & Samarapungavan, 1999; Nakhleh et al., 2005; Osborne & Cosgrove, 1983; Rahayu & Kita, 2010). Although these phenomena are very close to everyday life, these observed difficulties not only happen with school-age students but also with university students as well as pre-service teachers (Canpolat et al., 2006; Chang, 1999; Smith & Nakhleh, 2011). This lack of understanding might relate to the limitation in those contributing factors of interactions between particles (intermolecular forces) (Novick & Nussbaum, 1978) and the influence of temperature on those interactions. Besides, students' limited understanding about water vapor (Chang, 1999) and the conservation of matter during phase changes (Gabel et al., 1987; Othman et al., 2008) also may contribute to students' difficulties in comprehending the concept of phase change.

Molecular interaction

Insufficient understanding about how molecules interact with each other in a system also influences students' understanding about the process of dissolving (Nakhleh & Samarapungavan, 1999; Nakhleh et al., 2005; Smith & Nakhleh, 2011). Similarly, Valanides (2000) also reported pre-service teachers' difficulties in understanding dissolving process. Whereas, strong understanding of solution system is desired to explain phenomena in more advanced chemistry topics that mostly deal with solutions.

Gas Law

Likewise, the basic concept of gas also is a problem for students. Using a two-tier diagnostic instrument, Liang, Chou, and Chiu (2011) found that 8^{th} and 9^{th} grade students had difficulties in understanding the sub-microscopic image of gaseous particles. This research concluded that students do not readily consider pressure as a variable in the concept of gas. This finding is similar to previous research by Lin et al. (2000) which revealed that 11^{th}-grade students, as well as their teachers, had difficulties in developing a sound understanding about the relationship between variables in gases (pressure, volume, temperature, number of molecules), such as applying Boyle's Law and Charles' Law. The reason for this finding is that the concepts of gases and their properties are usually presented in an algorithmic way rather than as qualitative conceptual understanding. A study by Bak Kibar, Yaman, and Ayas (2013) also confirmed the tendency of pre-service teachers to use algorithms in explaining the ideal gas system without having comprehensive understanding of the correlations of the involved variables. Besides, Lin et al. (2000) also argued that many students used their intuitions instead of scientific conceptions to describe the movement of molecules at different temperatures.

In accordance with previous research studies, Treagust et al. (2010) examined students' understanding about the PNM and identified three conceptual categories of students' difficulties in learning this topic. The three conceptual categories were (1) the intermolecular spacing in solids, liquids, and gases, (2) the changes of states and intermolecular forces, and (3) diffusion in liquids and gases. Using 11 items of a two-tier diagnostic test, this study found nine possible alternative conceptions held by 148 high school students from four different countries with regard to the PNM. This result also showed the inconsistency of students' understanding about the related concepts in those three conceptual categories which are similar to the three main ideas of the PNM summarized by Novick and Nussbaum (1978): vacuum concept (space between particles), intrinsic motion, and interaction between particles.

3.5 Indonesian students' understanding about the particulate nature of matter

Regarding the issue of students' understanding about the particulate nature of matter, this section attempts to provide information about the depiction of the latest general state of Indonesian students' understanding about the PNM. The information is gathered from the TIMSS's (Trends in Mathematics and Science Study) results of the years 2007 and 2011. The reason for using the data from TIMSS is because this test was administered randomly to students in grade 8 in Indonesia, thus the result is expected to represent the average condition of students' achievement in Indonesia. The TIMSS was a pencil-and-paper test containing multiple-choice items and constructed-response questions.

The data used in this review are derived from the Item Almanac of TIMSS, which can be downloaded from the TIMSS website. The Item Almanac is one of the TIMSS reports that provide information about students' achievement in each item. Table 3.1 shows the test items of TIMSS 2007 and 2011 related to the particulate nature of matter.

Table 3.1 The item of TIMSS 2007 and 2011 related to the PNM. (Adopted from TIMSS Item Almanac 2007 and 2011)

Item Code	Label of Item	2007	2011
S032565	Density of salt solution	√	-
S032403	Liquid compared to a gas	√	-
S042061	Arrangement of particles in metal	√	-
S042294	Densities of liquids and disk	√	-
S022054	Expansion in thermometer	√	-
S022181	Sugar dissolving in water	√	-
S032156	Solubility/temperature graph	√	√
S032158	Molecules of gas when heated	√	√
S042404	Liquid on outside the pitcher	√	√
S042272	Molecules of liquid when it cools	√	√
S032502	Diagram representing water molecules	√	√
S042173A	Change-stay the same (density)	√	√
S042173B	Change-stay the same (mass)	√	√
S042173C	Change-stay the same (volume)	√	√
S042173D	Change-stay the same (molecule size)	√	√
S042173E	Change-stay the same (molecule speed)	√	√
S032272	Water level in heated container	√	√

Based on the data of students' achievement from Item Almanac of TIMSS, the graphs in Figures 3.2 and 3.3 show the comparison of achievement of Indonesian students with those of other neighbouring countries such as Malaysia, Singapore, Thailand, and Australia from the year 2007 and 2011, respectively. These graphs also show the average achievement of students from all countries involved in TIMSS in 2007 and 2011.

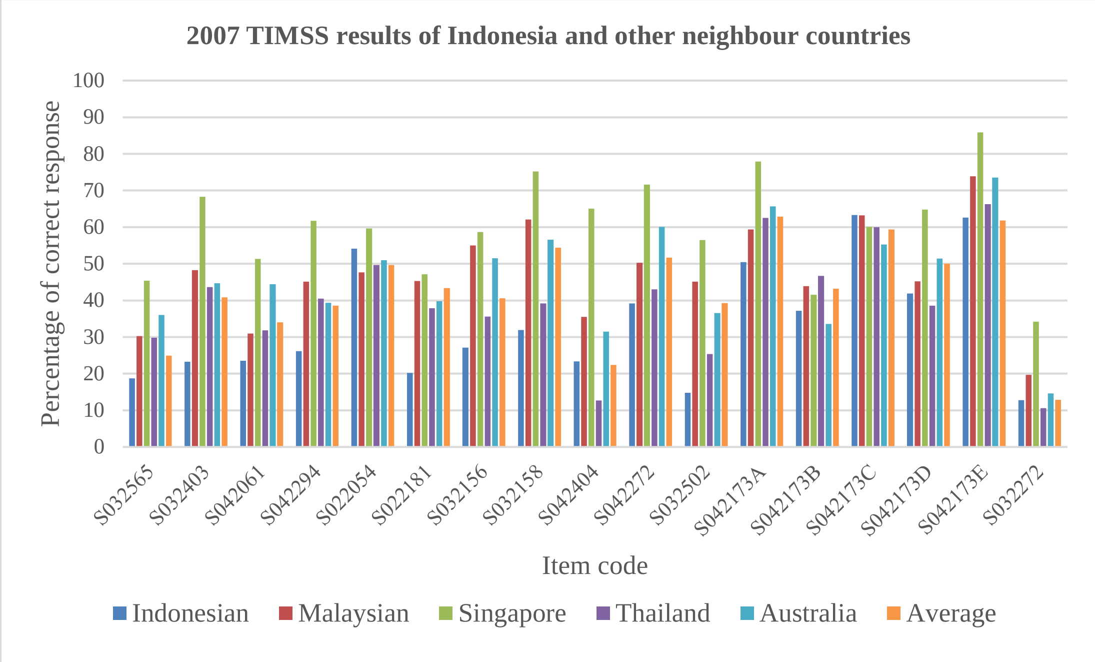


Figure 3.2 The achievement of Indonesian students compare to the students from other neighbour countries on TIMMS 2007.

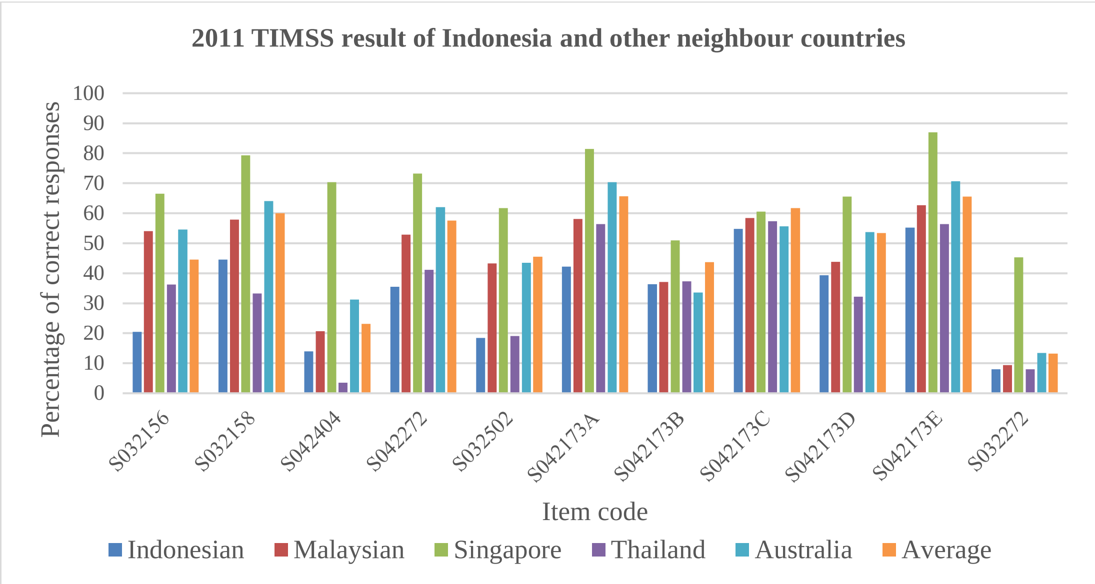


Figure 3.3 The achievement of Indonesian students compare to the students from other neighbour countries on TIMMS 2011.

The results in Figures 3.2 and 3.3 show that almost all of the scores for Indonesian students are below the average TIMSS score. The graphs also show that Indonesian students' achievement was below other neighbouring countries. These results indicate that Indonesian students' understanding of the concepts related to the PNM need to be improved because it will influence their further learning of chemistry (see Section 3.3.1).

The improvement of Indonesian students' understanding about fundamental concepts, such as particulate nature of matter, can be supported by teachers' knowledge about the concepts as well as the way to teach the concepts. Consequently, Indonesian teachers should be prepared with a strong understanding of fundamental knowledge about the particulate nature of matter that will support the improvement of their teaching quality. Hence, the TIMSS results about Indonesian students' achievement as provided above present a challenge for Indonesian teacher education institutions to prepare science teachers with a good understanding of these science concepts.

3.6 In what way (when and how) should students learn about the particulate nature of matter?

Dealing with a common concept which is present in daily life does not make the PNM an easy topic for students to learn. Based on the examples that are described above, students of different ages still experience difficulties in learning chemistry concepts related to the PNM. These facts become a challenge for science educators to create effective ways to teach meaningfully the subject of the PNM to students. The goal is for students to have a good understanding and long term retention of the basic concepts. Johnson and Papageorgiou (2010) emphasized that the way that the PNM is introduced to the students does become a limiting factor for them to develop their understanding.

As described earlier, because the PNM provides basic concepts for further learning of chemistry, an understanding of PNM is required before students learn other chemistry topics. The topics of the PNM consists mostly of abstract concepts that are needed for students to use their imagination to visualize those concepts.

Based on Piaget's theory about cognitive development, students are able to learn abstract concepts when they are at the stage of formal operational development (age 11 to approximately 15-20 years) as shown in Figure 3.4 taken from Nurrenbern (2001). This means that lower secondary school students (age 13-15 years) are intellectually ready to learn about an abstract concept such as the PNM. There is evidence that 5th grade students (age 11-12 years) are able to develop their understanding of particles (Gustafson et al., 2010) and 7th grade students had internalized the primary aspects of the model in explaining the concept of gas. Hence, the content about the PNM commonly exists in the curriculum for lower secondary school students in order to develop well-structured knowledge.

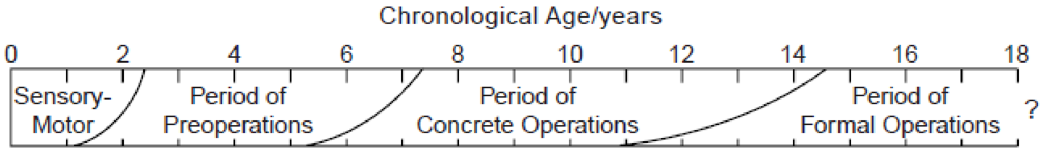


Figure 3.4 Qualitative representation of Piagetian cognitive developmental periods (taken from Nurrenbern (2001))

However, challenges emerge about the time allocated for teaching the PNM and for other topics related to the PNM in the school curriculum (Boz, 2006). As mentioned previously, basic concepts about the PNM are taught to lower secondary school students while further chemistry concepts such as chemical bonding are taught in upper secondary school. However, research by Boz (2006) has found that Turkish students (13, 15 and 17 years old) have difficulties in linking the concept of intermolecular forces with the process of melting and boiling. It was hypothesized that this condition might be due to different times that these topics were taught at school. The topic of melting and boiling is taught in lower secondary school while the topic of intermolecular forces is taught in upper secondary school. This difference of time may become a reason for students' difficulties to make a relationship between an advanced topic of chemistry with a fundamental one, as they might have forgotten the basic concepts. Students' limited understanding about the concepts related to PNM is also evidenced by the way this concept was taught in early stages of schooling when often, only the superficial part of the concept is discussed (Ayas, Ozmen, & Calik, 2010).

A study by Bak Kibar et al. (2013) also found similar problems in the pre-service teachers education. Pre-service teachers often forget the basic concept of a gas system although they had learned about it in high school, in the first year introductory chemistry unit, and in the thermodynamic unit. This fact confirmed that constructing a sound understanding of the PNM is important and challenging.

Points to consider in teaching about PNM related topics

Following the issues about students' difficulties in understanding, as well as the last problem mentioned about the different time of teaching concepts related to the PNM, many strategies have been suggested to overcome these problems. These strategies are organised within five key groupings: (1) Prior knowledge, (2) Visualisation of PNM, (3) Terminology used in PNM, (4) Teaching strategies, and (5) Building links with previous PNM concepts. These five points are elaborated in the following paragraphs.

Prior knowledge

The first suggestion for teachers to try to find out students' prior knowledge, ideas, or experiences about the concepts and phenomena related to the PNM (Duit & Treagust, 2003; Liang et al., 2011; Osborne & Cosgrove, 1983; Treagust & Chittleborough, 2001). Based on students' prior knowledge, teachers then design instructional strategies to support students to rethink and elaborate their ideas (Liang et al., 2011; Osborne & Cosgrove, 1983; Treagust, 2002).

Visualization

Developing students' understanding about the atomic model and providing them with some phenomena can help them develop appropriate interpretation about discrete particles (Albanese & Vicentini, 1997). It is also important to help students think about matter submicroscopically and clearly differentiate macroscopic properties and behaviour from those at the submicroscopic level (Boz, 2006; Nakhleh & Samarapungavan, 1999; Rahayu & Kita, 2010). This approach will be useful in stimulating students to think with submicroscopic representations so that they would be accustomed to make links between what they observe (macroscopic representation), how they explain their observation in symbols (symbolic representation) and how they describe the processes in a particulate way (submicroscopic representation). However, explaining three different representations may not be clear enough to prevent the students from acquiring further misconceptions. Thus, it is important to be clear about the process of explanation during the transition between one representation to another (Othman et al., 2008; Treagust & Chittleborough, 2001). Further, this interconnecting explanation of the concept should be clearly stated in the curriculum (Boz, 2006).

Terminology

Teachers should be aware of the abstract terminology that they use in their explanations especially at the submicroscopic level. Terminology or words used in the explanation should be clear and consistent to avoid misinterpretations and misuse (Treagust & Chittleborough, 2001). Teachers also should be aware of the technical words from their vernacular language which might represent a different meaning from scientific concepts (Rahayu & Kita, 2010).

Teaching Strategies

Teachers should try different teaching strategies such as inquiry, problem solving, laboratory work, or cooperative learning to create various learning experiences for the students (Treagust & Chittleborough, 2001). Karacop and Doymus (2013) have demonstrated the positive impact of jigsaw cooperative learning in students' understanding of chemical bonding and particulate nature of matter. Adadan et al. (2009) have also reported the impact of multiple representation teaching strategy on stimulating students' understanding of the PNM. Besides, teachers are also suggested to utilize the benefits of analogy (Harrison & Treagust, 2000; Treagust, Harrison, & Venville, 1998) and multimedia technology to provide a better explanation to the students. Instruction supported by the use of technology and multimedia has potential to provide conceptual explanations in support of molecular representations in either static or dynamic visualizations. This instruction could help students develop a better understanding at the submicroscopic level (Akaygun & Jones, 2013; Ardac & Akaygun, 2004, 2005; Williamson & Abraham, 1995). Moreover, Aktas and Bılgın (2014) reported the benefit of using the 4MAT (4 different application techniques to attend to students' different learning style) in teaching PNM to enhance students' learning motivation and to facilitate different learning styles. All in all, the important point that should be represented by those teaching strategies is the opportunity to facilitate students' conceptual change (Valanides, 2000).

Building links

Since the topic of the PNM involves many concepts and those concepts might be taught at different times to different levels of students, the structure of a spiral curriculum may be an advantage (Taber, 1996). Students would learn the basic concepts of the

PNM in a set time, and learn an advanced concept at another time. However, teachers should clearly emphasize the correlation of a new concept with the PNM (Othman et al., 2008).

All strategies that have been mentioned above show that developing students' basic knowledge needs extra effort and extra time to prepare students with a strong foundation to learn further concepts as well as to avoid the emergence of alternative conceptions. This attempt is valuable because preparing students with a well-structured basic knowledge will help teachers teach further knowledge effectively (Taber, 1996). Moreover, based on this principle, it is essential to develop students' qualitative understanding prior to learning the concepts quantitatively (Lin et al., 2000).

3.7 In-service teachers' and pre-service teachers' experience with the particulate nature of matter

As mentioned in the previous section of this chapter, the PNM is not only a problem for the school-age students but is also an obstruction to learning chemistry for pre-service teachers as well as in-service teachers. Çalik and Ayas (2005) reported that the final-year pre-service teachers in Turkey demonstrated limited understanding about the concept of dissolution processes, chemical change and gases. In similar research, other in-service chemistry teachers also have been found to have a problem in understanding the concept about condensation and boiling points (Chang, 1999), vaporization and vapour pressure (Canpolat et al., 2006), transformation of matter during dissolving (Valanides, 2000), and the concept about conservation of matter (Haidar, 1997). Furthermore, research in Taiwan also revealed chemistry teachers' difficulties in applying their knowledge about Boyle's Law and Charles' Law (Lin et al., 2000).

There are several reasons for these observations. Pre-service teachers' lack of understanding about the PNM is because they have not developed an appropriate and meaningful conceptual understanding in high school (Canpolat et al., 2006; Haidar, 1997). The students mostly depended on mere memorization of the concept statements (Ayas et al., 2010; Haidar, 1997). Thus, the concepts were stored in a fragmented manner without internalization in their knowledge structures. Regarding the idea about vaporization, Canpolat et al. (2006) argued that prospective teachers' difficulties might be attributed to the inadequate development of conceptual knowledge about vaporization in a tertiary institution and insufficient explanation of that concept during their learning.

In response to this issue, Chang (1999) suggested that teacher education should focus on developing fundamental concepts which may seem simple and easy, but teacher educators often overestimate students' understanding. It is recommended that teacher educators provide opportunities for preservice teachers to challenge and clarify their understandings (Çalik & Ayas, 2005; Lin et al., 2000). This can be facilitated in a practice of conceptual change based instruction (Valanides, 2000). Developing good-understanding about basic concepts will help pre-service teachers transform their knowledge to teaching strategies that are feasible for their students.

3.8 Summary of the chapter

Understanding the PNM is essential in learning chemistry because it provides a basic fundamental concept for other concepts. It also encourages students to think from a chemistry point of view by using the three representations: macroscopic, submicroscopic, and symbolic representation. On the contrary, most of the concepts and ideas related to the PNM are simple and familiar in everyday life. This condition makes most teachers underestimate those concepts and assume that their students have acquired sufficient understanding about them. This is the main problem about the topic of the particulate nature of matter.

Many research studies found evidence that show students' difficulties in learning about the particulate nature of matter. Several concepts that often become an issue for the students to understand PNM, because they are not well understood, are: (1) intermolecular spacing in matter, (2) changes of states and intermolecular forces, and (3) diffusion in liquids and gases. In response to those problems, some strategies also have been suggested in various scholarly reports which are summarized as five main points: (1) Prior knowledge, (2) Visualisation of PNM, (3) Terminology used in PNM, (4) Teaching strategies, and (5) Building links with the previous PNM concepts.

In Indonesia, students' comprehension about the PNM also needs further improvement. This issue also implies the need for the enhancement of science teacher quality in Indonesian teacher education institutions, especially on their understanding about the concepts related to the PNM. Previous research studies have suggested that the development of pre-service teachers' understanding about the PNM will be beneficial to minimize students' misconceptions. These facts provide recommendations for teachers education institutions and teacher educators in Indonesia to ensure the development of science teachers' basic knowledge.

CHAPTER 4

RESEARCH METHODS

4 .1 Introduction

The previous two chapters provided reviews of the literature that formed the basis of this study. The review highlighted the concerns about the development of the content knowledge of preservice teachers. With regards to this concern, the research examines the recent practice of content knowledge development in a teacher education institution in Indonesia. Besides, this research also discusses the implementation of a strategy that has potential for impr oving chemistry teacher education in Indonesia.

This chapter explains in three main sections the methods used in the present study. The first section is the introduction followed by the second section about the development of the research design that is discussed in six subsections, namely (1) the theoretical framework, (2) the stages of the research, (3) selection of participants, (4) data sources, (5) data analysis procedures, and (6) ethical considerations. The last section is the summary of the chapter.

4.2 Research design

This research is designed in two main parts. The first part is the evaluation of the current practice of the existing curriculum in a university in Indonesia. The curriculum evaluation attempts to overcome the issues regarding the quality of preservice teachers' content knowledge in one area of chemistry. The second part is the intervention involving the implementation of the Predict-Observe-Explain (POE) strategy in chemistry teacher education. This intervention involves the implementation of the POE strategy to help preservice chemistry teachers develop better understanding about the Particulate Nature of Matter (PNM).

Basically, this research is a case study (Creswell, 2012) that focuses on the activities involving individuals and groups. According to Yin (2009), the case study tries to explore the actual case and, in this present study, the case is about preservice chemistry teacher preparation in teacher education in a university in Indonesia. This research could be categorized as an instrumental case study (Creswell, 2012, p. 446) that is designed to provide an insight about a particular issue from different points of view. Furthermore, this study attempts to gather the data that might be collated and interpreted to describe (Merriam, 1988) the content knowledge development of a group of chemistry preservice teachers in Indonesia.

4.2.1 Theoretical framework

As mentioned previously, this research is intended to obtain a depiction about the recent praxis of the development of preservice teachers' content knowledge in a teacher education institution. To achieve this aim, this research is conducted under the framework of curriculum evaluation proposed by Treagust (1987) that has been modified from Goodlad et al. (1979). Within this framework, the curriculum will be evaluated in several aspects including the vision and intention of the curriculum as mentioned in the curriculum documents (*intended curriculum*), the users' interpretation and perception about the curriculum (*perceived curriculum*), the actual process of curriculum implementation (*implemented curriculum*), and the outcomes of the curriculum (*achieved curriculum*) as elaborated in Section 2.4. These aspects of curriculum evaluation provide different points of view about preservice teachers' content knowledge development. Using this framework, this research explores the development of chemistry preservice teachers' knowledge about basic chemistry concepts involving the particulate nature of matter.

4.2.2 The stages of research

In general, this research is divided into three stages as shown in Figure 1.1. Stage 1 consists of preliminary observation and pilot testing of the instrument. Stage 2 consists of further observations and interviews. Stage 3 involves the implementation of a POE strategy to overcome the problems that have been found in Stages 1 and 2.

The first stage consists of observations of classroom practice and a pilot test of the instrument in July and August after the end of the 2011/2012 academic year (during a condensed study period similar to a summer course). In this stage, the observations were focused on the implementation of the curriculum related to the development of chemistry preservice teachers' basic chemistry concepts. Observations were made as the course was conducted with the researcher playing the role of participant observer

(Creswell, 2012; Merriam, 2009) to elucidate the development of the chemistry preservice teachers' content knowledge without being involved in the lesson. At the end of this period, a pilot test was conducted in which the Particle Theory Diagnostic Test (PTDI) was administered. This pilot test involved 32 volunteers out of 77 students in the LS-Chem unit.

The second stage consisted of observations of the course conducted in the regular Semester 1 of the 2012/2013 academic year to obtain additional data about the implemented curriculum. Several interviews were conducted with lecturers, the head of Department, and preservice teachers at this stage with the purpose of elucidating their perceptions about the implemented curriculum. This stage ended with the administration of the PTDI as a pre-test and interviews with students to obtain information about the achieved curriculum.

The third stage was conducted during the last four weeks of the first semester of the 2012/2013 academic year with interventions of the learning process using the POE strategy. Four themes of POE strategy were implemented at this stage, such as, Solid, liquid, and gases in syringes; Gas laws; Liquid and gas diffusion; and Phase change (further elaborated in Section 7.3). These POE activities were developed following pre-service teachers' difficulties found during the observation that were also later confirmed by the pre-test results at the second stage. The pilot testing also has been done before the POE material was implemented. After instruction using the POE strategy the PTDI was administered as a post-test to obtain information about how the intervention influenced the preservice teachers' understanding. This stage also involved interviews with the students to obtain further explanations about their answers to the post-test as well as feedback about the POE learning strategy that was used in the intervention.

4.2.3 Selection of participants

This research used the purposeful sampling technique (Creswell, 2012) to intentionally select certain participants. The participants in this research were the preservice teachers who were enrolled in the unit of *Teaching and Learning Chemistry for Lower Secondary School* (LS-Chem). This unit was chosen because it covered the basic chemistry topics within a semester. As has been explained previously in Chapter 3, students' understanding of basic chemistry concepts will influence their understanding about other topics in chemistry. Thus, this unit is essential for chemistry preservice teachers. However, the status of this unit is as an elective unit which is available during the regular semester as well as during the condensed study period between two academic years. Although this unit is an elective unit, most of the chemistry preservice teachers are enrolled in this unit, with the majority of them taking this unit in the condensed semester between two academic years.

The first stage of the study involved 77 preservice teachers who took the LS-Chem unit in the condensed semester of the 2012 academic year. Of these students, 75 students were at the end of their 2nd year, one student from the 3rd year and one student in the fourth year. This course was taught by two lecturers, LA and LC, who had 24 and 27 years of experience, respectively. These two teacher educators were also involved as participants in the first stage of this study.

Participants in the second and third stages consisted of two lecturers and 12 preservice teachers. One lecturer was involved in the previous stage (LC), while the other lecturer with 22 years of experience of teaching in this Department, had only just started as a lecturer of this unit (LD). All preservice teachers involved in this third stage of research were females who had just started their 4th year. This research was more focusing the curriculum evaluation in Regular Semester in order to have a better depiction of the implementation during a normal teaching periods. Besides, the fact that there were less students in the regular semester compared to the condensed semester, there was a likelihood of a more effective opportunity to develop preservice teachers' understanding. Moreover, the 12 students involved in this stage had enrolled in most of the units related to content knowledge during their chemistry education program. This knowledge of these students' enrolment provided information about their understanding of chemistry concepts that have been developed not only during the lessons observed, but also during their study in almost four years of the chemistry teacher education program.

4.2.4 Data sources

According to the framework of the research, this research combined qualitative and quantitative methods of data collection and interpretation. The interpretative method (Erickson, 1986) was used to examine the intended curriculum, the perceived curriculum, and the implemented curriculum. While three of the above-mentioned aspects of curriculum evaluation were conducted qualitatively, the achieved curriculum was examined quantitatively with a simple descriptive statistical analysis followed by qualitative descriptions. The data sources on this study included official government and institution *documents*, *classroom observations*, *interviews*, *two-tier diagnostic test*, *pre-service teachers' journal of the POE activities* and *audio-taped materials*.

Official Documents

In order to gather information about the intended curriculum, data were collected from some documents that, explicitly or implicitly, mentioned the expectations of teachers' content knowledge. Several documents that were analyzed are presented in Table 4.1. The documents listed in the table all mentioned the expectations of teachers that support the national education system, while the documents about the science curriculum for secondary schools contains expectations of the students' knowledge.

Table 4.1 List of documents

Title of documents	Issuing Organization	Year of Issuing
• Act of The Republic of Indonesia No 20/2003 on the National Educational System	Presidency of Republic of Indonesia	2003
• Government of Republic of Indonesia Regulation number 19 of 2005 about National Education Standards	Presidency of Republic of Indonesia	2005
• Ministry of National Education Regulation number 16 of 2007 about Academic Qualification Standards and Teacher Competences	Ministry of National Education	2007
• Competencies Standards for Beginner Teachers	Directorate of Higher Education Ministry of National Education	2004
• Curriculum of Science for Secondary School (Competence-Based Curriculum)	Ministry of National Education	2007
• Curriculum of Science for Secondary School (2013 Curriculum)	Ministry of National Education	2013
• Curriculum of Chemistry Education Study Programme	Departement of Chemistry Education, Indonesian Institute of Teacher Education	
• Unit Description of the course of LS-Chem	Departement of Chemistry Education, Indonesian Institute of Teacher Education	2011

Classroom observations

The data associated with the implemented curriculum were based on the qualitative data from classroom observations that were conducted during Semester 1 in the 2012/2013 academic year. During these observations, the researcher acted as a participant observer (Creswell, 2012; Merriam, 2009). Table 4.2 shows the activities schedule of the data collections.

Table 4.2 The schedule of data collection activities

<table>
<tr><th>Month</th><th>Date</th><th colspan="2">Activities</th></tr>
<tr><td rowspan="5">July</td><td>3</td><td rowspan="8">Observation Condensed Semester</td><td rowspan="4"></td></tr>
<tr><td>11</td></tr>
<tr><td>17</td></tr>
<tr><td>24</td></tr>
<tr><td>25</td><td>Interview LC</td></tr>
<tr><td rowspan="3">August</td><td>1</td><td rowspan="3"></td></tr>
<tr><td>8</td></tr>
<tr><td>9</td></tr>
<tr><td rowspan="3">September</td><td>10</td><td rowspan="13">Observation Regular Semester</td><td rowspan="5"></td></tr>
<tr><td>17</td></tr>
<tr><td>24</td></tr>
<tr><td rowspan="6">October</td><td>2</td></tr>
<tr><td>8</td></tr>
<tr><td>10</td><td>Interview LC</td></tr>
<tr><td>14</td><td>Interview PST (perception)</td></tr>
<tr><td>15</td><td rowspan="5"></td></tr>
<tr><td>22</td></tr>
<tr><td rowspan="6">November</td><td>5</td></tr>
<tr><td>12</td></tr>
<tr><td>19</td></tr>
<tr><td>26</td><td>Interview LD</td></tr>
<tr><td>27</td><td colspan="2">PTDI Test I</td></tr>
<tr><td>30</td><td colspan="2">Interview PST (PTDI answer and PNM understanding)</td></tr>
<tr><td rowspan="7">December</td><td>3</td><td colspan="2">POE strategy implementation</td></tr>
<tr><td>6</td><td colspan="2">Interview LC</td></tr>
<tr><td>10</td><td colspan="2">POE strategy implementation</td></tr>
<tr><td>14</td><td colspan="2">POE strategy implementation</td></tr>
<tr><td>17</td><td colspan="2">PTDI Test II</td></tr>
<tr><td>20</td><td colspan="2" rowspan="3">Interview (PTDI answer and PNM understanding)</td></tr>
<tr><td>21</td></tr>
<tr><td rowspan="2">January</td><td>4</td></tr>
<tr><td>15</td><td colspan="2">Interview LC and LD</td></tr>
</table>

Interviews

The perceived curriculum was revealed from the teacher educators' and the preservice teachers' perceptions through one-on-one interviews as well as during focus group interviews (Creswell, 2012). The information from teacher educators' perceptions encompassed what they thought were the essentials of the unit, the reasons for the choice of the teaching method, and their expectations of preservice teachers. Likewise, the perceptions of the preservice teachers described their expectations from the unit and their opinions about the advantages of the unit.

Besides gathering information about the perceived curriculum, some interview sessions were also held to gather further information about students' explanations of their answers to the PTDI items. Although the second tier of the PTDI items provided information about the explanation of the answer to the first tier, the interviews were conducted to confirm the answers of the preservice teachers. To avoid any harm toward the participants, any remaining misconception found at the interview after post-test was guided with further discussion to assist pre-service teacher to reconstruct appropriate conceptual understanding. The summary of the interview schedule is presented in Table 4.2 and examples of questions are presented in Table 4.3. The full key interview questions are presented in Appendix B.

Table 4.3 Interview schedule and examples of interview question

Interviewee	Topic	Example of interview question
Lecturer	Perception of the program	Questions for the lecturer: - *Why do you think the unit is important for the pre-service teachers?* - *What are the topics that should be discussed in the LS-Chem unit?*
PST		Questions for pre-service teachers: - *Do you think that the chemistry content knowledge that you have learned from school is sufficient for you to be a teacher?* - *What is your expectation of this unit?*
	Confirmation of pre-test answer	*You mentioned the volume of gas decresed, why did it decrease?*
	Confirmation of post-test answer	*In the post-test you answered that the mass would not increase, how could you explain that?*

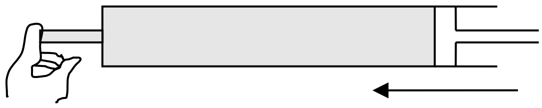
Two-tier Diagnostic test

Regarding the achieved curriculum, the Particle Theory Diagnostic Instrument (PTDI) consisting of 11 two-tier multiple-choice items was used to evaluate the preservice teachers' knowledge about the particulate nature of matter. This diagnostic instrument provided information about the existence of any alternative conceptions in the preservice teachers' understanding about the particulate nature of matter. Figure 4.1 shows one example of a PTDI item and the full instrument is presented as Appendix C.

This instrument was adopted from a previously validated instrument by Treagust et al. (2010). The reason for using this instrument was because the distractors in each item of this instrument were derived from common students' conceptions. Besides, this instrument had also been tested with various levels of respondents such as high school students, undergraduate students and even postgraduate students in Malaysia. This background of the instrument development provided a strong reason for using the instrument in this research.

Item 5
The diagram shows a coloured gas being compressed in a gas syringe until the plunger could not be pushed any further.

The experiment was repeated using the same volume of a coloured liquid.



It was found that the final volume of the gas was
A much less than that of the liquid.
B much greater than that of the liquid.

The reason for my choice of answer is:
1. The particles in the gas are more widely spaced.
2. The particles in the gas move more freely.
3. The particles in the gas move randomly in all directions.
4. Other: ………………………………………………………………

Figure 4.1 Item number 5 of the PTDI

Since the original instrument was in English, the instrument was translated to Bahasa Indonesia. The translation process was followed by a back translation (Brislin, 1970), in order to ensure the equivalence of the translated items with the original ones (Epstein, Osborne, Elsworth, Beaton, & Guillemin, 2015). According to Bracken and Barona (1991), Chang, Chau, and Holroyd (1999), and Chen and Boore (2010), the process of back translation involves four main stages, namely (1) the translation process of the original document from the source language to the target language; (2) the blind back translation process, which translates from the target language to the source language without looking at the original document; (3) the repetition of steps 1 and 2 until achieving appropriate translation; (4) the revision and modification of the sentences in the target language. Those processes mentioned above involved experts with proficiency in both languages. Based on the review, as well as from the pilot test, some modifications were also made to the diagrams used in the instrument to make the meaning of the items clearer for the participants.

Pre-service teachers' journals of the POE activities

The pre-service teachers are required to write their predictions, observations and also explanations in the journals provided (see Appendix D) during their learning process with the POE strategy. Information recorded in these journals was used to reveal the process of conceptual change during the implementation of the POE strategies.

Audio-taped materials

Audio-tapes were used in this research to record the information during the interview sessions as well as to record the learning process using the POE strategy. The recordings were done with permission from the participants.

4.2.5 Data analysis procedures

Since this research involved both qualitative and quantitative data, data analysis was divided into two categories. Qualitative data were derived from documents, observation results, transcripts of the interviews, and students' journals. Additional explanations provided by the pre-service teachers on responding to PTDI test also was analysed qualitatively. Data exploring to obtain a general sense of the data (Creswell, 2012) and data coding to classify the data were conducted to build the descriptions and the interpretations of the findings from all qualitative data.

Meanwhile, quantitative data derived from the results of the two-tier diagnostic test were analysed using data scoring techniques (Creswell, 2012) such as:

a. Single-item scores provided information about each preservice teachers' response to each question of the instrument. All responses including the first tier and both tiers were recorded. The first tier scores were derived from the correct responses in the first tier regardless the explanation given in that response. While both tier scores were only calculated for the correct responses followed by the appropriate explanations. Some of the explanations provided by the pre-service teachers' statements which had the same main ideas of the expected explanation also were categorized as correct explanations. In this study, the scoring system for PTDI is analysed for the correct answer of both tier. The calculation of correct answer on first tier only used to show that the right answer given by pre-service teachers is not always followed by an appropriate explanation. High scores on first tier but low scores on both tiers indicate that the pre-service teachers know the correct answer but cannot provide the appropriate explanation which often leads to reveal their alternative conceptions.

b. Summed scores that showed the pre-service teachers' score about a certain topic represented in different items. Pre-service teachers' responses were classified on each item and calculated on the first tier as well as both tiers. These data provide information about the number of pre-service teachers with correct responses and the number with correct responses followed by proper explanation of each item.

In order to validate the accuracy of the interpretations and the findings, this research applied three methods of acquiring validity suggested by Creswell (2012), namely:

a. Triangulation, by finding information from different sources using various methods to confirm the emerging findings.
b. Member checking, by bringing the data and the interpretation to the people who were involved in the data collection process to confirm the results.
c. Long term observations or repeated observations of the same phenomenon, by collecting data over a period of time.

4.2.6 Ethical considerations

One aim of the research was to analyse the results from the implementation of the LS-Chem unit. The position of the researcher in the first and second stages was only as an observer to make a thorough observation of the classroom, while the researcher also conducted some interventions in the last stage of the research. The written consent from the pre-service teachers as well as from the teacher educators were obtained after the researcher provided explanations to all participants about the purpose of this research and the role of the participants in this research (see Appendix E). The researcher also emphasized that the pre-service teachers' involvement in the research will not influence their final grade and all participants may withdraw at any stages of the research.

All the data collected will be stored confidentially and managed anonymously using nicknames as codes. Thus, the participants of the research cannot be identified further. Regarding the limited time of the unit timetable, the diagnostic test was administered and semi-structured interviews were conducted at specific times based on agreement with the participants.

4.3 Summary of the chapter

This chapter has presented a detailed description of the research study. This research consists of three stages (pilot study, curriculum evaluation and intervention) that focused on the acquisition of the basic chemistry concepts in the unit of *Teaching and Learning Chemistry for Lower Secondary School* by preservice teachers from a teacher education institution in Indonesia. Using a case study under the framework of curriculum evaluation, this research has attempted to evaluate the current content knowledge development of preservice chemistry teachers in a university in Indonesia. The intervention stage of the implementation of POE was also investigated using a case study to see the influence of teaching strategy to improve pre-service teachers' understanding about the particulate nature of matter. Using various data sources, this research is expected to provide comprehensive information about the development of chemistry preservice teachers' understanding of the particulate nature of matter.

CHAPTER 5
THE RESULTS OF CURRICULUM EVALUATION: THE INTENDED AND IMPLEMENTED CURRICULUM

5.1. Introduction

This chapter is intended to present the results of the curriculum evaluation. Every aspect of curriculum evaluation is elaborated in the sections of this chapter. The results about the intended and the implemented curriculum are elaborated in sections 5.2 and 5.3. The overall information from this chapter provides a depiction of the designed program of teachers' content knowledge development in a teacher education institution in Indonesia and the implementation of the program.

5.2 Intended curriculum

The elaboration about the intended curriculum is associated with the Research Question #1, namely "*What is the designed program to develop pre-service teachers' understanding of the particulate nature of matter in the Chemistry Education Program?"* As it is mainly related to the intention which is stated in the curriculum documents, this research question is answered by examining the documents that are related to teacher competences and teacher education especially those that relate to content knowledge. Several documents that are used to answer this question were categorized into two groups. The first group of documents related to the ideal curriculum consisting of the documents that mention the expectations about teachers' content knowledge and the documents about the school science curriculum. The second group is the written curriculum that was developed by the teacher education institution concerned that aimed to fulfil the expectations of the ideal curriculum. This grouping is beneficial to see whether the written curriculum is in line with the ideal curriculum. How does the written curriculum try to fulfil the needs/expectations mentioned in the ideal curriculum?

5.2.1 The ideal curriculum

Several documents that are categorized as the ideal curriculum include: (1) The act of The Republic of Indonesia No 20/2003 on the National Educational System, (2) The government of the Republic of Indonesia regulation number 19 of 2005 about National

Education Standards, (3) The Ministry of National Education Regulation number 16 of 2007 about Academic Qualification Standards and Teacher Competences, and (4) The Competence Standards for Beginning Teachers. These documents were analysed to find out what is expected of beginning teachers especially about teachers' content knowledge about content. This analysis also attempts to find out about the teachers' competences that are required based on the above-mentioned national documents.

The analysis begins with the content within these documents that is associated with the expectations of teachers' content knowledge, especially the knowledge about basic concepts in chemistry. The summary of this coverage is shown in Table 5.1.

Table 5.1 Contents of the documents related to the ideal curriculum about teachers' content knowledge

Type of documents	Content of documents
A. Act of The Republic of Indonesia No 20/2003 on the National Educational System	Article 40 paragraph 2a: Educators and education staff have an obligation to create a meaningful, interesting, creative, dynamic, and dialogic learning environment.
B. The Government of the Republic of Indonesia Regulation number 19 of 2005 about National Education Standards	Article 28 paragraph 3: The learning agent for primary education, secondary education, and early childhood education needs to have following competences: a. Pedagogical competence b. Personal competence c. Professional competence d. Social competence
C. The Ministry of National Education Regulation number 16 of 2007 about Academic Qualification Standards and Teacher Competences	The core of teachers' professional competences: 1. Mastery of the subject matter, the structure, the concepts and the paradigms that support the subject matter of their teaching (point 21). Mastery the competence standards and basic competences of the subject matter of their teaching (point 22). Some of the details of teachers' competences on point 22 for lower secondary Science teachers: 1. Understand the concepts, laws, and the theories of science as well as their applications in a flexible manner. 2. Understand the thinking process in the learning about process and natural phenomena. 3. Understand the relationship between various subjects of science, and the relationship between science and mathematics and technology. 4. Apply the science concepts, laws, and theories to explain various natural phenomena 5. Explain the application of science laws especially in technology in daily life. 6. Design science experiments for teaching and learning purposes as well as for research purposes.

Table 5.1 Contents of the documents related to the ideal curriculum about teachers' content knowledge (continued)

Type of documents	Content of documents
	Some details of teachers' competences on point 22 of the document for Chemistry teachers in upper secondary school: 1. Understand the concepts, laws, and theories of chemistry in the topics of structure, dynamics, energetics, and kinetics, as well as their application in a flexible manner. 2. Understand the thinking process in chemistry in the learning about process and natural phenomena. 3. Understand the structure of chemistry (the associations between the concepts in chemistry) and another relevant subject. 4. Apply the concepts, laws, and theories of physics and mathematics to describe chemical phenomena. 5. Explain the application of laws in chemistry in chemistry-related technology especially technology in daily life. 6. Design chemistry experiments for teaching and learning purposes as well as for research.
D. Competence Standard for Beginner Teachers	1. Describe the structure of chemical substances (the composition and the structure of matter, transformation of matter, stoichiometry, energetics and kinetic chemistry, and bio-processes) as well as the characteristics of chemistry concepts using macroscopic, sub-microscopic, and symbolic representations (point 1.1 pg. 15). 2. Make associations of chemistry concepts with their functions to understand and solve chemistry problems (point 1.8 pg. 15). 3. Mastery of the essential concepts of school chemistry (point 2.3 pg 16). 4. Link chemistry concepts to the concepts of Biology, Physics, Mathematics and other subjects to explain phenomena in the environment (point 4.1 pg. 16)

Document A provides a general description of the task for the teachers as educators. Based on this document, the teacher is expected to create a meaningful and creative learning environment that supports the students' learning process. Document B mentions more specifically about the four main competences that are expected of teachers. Further, Document C provides elaboration about the teachers' mastery of content knowledge as part of their professional competence (as one of the teacher competences mentioned in document B) that must be achieved by the teachers. Besides, Document C also provides the details about the scope of teachers' mastery of the competence standards and basic competences in the subject matter of science (for lower secondary school) and chemistry (for upper secondary school). Based on the points mentioned in Document C, the teacher is expected to have an ability to understand the concepts, laws, and the theories of science, and the relationship between various subjects of science. They are also expected to apply these concepts, laws and theories to explain natural and technological phenomena. All these expectations are covered in the dimension of content knowledge (Shulman, 1986; Tamir, 1988).

Further, before being able to apply the chemistry concepts, teachers need a sufficient understanding about the basic concepts of chemistry. Regarding this case, Document D provides details of the indicators of chemistry teacher competences in terms of their comprehension about the basic concepts in chemistry. This document states that chemistry teachers are expected to be able to describe the structure of chemical substances and their characteristics in three representations of chemistry (macroscopic, sub-microscopic, and symbolic representations). Chemistry teachers are also expected to master the related concepts and solve chemistry problems. Besides, they are also required to make relationships between chemistry concepts with the concepts from other science subject like Biology and Physics to explain natural and everyday phenomena. According to Nakhleh (1994), to be able to make good relationships between the chemistry concepts, teachers need to have a well-structured understanding of the basic concepts. Furthermore, to have a good understanding of chemistry concepts, teachers need to have adequate comprehension of the basic concepts such as the particulate nature of matter, which is the basis for other concepts in chemistry (Treagust, 2002; Williamson & Abraham, 1995).

Besides the documents about teachers' competences, analysis about the ideal curriculum also includes the documents about the school curriculum. The analysis of the school curriculum attempts to expose how the school curriculum covers the basic concepts to be taught and how the teachers are expected to teach the associated concepts. There are two kinds of science curriculum that were analysed in this research, namely: (1) the Competence-Based Curriculum of Science for Secondary Schools; and (2) 2013 the Curriculum of Science for Secondary Schools. This analysis involves two documents about the science curriculum for secondary schools because during the period of this research, the Indonesian education system had encountered curriculum transformation between the Competence-Based Curriculum and the 2013 Curriculum that was ongoing in mid-2015.

According to the statements in the school curriculum documents shown in Table 5.2, teachers should be able to provide an effective process for the students to learn about the topics. As is widely known, teachers' ability to teach effectively a certain concept depends on their understanding about that concept (De Jong et al., 2002; Yezierski & Herrington, 2011). In turn, teacher education institutions should be geared to prepare their pre-service teachers to have a good conceptual understanding about the concepts as well as to develop appropriate strategies to teach the concepts effectively.

Table 5.2 The contents of the documents related to the ideal curriculum about school curriculum

Type of documents	Contents of documents
A. Competence-Based Curriculum of Science for Secondary School	1. From the competence standard,-*Understand the phase of matter and their changes*, four basic competences are derived as follows: a. Investigate the properties of matter based on its phase and its application in everyday life. b. Describe the concept of density in everyday life. c. Perform the experiment related to the concept of expansion in everyday life. d. Describe the influence of heat on the change of the phase of matter and its application in everyday life. 2. From the competence standard, *Describe the concept of particle of matter,* three basic competences are derived as follows: a. Describe the concepts of atom, ion, and molecule. b. Associate the concepts of atom, ion, and molecule with chemical products in everyday life. c. Compare the molecule of an element with the molecule of a compound.
B. 2013 Curriculum of Science for Secondary School	1. Understanding the characteristics of matter and the chemical and physical changes of matter in everyday life (e.g., separation of mixtures) (Grade VII, point 3.5) 2. Perform the experiment to investigate the influence of heat on changes in temperature and phase changes of matter (Grade VII, point 4.7) 3. Investigate the properties of solutions in the environment using synthetic as well as natural indicators (Grade VII, point 4.11) 4. Comprehend the concept of atom and the constituent particles, ions and molecules, as well as its relationship with the material characteristics of substances used in everyday life.

The following section will elaborate the program developed by the Chemistry Education Department to enhance pre-service chemistry teachers' knowledge about the basic concepts of chemistry, often referred to as the written curriculum.

5.2.2 The written curriculum

In order to prepare pre-service teachers to have the expected competences in content knowledge, the Chemistry Education Department provides several units that focus on developing pre-service teachers' understanding of chemistry concepts. One of these units, namely *Teaching and Learning Chemistry for Lower Secondary School* (LS-Chem), involves the basic chemistry concepts that are covered in lower secondary school.

To gather the information about how the Chemistry Education Department designs its program to develop pre-service teachers' knowledge about basic chemistry concepts, this study analysed two documents, namely: (1) the Curriculum of Chemistry Education Study Programme, (2) the unit description of LS-Chem. The contents of these documents are presented in Table 5.3.

Table 5.3 The contents of the documents related to the written curriculum about the lower secondary curriculum

Types of documents	Content of documents
A. Curriculum of the Chemistry Education Study Programme	The competences that are expected from the graduates are: mastery the theoretical chemistry concepts, general pedagogical, personal, social, managerial, research and development, and the relevant knowledge that supports the ability to teach, train, research, and manage the implementation of chemistry education.
B. Unit description of the *Teaching and Learning Chemistry for Lower Secondary School* (LS-Chem)	The aims of the unit are to develop pre-service teachers to: 1. Master the scope of chemistry content for Lower secondary school in accordance with the Content Standards of the National Curriculum. 2. Master the chemistry concepts for Lower secondary school. 3. Master the appropriate learning process of chemistry of lower secondary students.

According to Document A (Curriculum of the Chemistry Education Study Program), the graduates are expected to master the theoretical chemistry concepts as well as other knowledge and skills that support their teaching qualification. In order to achieve this expectation, the Chemistry Education Department has conducted a number of units that are intended to facilitate the development of content knowledge of the pre-service teachers. Some of the units are General Chemistry, Fundamental Chemistry, and other units that discuss further concepts such as in Biochemistry, Physical Chemistry, Organic Chemistry, and Inorganic Chemistry. There are also some units that are aimed at strengthening pre-service teachers' knowledge about the content of the syllabus as well as to develop their pedagogical content knowledge, such as: School Chemistry I, School Chemistry II, *Teaching and Learning Chemistry for Lower Secondary School*, and Teaching and Learning Chemistry for Vocational School. Among all the units that have been mentioned, only the unit of *Teaching and Learning Chemistry for Lower Secondary School* (LS-Chem) focuses on the basic concepts of chemistry because this unit involves the chemistry concepts covered in the science curriculum for lower secondary schools in Indonesia (Grades 7-9).

According to the document B of the Unit Description of the LS-Chem, this unit attempts to develop pre-service teachers to:

(i) have an insight into the scope of the chemistry content in the science curriculum for lower secondary school

(ii) master the content of chemistry for lower secondary school

(iii) have an insight of the teaching and learning strategies to be implemented in lower secondary school chemistry

Those three expected outcomes supported by the above-mentioned pedagogical unit are expected to enable pre-service teachers to develop lesson plans that are suitable for lower secondary students. Table 5.4 presents the topics that are covered in the LS-Chem unit that relate to the particulate nature of matter according to the Unit Description of LS- Chem.

The means by which the LS-Chem unit provides pre-service teachers with adequate understanding about the basic chemistry concepts on the topics chosen in every lesson are shown in Table 5.4. These topics are the basic chemistry concepts that relate to the particulate nature of matter, such as the concept of particle, the properties of matter, the phases of matter and their changes, and the classification of matter. This unit also covers topics about chemicals in everyday life and also the addictive and psychotropic substances as additional topics from the national curriculum. The plan in Table 5.4 also shows that the aim of this unit is to prepare the pre-service teachers to teach these topics. This aim is evident from the allocation of time for specifically discussing the learning strategies of the topics that have been discussed the week before. This unit, therefore, has intentions to develop pre-service teachers with knowledge of strong fundamental concepts as well as the ability to teach these concepts.

Table 5.4 The coverage of the content in the LS-Chem according to Unit Description

Weeks	Topics
1	Review the scope of subject matter covered in the unit.
2	Chemistry science learning in lower secondary school. Overview about individual and collaborative task.
3	The particle as the smallest component of matter.
4	Teaching strategies about the concept of particle.
5	Physical and chemical properties of matter.
6	Teaching strategies about the physical and chemical properties of matter.
7	Phases of matter and their changes.
8	Teaching strategies about phase of matter and its change
9	Mid-semester test
10	Classification of matter.
11	Teaching strategies about the classification of matter
12	Chemical reactions
13	Teaching strategies about chemical reactions
14	Chemicals in everyday life
15	Teaching strategies about chemicals in everyday life
16	Addictive and psychotropic substances
17	Teaching strategies about addictive and psychotropic substances
18	Final Test

The document about the Unit Description of the LS-Chem also describes the learning strategies and the assessment techniques that can be used. The learning strategies that have been chosen to reach the expected goals are descriptive method, demonstration, and teaching practice. Pre-service teachers are required to develop learning material that consists of the summary about a certain topic. The pre-service teachers are also expected to design a lesson plan as well as a laboratory activity to express their idea about how to effectively teach the topic to their students. Moreover, they are also required to include the assessment technique to evaluate students' achievement in learning the topic.

Based on what has been mentioned in the documents, it is clear that teachers are expected to have mastery of content knowledge which needs to be supported by a strong understanding of fundamental concepts. The program in the Chemistry Education Department also has considered adequate understanding of basic concepts in chemistry. However, the achievement of the goal is not only determined by the plan stated in the curriculum documents. How the plan was conducted plays an important role to the goal achievement. The following section describes the observations of the implementation of the curriculum.

5.3 Implemented curriculum

This section presents the results of the observations that provide explanations to the following Research Question #2:

> "*How is the pre-service chemistry teachers' understanding of the particulate nature of matter developed through the unit of Teaching and Learning of Chemistry for Lower Secondary School?*

In response to this question, this section elaborates on the observations of classroom activities of the unit of Teaching and Learning of Chemistry for Lower Secondary School. As the observations were conducted over two periods, the observation results are divided into two parts. The first part describes the observations during the condensed semester (Academic Year 2011/2012, July – August 2012) and the second part describes the implementation of the unit during the regular semester (Academic Year 2012/2013, September – December 2012). The discussion covers the classroom situation and the activities that have been conducted within that period of time.

The descriptions of classroom activities are organized according to the topics of discussion. In every topic, there are descriptions about the explanation given by the lecturer as well as the explanation provided by the pre-service teachers. The explanations from pre-service teachers are derived from the presentation about the teaching strategy of a certain topic that has been developed.

5.3.1 Brief history about the LS-Chem unit

Before discussing the results of the observation, I will describe the brief history about the unit and the lecturers who were involved. This unit was initiated by a coordinator, namely Lecturer A, as a response to the competence-based national curriculum that included the chemistry component in the Science Curriculum for Lower Secondary School. This unit has been offered since 2007, conducted for five years during the regular semester (odd semester) and for four years during the condensed semester. There were three lecturers who collaborated in conducting this unit as a team teaching, Lecturer A, Lecturer B, and Lecturer C. Since the regular semester of the 2012/2013 academic year, Lecturer A and Lecturer B were no longer involved in this unit but were substituted by Lecturer D, due to academic reason of the lecturers in terms of number of credits to be taught. Thus, the team teaching in the LS-Chem unit during the research period was Lecturer C and Lecturer D.

5.3.2 Brief description about the LS-Chem unit

Classroom situation

The LS-Chem unit in the condensed semester was conducted in the largest room of the faculty that could accommodate the usually large number of students who enrol in this unit. In the semester under investigation in the condensed semester there were 77 pre-service teachers who were enrolled. The seats were arranged in such a way that all students were able to see the board in front of the class. The lesson in each session ran for 100 minutes from 7 a.m. to 8.40 a.m and was conducted twice a week.

Meanwhile, the classroom that was provided for the LS-Chem unit in the regular semester was smaller than the class for the same unit in the condensed semester. The capacity of the class was for 50 students, while the number of participants was only 12 pre-service teachers. Similar to the unit in the condensed semester, the lesson in every meeting in the regular semester ran for a duration of 100 minutes from 7 a.m. to 8.40 a.m, but was conducted once a week.

Activities

Although this unit has a document of unit description with an attached timetable, the structure of the topic discussed differed from the one that has been presented in the unit description (Table 5.4). The unit description mentioned that the topics about content and teaching strategy are discussed every two lessons in sequence, while in the implementation not all topics were in sequence. Some of the topics about teaching strategies were conducted during several lessons at the end. The arrangement was changed because the pre-service teachers were required to design and present the topic about teaching strategies. Table 5.5 presents the topics that were discussed in the LS-Chem unit in the Condensed Semester and in the Regular Semester of 2012.

Similar to the time table in condensed semester, the timetable of the topics discussed in the regular semester were also modified as shown in Table 5.5. In accordance with the objective of the unit, this unit was intended to develop pre-service teachers' understanding about a certain concept as well as their skills to teach that concept. Hence, the topic of the lecture was not only about the content but also about how to teach the content and how to prepare learning materials for the students.

Table 5.5. The topics in the condensed and regular semester of LS-Chem unit 2012

Lesson	Activities	
	Condensed Semester	**Regular Semester**
Lesson 1	- Review of the unit - Presenting the work of the students from the last term - How to make a good work sheet - How to make a good introduction in the learning module	- Review of the unit - Review about science curriculum for lower secondary school
Lesson 2	Particles of matter	Particles of matter, atoms, ions and molecules
Lesson 3	Teaching strategies of particles of matter	Teaching strategies in lower secondary school chemistry
Lesson 4	Teaching strategies of physical and chemical properties of matter	Phases of matter and their changes
Lesson 5	Classification of matter	Teaching strategies of phases of matter and their changes
Lesson 6	Addictive and psychotropic substances (Group presentation-PST session)	- Discussion about hand-out - Teaching strategies of the shapes of matter and their changes (Group presentation-PST session)
Lesson 7	Acids and bases (Group presentation-PST session)	Teaching strategies of chemicals in daily life (Group presentation-PST session)
Lesson 8	Physical and chemical properties of matter (Group presentation-PST session)	Physical and chemical properties of matter Teaching strategies of the particles of matter (Group presentation-PST session)
Lesson 9	Review (Lecturer A)	Mid Semester – Task submission
Lesson 10	Classification of matter (Group presentation-PST session)	Physical and chemical properties
Lesson 11	Particles of matter (Group presentation-PST session)	Phases of matter and their changes Classification of matter

5.3.3 The development of teaching and learning strategies in the LS-Chem unit

There were at least two reasons for allocating time for discussing teaching strategies. The first reason was to provide the basic knowledge about lesson plans, students' learning materials, and teachers' teaching materials. This was because most of the pre-service teachers who had enrolled in this unit in the Condensed Semester had not yet enrolled in the unit that taught them how to design a lesson plan for chemistry education. Thus the lecturer decided that the students needed to be introduced to the basic knowledge about lesson plans, students' worksheets, and other learning materials. The second reason was to provide pre-service teachers with the opportunity to combine their knowledge about pedagogy and content knowledge to enable them to be better prepared for teaching in the future.

The intention to provide pre-service teachers with good knowledge and skills about teaching and learning strategies was clearly indicated in the activities in every lesson, in both the condensed as well as in the regular semester. According to Table 5.5, various matters related to teaching and learning strategies in LS-Chem were discussed during the lesson, namely: (1) teaching strategies to teach the chemistry contents, and (2) how to prepare learning materials that would assist students in learning chemistry.

The discussion about teaching and learning strategies covered issues to be considered in preparing or designing the lesson plan, such as: (1) the time that will be allocated to discuss about the topic of particles of matter; (2) the selection of techniques that would effectively engage the students in the learning process; and (3) the teaching method that was suitable to teach a certain topic which was presented in the lesson plans. For the last issue, the lecturer provided some exemplary practices to teach several concepts in chemistry for lower secondary students, some of which were from the lecturer's experience of classroom observations in several schools in some districts in West Java. Some of the strategies that were included in the discussions involved applying the inquiry approach in teaching science and using diagrams, animations, and videos to help students develop better understanding about the concepts. The lecturer also mentioned the importance of the introductory explanations in every laboratory activity that could help to engage the students effectively in the activities.

Besides providing the pre-service teachers with the strategies to teach lower secondary chemistry, the lecturer also provided them with some advice on how to make good learning materials such as hand outs and students' worksheets. In addition, they were instructed on how to introduce a lesson in order to motivate and engage students in the topic that was going to be discussed.

5.3.4 The development of content knowledge in the LS-Chem

Besides the teaching strategies, there were some concepts that made up the main topics in the LS-Chem unit. There were six main topics that were discussed in this unit. (1)

the particles of matter; (2) physical and chemical properties of matter; (3) phases of matter and their changes; (4) classification of matter; (5) chemicals in everyday life; and (6) addictive and psychotropic substances. Meanwhile, there were three concept categories related to the particulate nature of matter that were the focus of this study, namely: (1) intermolecular spacing in matter; (2) influence of heat on physical change; and (3) diffusion. These concept categories were also discussed during the process of teaching and learning and were mostly embedded in the discussion about the Topic 1 about the particles of matter and Topic 3 about the phases of matter and their changes. Although all concept categories are covered in two main topics, valuable information was obtained from the observations of the lectures about other topics. However, the observation results presented here are only those which are related to the particulate nature of matter (Topic 1, 2 and 3).

The observation result of each topic is presented into two parts namely *Session by lecturer* and *Session by pre-service teachers*. According the time table in Table 5.4 and Table 5.5, every topic was presented by the lecturer in terms of the content. There were also some sessions for the pre-service teachers to present their design of a teaching strategy to teach a certain topic. Regarding this, the following section tries to present and elaborate the activities and also discourses that occur during the lesson in both sessions.

Topic 1: The particles of matter

Session by the Lecturer

The discussion about the particles of matter was based on the concept map in Figure 5.1.

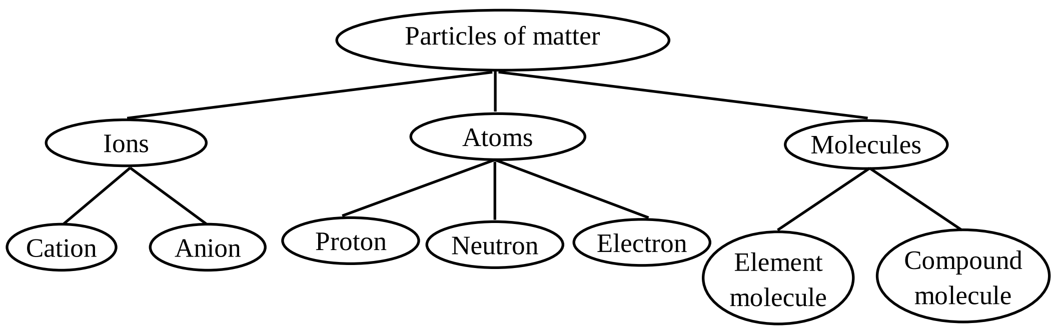


Figure 5.1. The concept map of particles of matter presented in the classroom

The objective of teaching about particles of matter was based on the competence standard of *Describe the concept of particle of matter* in the Competence Based Curriculum 2006 which is divided into three basic competences (see Table 5.2 Document A part 2), such as:

a. Describe the concept of atom, ion and molecule.
b. Associate the concept of atom, ion, and molecule to the chemical product in everyday life
c. Compare the molecule of element and the molecule of compound.

During the discussion, atom was defined as the smallest part of a matter. Lecturer C argued that the definition of atom that he mentioned is incorrect because atom is composed of smaller particles such as protons, neutrons, and electrons. Therefore, the lecturer provided further restriction of the definition of atom to be limited to represent the smallest part of matter that still has the properties of that matter.

> *Every element of metal or non-metal is composed by the smallest part called atom. According to Dalton, the smallest part of the substance is atom. The smallest part of living things are cells. However, after particles such as proton and neutron have been found, the definition needs a restriction. The restriction is that atom is the smallest particles that still have the same properties with the element/substance.*

The last statement is also incorrect, but the lecturer did not provide further explanation about that. He continued the discussion with the description about definition of molecules and ion.

> *A molecule is composed of two or more atoms combined together. If the molecule is composed of the same atoms it called as element molecule, and if it composed of different kinds of atoms it categorized as a compound molecule.*

> *Meanwhile, an ion is defined as a charged atom. For example, the Na atom can change to become an ion Na^+. An ion can be either positive or negative. An ion with a positive charge is called a cation, and an ion with a negative charged is called an anion. These ions with opposite charges can combine and neutralize each other to form a compound.*

Following the definition and the example about ion, the lecturer provided further explanations about NaCl. One concept that was emphasized by the lecturer in this part was the smallest particles of NaCl, the Na^+ and Cl^- ions.

> *Basically, NaCl is not a molecule. It differs from HCl that has covalent bonding so that the latter can be categorized as a molecule. Whereas in the crystal of NaCl, there are Na^+ and Cl^- ions arranged together. Thus we cannot say that the smallest particle of NaCl is a molecule. Although overall NaCl is a compound, the smallest particles of (NaCl) are Na^+ and Cl^- ions.*

The topic about particles of matter is expected to be taught in the beginning of students' experience in learning about chemistry because it can stimulate the students to think about abstract things. The skill to think about abstract things is an essential factor in learning chemistry. Besides, the students also need to be convinced about the existence of the smallest part of matter (atoms, ions and molecules).

Session by Pre-service teachers

When the pre-service teachers presented the learning strategies about this topic, there were some detailed explanations about the concepts in the topic of the particles of matter. One of the examples was the explanation about the properties of the substance that only appeared when the atoms had combined as a molecule.

> *When the atom is single, it could not show the properties such as colour, boiling point and melting point. But when the atoms join together with another atom, the properties of an element will be able to be observed.*

This statement was followed by the explanation that the properties will depend on how the atoms are arranged. Molecules from the same atom will have different properties if they have different structures. For example, although graphite and diamond are composed of the same atom they have different appearances and properties because they have different structures.

Another elaboration of this topic is about the sub-particles of an atom that consists of protons, neutrons and electrons. The explanation about this sub-component of the atom started from the discussion about the history of atomic theory. Further, after the explanation about atomic structure based on Bohr's theory that consisted of the nucleus in the centre and the electrons that rotate in an electron ring, they also introduced that the nucleus being composed of protons and neutrons. Moreover, the following discourse was about the relationship between the atomic number (Z) and atomic mass number (A) with the number of protons (p), electrons (e), and neutrons (n) that are present in the equation

$$^{A}_{Z}X \qquad A = p + n \qquad Z = p$$

The following activities involved determining the number of protons and neutrons, based on the data about atomic number and mass number that can easily gathered from the Periodic Table.

After the discourse about protons, electrons and neutrons as components of an atom that were covered in the concept map of the particles of matter (Figure 5.1). The next discussion was about ions and molecules including cations and anions as well as element molecules and compound molecules. The teaching and learning process about this typically started from the definition and the classification of the examples of each component. In addition, since one of the basic competences stated in the science curriculum is about *associating the concept of atom, ion, and molecule with the chemical products in everyday life* (see Table 5.2 Document A), the discourse about this topic also involved some products that contain ions and molecules.

Topic 2: Physical and chemical properties of matter

Session by the Lecturer

The review of this topic by the lecturer was about selecting properties of matter and categorizing these as physical or chemical properties. Among several properties of matter, the lecturer mentioned the example of the concept of density related to the submarine and air balloon.

Lecturer C: *Could you explain why the submarine is able to float in the sea? A submarine is made of metal which has higher density than water, right? So it supposed to sink, but why does it could float? Could you explain it?*

PST: *There is a ratio between water and air*

Lecturer C: *The ratio of water and air? Where is it? (try to confirm)*

PST: *Inside the structure of submarine*

Lecturer C: *Yes that' correct.*

Lecturer C: *Now, why does an air balloon can go up [to the sky]? Why if we blow up the balloon with our mouth it cannot keep going up? But why if we use hot gas the balloon can go up? You can further elaborate all of these question [in your lesson plan].*

He also mentioned about the process of nutrition transfer in plants that involved the concept of capillarity. These examples were discussed using the question 'Why it can happen?' and 'What is happening in the process?' Although not all the questions were answered by the pre-service teachers, the lecturer tried to encourage them to apply the concept to explain phenomena in everyday life.

Session by pre-service teachers

Similar with the previous topic, the presentation from pre-service teachers about the strategy to teach this concept started from the definition of the kind of properties followed by examples (the transcription is presented at Appendix F). Physical properties were defined as properties of matter that can be observed without changing the composition of the substance. Some properties that were categorized as physical properties included: (1) phases of matter, (2) colour, (3) solubility, (4) conductivity, (5) magnetic properties, (6) melting point, and (7) boiling point. Following this, the presenter provided an example of each property, such as: aluminium has conductivity as it is widely used as an electric cable. Meanwhile, chemical properties were defined as properties that could be observed by changing the composition of a substance. The properties that categorized as chemical properties were: (1) flammable, (2) degradable, (3) rusting, (4) explosive, and (5) toxic.

The next presentation was about physical and chemical changes. According to this presentation, physical change was defined as the change of matter that would not produce a new substance. There were three main characteristics of physical change, namely: (1) no new substance produced, (2) the substance that changed could be converted to the initial condition. (3) the change that only followed by the change of physical properties, not other properties. Some examples mentioned related to physical change were: melting process of ice and candle, vaporization process of water, dissolving process of sugar and salt. However, these examples were only associated with the fact that the process could be reversed in order to obtain the initial product, without providing detailed explanation about the process itself. Meanwhile, chemical change was defined as a change of matter that produced a new substance, with the characteristic that is opposite to that of physical change, such as: (1) produce a new substance, (2) could not be converted to the initial condition, (3) a change of chemical properties. Some examples of chemical change that were presented are: the burnt paper that produced ashes, rotten rice, rotten egg, rusting iron.

At the end of the presentation, the pre-service teachers, who did the presentation, played a video that showed the physical change and chemical change that happened to sugar. The first part of the video showed the process of sugar dissolving. The pre-service teachers explained that the process of sugar dissolving is categorized as physical change because it did not produce a new substance, was reversible, there was no change in the mass of the sugar and the water. The preservice teachers also described that there was no heat absorbed or released during the process of sugar dissolving. This explanation is incorrect. However, it seemed that they did not realize this. Further, through the process of vaporization of sugar solution, sugar can be reproduced. This fact demonstrated the reversible process that makes the process of sugar dissolving is categorized as physical change. The second part of the video involved pouring sulfuric acid solution onto some sugar which produced a big black mass of carbon. This experiment showed that in this process a new substance was produced, there was change in mass, and the process produced heat and was irreversible. Thus the pre-service teachers categorized this process as a chemical change.

After showing the video, the presenters described the applications of physical and chemical changes, especially in industry. They mentioned that several industries applied the principle of physical change such as the production of alloys and cane sugar. They also described the application of the principle of chemical change in some industries such as mineral ore processing, the production of plastics, and the production of fermented food. Regarding the example given in the presentation about physical change, the presenters seemed to rely on the ability of the matter to transform from one phase to another. They did not consider different properties of an alloy from its initial components.

Topic 3: Phases of matter and their changes

Session by the Lecturer

The lecturer started to teach about the phases of matter and their changes by showing the book written by some of science teacher educators from the Faculty and examples of the learning process based on his experience of classroom observations. Regarding the book, the lecturer mentioned the learning outcomes and the teaching strategies that were stated in the book. The example of teaching and learning processes was about the experimental method to show the students about phase changes of matter. Based on his description, the process of phase changes was conducted by heating a small amount of ice, water, and naphthalene on three different spoons. This lesson was intended to provide a real example to the students about the melting process, vaporization, and sublimation. However, the naphthalene melted into liquid when it was heated, while it was expected to change directly from solid to gas. The description about the exemplary practice of teaching about phases of matter and their changes ended with a question about how to make the lesson better. This question did not have any response from the pre-service teachers. A comment came from a pre-service teacher that was also emphasized by the lecturer. The comment was about the naphthalene used in the experiment which might not be pure naphthalene. The lecturer then gave additional reason that pure naphthalene is expected to transform from solid to gas (sublimate).

The lecturer (Lecturer C) also discussed the graph obtained using the data of increasing the temperature of a liquid when it was heated which was not as smooth as it appeared in the text book. But there were no responses from the pre-service teachers regarding the reasons for this discrepancy.

The discussion about this topic seemed not to be focused on the basic competences that should have been covered. The lecturer talked about the book that contained the concepts of density and diffusion. He also mentioned the need to present the macroscopic representation using a picture. Sometimes he talked about how to make a prologue before the experiment about diffusion. When he reviewed the teaching strategy created by the group of pre-service teachers, he posed several questions about how we should ask the students to do the observations during the process of boiling carefully. He mentioned about the bubbles that were produced during the process of boiling, and more bubbles would be observed at the boiling point, and also the relationship between this phenomenon and the saturated vapour pressure of water.

> *"To guide the student in doing observations, let us say 'there are some bubbles'. Yes, the students will see the bubbles. After that you can give the students a further question 'what actually is in the bubble?' and when it (the water) become hotter there will be more bubbles. So what do you think it is? It might something that correlate with the temperature, which produces higher pressure? Isn't it right? The presure around here and there (not so clear). As we know that there is also a saturated vapour pressure. Water has different saturated water pressure compared with alcohol."*

However, there was an interesting discussion between the pre-service teachers and the lecturer. The discussion began with the question raised by one of the pre-service teachers who presented on the topic of phases of matter and its changes. The question was as follows:

> *In the process of heating the water, what happened to the intermolecular forces between the molecules of water?*

Responding to this question, the lecturer tried to provide the explanation which developed the lively discussion as indicated below:

Lecturer: *Consider the physical condition of water when heated until it vaporizes (beyond its boiling point). Boiling not necessarily....*

PST-F: (interrupted the lecturer) *Boiling must involve vaporisation, but vaporisation does not necessarily involve boiling.*

Lecturer: *Is that true? What is the example? This is interesting.*

PST-F: *When we laundry our clothes, they will be wet. But if we hang the clothes they will become dry. It means the water just vaporizes without boiling.*

Lecturer: *When does the vaporization process occur?*

PST-F: *When the pressure in the liquid is same as the pressure outside.*

Lecturer: *That is the condition of boiling.*

PST-F: *Oh... ya... that is the condition for boiling. But vaporization can happen at room temperature.*

Lecturer: *There will be a boiling point and a flash point*

PSTs: *Flash point*?

Lecturer: *Flash point is a condition when a substance start to burst into flames.*

PSTs: *Can water can be burnt?*

Lecturer: *Petroleum engineering or the field related to petroleum often refers to the flash point [of a liquid]. Although some liquids have not reached their boiling point, these liquids spontaneously ignite when at a certain distance from a flame. Gasoline and diesel might have different flash points because gasoline ignites more readily than diesel when at the same distance from a flame. That is interesting, to vaporize does not necessarily involve boiling but boiling must involve vaporising. PST-A, do you have any idea?*

PST-A: *I am still confused about the vaporization process*

Lecturer: *At noon, the water can vaporize.... but at night, there is something on the clothes after the water has vaporized.*

PSTs: *Yes*

Lecturer: *But that is not the process of boiling, am I right? There is still some vapour that has become liquid and is now on the clothes.*

PST: *The vapour has condensed*

Lecturer: *Condensation must involve vaporization first. But it is not boiling, right? Thus, when.... hmm… is that how your Physical Chemistry lecturer explained this?*

Further, the lecturer tells that sometimes we need to understand the concept at the sub-microscopic level, but the lecturer also mentioned the difficulties of teaching lower secondary students using this sub-microscopic explanation.

Lecturer: *I think, in the boiling process, the vapour pressure [of the liquid] will be the same [as atmospheric pressure]. But [This means that before the boiling point] the vapour pressure tries to reach it (atmospheric pressure). It might be like that. Might be, um.... As I said before, it (water) was going to… reach 760 mmHg, and before it reaches 760 mmHg some (water molecule) have been released, right? According to the principle of boiling point, the released molecules might most likely be from the surface of the liquid. Is that right? But if we supply some heat from 700 to 760 mmHg, in my opinion, all particles in there will be released simultaneously. If it is only the upper level which has bigger cohesion... cohesion or adhesion? Adhesion isn't it? The adhesion and cohesion of the upper part were not balanced so some water molecules are released. But this releasing process does not simultaneously happen to all molecules. This is my opinion, I don't know about others (pause). Because if we say it has been released, entirely, it can only happen when it has reached its boiling point, when the vapour pressure is the same as the atmospheric pressure. Right? In my opinion, in this condition, all the particles have potential to do that...to vaporize. But in the condition below that, only the particles on the surface can be vaporized, ok? Maybe that is [my explanation] for the time being, but you may (pause). In actual fact, what happened is when the water is heated, the [particle] movements are fast,* *thus the pressure goes higher and the condensed vapour pressure… (pause). If the [vapour] pressure is the same as the atmospheric pressure it can be vaporized, right? Ok? Well, if we put the lid on, the water can boil faster. Is that right? Do you know why?*

PSTs: *Because the pressure is getting bigger*

Lecturer: *In the beginning, the discrepancy is very small. This can be bigger which is enough to bring some of the vapour [filling all the space of the pot]? Ok, it could be.*

Lecturer: *Ok PST-D. Is that [explanation] enough? Or do you have another point of view?*

PST-D: *What about the macroscopic property, Sir?*

Lecturer: *Macroscopic?*

PST-D: *When the water is boiling, the intermolecular forces between the molecules are stretched*

Lecturer: *Yes*

PST-D: *When it [the water] is heated, the water molecules stretch back to the water [in the initial condition]. How it could be, Sir? What happened to the intermolecular force?*

Lecturer: *Ok, if it is related to bonding, it seems that it can be separated, might be because of the attractive force between the groups of molecules. It may be reduced. Yes, so it can be separated. This separation is caused by something that happened, right? It is possible, but we cannot explain what kind of bonding is that. Is that right? The truth is that it [the distance] was stretched. It could be, but not the bonding inside the molecule, between the groups of molecules. Yes, because the molecules were not released as a single molecule, but as a group of molecules. So let say if the stretching happened in the molecule, at one point it can be broken. Yes it is. To break the bonding like that needs a reaction, chemical reaction. [But here], it is only a physical change.*

According to the discussion above, it appears that the lecturer had difficulties in understanding the difference between vaporisation and boiling. His explanation implies his conception that the liquid can transform into gas at the boiling point. He knew that the boiling point is scientifically defined as a temperature when the pressure in the system is equal to the atmospheric pressure, but he interpreted that the initial vaporization happens when water has reached the condition of boiling point. It was hard for him to correlate several variables involved in the boiling process such as heat, particles movements, vapour, pressure, condensed vapour pressure, atmospheric pressure. The missing part was on the relationship between vapour and pressure. He knew that, during the boiling process, additional heat will increase the pressure but he did not realize that the increasing pressure comes from the increasing number of vapour particles from the liquid that has been vaporized. This missing point in the conception about the boiling process appeared to create the difficulty in explaining the difference between boiling and vaporization.

Session by the Pre-service teachers

The session by the pre-service teachers started with a brief presentation about the lesson plan followed by microteaching. The presentation by the pre-service teachers started from mentioning the competence standard and basic competence that represented the topic about phases of matter and their changes. The competence standard is *Understand the phases of matter and their changes*, and the basic competences are as shown in Table 5.2 Document A part 1. The presenter also mentioned four concepts that were covered: (1) phases of matter and their changes, (2) density, (3) expansion, (4) heat. Furthermore, the strategies that they designed to teach those concepts consist of four main activities as follows:

- Do the experiment about the phase changes of matter
- Discuss how the particles are arranged in each phase.
- Observe the difference of cohesion and adhesion through the experiment.
- Apply the concept of capillarity.

When the pre-service teachers presented how they were going to teach they started by showing the pictures of different materials, and asked the students to categorize them into solid, liquid, or gas. They continued with the definition of these three phases, as well as guiding the students to differentiate between them based on the shape, volume, compressibility, and density. They said that they did this to make it easier for the students to understand. They also suggested to begin the lesson by showing the picture or the video about the particle arrangement in solids, which have strong attractive forces between the particles as the particles are close to each other. Further, they explained that the particles in liquids have more space between them so that they can move freely, while the particles of gas are able to move more freely, thus they are far apart from each other. This explanation is inappropriate because there is actually no space between the particles in the liquid. The ability of the particles to move around is due to the loose interaction between the particles. The dialog between PST-J (acted as a teacher) and the other pre-service teachers (acted as students) during the presentation, which demonstrated as teaching and learning process, is presented below.

PST-J (Teacher): *For volume, when a gas was filled into this bottle, did the volume change or stay the same? When the air in this balloon is moved into the bottle, does the volume change or stay the same?*

PST (Student): *The assumption is that nothing more goes in or out, right Miss?*

PSTs: *Alright... the volume stays the same.*

PST-J (Teacher): *So, what is the conclusion? Is the shape of the gas fixed, does it change, or depends on the shape of its container? Thus, the volume of the gas depends on the volume of the container. But when a liquid from the bottle is poured into this plastic glass, does the volume stay the same or change? This volume cannot be assumed as concentration. So, will the volume of liquid stay the same or be different?*

PST-E: *The volume of the bottle differs from the glass, so the volume will be different.*

PST-F: *No, only if we assume that the glasses have different shapes.*

PST-E: *The concentration will be the same, but the volume is different*

PST-F: *The teacher wants to show the different shapes of the containers, but the capacities are the same, I think that's what she means.*

PST-J (Teacher): *So the volume of the liquid is the same, right? What about the solid? If I put this solid in this glass will it be the same or will it change?*

PSTs: *It will stay the same*

PST-J (Teacher): *So, could you make a conclusion about the differences between liquid, gas and solid based on its fluidity, and the volume. PST-K, could you?*

PST-K: *Based on the fluidity, gas and liquid are easy to flow while the solid cannot. About the volume, solid and liquid have fixed volume while the volume of gas depends on its container.*

PST-J (Teacher): *What about the particle arrangement in these three phases?*

PST-F: *The particles in the solid are close to each other.*

PST-J (Teacher): *What about the liquid?*

PST-F: *More distant than in the solid*

PST-J (Teacher): *What about the gas?*

PST-F: *It has much bigger spaces [between the molecules] than in a solid and liquid.*

PST-J (Teacher): *Yup, that is right what has been mentioned by PST-F. Now I'm going to show the video about the arrangement of the particles in these three phases. If we have a look closely, the particles in the solid, are very close to each other, right? In a liquid, there is a slightly larger gap between the particles. They are close to each other, but still have a gap. On the other hand, a gas can move freely. Now, would you please make a conclusion about the particles in these three phases?*

PST: *Particles in the solid are arranged neatly but the particles of liquid have little gaps between the particles, and gas particles have bigger gaps [than in a liquid] so the particles can move freely.*

About the concept of density, students are going to measure the volume and the mass of three different sizes of iron. The measurement results were then put in the table to help the students make a conclusion about the concept of density based on the calculations.

Meanwhile, the concept of expansion is designed to be introduced by practical work using solids, liquids and gases. The expansion of a solid is designed to be conducted by heating different materials and recording the volume before and after heating and comparing the coefficient of length expansion and volume expansion of these materials. The expansion of liquids is investigated using water, vegetable oil, and alcohol. These three liquids will be heated to see how they expanded. About the expansion of the gas, the presenter showed the diagram of the apparatus that consisted of two Erlenmeyer flasks, rubber stoppers, glass pipe, spirit burner, and glass beaker. The Erlenmeyer flask is heated and then we have to observe what happens to the liquid inside the pipe, and whether the liquid will evaporate or not?

Moreover, the topic discussed in this presentation also covered the concept about heat and the influence of heat on the changes of phase by observing the result of heating some substances.

Next, the presentation involved practical work about the phase changes on heating ice, naphthalene, and water. There were three kinds of demonstrations. In the first experiment the teacher lit the spirit burner and put some ice into the glass beaker, and asked the students to see what happened?

PST-D (Teacher): *Is this clear for you at the back? Can you predict, what happened if the solid ice is heated? As we can see, there is part of the ice that starts to melt. The second demonstration is about vaporization, a change from liquid to gas... can you see the vapor?. Meanwhile, in the third demonstration the naphthalene was placed in the glass beaker.*

PST-D (Teacher): *What is the phase of naphthalene?*

PSTs: *Solid*

PST-D (Teacher): *Please predict, if we heat it, the phase will change into...? PST-A, would you come here? Can you smell the scent of naphthalene? What is the conclusion for the heating of naphthalene? So there is a vaporisation process, right? Although, not all the naphthalene has vaporized.*

5.3.5 Finding from the unit implementation

According to the observations about the implementation of the unit, some findings are summarized below.

There was more discussion about teaching strategies rather than basic concept development

Based on the timetable shown in Table 5.5, the topic about learning strategies of the concepts was designed to be delivered after the discussion about the concepts. However, the sessions allocated to discuss the concepts often consisted of the discussion about how to teach the concept. This means that during the lesson, there was less opportunity for the pre-service teachers to strengthen their understanding about the basic chemistry concepts.

Moreover, the discussions about teaching strategy were often explained by the description about the lecturers' observation about the teaching and learning processes in the classroom. However, although the lecturer tried to explain in detail, the explanation was only directed verbally, thus the descriptions about the process of teaching and learning were still unclear and ineffective. It would be more beneficial if the lecturer provided an example of the teaching and learning process through video presentations.

Teach about terminology

Most of the teaching and learning processes tended to be more focused on introducing terminology, followed by its definition and the example of the term or the application. There were no explanations at the sub-microscopic level about particle movement in the processes that were introduced, even when the influence of heat on the changes of the phases of matter were introduced.

Insufficient and unclear explanation about PNM

Although the content about particulate nature of matter could be a part of some topics discussed during the lesson, there was no clear explanation about that. The class still had difficulties getting a satisfactory explanation from the lecturer for the question that related to PNM. The answer and the explanation about the PSTs' questions were often insufficient and unclear.

Sub-microscopic representation development

According to the discussion during the lesson, the explanation often used the sub-microscopic level to represent the particle movement and structure. However, the questions posed by pre-service teachers indicated that they needed further explanation about the concept involving sub-microscopic representations. They still needed assistance to reconstruct a comprehensive conceptual understanding that involved the understanding of the three representations as well as the relationships among these representations.

Inappropriate example and explanation

There were some concepts that was not correctly defined. For example, the explanation about atom as the smallest part of matter that still has the properties of that matter. Whereas the properties of matter only appear when the number of atoms are arranged in a certain structure.

Another inappropriate explanation occurred when the pre-service teachers tried to explain the process of dissolving. The pre-service teachers have an assumption that heat is released or absorbed during a chemical reaction or chemical change. Meanwhile, they wanted to mention that the dissolving process is categorized as physical change because there was no change in the mass of the sugar and water. Besides, there was also no heat absorbed or released during the process of dissolving. While actually heat is involved in the process of dissolving.

Besides the inappropriate explanation, the use of examples sometimes was also inappropriate for the lower secondary students. Although, it is challenging to limit explanations to appropriate levels, as well as to select and use suitable terminology and reactions as examples, teaching strategies should be developed to address this.

PST are still challenged to select the concepts that are appropriate for lower secondary chemistry.

On one hand, the LS-Chem unit is intended to provide the PSTs with sufficient knowledge about the concept covered in the Lower Secondary Curriculum, as well as to provide them with teaching and learning strategies. However, sometimes the discussion was not limited to the content for lower secondary chemistry, but at the end the lecturer expected the PST to select the topics, contents, and also examples that are suitable for lower secondary students.

A discussion emerged from one pre-service teacher about the need to introduce the sub-particle of atom such as the proton, neutron, and electron. Some pre-service teachers thought that this concept was too demanding for the lower secondary students. Responding to this discussion, the lecturer said that there is no limitation in discussing the topic. The lecturer even drew an atomic structure and discussed the nuclear size and its comparison to the nearest electron ring. In this part, the lecturer also explained about the concept of excitation and ionisation.

However, in the closing part of the lesson, the lecturer emphasized that it will be a challenge for the pre-service teachers to select the content that is suitable for the topic about particles of matter for lower secondary school. The pre-service teachers also have a task to determine the structure of the concepts that are going to be taught. Besides, there will be another challenge to design the lesson plan to ensure that the students are interested in learning chemistry.

The need to standardize the implementation of the unit

The observation from condensed and regular semesters showed that there were different activities during those two semesters. According to the objective of the LS-Chem unit as presented in Table 5.3 Document B, it was a great challenge to cover those three objectives in the two-credit unit. Thus, the minimum standard of implementation of the unit was needed to run the unit effectively in a tight schedule.

An alternative way to standardize the implementation of this unit is to put more details about the learning outcome in every session that presented in the unit description.

These learning outcomes should guide the implementation of the unit although the lecturer and the strategy are different.

5.4 Summary of the chapter

According to the findings described above, all the documents about the ideal curriculum stated the conceptual knowledge that needed to be developed in science learning. The documents in Table 5.1, expect the teachers to have a good understanding about the concepts of chemistry and even expect the chemistry teachers to be able to make a connection between chemistry and other subjects.

However, in the written curriculum, especially the unit description of the LS-Chem unit, not all topics mentioned in the school curriculum are covered in the LS-Chem unit, for example, the concept of density and the concept about the influence of heat on changes of the phases of matter and its application in everyday life. Although hierarchically these topics are embedded or are the expansion of the concept about phases of matter and their changes, based on what has been implemented, there were no such explanation of that.

According to the results of the analysis of the implemented curriculum, the time spent for discussing a learning strategy exceeded the time for strengthening content knowledge. The flow of the lecture session also seems not to follow a certain outline. It rather depended on the improvisation by the lecturer. It reveals that there was a tendency to run the lesson based on the interest of the lecturer, not based on the needs of the pre-service teachers. There are at least two reasons that support this argument. The first is when the lecturer was interested in elaborating the discussion about teaching and learning strategy, although it was time for him to teach about the content. The second is when the lecturer was interested in discussing a certain concept, he would elaborate on the explanation although that explanation was too detailed for lower secondary students. This occurrence showed that the implemented curriculum did not meet the expectations of the pre-service teachers.

CHAPTER 6
THE RESULTS OF CURRICULUM EVALUATION: THE PERCEIVED AND ACHIEVED CURRICULUM

6.1 Introduction

Following the previous chapter about the intended and implemented curriculum, this chapter elaborates the result of curriculum evaluation for the aspects of the perceived and achieved curriculum. Section 6.2 elaborates the lecturer's perception in terms of the objective and the scope of the topic discussed in this unit. This section also presents the pre-service teachers' perception about the unit especially about their objective and expectation of enrolling in this unit. Section 6.3 reports the results about the achieved curriculum which is presented in three subsections corresponding to the three conceptual categories of intermolecular spacing in matter, diffusion in liquid and gases, and the influence of intermolecular forces on changes of states.

6.2 Perceived curriculum

The section about the perceived curriculum is associated with presenting the data related to the following Research Questions #3 and 4:

Research Question #3: "*What are the chemistry teacher educators' perceptions about the chemistry education curriculum in terms of enhancing pre-service teachers' understanding of the particulate nature of matter?*"

Research Question #4: "*What are the pre-service teachers' perceptions about the chemistry education curriculum in terms of enhancing their understanding of the particulate nature of matter?*"

The answers to these questions were obtained in interview sessions with the lecturers and the pre-service teachers. The purpose of the interviews was to enquire about the role of the LS-Chem unit in the development of the pre-service teachers' understanding about the basic concepts in chemistry. The summary of the interview results with the lecturers as well as the pre-service teachers is discussed in the following section.

6.2.1 Lecturers’ perceptions

The interview session with the lecturers took place in the regular semester. Based on the interview session with the lecturers there are two main points that can be summarized, namely: the scope of the topic discussed in the unit of *Teaching and Learning of Chemistry for Lower Secondary School*, and the objective of the unit.

The scope of the topic discussed in this unit

According to Lecturer C, this unit not only confirmed the topic about the content of chemistry but also consisted of discussion about how to teach chemistry in the classroom, especially to lower secondary students. As has been mentioned in Section 4.2.3, the LS-Chem unit is an elective unit which is available in the regular semester and in the condensed semester; the majority of the pre-service teacher enrolled in this unit during the condensed semester. However, most of the pre-service teachers who were enrolled in the unit during condensed semester are in Year 2, while the pre-service teachers who were enrolled in regular semester are in Year 4. It means that most of the pre-service teachers enrolled in this unit during the condensed semester had not enrolled in the unit about designing teaching strategies for chemistry learning. Thus, the lecturer was expected to cover some of the topics about the basics of teaching and learning strategies, including how to prepare learning materials for the students. He argued that the discussion about the teaching strategy in this unit helped students to perform better in other unit about designing chemistry learning and micro teaching.

> *The pre-service teachers who were enrolled in this unit during the condensed semeseter, had mostly not enrolled in the units about teaching strategies. Thus, this unit had to include some strategies on how to teach chemistry. According to the experience of the two previous cohorts, they had performed better in the units about teaching strategies, because they had learned some basic skills of teaching in the unit of Teaching and Learning of Chemistry for Lower Secondary School, including how to develop students’ worksheets and write lesson plans.*

This explanation was based on his personal and informal observations during the previous two years. According to his observations, students who had previously enrolled in lower secondary chemistry unit performed better in designing chemistry learning and micro-teaching units. The lecturer explained that the better performance of students might be related to the previous depiction of how to teach chemistry that was/had been introduced in the LS-Chem unit.

Following his explanation, Lecturer C also gave a further description about the topic of teaching strategies that had been introduced in the LS-Chem unit that involved how to develop students' worksheets' and write lesson plans. He also added that there was some intention to discuss how to develop laboratory work for lower secondary students, but the time was not suficient to cover all the topics mentioned, especially to give some feedback for the students. Regarding the topic about the content, Lecturer C explained that the focus was on the chemistry content not on all the science content. Of course there are some physics topics that also were mentioned during the course such as diffusion, density, and expansion. But, since this unit is only dedicated for chemistry topics, the discussion about physics concepts was not as detailed as the concepts in chemistry.

> *Sometimes, there were some students who elaborated the process of evaporation when they discussed the topic of phases of matter. We rarely discussed physics concepts in depth because these concepts are supposed to be taught in the physics course. Although we are all agree that pre-service teachers should have good understanding about these physics concepts, what we usually discussed during this unit was only about chemistry concepts.*

Unlike the perceptions of Lecturer C about the concepts that should be covered in the LS-Chem unit, Lecturer D perceived the need to emphasise the development of strong basic knowledge of chemistry content. There are at least three points that were emphasized by Lecturer D regarding the scope of topics discussed in the LS-Chem unit: 1) The chemistry content discussed in the LS-Chem unit needs to be clearly distiguished from the chemistry content for high school; 2) The strategies to teach chemistry to lower secondary school students, and 3) The teaching of chemistry to lower secondary students has to be structured, clear, and avoid the tendecy to introduce terminology/definitions that will lead the students to do rote learning. In his statement, Lecturer D noted that the need to discuss teaching strategies did not mean writing lesson plans, learning materials (book chapter/reading material) and presentation slides. The most important thing is that the teacher knows how to teach the content in a structured manner so that it can be easily understood by the students.

Considering the time allocated for this unit (involving only two credits), it will be more effective if the discussion in the LS-Chem unit is about the exploration of the content that is appropriate for lower secondary students. The teaching strategies should provide examples that make pre-service teachers realize the best ways to teach chemistry to lower secondary students. Further, preservice teachers should know what is needed to be considered in teaching, especially students' cognitive development that involved determining the content selections and teaching strategies.

The objective of this unit

According to Lecturer C, this unit is intended to develop chemistry pre-service teachers to be ready to teach in the lower secondary school. Lecturer C also referred to the unit objective that is stated in the document of the unit description. According to the document on the description of the LS-Chem unit, the aim is to develop pre-service teachers to:

(1) have insight about the scope of the content of chemistry according to the science curriculum for lower secondary school
(2) master the content of chemistry for lower secondary school
(3) have insight about the teaching and learning strategies to be implemented in chemistry learning in lower secondary school

On the other hand, according to Lecturer D, the main objective of this unit is to strengthen pre-service teachers' conceptual understanding about the content of chemistry for lower secondary school that is clearly different from the content for high school. This intention is based on field observations that science teachers in lower secondary schools often find difficulties in determining the chemistry content to be taught.

6.2.2 Pre-service teachers' perceptions

Pre-service teachers' perceptions derive from the interview sessions during the regular semester. According to the interview with pre-service teachers, it has been known that pre-service teachers need to learn more chemistry content because they realize that their prior knowledge from high school is not sufficient for them to be teachers.

Interviewer: *Do you think that the chemistry content knowledge that you have learnt from school is sufficient for you to be a teacher?*

PST E: *When I was in high school I thought that I have mastery of the chemistry concepts. But when I started to learn chemistry in the university, I found many concepts that I have not really understood.*

PST F: *I think that my knowledge of chemistry that has been learned from my high school is not sufficient at all because my school is in the remote area of North Sumatera. I found many new things that I learned during my study here in this university. Although my school had good facilities, like laboratory aparatus and learning materials, the teacher did not introduce them all to the students. I started to understand only when I learned about general chemistry.*

PST J: *I went to vocational school for my high school, and I think that my experience of studying in vocational school allowed me to learn many skills that are usefull for laboratory activities. However, I think there were not so many concepts that I had learned in vocational school, so I have to learn many more concepts during my study in university.*

Based on this discussion, all pre-service teachers involved in this interview session agreed that they needed some units that gave them the opportunity to strengthen their knowledge about chemistry concepts.

Regarding pre-service teachers' decision to enroll in the LS-Chem unit, they enrolled in the elective unit that was related to teaching and learning to support their future career as teachers. Since the title of this unit is *Teaching and Learning of Chemistry for Lower Secondary School*, they expected to learn about the chemistry content and the strategies to teach chemistry to lower secondary students.

Interviewer: *What is your expectation of this unit?*

PST I : *To teach lower secondary students this will be different to teaching upper secondary students. Lower secondary students have more curiosity, so I think I have to learn to face their curiosity.*

PST F : *I intend to prepare myself to teach chemistry to lower secondary students and to enhance their motivation to learn science. Thus, I think I have to learn how to teach science effectively so that the students would love to learn about science, especially chemistry.*

PST L : *I want to teach chemistry in high school not in lower secondary school. However, I think I need to learn chemistry for lower secondary school to strengthen my knowledge about basic concepts in chemistry that will support my teaching practice in high school.*

PST G : *I enrolled in this unit to find out how to teach chemistry to lower secondary students. We already have images of how to teach chemistry in high school based on our prior* *experience of learning chemistry in high school, but we do not have any experience of learning chemistry in lower secondary school.*

According to the interview record as presented above, it can be revealed that these two pre-service teachers expected to learn about chemistry content that will strengthen their basic knowledge of chemistry. PST-I thought that she needed to strengthen her knowledge to be able to give good explanations when she has to face the questions raised by lower secondary students. She thought that lower secondary students have high curiosity that have to be facilitated with the right responses to nourish their motivation to learn. The second pre-service teacher is PST-L who only wanted to teach high school chemistry, not lower secondary chemistry. But she realised that to teach chemistry effectively to high school students, as a teacher, she has to have a comprehensive understanding about chemistry. Thus through this unit, she has an expectation to learn about the basic concepts in chemistry to strengthen her chemistry understanding. The other pre-service teachers mentioned that their expectation of this unit is about to learn how to teach chemistry effectively to lower secondary students. Some pre-service teachers (PST-F, PST-H, PST-I, PST-L) think that they need to know an appropriate strategy to teach chemistry to assist lower secondary school students in developing fundamental knowledge of chemistry that will minimize the misconception. Some other pre-service teachers (PST-E, PST-G, PST-I, PST-J, PST-K) realize that the students in lower secondary school have different characteristics to high school students. Thus they need to learn how to effectively engage and motivate lower secondary students in chemistry learning.

However, after almost one semester in the LS-Chem unit, the pre-service teachers found that what they experienced did not meet their expectations. The main reason is that they were unable to clearly see the differences between teaching chemistry concepts for lower secondary school and chemistry concepts for high school.

Interviewer : *Do you think your expectations have been achieved?*

PST J : *No, because I still cannot really envisage the difference between chemistry teaching and learning in lower secondary school and in high school. It is still vague to me.*

PST K : *Not yet, because I still found similar ways to teach several concepts for high school and for lower secondary school. The differences are still unclear to me.*

PST E : *Still confused about the difference between teaching chemistry for high school and for lower secondary school. During the lesson, sometimes the lecturer explained the concepts in detail. When we confirmed, he said that this explanation was for high school students, so we had to design an appropriate explanation for lower secondary students. Hence, we are still confused about how to teach the concepts to lower secondary students.*

PST G : *When I did my task (to develop learning materials) I was confused about the topics that were suitable for lower secondary students and when I tried to refer to the students' textbook, I found some topics that were too complicated to be taught to lower secondary students.*

PST F : *The explanations that were presented by the lecturer were often too detailed so we were still confused about the concepts that are suitable for lower secondary students. We are also still confused where the boundary for secondary school students should be drawn, because we will adopt the way the lecturer taught us when we teach our students.*

All the pre-service teachers had the same disenchantment regarding the unclear difference between the topics selected for lower secondary school and those for upper secondary school. They had expected to have a clear distinction between the topics for these two different levels of students. They believed that their experience in learning how to teach during the course would inspire them when teaching their students later. That is what they expected from the LS-Chem unit.

6.3 Achieved curriculum

This section about *the achieved curriculum* provides the answer to the Research Question #5: "*What are pre-service chemistry teachers' understanding of the particulate nature of matter after enrolling in the unit of Teaching and Learning of Chemistry for Secondary School?*" As described in Chapter 4, this research question is pursued by examining pre-service teachers' responses to the 11 items of the Particulate Theory Diagnostic Instrument (PTDI) (Treagust et al., 2010). Table 6.1 presents the scores of pre-service teachers' in response to the 11 items of the PTDI.

The data in Table 6.1 show that the pre-service teachers' correct answers to the first tier was much higher than those to the combined tiers for all the items, as shown in Figure 6.1. The average for the first tier was 72%. However, their average correct responses to the combined tiers was 38%. This fact indicates that the pre-service teachers did not provide correct explanations for almost half of their answers to the first tier of the questions. This suggests the pre-service teachers may have alternative conceptions relating to particulate theory.

Table 6.1 Pre-service teachers' achievement on PTDI (n = 12)

Code of students	**Score (*Max Score is 11*)**	
	1st Tier	**Both tiers**
PTS-A	8	7
PTS-B	10	6
PTS-C	9	4
PTS-D	10	7
PTS-E	6	2
PTS-F	8	3
PTS-G	7	2
PTS-H	7	3
PTS-I	8	4
PTS-J	10	5
PTS-K	5	3
PTS-L	7	4
Average	7.92 (72%)	4.2 (38%)
Standard Deviation	1.62	1.75

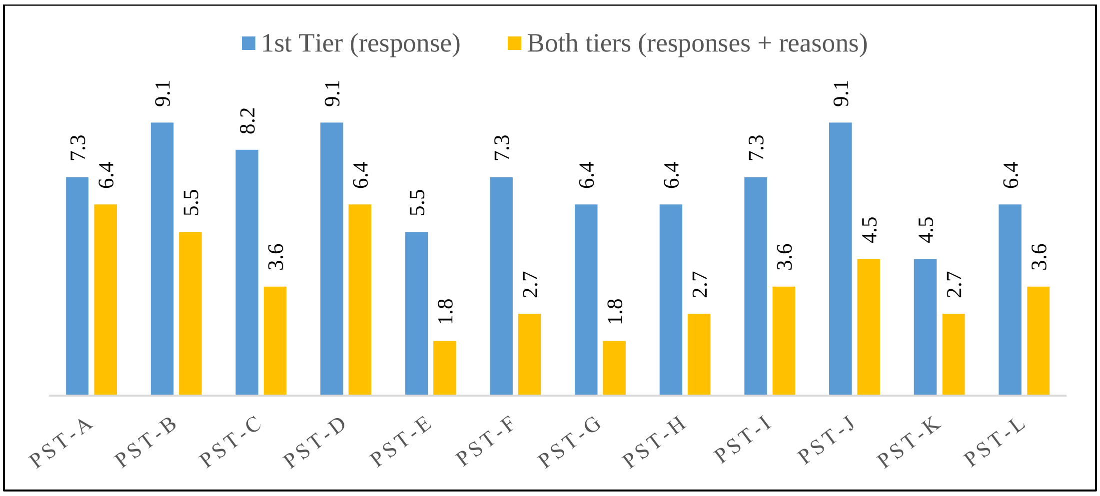


Figure 6.1 Pre-service teachers achievements on PTDI test

The low achievement of the pre-service teachers on the combined tiers in the items of the PTDI needs greater attention. The reason for this low understanding may be because the 11 items of the PTDI involved the chemistry concepts that the pre-service teachers had recently learned in the unit that focused on the basic concepts in chemistry. They also have enrolled in several other units related to content knowledge such as Physical Chemistry, Organic Chemistry, Inorganic Chemistry, Biochemistry and other advanced chemistry content units. The pre-service teachers were in the 4th-year of their chemistry teacher education and have to be ready for their teaching apprenticeship program in the next semester.

Table 6.2. Number of pre-service teachers with correct answer on each PTDI item

Item No	Number of pre-service teachers with correct answer	
	1st tier	**both tier**
(1) intermolecular spacing in matter		
3	12	6
4	8	6
5	12	7
11	7	7
Average	9.75	6.50
Standard Deviation	2.63	0.58
(2) diffusion in liquid and gases		
1	6	1
2	6	6
6	3	1
7	11	11
Average	6.50	4.75
Standard Deviation	3.32	4.79
(3) influence of intermolecular forces on changes of state		
8	9	4
9	11	4
10	10	6
Average	10.00	4.67
Standard Deviation	1.00	1.15

To find out more about this low achievement, further analysis was performed on the reasons given by the pre-service teachers' for each PTDI item. The results of this analysis is presented in the following subsections which are divided into three parts based on the concept categories of the PTDI items as shown in Table 6.2. This analysis provides information about which concepts need to be strengthened further in the future curriculum.

6.3.1 Intermolecular spacing in matter

As shown in Table 6.3, the topic about intermolecular spacing in matter was tested in PTDI items number 3, 4, 5, and 11. These items are related to the concepts that the spacing between the particles in the liquid is fixed, but the intermolecular forces between the particles allowed them to move around. While, in the gaseous state, there are large spaces between the particles and the particles are able to move freely in that space.

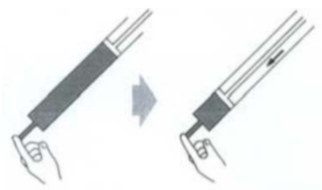
Table 6.3. Pre-service teachers' achievement on PTDI items of intermolecular spacing in matter

Item No.	Number of students with the correct answer		Understanding evaluated by items
	first-tier	both tiers	
3	12	6	Volume of a liquid remains constant although in different shapes because the number of particles and the spacing between the particle are fixed.
4	8	6	During the compression process, the volume of gas decreases because the widely spaced particles are pushed closer together, without affecting the mass.
5	12	7	A gas is compressed easily as there are wide spaces between gas particles.
11	7	7	The decreasing of volume when two liquids are mixed is caused by the particles of one liquid occupying the space between particle of the other liquid.
Average	9.75 (81.25%)	6.5 (54%)	
Standard Deviation	2.63	0.58	

According to Table 6.3, although 81.25% pre-service teachers provided the correct answers to the PTDI items about the intermolecular spacing in matter, only 54% of them provided the right explanations for their answer. This fact indicates that the pre-service teachers might have alternative conceptions about the intermolecular spacings in matter. To reveal details of possible alternative conceptions about intermolecular spacing in matter possessed by the pre-service teachers, the following is the analysis of pre-service teachers' responses to item 4 of the PTDI.

Item no 4

The diagram shows a pump containing a coloured gas that is compressed by pushing the plunger down.



We can conclude that

A. the volume and mass of gas have decreased
B. the volume of gas has decreased while the mass has increased
C. the volume of gas has decreased while the mass remains constant

The reason for my choice of answer is:

1. Gas particles can be readily compressed and pushed closer together
2. The widely-spaced gas particles have been pushed closer together
3. The number of gas particles has decreased.
4. Other: ....

Figure 6.2. Item number 4 of the PTDI

The conceptual understanding evaluated by PTDI item number 4 (shown in Figure 6.2) is about the compressibility of a gas due to the existence of wide spacings between the gas particles. Responding to this question, eight of the 12 pre-service teachers believed that the volume of the gas will decrease while the mass will remain constant during the process of compression. However, there were various reasons for their answers, and some of the pre-service teachers preferred to provide their own reason with their own words. There were also various reasons for those who provided different answers in the first tier implying their alternative conceptual understanding. Table 6.4 summarises the explanations provided by the pre-service teachers for their response to item number 4.

Table 6.4 Pre-service teachers' explanations in answering item number 4

Type	Explanations	Frequency
A*)	When a gas is compressed, the volume decreases whilst the mass remains constant as the widely spaced particles are pushed closer together	6
B	When a gas is compressed, the volume decreases whilst the mass remains constant because V is equal with 1/P.	1
C	When a gas is compressed, the volume decreases whilst the mass remains constant as no particles move in or out.	1
D	The volume decreases whilst the mass increases when a gas is compressed to get closer each other.	3
E	The volume and mass both decrease when a gas is compressed because the molecules become closer to each other.	1

*) The preferred explanation

Among the eight pre-service teachers who believed that the volume of gas will decrease while the mass remained constant during the process of compression, six of them explained that this fact was related to the wide spaces between gas particles (Type A). Two other pre-service teachers just simply related the fact to the ideal gas equation (Type B) and the constant number of particles since there were no particles coming in or out (Type C). The pre-service teacher who explained with explanation Type B showed her ability to use her understanding about symbolic representations instead of sub-microscopic representations. Moreover, the explanation Type C shows that this student demonstrated good logical thinking but did not challenge herself to explain the process of the gas compression.

Interestingly, three pre-service teachers (PST-E, PST-H, and PST-K) believed that during the compression of gas, the volume decreases and the mass increases (Type D).

This explanation showed their confusion about the term mass and the concept of density. The interview trancriptions from these three pre-service teachers that recorded their explanation about their answer to PTDI item number 4 provide evidence of their confusion between mass and density.

Interview PST-E

Interviewer : *If the gas is pushed, then it will become as shown in the picture like this (pointing to the picture in the paper, that shows the decrease of the volume). Then it will make the volume decrease (according to your answer). Why did the volume decrease?*

PST-E : *If we observe physically, from this amount at initial condition (pointing to the picture in the paper), becomes less like this (pointing to the picture in the paper) when it is pushed, so that the volume decreases.*

Interviewer : *So what do you mean by the increased mass?*

PST-E : *Here, (pointing to the picture of the initial condition) the spaces between the particles are greater (more-spacious), and when it is compressed, it become denser and, let say, if we weigh it, it will be heavier, because the spaces are closer.*

Interview PST-H

Interviewer : *According to your response (to item number 4), if the gas is compressed then the volume will decrease.*

PST-H : *Yes*

Interviewer : *What do you mean?*

PST-H : *No, not decreased ... eh..yes decreased.. because the space between gas particles are wide, when it is pushed, compressed, the space becomes closer.*

Interviewer : *So, the volume will be decreased?*

PST- H : *Hmmm..... yes.. decreased (seems not really sure)*

Interviewer : *Are you sure?*

PST-H : *Yes Miss, decreased.*

Interviewer : *Now, what do you mean by the increasing of mass? How do you explain it?*

PST-H : *When it (the gas) was not compressed yet, it (the particles) was (were) spread, so that when the mass was measured it (the mass) will be small. But when it (the gas) is compressed, we can say it as... not solidify but getting closer... and it will make the mass increase.*

Interview PST-K

Interviewer : *When the gas inside the syringe is pushed, the volume is decreased and the mass...*

PST-K : *The mass is increased.*

Interviewer : *You wrote here, the reason is the movement of the gas particles was free and the volume was big, and the mass was light. But when it was pushed, the volume decreased. Why the volume is decreased?*

PST-K : *Because the particles' movement become not so free*

Interviewer : *Do you mean there was less room for the particles to move around?*

PST-K : *Yes*

Interviewer : *So why did the mass decrease?*

PST-K : *The mass increased, Miss...*

Interviewer : *Oh ya... why did the mass increase?*

PST-K : *The mass increased, I just think it will be heavier.*

Interviewer : *Because it was more compressed?*

PST-K : *Yes*

Interviewer : *So, let's say, if the color of the gas is light blue, if it is compressed....*

PST-K : *....the color become dark blue, and the mass increased.*

According to those three interview transcriptions, all three pre-service teachers thought that when the gas is compressed, the particle will get closer to each other. This is true but it leads to a wrong answer when they thought that as the particles become closer to each other, the gas will be heavier. While actually, as the number of particles remains constant, the mass will not change.

Beside the confusion between the concepts of mass and density, there was also one pre-service teacher (PST-G) who thought that during the compression the volume and mass both decrease because the molecules are getting closer to each other (Type E). The following interview transcription shows her difficulty in explaining the process of gas compression.

Interview PST-G

Interviewer : *You mentioned the volume of gas decresed, why did it decrease?*

PST-G : *Because the space that was occupied became smaller, thus the volume decreased*

Interviewer : *What about the mass? Why did the mass decrease?*

PST-G : *Hhmm... the mass has not decreased...*

Interview : *Why did the mass not decrease?*

PST-G : *Yes... the mass also decreased?*

Interviewer : *Decreased or not?*

PST-G : *Decreased*

Interviewer : *Why did the mass decrease?*

PST-G : *But there were nothing moving in and out, am I right? How could it decrease?*

Interviewer : *So, how? Did the mass decrease or not?*

PST-G : *Decreased..*

Interviewer : *Why?*

PST-G : *Because, previously (the space) here is spacious, am I right? So the air particles can be spread in all directions. But when the space is decreased, so the amount..., not the amount, the space between particles becomes less.*

Interviewer : *So, what is the relationship between the space between the particles and the mass?*

PST-G : *That is the point, I dont know, Miss.*

As shown in the interview transcription above, this pre-service teacher had built the right images of the process during the gas compression. She knew that, in the initial condition, the air particles are spread in all directions. She also knew that when the gas is compressed then the volume decreased and the space between particles becomes less. She even realized that no particles came in and out during the process of gas compression. But she could not apply her understanding to explain her answer that she was not really sure about it. This doubt in explaining phenomena which are related to the basic concept of chemistry shows the limited comprehension of pre-service teachers' content knowledge that has to be anticipated by teacher educators.

How the topic of intermolecular spacing in matter was discussed in the implemented curriculum?

According to the unit description of the LS-Chem unit, in Section 5.1, the topic about intermolecular spacing in matter is supposed to be covered when discussing about the particles of matter (Week 3) and the phases of matter and their changes (Week 7). However, based on the Table 5.5 about the timetable of the unit, the discussion about how the particles are arranged in matter is only covered in week 7 when a group of PSTs presents the teaching strategy to teach about the phases of matter and how it changes. The topic was discussed during the discussion between the pre-service teachers who played the role of the teacher and the other pre-service teachers that pretended to be students (the transcription of the discussion was presented in pages 91-93). In summary, the presenter tried to involve the other pre-service teachers to explain differences in the properties between solids, liquids and gases in terms of their shapes in different containers.

During this discussion, the presenter also played the animation video that showed molecular images of solids, liquids, and gases. According to the animation, the presenters explained that the particles in a solid are arranged neatly close to each other, while in a liquid there were little gaps between the particles, and there were much wider gaps between gas particles. This explanation differs from the scientific explanation of the estimation of the comparison of spaces between particles in the three states to be in the approximate ratio 1:1:10 (Harrison & Treagust, 2003). Regarding this, it is important to remind the pre-service teachers about the need of careful consideration in selecting the animation for teaching purposes. We have to make sure that the animation is scientifically correct.

In this presentation, the topic about phases of matter and their changes also consists of the concept of density, because in the curriculum document of science for lower secondary school, there is also a competence standard related to density which states "*Describe the concept of density in everyday life*". Subsequently, the pre-service teachers designed an inquiry learning strategy to teach their students about the concept of density. During the presentation, they explained that their strategy was designed to involve the students in measuring the volume and mass of different sizes of pieces of iron. Through this strategy, the students were encouraged to make a conclusion about the concept of density based on their calculations. Through this strategy, the PSTs were expected to provide evidence that the density of iron will always be the same even in different sizes.

Considering the data that would be gathered by the students, this evidence and example are not sufficient to build a sound understanding about density. Besides the fact that a material of different sizes would have the same the density the pre-service teachers should also have to be conviced that different materials of the same size may have different densities. These two facts might be sufficient for the students to arrive at a conclusion about the concept of density. Furthermore, their understanding about the concept of density could be applied to explain the processes when a gas is compressed or expands. However, there were no comments from the lecturers as well as from the other pre-service teachers regarding this strategy in terms of the adequacy of the data in support of students' conceptualization.

6.3.2 Diffusion in liquids and gases

As shown in Table 6.5, the topic about diffusion in liquids and gases was evaluated by PTDI items number 1, 2, 6, and 7. These items concern the concepts involving the process of diffusion which are related to the understanding about the movement of particles within the liquid and/or gas. These items also involve the concept about the existence of air molecules in open air and also the concept of a vacuum environment.

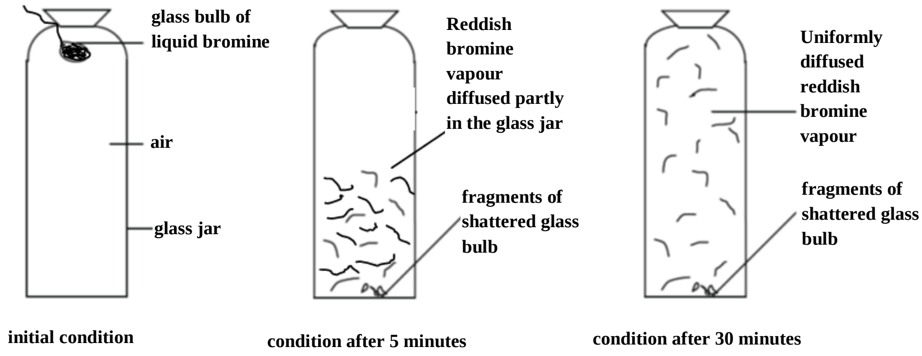
Table 6.5. Pre-service teachers' achievement on PTDI items about diffusion in liquids and gases

Item No.	Number of students with the correct answer		Understanding evaluated by items
	first-tier	both tiers	
1	6	1	Continuous collisions between smoke particles and air molecules resulted an observable movement of the smoke particles in a zigzag manner.
2	6	6	A gas diffuses more rapidly in partial vacuum due to much fewer collisions between gas particles and air particles.
6	3	1	Continuous collisions between dye particles and water molecules enable the dye to diffuse in the water although it takes a long time to diffuse throughout the water.
7	11	11	An inflated balloon gradually decreases in size as air particles diffuse out through the pores in the balloon skin.
Average	6.5 (54%)	4.75 (40%)	
Standard Deviation	3.32	4.79	

According to the results presented in Table 6.5, on the average, 54% of pre-service teachers provided the correct response on the first tier and 40% on both tiers to the items that evaluated their understanding about diffusion. The highest achievement was on item number 7 that evaluated the deflation of a balloon due to gas diffusion through the pores on the balloon skin. Meanwhile, 50% of pre-service teachers correctly answered the item number 2 about gas diffusion. The lowest achievement was on item number 6 about diffusion in liquids. Only 25% of the pre-service teachers provided the correct response on the first tier on item number 6 and only 1 preservice teacher provided the appropriate explanation. To explore pre-service teachers' understanding about diffusion in gases and liquids, this subsection will provide further analysis of pre-service teachers' responses to the PTDI item number 2 (shown in Figure 6.3) that represents the topic of diffusion in gases.

Item No 2

A small glass bulb containing liquid bromine was dropped into a tall jar of air and the jar was immediately stoppered. The bulb shattered on hitting the bottom of the jar, releasing bromine vapour. After several hours, reddish bromine vapour had diffused uniformly throughout the jar.



If the experiment is repeated after pumping out most of the air from the jar, we would expect the reddish bromine vapour to diffuse and fill the jar within a few seconds.

A True B False

The reason for my choice of answer is:

1 The heavier bromine molecules will sink to the bottom of the jar.
2 Fewer collisions occur between the bromine molecules in the absence of air particles.
3 Bromine molecules can now occupy the extra space that was previously taken up by the air particles.
4 Bromine molecules diffuse slowly in a random zigzag manner to fill the jar.
5 Bromine diffuses faster because fewer collisions occur between bromine and air particles.
6 Other: …………………………………………………………………………………
………………………………………………………………………………………………

Figure 6.3. Item number 2 of the PTDI

As presented in Table 6.5, conceptual understanding evaluated by PTDI item number 2 is a rapid difussion of gas in a partial vacuum due to many fewer collisions between gas particles and air particles. Responding to this question, six of 12 pre-service teachers believed that the diffusion will happen more rapidly and all of them agreed with the reason that this was due to fewer collisions between gas particles and air molecules. However, there were six other pre-service teachers who believed that the gas will not diffuse faster in a vacuum. The reasons for their answer are presented in Table 6.6.

Table 6.6 The pre-service teachers' explanations in answering item number 2

Type	**Explanations**	**Frequency**
A*)	Bromine molecules diffused faster because of less collisions between the molecules and air particles.	6
B	The heavier bromine molecules will precipitate at the bottom of the jar.	1
C	Less collisions between bromine molecules and air particles make diffusion becomes slower.	4
D	The diffusion will be slower because bromine molecules will occupy the spaces that were previously occupied by air particles.	1

*) The preferred explanation

According to Table 6.6, there were four types of pre-service teachers' explanations in item no 2. Explanation Type A shows the right answer that recognises the existence of air particles that will collide with bromine molecules in the jar, while the absence of air particles would reduce the frequency of collisions. Thus the bromine molecules can spread easily throughout the tube because they don't need to collide with the air particles. The explanation Type B is based on the fact that bromine has large atomic mass that makes the bromine particles to precipitate at the bottom of the jar/tube. Meanwhile, the explanation Type C shows their thinking about the effect of the collisions between air particles and molecules of bromine in the diffusion process. They thought that, to be able to spread out all over the jar, the bromine molecules need to collide with the air particles. These students confused the movement of smoke particles by collisions with gases. They ignored the ability of gas particles to move spontaneously to all directions. They also might not realize that liquid bromine will spontaneously transform to a gas in ambient temperature and pressure. The explanation Type D just simply suggests that the bromine particles can spread out to replace the air particles (need further explanation why she thought that it will become slower).

According to the answers provided by the pre-service teachers, those who did not choose the right answer might not have the correct choice picture about the structure and the movement of gas particles. They also have insufficient understanding about the phase of bromine at room temperature, and how it is a liquid in the small glass ball. They were also unable to explain the spontaneous spreading of gas molecules throughout the container. That is why four of them thought that bromine molecules will only be able to move because of collisions with the air particles, while one pre-service teacher suggested that the heavy molecules will precipitate no matter the phase of the substance.

How was the topic of diffusion in gases and liquids discussed in the implemented curriculum?

The topic about diffusion was not discussed during the whole semester of the LS-Chem. There were two main reasons for not covering the topic of diffusion in the discussion. The first reason was the fact that the topic about diffusion does not exist in the document of the science curriculum for lower secondary school. While the second reason was that the discussion about the phases of matter was not as detailed as the movement of the particles of the substance. The topic about diffusion involved discussion of the particle movements within gases or liquids. During the discussion about the phases of matter, the pre-service teachers described that particles in the solid are very close to each other, while in the liquid there are little gaps between the particles, and the particles of gas have wider spaces between them and move freely. In fact, they did not mention about the movement of particles in the liquid and they did not apply the concept of particle movement to the phenomenon of diffusion.

6.3.3 The influence of intermolecular forces on changes of state

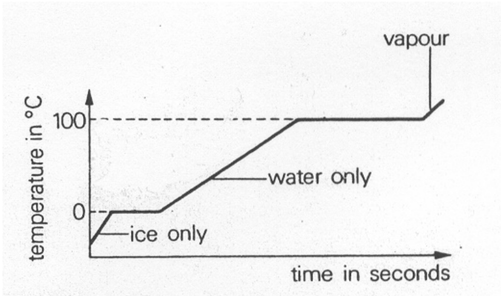
As shown in Table 6.7, the topic about the influence of intermolecular forces on changes of state was evaluated in the PTDI items number 8, 9, and 10. These items are related to the concept that heat is involved to weaken/strengthen the intermolecular forces between particles in the process of change of state of matter.

Table 6.7. Pre-service teachers' achievement on PTDI items about the influence of intermolecular forces on changes of state

Item No.	Number of students with the correct answer		Understanding evaluated by items
	first-tier	both tiers	
8	9	4	The temperature remains constant during melting as the heat energy absorbed is used to weaken intermolecular forces and enable the particles to move freely.
9	11	5	A substance remains in the liquid state at its boiling point until the intermolecular forces have been weakened between all the particles enabling the particles to move more freely.
10	10	6	Heat energy is absorbed during melting and boiling to weaken the intermolecular forces and enable the particles to move more freely.
Average	10	5	
Standard deviation	0.816	1	

According to the results presented in Table 6.7, most of the pre-service teachers had chosen the correct answers for the first tier, but less than 50% provided the right explanation for their answer in the first tier. In general, this fact reveals the limited understanding about the influence of intermolecular forces during the process of changes of state. To elaborate pre-service teachers' understanding about this, the following part of this subsection presents further analysis of pre-service teachers' responses to the PTDI item number 9 (shown in Figure 6.4) that represents the topic of the influence of intermolecular forces on changes of state.

Item No 9
The diagram shows how the temperature changes when some ice at a temperature below 0^{o}C is heated to above 100^{o}C.



We may deduce that liquid water can exist at its boiling point of 100^{o}C.

A True B False

The reason for my choice of answer is:
1 At the boiling point water molecules change immediately into steam.
2 The molecules are moving fast enough to change completely into steam.
3 The attractive forces between all the water molecules have to be weakened.
4 Other:………………………………………………………………………………
………………………………………………………………………………………

Figure 6.4. Item number 9 of the PTDI

As presented in Table 6.7, conceptual understanding evaluated by PTDI item number 9 (shown in Figure 6.4) is about the remaining substance in the liquid state at its boiling point until the intermolecular forces between all particles have been weakened. These weak intermolecular forces enable the particles to move more freely, thus they change from liquid to the gaseous state. Responding to this question, 11 of 12 pre-service teachers believed that at 100^{o}C there will be some water remaining in the jar, but only five of them associated that fact to the attractive intermolecular force that had to be weakened during this stage. The other pre-service teachers provided the other reasons that are summarized in Table 6.8.

Table 6.8 The pre-service teachers' explanations in answering item number 9

Type	**Explanations**	**Frequency**
A*)	At 100^{o}C some water molecules still remain in the jar because the attractive forces between the molecules have to be weakened.	5
B	At 100^{o}C not all water molecules change to become vapor, because this temperature is not enough to break all the intermolecular force of water molecules, so not all water can be vaporized at 100^{o}C.	1
C	No reason provided but stating theory or observation	3
D	Inconsistency between answer and explanation	3

*) The preferred explanation

As shown in Table 6.8, there are four main types of reasons that are explained by pre-service teachers in responding to item number 9. Type A shows the correct answer with the right explanation, while the pre-service teacher with the reason Type B mentioned that it needs higher temperature to vaporise all the water molecules. This argument revealed that the pre-service teacher did not interpret the flat line at 100°C in the graph correctly, and this also becomes an example of pre-service teachers' limitation in building links between the macroscopic, sub-microscopic, and symbolic representations. While there were two other reasons (Types C, D) provided by the pre-service teachers, that cannot be described further because they do not clearly explain the reason and consist of inconsistencies between the answer to the first tier and the reason.

How was the topic of the influence of intermolecular forces on the change of state discussed in the implemented curriculum?

According to the unit description of the LS-Chem unit, in Section 5.1, the topic about the influence of intermolecular forces on the changes of state of matter is supposed to be covered when the phases of matter and their changes are discussed (Week 7). The change of phase of matter is closely related to the change of the strength of intermolecular forces between the particles of matter involved. Therefore, the National Curriculum of science for lower secondary school also consists of the competence standard, "*Describe the influence of heat to the change of the phases of matter and its application in everyday life*".

During the lesson, the topic about the influence of heat on the change of the phase was discussed in the teaching strategy that had been described by the lecturer as well as by a group of pre-service teachers. The teaching strategy was about doing experiments to heat ice, water, and naphthalene. But, the focus of these experiments is only intended to show the process of changing phase affected by heat, and to show the example of the process of, melting, vaporisation, and sublimation. The discussion that comes after the description about this learning strategy is about how to improve the lesson because the naphthalene melts during the heating process, while it is actually expected to change directly from solid to gas (sublime). Both the presentations by the lecturer as well as by the pre-service teachers were not followed by the explanation beyond the process of changes of state. There was no explanation about the process and its relationship with the intermolecular forces within the substance.

There was no explanation about the reason why they did not include the discussion about the intermolecular forces. Whereas, there was an excellent question from a pre-service teacher regarding this: “In the process of heating the water, what happens to the intermolecular forces between the molecules of water?”. This question arose in the first session after the explanation from the lecturer. According to this question, it seems that the pre-service teacher really needed assistance to build an understanding that will help her in making a link between the prior understandings about phases of matter and their changes that they already possess. Unfortunately, the pre-service teacher did not receive any clear explanation to raised question.

Actually, the explanation about intermolecular force is very important even for lower secondary students because they only have one opportunity to learn about the process of changing of state. So, we have to use this opportunity to build an appropriate understanding about this concept. Besides, this concept and the explanation are basic to support their comprehension of other concepts in chemistry. Moreover, the lower secondary students also need to be encouraged to understand chemistry in three different representations, to use three representations in chemistry and to make connections between the three representations.

According the explanation Type B that mentioned the existance of an equilibrium state during the vaporization process, there was a discussion about the difference between boiling and vaporization during the first session. Based on the interview transcription recorded, it can be deduced that these pre-service teachers are able to differentiate between vaporization and boiling. They understood that vaporization is a change of state based on the concept of equilibrium between liquid and gas that can occur anytime. While boiling is defined as a change of state that occurs when the vapour pressure of the liquid is equal to that of the environment; in the case of water at 100°C (at 1 atm or 760 mmHg atmospheric pressure). However, during this discussion there was no further explanation about the role of intermolecular forces.

6.4 Summary of chapter

According to the pre-service teachers' perceptions, their purpose of enrolling in the LS-Chem unit was to strengthen their knowledge about basic chemistry concepts as well as to enrich their skills to teach chemistry to lower secondary students. Thus, the main grievance of the pre-service teachers was the fact that the discussion sometimes went beyond the capacity of lower secondary school students, and they had to find out themselves the distinction between teaching chemistry for lower secondary school and chemistry for high school.

The results of the pre-service teachers' achievement that were analyzed as the achieved curriculum showed that there were some pre-service teachers who still had limited understanding about several basic concepts such as, density, volume, influence of heat on intermolecular forces, the role of intermolecular forces in the states of matter, and the movement of particles within three different states.

In summary, there are inconsistencies between the intended, implemented and the perceptions of the lecturer and pre-service teachers that resulted in unsatisfactory achievement of the pre-service teachers regarding their understanding about basic chemistry concepts. To overcome this situation, it will be beneficial to restructure the unit description and to state the expected skills of the pre-service teachers in greater detail to make the unit more focused on the intended curriculum. Besides, the unit also needs new strategies that are effective in providing opportunities for the pre-service teachers to reconstruct their understanding about basic chemistry concepts. Considering the prior knowledge that has been learned and constructed previously, helping pre-service teachers to reconstruct their understanding about a certain concept is not as easy as giving explanations about the right concept. Pre-service teachers have to be facilitated to realize the limitations of their previous understandings, so that they will be able to challenge themselves to restructure their own conceptual understanding.

Another important finding of this research is that we cannot overestimate pre-service teachers' understanding about basic concepts in chemistry. The easiness of the content covered in the curriculum can not make us pay less attention in the conceptual knowledge development, because the pre-service teachers may develop certain alternative conceptions about a certain basic concept. This is the challenge for teacher education institutions that have to find effective ways to assist the pre-service teachers to reconstruct their conceptual understanding.

CHAPTER 7
THE INFLUENCE OF POE STRATEGY TO ENHANCE PRE-SERVICE TEACHERS' UNDERSTANDING ABOUT THE PARTICULATE NATURE OF MATTER

7.1 Introduction

After the elaboration about the results of curriculum evaluation in Chapter 5 and pre-service teachers' (PST's) conceptual understanding in Chapter 6, this chapter will discuss the influence of the teaching and learning processes using POE (Predict-Observe-Explain) as a strategy to enhance pre-service teachers' conceptual understanding about the Particulate Nature of Matter (PNM). This discussion addresses Research Question #6: *How does the POE strategy effect pre-service teachers' understanding of PNM?* The improvement of pre-service teachers' understanding will be investigated from the results of the Particulate Theory Diagnostic Instrument (PTDI) test and interview record with each student before and after the implementation of the POE strategy. Moreover, the process of changing of preservice teachers' understanding also will be investigated by the data from students' journals that were written during the lesson.

7.2 The background of choosing the POE strategy

Primarily, the implementation of lessons with POE is offered as one alternative strategy to develop better understanding about the basic concepts of chemistry, especially the topic of the PNM. Through the phase of predict, observe and explain, this strategy is expected to facilitate pre-service teachers learning experience to assist them having a meaningful learning process as well as to facilitate them reconstructing their conceptual understanding. Some considerations in determining the POE as an alternative strategy will be elaborated below.

Firstly, according to Liew (2009), the POE strategy can be an effective way to diagnose students' understanding about science concepts. In this research, that potential of POE is used to challenge pre-service teachers' existing knowledge. Because we know that those pre-service teachers have learned science from elementary through high school, their experiences vary as do their level of understanding. In order to strengthen their knowledge about the concepts, the students may have had experiences that challenges their previous knowledge rather than only being given an explanation about the concept which is delivered orally by the lecturer. The stage of predict invites the students to recall and apply their previous knowledge in giving an explanation of their prediction. The observation stage provides a phenomena that might contradict with the students' predictions. At this stage, students are presented with a phenomenon designed to challenge their prior knowledge and they have to recall some other concepts that may contribute to explaining the unexpected phenomena. Thus, this stage also provides students with the opportunities to make interconnections among concepts that they already knew beforehand. At the last stage, the explanation stage, the students provided an explanation from the discussion activity that will guide them to develop a better understanding of the concepts. This learning process in each of the stages of the POE strategy illustrates its power to challenge students' prior knowledge.

Secondly, it has been stated by Liew (2009) that POE can be effective in diagnosing the types of students’ responses to contradictory observations. As the students are pre-service teachers, they not only learn for their own understanding, they also learn to be able to make their future students understand. It is also widely believed that teachers will teach their students in the way they were taught. These are the main points for the decision to use POE in an effort to provide a meaningful learning experiences for the pre-service teachers. Through the experience of having observations that are contrary to their pre-knowledge, pre-service teacher are expected to change their understanding and construct their new understanding by themselves. This process of learning will become a meaningful experience for the PST that they may decide to implement in their teaching practice in their own classrooms.

7.3 The POE strategy to teach the particulate nature of matter

As mentioned previously in Chapter 4, the time allocated for the implementation of the treatment with the POE strategy is only four weeks. The strategy consists of three themes which are related to each of the concept categories of PNM as defined by Treagust et al. (2011). However, during the first implementation, it was found that the pre-service teachers also needed strengthening in the concepts of the ideal gas law. So an additional theme about gas laws was included. Thus, the overall themes became four which represent three concept categories of particulate nature of matter, as shown in the Table 7.1. The detail lesson plans of the POE strategy are presented at Appendix F.

Table 7.1 The matrix of the theme of POE strategy with concept categories of PNM

3 Concept Categories of PNM	Themes of POE Strategy
1. *Intermolecular spacing in matter*	a. Solid, liquid, and gases in syringes b. Gas Laws
2. *Diffusion*	Liquid and Gas Diffusion
3. *Influence of intermolecular forces in changes of states*	Phase Change

7.3.1a Solid, liquid and gases in syringes

This theme of the POE strategy was addressed to assist the pre-service teachers to reconstruct their understanding about the concept of intermolecular spacing in matter. In this task, pre-service teachers in a group of three were given three 10 mL syringes for each group as presented in Figure 7.1. Those three syringes were filled with three different phases of matter. First syringe was filled with ice which was made when 10 mL of water inside the syringe was put in the freezer overnight. The second syringe contained 10 mL of water that was filled by the pre-service teachers during the lesson. While the third syringe contained gas from the surrounding air that also was filled by the pre-service teachers during the lesson. The experiment in this task was to press the plunger of the three syringes while the end of the syringes were closed.

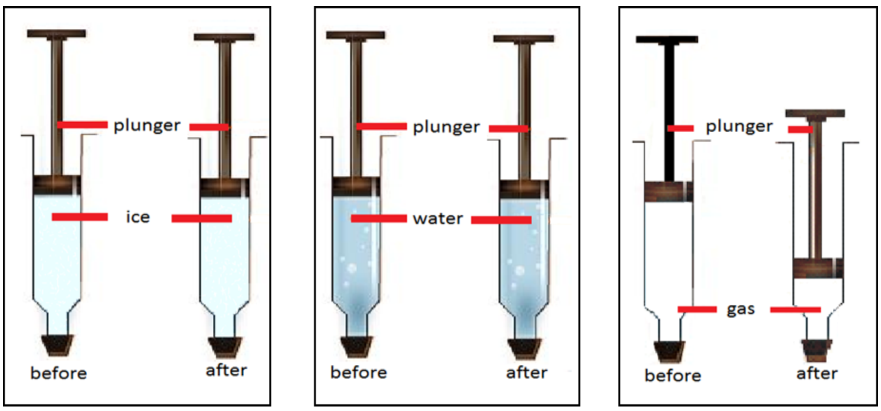


Figure 7.1. The diagram of the process of pushing the three syringes

Next, the pre-service teachers were required to predict what would happen if they pushed the plungers of three syringes that contained three different states of matter namely solid, liquid and gas (ice, water, and gas). During this prediction stage, the pre-service teachers were required to write down their prediction, as well as the reason. After they made a prediction, they performed the experiment and observed the changes. This observation stage was then followed by the discussion in the explanation stage. Then, the pre-service teachers were required to compare their observations with their prediction and were invited to provide an explanation of their findings in the explanation stage.

7.3.1b Gas law

The second theme of the POE strategy was also an attempt to assist the pre-service teachers to reconstruct their understanding about the concept of intermolecular spacing in matter. Different from the previous strategy, the Gas Law POE was expected to promote the pre-service teachers' understanding about the ideal gas law. The decision to include this theme into the lesson stems from the discussion stage during the previous lesson that the pre-service teachers still were confused with some concepts about the gas laws.

In the POE task about gas laws, the pre-service teachers were asked to examine the dry-lab experiment about the properties of gases with the aid of an animation from ***www.mhhe.com/physsci/chemistry/essentialchemistry/flash/gasesv6.swf*** that was shown in front of the class. In this animation four conditions of experiments can be applied to see the influence of each variable to other variables of gases. These four conditions are (1) increase pressure at constant temperature, (2) increase temperature at constant pressure, (3) increase temperature at constant volume, and (4) increase the number of gas particles as shown in Figure 7.2. Pre-service teacher activities during this POE task were to make a prediction if one variable was changed, what happened to other three variables. In the observation stage, the lecturer did a simulation through the multimedia animation and showed the animation in front of the class using a projector.

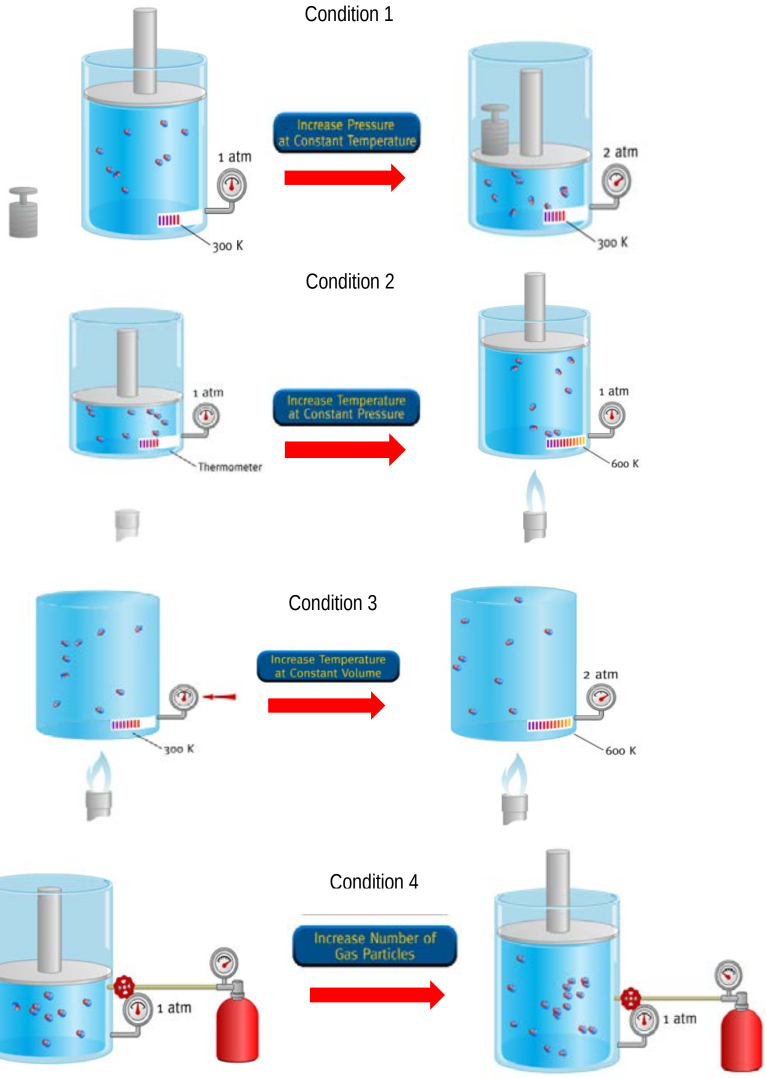


Figure 7.2. The diagram of the process in the Gas Law animation

During the prediction stage, the pre-service teachers were expected to analyse four variables of an ideal gas system (P, V, n, T). They were encouraged to make predictions about what would happen to two variables if one variable was changed while the fourth variable remained constant. They were provided with a table in a journal (as shown in Figure 7.3) for them to write down their predictions. The same table was also provided to record their observations.

Condition	Variables of ideal gas				Comments
	P	V	n	T	
1	↑			C	
2	c			↑	
3		c			
4	c		↑		

(Note: P is pressure, V is volume, n is number of moles, T is temperature, and 'c' represents the constant variable)

Figure 7.3. A data recording table to record the prediction and observation results

7.3.2 Liquid and gas diffusion

The POE task about liquid and gas diffusion consists of two different activities. The first activity was about diffusion in a liquid by dropping some red food dye into two glasses of water with different temperatures. In this task, the pre-service teachers were asked to predict the influence of temperature on the diffusion process. This activity encouraged them to think about the difference of particle movement at two different temperatures. It was expected that the students would think in a molecular way to provide an explanation about this task.

In the second activity, the task was about the diffusion of bromine gas. In this task, the preservice teachers examined the video from YouTube with the following link *www.youtube.com/watch?v=ZAGloLXO9L0* that was shown in front of the class. The video showed the process of liquid bromine being spontaneously vaporized to be a gas and it also showed how the gas was distributed evenly in the tube. There were two conditions of the tube that become the main point of this activity. In the first condition, the tube was filled with air. The students saw how the bromine gas was distributed to fill the tube while there were some air molecules inside the tube. The video showed that it needed time to have the bromine gas become uniformly distributed. In the second part, the experiment was repeated by firstly removing the air inside the tube. The video was then paused at the time when it will show how the bromine gas distributed if there was no air molecules inside the tube. At this stage, students were encouraged to make a prediction of how the bromine gas will be diffused in a vacuum tube. Students were expected to find out the influence of the existence of air particles on the process of bromine gas diffusion.

7.3.3 Phase change

The fourth experiment was associated with the concept of the influence of heat to phase change. This experiment was held by heating a glass of ice until it melted and boiled. The ice in the glass was not an ice cube, but a glass of water that had been purposively frozen with a termometer dipped into it. This apparatus was expected to give accurate temperature data verses time when the process of heating occured. In this task, students were asked to predict what would happen if the ice was heated and what kind of data will be obtained regarding the variables of temperature and time.

7.4 Student achievement after learning about the PNM with POE

In general, there were increasing scores for almost all students as shown in Table 7.2.

Table 7.2 Pre-service teachers' achievement on pre and post-test

Code of Pre-service teachers	Score (*Max Score is 11*)			
	Pre-test		Post-test	
	1st Tier	Both tiers	1st Tier	Both tiers
PST-A	8	7	11	7
PST-B	10	6	11	8
PST-C	9	4	11	10
PST-D	10	7	11	6
PST-E	6	2	11	6
PST-F	8	3	11	4
PST-G	7	2	10	9
PST-H	7	3	11	9
PST-I	8	4	9	5
PST-J	10	5	10	7
PST-K	5	3	9	8
PST-L	7	4	8	6
Average	7.92	4.17	10.25	7.08
Standard Deviation	1.55	1.67	1.01	1.71

The scores in Table 7.2 depict the number of right answers for the first tier and for both tiers of the instruments for each pre-service teacher. Data in Table 7.2 indicates that all pre-service teachers, except PST-D, have a better score in the post-test. The data also shows that more than half of the PSTs got a perfect score for their first tier answers. However, the results of pre-test and post-test show that pre-service teachers' right answer for both tier is less than the score in first tier only. Actually, this pattern has been observed in earlier studies (Othman et al., 2008; Sia, Treagust, & Chandrasegaran, 2012; Tan & Treagust, 1999; Treagust, 1986; Treagust et al., 2011), and reveals that students might have chosen the correct answer for the first tier based on their rote learning or guessing without a deep understanding about the concept that the item was focused on (Othman et al., 2008).

The improvement of these PSTs' achievement not only appears in the score for each PST, as shown in Table 7.2, but also from the data of the number of PSTs with the right answer for each item. Table 7.3 shows the number of students with the right answer for each item arranged by the three conceptual categories of the particulate nature of matter.

Table 7.3 Number of pre-service teachers with correct response on each PTDI item in the pre and post-test

Item No	Number of pre-service teachers with correct answer			
	Pre-test		Post-test	
	1st tier	both tier	1st tier	both tier
(1) intermolecular spacing in matter				
3	12	6	9	7
4	8	6	11	11
5	12	7	12	7
11	7	7	11	11
Average	9.75	6.50	10.75	9.00
Standard Deviation	2.63	0.58	1.26	2.31
(2) diffusion in liquid and gases				
1	6	1	9	9
2	6	6	12	6
6	3	1	12	4
7	11	11	12	12
Average	6.50	4.75	11.25	7.75
Standard Deviation	3.32	4.79	1.50	3.50
(3) influence of intermolecular forces on changes of state				
8	9	4	11	11
9	11	4	11	5
10	10	6	12	0
Average	10.00	4.67	11.33	8.00
Standard Deviation	1.00	1.15	0.58	4.24

This set of data shows that most of students' achievement for the first tier on all items increased except for item number 3. The improvement also appears for students' answers on both tiers except for item number 2 and 10. However, although most of the pre-service teachers have the right answers for the first tier on the post-test, they still have different reasons for their answers and this fact shows that there is still a deficiency in their understandings even after the implementation of POE strategy.

In order to get a further explanation about this pre and post test result, the rest of this chapter discusses PSTs' achievement based on the improvement of their understanding on three conceptual categories of the PNM. These three main ideas are (1) intermolecular spacing in matter, (2) diffusion in liquid and gases, and (3) influence of intermolecular forces on changes of state, and are represented in the sections 7.5, 7.6, and 7.7, respectively.

7. 5 Pre-service teachers' understanding about intermolecular spacing in matter

The improvement of pre-service teachers' understanding about the concept of intermolecular spacing in matter is represented by their responses to PTDI items numbers 3, 4, 5, and 11. Table 7.4 shows the number of pre-service teachers' who have chosen correct response to these PTDI items that are related to intermolecular spacing of matter.

Table 7.4. Number of pre-service teachers with correct response on each item about intermolecular spacing in matter

Item No	Number of students with the correct answer to both tiers		Understanding evaluated by items
	Pre-test	Post-test	
3	6	7	Volume of a liquid remains constant although in different shapes because the number of particles and the spacing between the particles are fixed.
4	6	11	During the compression process, the volume of gas decreases because the widely spaced particles are pushed closer together, and it does not have any impact on mass.
5	7	7	A gas is compressed easily as there are wide spacing between gas particles.
11	7	11	The decreasing of volume when two liquids are mixed is caused by the particles of one liquid occupying the space between particles of the other liquid.
Average	6.50	9.00	
Standard Deviation	0.58	2.31	

As shown in Table 7.4, the number of pre-service teachers who answered both tiers correctly in the post-test increased for items 3,4 and 11, with substantial improvement for items 4 and 11. In order to obtain more information about how the POE strategy assisted the pre-service teachers to develop their understanding about the concept, we needed to further analyse the explanations provided by the pre-service teachers in answering the PTDI items.

According to the analysis of the results, there are four main findings related to pre-service teachers' understanding about intermolecular spacing in matter. The first finding based on pre-service teachers responses to PTDI item number 4 shows that pre-service teachers have better understanding of the concept of density. The improvement of pre-service teachers' responses to item number 4 also indicated that pre-service teachers have developed a better understanding about the space between the molecules of a liquid. Moreover, the item number 11 had challenged pre-service teachers' understanding of the concept of volume. Meanwhile, pre-service teachers' responses to PTDI item number 5 have shown that the pre-service teachers were indecisive on the selection of reason for compressibility of gas: i.e *the wide spaces between particles* or *the free movement of particles* as the major reason for the compressibility of gas. The following section elaborates the findings in greater detail.

Better understanding about the concept of density

The PTDI item number 4, as shown in Figure 6.2, challenged pre-service teachers' understanding about the compressibility of gas that was determined by the composition of particles within the gas which have a wide space between them. There were various explanations given by pre-service teachers' in response to this item summarized in Table 7.5.

Table 7.5 The pre-service teachers' explanations in answering item number 4

Type	Explanations	Frequency	
		Pre	**Post**
A*)	When a gas is compressed, the volume decreases whilst the mass remains constant as the widely spaced particles are pushed closer together	6	11
B	When a gas is compressed, the volume decreases whilst the mass remains constant because V is equal with 1/P.	1	0
C	When a gas is compressed, the volume decreases whilst the mass remains constant as no particles move in or out.	1	0
D	The volume decreases whilst the mass increases when a gas is compressed to get closer each other.	3	1
E	The volume and mass both decrease when a gas is compressed because the molecules become closer to each other.	1	0

*) The preferred explanation

As has been described in Chapter 6, eight pre-service teachers on the pretest using PTDI believed that the compression will decrease the volume of gas while the mass remain constant. Only six pre-service teachers correlated this fact to the wide spaces between gas particles (see Table 7.5 Explanation Type A). However, on the post-test, almost all pre-service teachers provided the right answer with the right explanation (Type A). This suggests that the process of learning with the POE has the potential to promote pre-service teachers building an understanding of a correlation between the variables of volume and pressure with the intermolecular spacing within the system of gas.

The POE is also designed to assist pre-service teachers to reconstruct their conceptual understanding about mass and density. According to the post-test result, among three pre-service teachers (PST-E, PST-H, PST-K) who had confusion about the concept of mass and density, two of them (PST-E and PST-H) have developed a better understanding about the influence of compression to mass and density. Whereas PST-K still believed that the volume decreases and the mass increases during the compression of gas (see Table 7.5 Explanation Type D). The interview trancriptions from these three pre-service teachers that recorded their explanations about their answers of PTDI item number 4 before and after the POE provide evidence of how their understandings have changed for PST-E and PST H, and how the conceptual understanding of PST-K remained unchanged.

Interview PST-E before POE (Repeated from Chapter 6)

Interviewer : *If the gas is pushed, then it will become as shown in the picture like this (pointing to the picture in the paper, shows the decrease of the volume). Then it will make the volume decrease (according to your answer). Why did the volume decrease?*

PST-E: *If we observe physically, from this amount at initial condition (pointing to the picture in the paper), become less like this (pointing to the picture in the paper) when it is pushed, that volume is decreased.*

Interviewer: *So what do you mean by increased mass?*

PST-E : *Here, (pointing to the picture of the initial condition) the spaces between the particles are more tenous (spacious), and when compressed, it becomes denser and, let say, if we weigh it, it will be heavier, because the spaces are closer.*

Interview PST-E after POE

Interviewer: *In the post-test you answered that the mass would not increase, how could you explain that?*

PST-E: *Because the mass of all gas are the same, only the space between particles that get closer to each other.*

Interviewer: *what is the reason? Why the mass of the gas remain the same?*

PST-E: *is the mass of the gas equal with 'n'? is it different? isn't it?*

Interviewer: *'n' is the symbol for number of particles, while m is (the symbol) for mass*

PST-E: *Oo I see*

Interviewer: *Is there any correlation between 'n' and 'm'?*

PST E: *m is equal to n/v....(She was not sure with her statement).*

Interviewer: *Does 'm' influenced by 'n'? that is the question.*

PST-E: *Yes Miss, the more 'n' means it is heavier.*

In summary, PST-E was still confused with her own answer, especially about what actually has been measured when the gas was weighed. This interview went further into the discussion until PST-E understood what was actually being weighed when we weigh the gas. This fact has shown that the interview process also has the potential to facilitate pre-service teachers to reconstruct their conceptual understanding (Duit, Treagust, & Mansfield, 1996; Sherin, Krakowski, & Lee, 2012).

Interview PST-H before POE (Repeated from Chapter 6)

Interviewer: *According to your response (to item number 4), if the gas is compressed then the volume will decrease.*

PST-H: *Yes*

Interviewer: *What do you mean?*

PST-H: *No, not decreased ... eh..yes decreased.. because the space between gas particles are wide, when it pushed, compressed, the space become closer.*

Interviewer: *So, the volume will be decreased?*

PST- H: *Hmmm..... yes.. decreased (seems not really sure)*

Interviewer : *Are you sure?*

PST-H: *Yes Miss, decreased.*

Interviewer: *Now, what do you mean by the increasing of mass? How do you explain it?*

PST-H: *When it (the gas) was not compressed yet, it (the particles) was (were) spread, so that when the mass was measured it (the mass) will be small. But when it (the gas) is compressed, we can say it as... not solidify but getting closer... and it will make the mass increase.*

Interview PST-H after POE

Interviewer: *in the post-test you said that the mass of gas after compression is constant (won't be increased). How could you explain that?*

PST-H: *because there is no change in the number of particles so the mass will remain the same.*

Interviewer: *Is the mass influenced by the nuber of particles?*

PST-H: *Mmm, I mean since the number of particles are the same then the mass will remain the same.*

Interviewer: *So, the mass will be influenced by the number of particles?*

PST-H: *Yes, if the number of particles increases then the mass will also increase.*

From those discussions with two pre-service teachers who changed their answers on the post-test, it reveals that they have changed their understanding about the concept of density. However, although PST-E had a better understanding about density, there are some aspects about a gas that have not been strongly developed in her mind, such as the concept about volume and the fact that gas particles have mass.

Meanwhile, one pre-service teacher (PST-K) choose the same answer in the pre-test and post-test that shows her misunderstanding about density. This fact is presented in the following interview transcription.

Interview PST-K before POE (Repeated from Chapter 6)

Interviewer: *When the gas inside the syringe is pushed, the volume is decreased and the mass...*

PST-K: *The mass is increased.*

Interviewer: *You wrote here, the reason is the movement of the gas particles was free and the volume was big, and the mass was light. But when it (the plunger) was pushed, the volume decreased. Why has the volume decreased?*

PST-K: *Because the particles movement become not so freely*

Interviewer: *Do you mean there was less room for the particles to move around?*

PST-K: *Yes*

Interviewer: *So why did the mass decreased?*

PST-K: *The mass increased, Miss...*

Interviewer: *Oh ya... why did the mass increased?*

PST-K: *The mass increased, I just think it will be heavier.*

Interviewer: *Because it was more compressed?*

PST-K: *Yes*

Interviewer: *So, let say, if the color of the gas is light blue, if it is pressed....*

PST-K: *....the color (will be darker) become dark blue, and the mass increased.*

Interview PST-K after POE

Interviewer: *what happen if we press the gas (with the plunger)? What happen with the mass? Is it going to be changed or remain the same?*

PST-K: *it will remain the same*

Interviewer: *but here (in your answer sheet) you said that it (the mass) will increase?*

PST-K: *mmm, i thought ... because at intial condition the space (in the syringe) is long, then it is pressed (the space in the syringe) become shorter, so I think it will be heavier.*

Interviewer: *when it (the syringe) is long like this, the volume is big and it has mass, isn't it?*

PST-K: *Yes*

Interviewer: *What is actually weighed?*

PST-K: *The molecules*

Interviewer: *The molecules?*

PST-K: *Yes*

Interviewer: *And if we compressed then we weighed, what actually was weighed?*

PST-K: *The molecules too, and there were no molecules in and out, so it (the mass) will be the same.*

Interviewer: *But here (in your answer sheet) you said that it (the mass) will increase. What do you mean?*

PST-K: *Because it denser so it will be heavier, Miss.*

According to this interview transcription, this pre-service teacher has contradicted herself. She knew that since there were no particles coming in and out, then the mass will remain the same. On the other hand, she also thought that in the denser condition, the gas become heavier. It seems that it was not easy for her to change her belief about denser being equal to heavier.

Besides the PTDI test results and the interviews before and after POE, the students' journals also provided information about improvement in the pre-service teachers' understanding. However, the journal entries also revealed that the pre-service teachers were confused about the difference between density and the number of molecules. Below are examples of pre-service teachers' (PST-H) explanations before they learned about the change of pressure of an ideal gas at constant temperature. In her journal PST-H wrote that

"*The increasing of pressure will reduce the volume. If the temperature is constant, the number of molecules will increase due to the smaller volume.*" (Journal POE 1b – PST-H)

This explanation shows that PST-H thought that in a smaller volume, there will be less space for the molecules. The molecules will be closer to each other so the system will be denser. Furthermore, her statement implies that she did not differentiate between density and number of molecules which shows that she has an alternative conception about density. This conceptual understanding is similar to her explanation during the interview session after the pre-test. However, after she saw the animation during the lesson with POE, her explanation changed as follows:

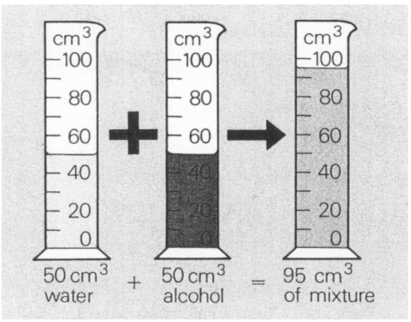
"*If the temperature is constant and (the) pressure is increased, (the) volume will decrease while the number of molecules will (be) constant due to no molecule (moving) in/out of the system.*" (Journal POE 1b – PST-H)

This statement is recorded from PST-H's observation which shows the change of her conceptual understanding during the stage of observation with the aid of the animation as a learning media. It can be argued that conceptual understanding could occur because of the animation shown during the POE with the theme of Gas Law (presented in Figure 6.2), not necessarily because of the POE strategy. However, the opportunity for pre-service teachers to express their understanding in the prediction stage provided an opportunity for them to reveal and realize their own understanding. Further, during the learning process, they were able to evaluate the quality of their previous conceptual understanding from the written explanations of their prediction. This is one example showing the benefit of the three stages in the POE which offer some opportunities for the pre-service teachers to reconstruct their understanding.

Better understanding about the space between the molecules of a liquid

PTDI item number 11 (shown in Figure 7.4) evaluated pre-service teachers' understanding about the spaces between the particles in the liquid that can be occupied by the other liquids with smaller sized particles. The responses of pre-service teachers to this item are summarized in Table 7.6

Item 11



The diagram shows that the total volume of liquid decreases when water and alcohol are mixed together.

We can conclude that some of the alcohol has evaporated.

A True B False

The reason for my choice of answer is:

1. The molecules of the two liquids occupy the spaces between each other.
2. The alcohol molecules have dissolved in water thus reducing the total volume.
3. Collisions between the molecules cause some molecules to escape.
4. Molecules of the two liquids repel each together.
5. Other: …………………………………………………………………………

Figure 7.4. Item number 11 of the PTDI

According to the data on Table 7.6, seven pre-service teachers in the pre-test and eleven in the post test agreed that the decrease of the final volume is not because of the evaporation of alcohol molecules. The decrease of the final volume is caused by the occupancy of the spaces between the particles by molecules of water as well as molecules of alcohol (explanation Type A).

Table 7.6 The pre-service teachers' explanations in answering item number 11

Type	Explanations	Frequency	
		Pre	Post
A*)	The decrease of the final volume is not caused by the evaporation of alcohol, it is caused by those two molecules occupy the spaces between each other	7	11
B	The decrease of the final volume is caused by the evaporation of alcohol as the container was open	1	0
C	The decrease of the final volume is associated to the evaporation of alcohol which is caused by the collision of the molecules of alcohol.	2	0
D	The final volume decreased because some alcohol molecules have evaporated and some dissolved in water	1	0
E	The volume decreases because the molecules of two liquids occupy the spaces between each other. But there are also some alcohol molecules that have evaporated	1	1

*) The preferred explanation

The data from pre-test show various explanation provided by pre-service teachers in response to item number 11. Three pre-service teachers believed that the volume decreasing was more likely caused by the evaporation of alcohol molecules that was triggered by the open container (Type B) or the collision between water and alcohol molecules (Type C). There was also one pre-service teacher who could not ignore the possibility of the dissolution of alcohol molecules (Type D) in addition to her belief about evaporation as the main reason for the decrease of the volume of the mixture. Meanwhile, one pre-service teacher who had recognized the occupancy of molecules within the space between other molecules also could not ignore her understanding about the property of alcohol that is more volatile than water. Thus, she used these two concepts in explaining the decreased volume of the mixture of water and alcohol (Type E).

Interestingly, in the post-test, all pre-service teachers explained that the decrease volume of the mixture was because of the occupancy of the space between the molecules. However, one pre-service teacher still took into account the concept about the evaporation of alcohol as her answer in the first tier.

The confusion between the wide space between particles and the free movement of particles was the major reason given for the compressibility of gas.

The understanding evaluated by item number 5 (shown in Figure 4.2) is about the concept that *a gas is compressed easily as there is wide spacing between gas particles*. According to the responses of pre-service teachers in the pre-test and post-test, all of the pre-service teachers agreed that the volume of gas will be much less than that of the liquid after the compression. However, there were two major reasons for that statement. The first reason is based on the wide space between gas particles (Type A) as the correct explanation for the compressibility of gas which allow the gas to be compressed resulting in a much smaller volume. While the other reason relies on the free movement of gas particles (Type B) as shown in Table 7.7.

Table 7.7 The pre-service teachers' explanations in answering item number 5

Type	Explanations	Frequency	
		Pre	Post
A*)	The final volume of the gas after compression was much less than that of the liquid because the particles in the gas are more widely spaced.	7	7
B	The final volume of the gas after compression was much less than that of the liquid because the particles in the gas move more freely	5	5

*) The preferred explanation

According to the data in Table 7.7, there were seven pre-service teachers with the correct explanation (Type A) in the pre-test as well as in the post test. Although the numbers are the same, they do not represent the same pre-service teachers. In the post test, there were three pre-service teachers who changed their explanation from Type B to Type A. There were also three pre-service teachers who changed their answer from Type A in the pre-test to Type B in the post-test. These data reveal the pre-service teachers' knowledge about two main properties of gas; they know that gases have wide space between the particles, and they also know that gas particles move randomly. But they were not really sure which properties best describe the compressibility of a gas.

Challenge pre-service teachers' understanding about volume

PTDI item number 3 (Figure 7.5) evaluated understanding of "*the volume of a liquid remains constant although in different shapes because the number of particles and the spacing between the particle are fixed*". Similar to the other item, there were various ways for pre-service teachers' to answer this question. Five types of PSTs' explanations are summarized in Table 7.8.

Item 3

When orange juice from a soft drink can is carefully poured into a tall wide glass without any spillage, the volume of the liquid remains approximately the same.

A True B False

The reason for my choice of answer is:

1 The particles are able to move about freely.
2 The particles are able to move within a fixed volume.
3 Some of the particles may have escaped as the liquid evaporated.
4 Other: ……………………………………………………………………………
………………………………………………………………………………

Figure 7.5 Item number 3 of the PTDI

Table 7.8 The pre-service teachers' explanations in answering item number 3

Type	Explanations	Frequency	
		Pre	Post
A*)	The volume of the liquid remain approximately the same because the particles are able to move within a fixed volume.	7	6
B	The volume of the liquid remains approximately the same because the number of particles was almost the same although the shapes are different.	3	2
C	The volume of the liquid remain approximately the same. Because, initially, there was a vacuum in the soft drink can. When the can was opened, the air from the upper part of the can was released. So there was only the volume of air that decrease, not the volume of liquid.	1	
D	The volume of liquid will be different because the particle can move about freely.	1	1
E	The volume of liquid will be different, depend on the surface area of the container. This is caused by the irregular arrangement of particles in the liquid.		2

*) The preferred explanation

According to the data in Table 7.8, eleven pre-service teachers thought that the volume of liquid remains the same in different shapes of containers with three different explanations (Type A, B, and C). But three of them referred to the constant number of particles instead of the movement of particles (Type B), and one of them had a lack of understanding about the system inside the soft drink can (Type C). Only seven explained that liquid particles are able to move freely within the fixed volume (Type A).

Surprisingly, this number of correct responses is reduced in the post test. Three pre-service teachers believed that the volume will change in different shape of containers. These pre-service teachers were misled by the fact that the liquid particles are able to move freely and also the fact that different shapes of containers might have different volumes. This statement is supported by the explanation provided by PST-G in the post-test answer as an example. In her explanation, she mentioned that there was no change of mass because no substance was added. However, she also mentioned that volume change depends on the shape of the container due to the ability of particles of liquid moving freely and occupying the available space.

The interview results with some pre-service teachers provides evidence of understanding about the change of volume within different shape of containers. Besides, the interview transcription also revealed pre-service teachers' difficulties in understanding the concept of volume. As an example, the interview with PST-G follows.

Post POE interview with PST-G

Interviewer: *If I have 25 mL liquid, and two different size of measuring glass. Which glass is bigger? Which glass has a bigger volume?*

PST-G: *This one* (pointing to the bigger size of measuring glass)

Interviewer: *If I pour this liquid into this measuring glass, and I pour it into another measuring glass, in which glass will the liquid have the biggest volume?*

PST-G: *Actually, we have to count it.*

Interviewer: *What do you mean*?

PST-G: *It depends on the volume. We cannot determine which one is bigger, because this one is higher than another and this one is wider than another*.

Interviewer: *What does it mean*?

PST-G: *It means that depends on the container*.

Interviewer: *If we reverse the steps so that the liquid is back to the initial measuring glass, how much is the volume?*

PST-G: *25 mL* (spontaneously mentioned the volume before the process of pouring has finished)

Interviewer: *So, how is the volume here and there*?

PST-G: *Also 25* (answering with low voice and doubtful) *eh*?

Interviewer: *Different or the same?*

PST-G: *Different*

Interviewer: *Could you please count and put the mark in the measuring glass?*

PST-G: *25 too* (laughing finding the fact)

Interviewer: *hmm?*

PST-G: *Yes 25. (She poured the liquid to another measuring glass)*
Yes Miss, these are the same, 25.… umm how come? But that's also 25?

Interviewer: *What do you mean by volume?*

PST-G: *Room*

Interviewer: *Room?*

PST-G: *Area… eh area multiply by height*

Interviewer: *Based area multiply by height?*

PST-G: *Yes*

Interviewer: *That is for the object with regular shape. But how to determine the volume of the object with irregular shape?*

PST-G: *There is a way to count it, but I forget the name.*

Interviewer: *Put the liquid into a big measuring glass, then put the irregular object into the liquid and then check the change of the volume.*

PST-G: *O ya*

Interviewer: *What about the volume of these two glasses are they the same or different?*

PST-G: *They are the same*

Interviewer: *How about the shape?*

PST-G: *The shape is different*

Interviewer: *What about the volume?*

PST-G: *Also the same*

Interviewer: *If we pour the liquid into the container with triangle shape, the liquid will also be a triangle.*

PST-G: *But the volume remains the same*

Interviewer: *Yes the volume remains the same*

Post POE interview with PST-L

Interviewer: *How much is the volume of the liquid in this measuring glass?*

PST-L: *20 mL*

Interviewer: *How much is the volume if I poured the liquid into another measuring glass?*

PST-L: *20 mL*

Interviewer: *Then how much is the volume of the liquid if we poured it into this glass?*

PST-L: *Also 20 mL, Miss.*

Interviewer: *Which measuring glass is higher?*

PST-L: *This one*

Interviewer: *How much is the volume in this glass? And how much is the volume in that glass? Are they the same?*

PST-L: *(answering in very low voice, seemed she was doubt with her answer) the volume of the liquid are the same, 20 mL, but the height …hmm… (laughed) the height is different Miss.*

Interviewer: *The height of the container?*

PST-L: *Yes Miss, the height of the container is different.*

Interviewer: *What about the volume?*

PST-L: *The volume are the same*

Interviewer: *How could they have the same volume while the height are different?*

PST-L: *Because the liquid particles are not stiff. Thus, if they were in the tall container, the particles will arranged to be at the top. Meanwhile, if the surface area were wide, then the particles will spread on that wide surface.*

Interviewer: *So, what is the difference between these two glasses?*

PST-L: *Surface area*

Interviewer: *So which volume is differ in your answer?*

PST-L: *Hmm… I thought that when the liquid is poured (into different container) the shape will be different and the volume is also different, while the volume of the liquid will be the same.*

Interviewer: *So, whose volume is different?*

PST-L: *The volume of the container*

Interviewer: *What about the volume of the liquid?*

PST-L: *Remain the same*

According to the two conversations above, these two pre-service teachers initially thought that the same liquid will have different volume in different shapes of the containers. But at the end of the conversations, they realized that the volume of the liquid will stay the same. However, the result presented in Table 7.8 shows that the pre-service teachers who gave incorrect answer were misled by their understanding about the volume. Revealed from the explanations provided by these pre-service teachers, besides challenging their understanding about the volume of liquid in different containers, this item also challenged pre-service teachers to reconstruct their understanding about the concept of volume.

7.6 Pre-service teachers' understanding about diffusion in liquids and gases

Similar to the concepts about intermolecular spacing in matter, the pre-service teachers' understanding about diffusion in liquids and gases also encountered some changes of a positive trend. Data in Table 7.9 show the number of pre-service teachers with the correct responses to PTDI items related to the concept of diffusion.

Table 7.9 Number of pre-service teachers with the correct response on each item about diffusion in liquid and gases

Item No	Number of students with the right answer *(Total number of students = 12)*		Understanding evaluated by items
	Pre-test	Post-test	
1	1	9	Continuous collisions between smoke particles and air molecules resulted an observable zigzag manner.
2	6	7	A gas diffuses more rapidly in partial vacuum due to much fewer collision between gas particles and air particles.
6	1	8	Continuous collision between dye particles and water molecules enable dye to diffused in the water although it takes long time to diffused thoroughly.
7	11	12	An inflated balloon gradually decreases in size as air particles diffuse out through the pores in the balloon skin
Mean	4.75	9	
Standard Deviation	4.79	2.16	

According to the analysis of the results there are two main improvements on pre-service teachers' understanding about diffusion after the lesson with the POE. The pre-service teachers had better understanding about the collision of particles in the process of diffusion. They built better visualisation about the process of diffusion in liquids as well as gases. The following section elaborates the improvement in more detail.

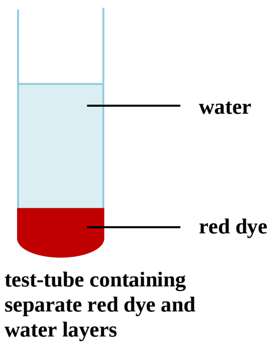
Better visualisation of diffusion in liquid

The better visualisation about diffusion in liquids built by the pre-service teachers is shown in their responses to PTDI item number 6 (Figure 7.6). This item evaluated pre-service teachers' understanding about the continuous collision between dye particles and water molecules which enable the dye to diffuse throughout the water although it takes a long time. Explanations provided by pre-service teachers in response to item number 6 are summarized in Table 7.10.

Item No **6**

A small amount of red dye was carefully placed at the bottom of a test-tube containing some water as shown in the diagram.

After several hours, the particles of red dye would have diffused throughout the water producing a uniformly red solution.



A. True B. False

The reason for my choice of answer is:

1. The particles of the red dye readily dissolve in water
2. The heavier particles of red dye sink to the bottom of the test-tube
3. The particles of the red dye are in constant random motion.
4. The red dye and water particles do not mix.
5. Other: ....
....

Figure 7.6. Item number 6 of the PTDI

According to the data presented in Table 7.10, there were various responses from pre-service teachers regarding the possibilities of dye diffusion in water. On the pre-test, one pre-service teacher (PST-D) believed that the dye will be diffused in water due to its collision with water molecule (Type A). The other five pre-service teachers explained that the diffusion of dye depends on the properties of the dye such as the solubility and the polarity of dye (Type B). While six pre-service teachers believed that dye would not be diffused in water because dye molecules will precipitate in the bottom of the tube (Type C). Meanwhile on the post test result, eight pre-service teachers responded to this item with explanation Type A. Two others still consider that the properties of the dye enabled the diffusion in water (Type B). While two other pre-service teachers believed that the dye will be diffused in water without any further explanation (Type D).

Table 7.10 The pre-service teachers' explanations in answering item number 6

Type	Explanations	Frequency	
		Pre	Post
A*)	Dye is randomly and constantly moving due to its collision with water molecules	1	8
B	The possibility of diffusion is based on the dye properties (e.g.: solubility, polarity)	5	2
C	There will be no diffusion because dye will precipitate at the bottom of the tube due to its weight	6	-
D	The dye particles will be diffused thoroughly in the water as the time passes by (no clear explanation about the reason)	-	2

*) The preferred explanation

The number of pre-service teachers who provided correct explanations (Type A) improved from 1 in the pre-test to 8 in the post-test. This satisfactory result shows that the lesson with the POE strategy helped the pre-service teachers to have a better understanding about the diffusion process. From the experiment, these pre-service teachers can observe the factual phenomena of the process of dye diffusion in water. Two experiments which were conducted in two different temperatures allowed pre-service teachers to make a connection between the particles' movement and diffusion. Thus, the pre-service teachers can provide their explanation using their own words in the post-test as well as in the interview after the post-test resembled their understanding.

"The diffusion of dye in the water resulted from the empty spaces in the water that can be occupied by the dye particles. The movement of the dye itself is a result of the collisions between dye particles and water molecules" (Post-test, PST-L).

"Dye particles move because they collide with water particles. This process involves the random movement of dye particles" (Interview, PST-A).

"When the dye dropped into the water, the dye [particles] will be surrounded by water [particles]. Thus when the water moves freely, the dye will follow the movement of the water" (Interview, PST-C).

Meanwhile, the pre-service teachers who provided an explanation of Type B only focused on the possibilities of dye diffusion according to the properties of the dye. They did not specifically explain the reason according to how the process happened at the molecular level. However, the sub-microscopic representation was expressed after the pre-service teachers' thoughts were triggered during the interview session.

Interviewer: *Your answer is because the dye can be easily dissolved in water?*
PST-E: *Yes*
Interviewer: *What happens in the dissolving process?*
PST-E: *The dye particles were surrounded by water molecules*
Interviewer: *Is there any collision in that process?*
PST-E: *Yes it is*

It is interesting that according to the interview session with PST-E, although she provided the explanation Type B, this explanation did not mean that she did not know the process of diffusion at the sub microscopic level. This was only the simplest way to explain the diffusion of dye in water. Although she did not provide a clear explanation about the reason she had already built a visualisation about the process of diffusion in liquids at the molecular level of representation that involved the movement of dye particles surrounded by water molecules.

Another interesting fact shown by PST-F's responses is that in the pre-test, she thought that the dye will precipitate but during the observation of the lesson using POE, she noted that the dye was diffused. Thus, in the post-test she responded that the dye will be slowly diffused in water. However, she did not provide appropriate explanations in her answer, when she confirmed that diffusion is related to random movement of dye particles, she explained that this was not random.

Interviewer: *Do dye particles move continuously and randomly?*
PST-F: *No*
Interviewer: *Why?*
PST-F: *The particles did not move in random, they spread like this [in a certain pattern], how can I say that? They did not spread spontaneously in all direction, they spread slowly and this takes a long time to be diffused [thoroughly]*

This interview shows that PST-F provides her explanation on what she had observed during the experiment she did in the lesson with POE, but she did not involve the process at the molecular level. In other words, she built her explanation only on the macroscopic representation about how the dye diffused in water and did not involve the sub-microscopic representation about what actually happened with the molecules during the diffusion process. Meanwhile PST-E also explained the influence of molecular movement and collisions in the process of diffusion after she was stimulated during the interview.

Better visualisation of gas diffusion

The better visualisation about gas diffusion was revealed by the pre-service teachers' responses on PTDI item number 2 (Figure 6.3). This item evaluated pre-service teachers' understanding about gas diffusion which was more rapid in a vacuum due to less collision between gas particles and air particles. Explanations provided by pre-service teachers in response to item number 2 are summarized on Table 7.11.

Table 7.11 The pre-service teachers' explanations in answering item number 2

Type	Explanations	Frequency	
		Pre	Post
A*)	Bromine molecules diffused faster because of less collisions between the bromine molecules and air particles	6	7
B	Diffused faster because less collision between bromine molecules	-	1
C	Diffused faster because they will ocupy the space that were previously occupied by air particles	-	4
D	The heavier bromine molecules will precipitate at the bottom of the jar	1	-
E	Less collisions between bromine molecules and air particles makes diffusion becomes slower	4	-
F	The diffusion will be slower because bromine molecules will occupy the spaces that were previously occupied by air particles	1	-

*) The preferred explanation

According to the data presented in Table 7.11, there were various responses from pre-service teachers regarding the possibilities of bromine gas diffusion in a vacuum compared to one in the atmospheric condition. On the pre-test, there were equal numbers of pre-service teachers between those who answered that bromine gas will diffuse faster in a vacuum and diffuse slower in a vacuum. Most of the pre-service teachers who thought that the diffusion becomes slower seemed to apply their understanding about the need of collisions in the diffusion process similarly to what happens in a liquid. They might have forgotten that the properties of gas will spontaneously move freely to all directions. This also might be because they did not realize the properties of bromine which evaporates easily in standard temperature and pressure.

In the post test, all the pre-service teachers agreed that the bromine gas will diffuse faster in the vacuum condition. Although the answers in the post test are the same, they have different explanations in reasoning their answers. Seven pre-service teachers explained that the faster diffusion in vacuum condition was due to less collisions between bromine molecules and air particles (Type A). Another pre-service teacher believed that the faster diffusion is due to less collisions between bromine molecules (Type B). It seemed that she only focused on the bromine molecules, and ignored the existence of air particles inside the tube under atmospheric conditions. The other four pre-service teachers' understanding involved the concept of the empty space in explaining that the faster diffusion is due to the available space. The pre-service teachers believed that previously the space was occupied by air particles that are not present in the vacuum condition. Thus, in the vacuum, the space is available to be occupied by bromine molecules (Type C). The explanation Type C shows that the pre-service teachers only focused on the empty space and did not consider the collision between particles.

7.7 Pre-service teachers' understanding of the influence of intermolecular forces on changes of state

The positive trend also occurred in the changing of pre-service teachers' understanding of the influence of intermolecular forces on changes of state. The data in Table 7.12 shows the number of pre-service teachers with correct responses to PTDI items related to this concept.

Table 7.12 Number of pre-service teachers with the correct response on each item about intermolecular spacing in matter

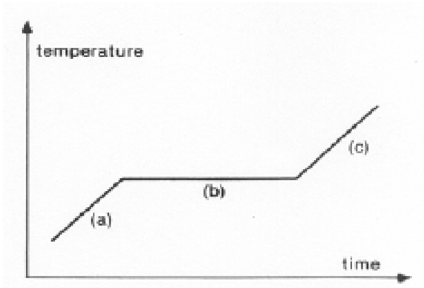
Item No	Number of students with the correct answer *(Total number of students = 12)*		Understanding evaluated by items
	Pre-test	Post-test	
8	4	11	The temperature remains constant during melting as the heat energy absorbed is used to weaken intermolecular forces and enable the particles to move freely.
9	5	9	A substance remains in the liquid state at its boiling point until the intermolecular forces have been weakened between all the particles enabling the particles to move more freely.
10	6	1	Heat energy is absorbed during melting and boiling to weaken the intermolecular forces and enable the particles to move more freely.
Average	5	7	
Standard Deviation	1	5.29	

According to the results shown in Table 7.12, there is an improvement in pre-service teachers' understanding about the weakening of intermolecular forces during the process of phase changes. This was evident in the increased number of pre-service teachers who provided the correct answer and explanation on PTDI item numbers 8 and 9. There is an increase in the number of pre-service teachers who explained that intermolecular forces need to be weakened in the process of a phase change as appeared in the increment of pre-service teachers who provided correct explanations in their answer for numbers 8 and 9. However, almost all pre-service teachers did not consider the weakening of intermolecular forces in answering PTDI item number 10 on the post-test. Almost all pre-service teacher choose the explanation that energy is absorbed to enable the particles to move away from each other. The following section elaborates the analysis of these results in more detail.

Better understanding about the weakening of intermolecular forces in the phase changes

As mentioned previously, the results of pre-service teachers' responses to PTDI item number 8 (Figure 7.7) showed improvement of their understanding about the weakening of intermolecular forces during the process of phase changes. This item evaluated pre-service teachers' understanding about the flat line on the graph between temperature and time in the process of heating the ice into the water. The flat line actually represents the condition of constant temperature in which the heat energy absorbed is used to weaken intermolecular forces and enable the particles to move freely. This is the condition of the melting process.

Item No **8**



The diagram shows how the temperature changes when a solid like ice is heated gently until it melts.

In which section of the curve is the heat energy that is absorbed not heating up the ice?

A. (a) B. (b) C. (c)

The reason for my choice of answer is:

1. Heat energy absorbed is used to break the bonds in the ice molecules.
2. Heat energy absorbed is used to weaken the forces between the ice molecules
3. Heat energy is absorbed to increase the kinetic energy of the ice molecules
4. *Other*: ....
   ....

Figure 7.7. Item number 8 of the PTDI

This graph is introduced in the science curriculum for lower secondary school. Thus the pre-service teachers are expected to be able to provide a correct answer as well as an explanation for this item. However, there were various explanations provided by the pre-service teachers in the pre-test. After they did the experiment with the POE, eleven pre-service teachers choose the correct answer followed by the appropriate explanation. Another pre-service teacher (PST-L) choose the incorrect curve although she also gave consideration of intermolecular forces. The explanations provided by the pre-service teachers in responded item number 8 on pre and post-test are summarized on Table 7.13.

Table 7.13. The pre service teachers' explanations in answering item number 8

Type	Explanations	Frequency	
		Pre	Post
A*)	Curve B, because energy is absorbed to break the bonds in ice molecules	3	
B	Curve B, because heat energy absorbed to weaken the intermolecular forces	4	11
C	Curve B, because energy absorbed to increase the kinetic energy of the molecules	2	
D	Curve C, because heat energy absorbed to break the bonds in the molecules.	1	
E	Curve C, because heat energy absorbed to weaken the forces between the molecules		1
F	Curve C, because heat energy absorbed to increase the kinetic energy of the molecules	1	

*) The preferred explanation

A similar result also was shown in the pre-service teachers' responses in answering PTDI item number 9 (Figure 6.4). This item evaluated pre-service teachers' understanding about the process of weakening intermolecular forces of water in the boiling process, though some of the substances remain in the liquid state at this stage.

Although this graph is also introduced in the science curriculum for lower secondary school, there were various explanations provided by the pre-service teachers in the pre-test. But after they did the experiment with the POE, the number of pre-service teachers who choose the correct answer followed by the appropriate explanation increased. The explanations provided by pre-service teachers in response to item number 6 on the pre and post-tests are summarized on Table 7.14.

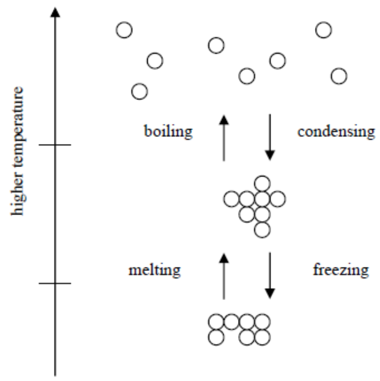
Table 7.14 The pre-service teachers' explanations in answering item number 9

Type	Explanations	Frequency	
		Pre	Post
A*)	At $100^{o}C$ some water molecules still remain in the jar because the attractive forces between the molecules have to be weakened.	5	9
B	At $100^{o}C$ not all water molecules change to become vapor, because this temperature is not enough to break all the intermolecular force of water molecules, so not all water can be vaporized at $100^{o}C$.	1	1
C	At $100^{o}C$ not all water molecules change to become vapor because energy is absorbed to raise the temperature	0	1
D	At $100^{o}C$ all water molecules have vaporised because the movement of water molecules is fast enough to change all the molecules becomes vapour.	0	1
E	No reason provided but stating theory or observation	3	0
F	Inconsistency between answer and explanation	3	0

*) The preferred explanation

Explanations Type A-C believe that at the boiling point of water (100°C) some water still remains in the jar, while the explanation Type D believe that all the water has vaporized. In the pre-test, there are five pre-service teachers who choose the correct answer with right explanation which based on the the attractive forces between the molecules that have to be weakened (Type A). There was also one pre-service teacher who explained that the temperature need to be increased to vaporize all water molecules (Type B). The other three pre-service teachers rely their explanation on the definition of boiling point or describing their observation instead of provide a clear reason of their answer (Type E). Further, there were also three preservice teachers who provided explanations which are inconsistent with the answer (Type F). Remarkably, in the post-test, nine pre-service teachers provided explanation Type A. Meanwhile, the other two pre-service teachers considered the aspect of temperature (Type B and C), both of them agreed that some water molecules still exist in the liquid state at 100°C. However, instead of thinking that the heat is absorbed by weakening the intermolecular force, they thought that the heat was absorbed to raise the temperature and all water molecules could be vaporized at the higher temperature. Lastly, another pre-service teacher has chosen the wrong answer with the explanation that relied on particle movement (Type D).

Item No **10**



The diagram shows the arrangement of particles in different states of matter

In which of the changes of state will heat energy be absorbed?

A. solid → liquid → gas
B. gas → liquid → solid

The reason for my choice of answer is:
1. The H_2O molecules are moved further away from each other.
2. The bonds in the H_2O molecules are broken.
3. The attractive forces between the H_2O molecules are weakened.
4. *Other*: ....
....
....

Figure 7.8. Item number 10 of the PTDI

However, unsatisfactory results were shown in the pre-service teachers' responses to the PTDI item number 10 (Figure 7.8). This item also evaluated pre-service teachers' understanding about the weakening of intermolecular forces to enable the particles to move freely by heat absorption during the process of phase changes.

Table 7.15 The pre-service teachers' explanations in answering item number 10

Type	Explanations	Frequency	
		Pre	Post
A*)	The attractive forces between the H_2O molecules are weakened	6	1
B	The H_2O molecules are moved further away from each other	1	10
C	The bonds in the H_2O molecules are broken	2	-
D	The phase change needs to absorb heat energy	1	
E	When ice turn to liquid, heat is absorbed to weaken the intermolecular force of H_2O. While in the proces of liquid turns into gas, heat absorbed to change to be kinetic energy		1
F	G to L to S absorbed heat because it needs to weaken the attractive force	1	
G	G to L to S absorb heat because G to L need to absorb more energy (endoterm) while S to L releases energy	1	

*) The preferred explanation

According to the explanations provided by the pre-service teachers in the pre and post-test (Table 7.15), there are various answers and explanations provided in response to item number 10. In the pre-test, ten pre-service teachers believed that the energy absorbed in the process of changing phases from solid to liquid to gas with various explanations following their answers (Type A-E). While two pre-service teachers thought that energy is absorbed in the process of phase change from gas to liquid to solid (Type F-G). But in the post-test, all pre-service teachers agreed that the energy is absorbed in the process of phase changes from solid to liquid to gas. However, only one pre-service teacher explained that the absorbed heat is used to weaken the attractive force between the water molecules (Type A). Another pre-service teacher mentioned that the weakening of intermolecular forces only happens in the phase changes from solid to liquid, while the process of phase changing from liquid to gas is related to the change of kinetic energy (Type E). The other ten pre-service teachers did not consider the weakening of intermolecular forces in answering PTDI item number 10 on the post-test. Almost all pre-service teachers choose the explanation that energy is absorbed to make the particles move away from each other (Type B).

According to the result presented above, there was an improvement of pre-service teachers' understanding about the influence of intermolecular forces in the phase change as indicated by the results for number 8 and 9. However, this understanding was not really convincing as most of pre-service teachers did not apply this concept in explaining their answer for number 10.

There are at least two problems regarding the development of pre-service teachers' understanding of the influence of intermolecular forces in phase changes. The first one is the ineffectiveness of experiment simplification to show the process of phase changes. The experiment was conducted using a spirit burner and beaker glass covered with aluminium foil-covered, instead of using distillation set and Bunsen burner or hot plate. The initial idea to simplify the activity is to show the PST that the concept of phase changes can be demonstrated by simple apparatus that might possibly available in their teaching field in the future. However, this use of spirit burner did not provide homogenous heat to the flask, especially if there was any wind around. The use of aluminium foil also did not sufficiently seal the flask at the stage of saturated vapour in the boiling process. Consequently, the data cannot produce the graph as expected. Regarding this, the set of apparatus is only appropriate to show the process qualitatively. This technique did not work well to be used to gather the quantitative data. Whereas, to challenge pre-service teachers' understanding the data must be as accurate as possible.

The second problem is the diagram in item number 10 which may have mis-led pre-service teachers in answering the question. The diagram depicts different arrangement of molecules in three different phases. This diagram obviously shows the larger space between molecules in gaseous state than in the other two states. Thus, the aspect of space is clearer than the aspects of intermolecular forces. This might be the reason why almost all pre-service teachers' explained that the heat was absorb to move the molecules further away from each other instead of to weaken the intermolecular force.

7.8 Summary of the Chapter

This case study describes the way that the POE can assist pre-service teachers to reconstruct their understanding. According to the results presented above, this strategy has provided a meaningful learning experience for the pre-service teachers. In the concept about intermolecular spacing in matter, the pre-service teachers have developed better understanding of the concept of density and also about the existence of the spaces between the molecules of liquids. The POE strategy with the theme *Solid, Liquid, and Gases in Syringes* assisted pre-service teachers in constructing better understanding about the influence of compression to mass and density. Meanwhile, the POE strategy with the theme *Gas Law* has the potential to promote pre-service teachers in building an understanding of a correlation between the variables of volume and pressure with the intermolecular spacing within the gas system. However, after the pre-service teachers had learned about the concept of intermolecular spacing in matter with the POE strategy, they still had some confusion about the major reason for the compressibility of a gas. Some pre-service teachers were not really sure whether the wide space between particles or the free movement of particles is the reason for gas compressibility.

Regarding the concept about diffusion, the POE strategy namely *Liquid and Gas Diffusion* assisted these pre-service teachers to have a better understanding about the collision of particles in the process of diffusion. They built better visualisation about the process of diffusion in liquids as well as in gases. This result may be ascribed to the activity during the experiment when the pre-service teachers observed the factual phenomena of the process of dye diffusion in water. The two experiments which were conducted in two different temperatures allowed pre-service teachers to make a connection between particle movement and diffusion. Further, the POE strategy with the theme *Phase Change* improved pre-service teachers' understanding about the weakening of intermolecular forces during the process of phase changes.

The role of POE relies on the three stages of the POE strategy that are simple and easy to implement. The prediction stage allowed the pre-service teachers to express their thought and provided an opportunity for them to reveal and realize the quality of their their understanding (Coştu et al., 2010). This stage is considered as an important part to initiate the process of conceptual change (Johnston & Scott, 1991). During the observation process, the pre-service teachers were shown a phenomena that may have contradicted their understanding. At this stage, they were provided with the opportunity to evaluate the quality of their previous conceptual understanding from the written explanations of their prediction. At the stage of explanation, the pre-service teachers were facilitated to reconstruct their understanding assisted by the discussion process with other pre-service teachers. These are the examples showing the benefit of the three stages in the POE which offer some opportunities for the pre-service teachers to reconstruct their understanding.

According to the description above, it is has been demonstrated that providing an opportunity to challenge pre-service teachers' understanding seems more powerful than providing them with the correct explanation of a basic concept. The implementation of the POEs fulfil pre-service teachers' need for the opportunity to clarify their understanding (Lin et al., 2000). The improvement of pre-service teachers understanding through POE strategy was also consistent with the idea which stated the need of opportunities for pre-service teachers to challenge their own understanding in order to restructure and strengthen their conceptual understanding (Haidar, 1997; Magnusson et al., 1999; Treagust & Chandrasegaran, 2007)

Furthermore, the POE strategy also enables the pre-service teachers to realize that conceptual understanding can be challenged in learning chemistry using simple materials. As has been explained by Bak Kibar et al. (2013), the pre-service teachers need to experience the learning process which enables them to get inspired to design meaningful learning strategies in their future teaching practices. Further to this, the POE can be one alternative strategy that can be implemented in teacher education especially in the program of strengthening pre-service teachers' content knowledge.

CHAPTER 8

DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS

8.1 Introduction

The three previous chapters (Chapter 5, 6 and 7) presented the results of this research. Chapter 5 elaborated the results about curriculum evaluation in terms of the intended and implemented curriculum, and Chapter 6 presented the perceived and achieved curriculum. Chapter 7 described the results of the implementation of the Predict-Observe-Explain (POE) strategy to improve pre-service teachers understanding of the Particulate Nature of Matter (PNM). The purpose of this chapter is to compile the findings according to the research questions outlined in Chapter 1. This chapter also intends to summarize the conclusions and present the limitations of this study. Besides, this chapter also attempts to discuss the implications of this research in future pre-service teacher education.

8.2 Major findings and discussion

The following sections discusses the major finding of this research in accordance with research questions and the relevant literature.

8.2.1 The *intended* curriculum - Research Question 1

The discussion about the intended curriculum addresses Research Question #1*"What is the designed program to develop pre-service teachers' understanding of the particulate nature of matter in the Chemistry Education Program?"* This research question is designed to reveal the kind of program that has been designed by the Chemistry Education Department regarding the development of pre-service teachers' understanding about chemistry content, especially about the particulate nature of matter. In order to answer this question, the discussion began with the analyses of the documents that contained the expectations about teachers in terms of their content knowledge (ideal curriculum) followed by the analyses about the curriculum at an institution level that have been designed to achieve the expectation (written curriculum). Table 8.1 presents the list of documents for the analyses relating to the intended curriculum.

Table 8.1 List of documents analysed relating to the intended curriculum

Code	Title of documents	Year	Issuing Organization	Content	Category
A	Act of The Republic of Indonesia No 20/2003 on the National Educational System	2003	Presidency of Republic of Indonesia	Teachers' Content Knowledge	Ideal Curriculum
B	Government of Republic of Indonesia Regulation number 19 of 2005 about National Education Standards	2005			
C	Ministry of National Education Regulation number 16 of 2007 about Academic Qualification Standards and Teacher Competences	2007	MoNE		
D	Competence Standards for Beginner Teachers	2004	Directorate of Higher Education MoNE		
E	Competence-Based Curriculum of Science for Secondary School	2007	MoNE	School Curriculum	
F	2013 Curriculum of Science for Secondary School	2013			
G	Curriculum of Chemistry Education Study Programme	2013	Departement of Chemistry Education, Indonesian Institute of Teacher Education	Program developed by the institution	Written Curriculum
H	Course Description of the course of Chemistry for Lower Secondary School	2011			

As discussed in Section 5.2, Document A mentioned that teachers are expected to create a meaningful and creative learning environment that supports the students' learning process. This statement is further supported by Document B and C which stated that mastery of content knowledge is one of the main teachers' competences. The competences related to content knowledge is further elaborated in document D which mentioned that the teachers are expected to be able to describe the structure of chemical substances and their characteristics in three representation of chemistry (macroscopic, sub-microscopic, and symbolic representations). According to these documents, it can be summarized that teachers are expected to have a well-constructed understanding of the content knowledge of the subject that they teach because a comprehensive content knowledge will support them to create a meaningful learning environment in their own classrooms.

Documents E and F, which were also categorized as an ideal curriculum, contained the science curriculum for lower secondary school that were being implemented in the Indonesian National Education System during the research period. These documents described science concepts that are supposed to be taught in secondary schools. Thus, this information becomes the minimum requirement of content knowledge that has to be mastered by the pre-service teachers.

Within documents E and F, it has been mentioned that the concepts relating to the topic about the *phases of mater and its changes* become the competence standard that has to be achieved by lower secondary students. This topic covers the basic concepts of chemistry that are widely known as particulate nature of matter. Regarding this, the pre-service teachers are required to have a deep comprehension about this topic because they are expected to assist the students to develop comprehensive understanding about the particulate nature of matter.

In response to the expectations mentioned in the ideal curriculum, the Chemistry Education Department has a concern about the development of pre-service teachers' content knowledge. This concern is shown in the curriculum for the 4-year program of Chemistry Teacher Education that has a unit which specifically elaborates the chemistry concepts for Lower Secondary School and also discusses the aspect of the teaching strategy to lower secondary school. The title of this unit is Teaching and Learning of Chemistry for Lower Secondary School (LS-Chem).

8.2.2 The *implemented* curriculum - Research Question 2

The Research Question #2 *"How is the pre-service chemistry teachers' understanding of the particulate nature of matter developed through the unit of Teaching and Learning of Chemistry for Lower Secondary School?"* describes the processes that happened in the program of pre-service teacher's content knowledge development especially about the topic of the particulate nature of matter. The discussion elaborated the results from the researchers' observation of the teaching and learning process in the LS-Chem unit.

According to the results discussed in Section 5.3 it was found that the timetable between those two semesters are different (see the comparison in Table 5.5). Those timetables also differ from what has been designed and stated in the document of Unit Description (see Table 5.4). Furthermore, there are some findings related to the implementation of the program. The summary of these findings are listed below:

1. More discussion about teaching strategies rather than basic concept development.
2. The course was run based on the interest of the lecturer, not based on the timetable that had been designed in the Unit Description.
3. One of the discussions about teaching and learning strategies covered the topic about the exemplary practice of chemistry lesson in lower secondary school based on the field observation experienced by the lecturer.
4. Another topic of discussion of teaching and learning strategy is about how to design the lesson plan for chemistry in lower secondary school including the preparation of good learning materials and laboratory worksheets.
5. When it comes to the discussions about the concepts of chemistry, it was often conducted by explaining the series of terminologies and definitions covered in the topic. There was limited explanation about the process involved and the reasoning of a certain concepts.
6. Insufficient and unclear explanation about concepts related to PNM
7. The PSTs have indicated need for more assistance in developing understanding of sub-microscopic representations.
8. The PSTs still need more assistance in the concept selections that are suitable for lower secondary students.

These findings have proven that strengthening of pre-service teachers' conceptual understanding as well as developing their teaching skill are challenging tasks for teacher educators. According to Loughran (2005), there are several things to be considered by teacher educators in teachers' knowledge development. Teacher educators should provide meaningful learning experiences for pre-service teachers. Besides, modelling is also essential in teacher education, because pre-service teachers learn more from what have been done than what have been said. These points need to be considered in the future implementation of teacher education program.

8.2.3 The *perceived* curriculum - Research Questions 3 and 4

There are two Research Questions related to the perceived curriculum. Research Question #3 *"What are the chemistry teacher educators' perceptions about the chemistry education curriculum in terms of enhancing preservice teachers' understanding of the particulate nature of matter?"* aimed to learn about the lecturers' perceptions of the existing curriculum especially their perceptions about the LS-Chem unit. The Research Question #4 *"What are the preservice teachers' perceptions about the chemistry education curriculum in terms of enhancing their understanding of the particulate nature of matter?"* was directed to find out the pre-service teachers' perceptions about the LS-Chem Unit as a program that has been designed to strengthen their content knowledge about the particulate nature of matter.

According to the curriculum, the LS-Chem Unit was intended to elaborate the chemistry concepts for Lower Secondary School and also discussed the aspect of the teaching strategy to lower secondary school. Both teacher educators considered the main aim of the Unit, but they had a different emphasis. Although Lecturer C realized that pre-service teachers' understanding needed to be strengthened, the topics of his discussion were more about teaching strategies and how to prepare learning material than content. Meanwhile, Lecturer D found that pre-service teachers still needed assistance to build a comprehensive understanding even for the basic concepts. Thus he thought that the tasks given to pre-service teachers to make learning materials have to be more simple. Pre-service teachers need tasks that can provide opportunities for them to reconstruct their conceptual understanding. However, Lecturer D's opinion had not been implemented during that time as he was involved in the LS-Chem unit for the first time that semester.

Regarding the perception of pre-service teachers, the purpose of enrolling in the LS-Chem unit course was to strengthen their knowledge about basic chemistry concepts as well as to enrich their skills to teach chemistry to lower secondary students. They realize that their conceptual understanding about basic concept of chemistry is not sufficient to effectively teach lower secondary students. This situation is similar to the research where Tekkaya et al. (2004) reported that the Turkish pre-service teachers had lower levels of confidence to teach science at conceptual level. Therefore, the pre-service teachers need the opportunity to restructure and strengthen their conceptual understanding to convince themselves of their competence to teach.

Besides having an aim to strengthen their knowledge about chemistry concepts, the pre-service teachers are also expected to learn how to teach chemistry to lower secondary students. This fact is in coherence to one of the assertions by Loughran (2005) which mentioned that one of the objectives of preservice teachers enrolling into the teacher education program is to learn how to teach. However, at the end of the semester, they still were confused with the selection of topics that would be appropriate for teaching chemistry to lower secondary students. Thus, teacher educators have more challenges to provide an opportunity and also to encourange pre-service teachers to actively strengthen their knowledge and develop their teaching skills.

8.2.4 The *achieved* curriculum - Research Question 5

The discussion about the achieved curriculum tried to address Research Question #5 *"What are preservice chemistry teachers' understandings of the particulate nature of matter after enrolling in the unit of Teaching and Learning of Chemistry for Lower Secondary School?"* The data analysis attempted to explain the general idea about the quality of PSTs understanding about the concepts related to the particulate nature of matter. The analyses also tried to identify whether there are any concepts that still may be a problem for PSTs to understand? If so, which part of the process of teaching and learning should be optimized in the future development of the program.

In general, the results show that the PSTs in this study still have limited or fragmented understanding of content knowledge especially in the concepts related to the particulate nature of matter. More specifically, there were some basic concepts which were still a problem for some PSTs such as density, volume, influence of heat on intermolecular forces, the role of intermolecular forces in the states of matter, and the movement of particles within three different phases. This fact is in accordance with what has been stated by other scholars that limited or fragmented understandings of content knowledge are still possessed by pre-service teachers (Cheung, 2009; Gess-Newsome, 1999a; Haidar, 1997; Niess & Scholz, 1999). In chemistry cases, De Jong

(2002) stated that many chemistry teachers also have a problem in understanding basic chemistry concepts.

According to the results about pre-service teachers' achievement (Section 5.5), the concepts that were still obstacles for pre-service teachers were the fundamental concepts in chemistry. These concepts were supposed to be learnt by pre-service teachers when they were at lower and upper secondary school. It means that the pre-service teachers should have already built a thorough understanding about those concepts when they enrolled to the LS-Unit. However, since there was a variety of school learning experiences, the qualities of pre-service teachers' conceptual understanding also may vary. Thus, the teacher education institution has a challenge to design a program that can provide opportunities for pre-service teacher to evaluate their own understanding and assistance to reconstruct their understanding.

8.2.5 The effect of POE strategy on pre-service teachers' understanding about PNM - Research Question 6

The discussion about the effect of POE strategy attempts to address Research Question #6 *"How does the POE strategy effect pre-service teachers' understanding of PNM?"* The data analysis was conducted to find out pre-service teachers' understanding after the implementation of POE strategy. The analysis also attempts to find out which stages of the POEs assisted pre-service teachers to develop better conceptual understanding about PNM.

The results presented in Chapter 7 showed that, after they join three lessons with POE strategy, pre-service teachers' understanding generally improved but to varying degrees. Table 8.2 shows the summary of the changes of pre-service teachers' understanding about the concepts relating to the PNM.

Table 8.2 The summary of the changes of pre-service teachers' understanding about the concepts related to the PNM.

Conceptual Categories of PNM	The changes of PSTs' understanding
Intermolecular spacing in matter	Better understanding about the concept of density
	Better understanding about the space between the molecules of liquid
	Better understanding about the influence of compression to mass and density
	Better understanding about the system of gas related to the variables of volume and pressure with the intermolecular spacing
	The confusion between the wide space between particles or the free movement of particles was the major reason given for the compressibility of gas
	The limitation of pre-service teachers' understanding about volume relating to different shapes of container
Diffusion in liquid and gases	Better visualisation of diffusion in liquid
	Better visualisation of gas diffusion
The influence of intermolecular forces on changes of state	Better understanding about the weakening of intermolecular forces in the phase changes

According to pre-service teachers' post-test results, there were some improvements in their understanding of several concepts related to PNM after the implementation of POE. It was noticed that after the pre-service teachers experienced the POE learning entitled *Solid, liquid and gases in syringes* and *Gas Law*, they had a better understanding about density and the space between molecules of liquid. The process of learning with the POE also assisted pre-service teachers to build comprehensive understanding about the system of a gas related to the variables of volume and pressure with the intermolecular spacing. Besides, these POEs also assisted those pre-service teachers in building understanding about the influence of compression to mass and density. However, the pre-service teachers were still confused to determine the appropriate aspects of gas in explaining the phenomena of gas compressibility.

The result also shows that these POE activities could not assist the pre-service teachers to construct a sound understanding about the concept of volume in terms of the volume of liquids in different containers. During the interviews after the post-test, some pre-service teachers were identified still having difficulties in describing the concept of volume related to different shapes of containers. This fact shows an example of a basic concept whose difficulty cannot be overestimated. Consequently, there is need to intentionally assist pre-service teachers' reconstruction of their understanding about volume and its relation to different shapes of containers.

Regarding the concept categories about diffusion in liquids and gases, the pre-service teachers developed better visualization of particle movement after having experience learning with POE. This understanding was supported by the POE strategy about Liquid and Gas Diffusion to build pre-service teachers' understanding about particle movement in the process of liquid and gas diffusion. The similar result also happened to the POE about the influence of intermolecular forces on changes of phase. Pre-service teachers developed better understanding about the weakening intermolecular forces in the process of phase changes. These findings confirm the theory proposed by Gilbert (2005), which stated that a visualization of chemical phenomena in particulate behaviour is essential in the development of conceptual understanding of chemistry, especially in understanding about the PNM as has been elaborated by Abraham et al. (1994) and Harrison and Treagust (2003).

The roles of POE in improving pre-service teachers' understanding were providing opportunity for them to articulate their concept which helped them recognize their own understanding. This is an essential part to promote conceptual change (Johnston & Scott, 1991). During the observation activities, the POEs challenged their conceptual understanding to further explain the phenomena that may have been in contradiction with their predictions. In the stages of observation and explanation, they were able to evaluate their previous understanding and reconstruct new concepts. These facts clearly show that all stages of POE can provide opportunities to clarify their conceptual understandings and facilitate them to re-construct their own understandings to develop a well-structured knowledge as has been suggested by previous research studies (Haidar, 1997; Lin et al., 2000; Magnusson et al., 1999; Treagust & Chandrasegaran, 2007).

8.3 The conclusions of the thesis

This study has illustrated how curriculum evaluation using the framework of curriculum inquiry has potential to be utilized as an evaluation tool of the program at the institutional level. The evaluation was conducted from different aspects including what have been expected from the program (intended curriculum), the perceptions of the personnel involved (perceived curriculum), the practice of the program (implemented curriculum), and the students' achievement after the program (achieved curriculum). Therefore, the results of this study were able to provide comprehensive information about current program and the conditions of the institution. Further, the results of this study also can be summarized as the strengths and challenges that will be very valuable for further development of the pre-service teacher education program.

According to the results of curriculum evaluation, several potential aspects were presented at the Chemistry Education Department. The first potential is the concern of the Department on pre-service teachers' content knowledge development. The Chemistry Education Department considered the importance of strengthening pre-service teachers' content knowledge by providing content-related units. Regarding the topics about the Particulate Nature of Matter, the Department also provided a LS-Chem Unit that was specifically aimed to enrich pre-service teachers with good understanding of basic chemistry concepts as well as preparing them with strategies to teach chemistry at the lower secondary school.

The second potential is the awareness of the lecturers about the importance of basic knowledge of understanding of chemistry. According to the results relating to the lecturers' perceptions, it has been known that the lecturers realized that it is essential for pre-service teachers to have strong conceptual understanding, especially for the basic concepts. However, according to observation, they still need more support and resources to create teaching and learning activities that challenge PST's understanding.

The third potential is the awareness of PSTs about their limitations and their expectations of learning. During the interview session, the pre-service teachers stated that teaching chemistry to lower secondary students might be different from teaching chemistry to upper secondary students. Teaching chemistry to lower secondary students not only should be able to build fundamental conceptual understanding, but also to trigger students' motivation to learn chemistry. Thus, they were expected to strengthen their understanding of basic concepts of chemistry as well as to learn how to teach chemistry to the students at the lower secondary school. This fact shows that the pre-service teachers were aware of their own learning. According to Haidar (1997), this self-awareness should be empowered during the pre-service teacher education because it could raise their motivation which would make their learning process more effective.

Besides some potential aspects that have been mentioned above, the curriculum evaluation also revealed at least two challenges for the Chemistry Education Department. The first challenge relates to pre-service teachers' understanding about basic concepts which cannot be overestimated. Although the basic concepts have been covered in the curriculum of science for lower secondary school, we cannot make assumptions that those pre-service teachers have built conceptual understanding about those concepts appropriately. The evaluation results about pre-service teachers' understanding (*achieved curriculum*) showed that some of the pre-service teachers still have a problem in understanding several basic chemistry concepts for instance, density, volume, influence of heat on intermolecular forces, the role of intermolecular forces in the states of matter and the movement of particles within three different states. This fact supports what has been stated in literature that pre-service teachers still have limited and fragmented understanding even in the basic concepts of chemistry (De Jong, 2002) and even when they graduate from university (Cheung, 2009; Gess-Newsome, 1999b; Haidar, 1997; Niess & Scholz, 1999).

The second challenge is assisting PST to reconstruct their knowledge. Considering the prior knowledge that has been learned and constructed, this task is not as easy as providing explanations about the right concepts, As mentioned by Lederman and Gess-Newsome (1999), developing well-structured conceptual understanding during pre-service teacher programs is challenging. Accordingly, PSTs need to be facilitated to realize the limitations of their previous understandings, so that they will be able to challenge themselves to restructure their own conceptual understanding (Haidar, 1997; Lin et al., 2000; Magnusson et al., 1999; Treagust & Chandrasegaran, 2007). In brief, in order to strengthen PST content knowledge, the Chemistry Education Department has a challenge to develop teaching strategies that are effective to provide opportunities for the pre-service teachers to reconstruct their understanding about basic chemistry concepts.

Regarding the implementation of the POE strategy, this study also has shown the potential of the POE strategy as an alternative strategy to strengthening PSTs' conceptual understanding about basic concepts in chemistry. This strategy can assist pre-service teachers in developing a better understanding about density, volume, the space between molecules, particle movements, and variables relating to the gas system.

The advantages of the POE strategy presents in all stages of the Predict-Observe-Explain which provide meaningful learning for pre-service teachers as described in Chapter 7. Substantively, this process of learning has fulfilled one of the criteria of pre-service teachers' education, which is to facilitate pre-service teachers to reflect the quality of their previous understandings. They then will be able to challenge themselves to restructure their own conceptual understanding (Haidar, 1997; Lin et al., 2000; Magnusson et al., 1999; Treagust & Chandrasegaran, 2007).

Besides enhancing pre-service teachers' understanding, the implementation of the POE also provided pre-service teachers with a meaningful learning experience at every stage of POE, as described above. This real experience is an example for pre-service teachers to create meaningful learning in their classrooms. Thus they are not only taught with theory but also with a real experience as one of the efforts to improve the quality of teacher education programs as has been advised by Diez (2010) and Russell (1997).

To sum up, this study was designed to improve the quality of the teaching and learning process in a teacher preparation program. The curriculum evaluation attempted to obtain information about the current situation in the field which was presented as potentials and challenges as mentioned above. In the framework of curriculum inquiry, the program implementation as well as the perception of the persons involved are also taken into account in the process of evaluation. Information gathered from the curriculum evaluation can be considered in the improvement of the program. Thus, this study of curriculum evaluation can be a model to evaluate pre-service teacher education programs in Indonesia and in other countries. Moreover, the study of the implementation of POE strategy also provided information about the usefulness of that strategy in challenging and reinforcing pre-service teachers' content knowledge in the teacher education process. In turn, this study about chemistry teacher education is an effort to contribute to the improvement of science education in Indonesia. This study also can be counted as an endeavour to fulfil the lack of research study dealing with teacher development program which called as a 'blank space' by De Jong (2002), and this is especially the case in Indonesia.

8.4 Limitations of the study

The most severe limitation in this study is the small number of students involved in the pilot test of the instruments and in the class being observed. Therefore, the improvement of pre-service teachers' understanding cannot be calculated statistically. This was an unpredictable situation because there was usually about twenty five pre-service teachers enrolled in the LS-Chem unit during regular semester. Due to the limitation of time, the researcher could not conduct additional data collection in other semester. The second limitation is there was not any control group involved in this study, due to the small number of pre-service teachers. The third limitation is regarding the technical issue in the implementation of POE. The use of plastic syringe with rubber plunger resulted a little change in the rubber when it was pressed. This condition made some pre-service teachers keep thinking that there is a space between liquid molecules. Another issue was in the experiment during the POE activity about the influence of intermolecular forces in change phase which resulted the data that did not produce the expected graph.

8.5 Implications relating to this study

This section elaborates the implication that is related to the study about curriculum evaluation and study about the impact of the implementation of the POE strategy. The implications are about several points to be conducted in further study.

8.5.1 Improving the validity of the instrument

In order to improve the quality of future study, the scope of the participants can be broaden that might be possible to conduct a better pilot test which resulted better validity of the instrument.

8.5.2 Similar research in a broader scope of unit, and cohort study

Since this study is related to curriculum evaluation and the implementation of POE as one alternative of teaching and learning strategy in a teacher preparation program, the result of this study offers an extensive opportunity for further study. The similar study can be conducted to evaluate the process of teacher education program in different units or groups of units to examine the development process of various aspects of pre-service teachers' knowledge. Study in the framework of curriculum inquiry is also beneficial for the lecturers to evaluate their teaching practice as a means for reflective practice. This study is also potential as a program evaluation method at the institution level. It will be very worthwhile to conduct a cohort study of this framework in a 4-year program of other teacher education institutions. This study could generate information about which units are effective to develop the aspect that is being studied, which unit is needed for further development, and in which level the units should be implemented.

Regarding the implementation of the POE, similar studies can be conducted with different methods of POE strategies to strengthen pre-service teachers' understanding of concepts related to the particulate nature of matter. The similar experiment of the POE strategies can be implemented with several changes such as, the use of plastic syringes will be replaced by glass syringes. Besides, the use of spirits burner in the experiment about phase changes will be replaced by Bunsen burner, in order to obtain more homogenous heat, which is expected to provide data which can resulted the expected graphs.

POE strategies also can be implemented for other concepts as long as they can be presented with the phenomena that is suitable for the POE strategy. For example, the POE strategy for the topic of chemical reaction using iron wool in the two pans analytical balance. The pre-service teachers are required to predict what happen if one of the iron wool is burnt. Thus, an experimental study can be performed regarding the implementation of the POE strategy in order to improve pre-service teachers' understanding of chemistry concepts.

References

Abraham, M. R., Williamson, V. M., & Westbrook, S. L. (1994). A cross-age study of the understanding of five chemistry concepts. *Journal of Research in Science Teaching, 31*(2), 147-165.

Adadan, E., Irving, K., & Trundle, K. C. (2009). Impacts of multi-representational instruction on high school students' conceptual understandings of the particulate nature of matter. *International Journal of Science Education, 31*(13), 1743-1775.

Akaygun, S., & Jones, L. L. (2013). Dynamic visualizations: Tools for understanding the particulate nature of matter. In G. Tsaparlis & H. Sevian (Eds.), *Concept of matter in science education* (pp. 281-300). Dordrecht: Springer.

Aktas, İ., & Bılgın, İ. (2014). The effect of the 4MAT learning model on the achievement and motivation of 7th grade students on the subject of particulate nature of matter and an examination of student opinions on the model. *Research in Science & Technological Education, 33*(1), 1-21.

Albanese, A., & Vicentini, M. (1997). Why do we believe that an atom is colourless? Reflections about the teaching of the particle model. *Science and Education, 6*, 251-261.

Andersson, B. (1990). Pupils' conceptions of matter and its transformations (age 12-16). *Studies in Science Education, 18*(1), 53-85.

Ardac, D., & Akaygun, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students' understanding of chemical change. *Journal of Research in Science Teaching, 41*(4), 317-337.

Ardac, D., & Akaygun, S. (2005). Using static and dynamic visuals to represent chemical change at molecular level. *International Journal of Science Education, 27*(11), 1269-1298.

Ausubel, D. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.

Ayas, A., Ozmen, H., & Calik, M. (2010). Students' conceptions of the particulate nature of matter at secondary and tertiary level. *International Journal of Science and Mathematics Education, 8*(1), 165-184.

Bak Kibar, Z., Yaman, F., & Ayas, A. (2013). Assessing prospective chemistry teachers' understanding of gases through qualitative and quantitative analyses of their concept maps. *Chemistry Education Research and Practice, 14*(4), 542-554.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191-215.

Barke, H.-D. (2009). *Misconceptions in Chemistry: Addressing Perceptions in Chemical Education*. Berlin, Heidelberg: Springer Berlin Heidelberg.

Becker, N., Rasmussen, C., Sweeney, G., Wawro, M., Towns, M., & Cole, R. (2013). Reasoning using particulate nature of matter: An example of a sociochemical norm in a university-level physical chemistry class. *Chemistry Education Research and Practice, 14*(1), 81-94.

Boz, Y. (2006). Turkish pupils' conceptions of the particulate nature of matter. *Journal of Science Education and Technology, 15*(2), 203-213.

Bracken, B. A., & Barona, A. (1991). State of the art procedures for translating, validating and using psychoeducational tests in cross-cultural assessment. *School Psychology International, 12*(1-2), 119-132.

Brislin, R. W. (1970). Back-translation for cross-cultural research. *Journal of Cross-Cultural Psychology, 1*(3), 185-216.

Bruner, J. S. (1986). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.

Çalik, M., & Ayas, A. (2005). A comparison of level of understanding of eighth-grade students and science student teachers related to selected chemistry concepts. *Journal of Research in Science Teaching, 42*(6), 638-667.

Canpolat, N., Pinarbasi, T., & Sözbilir, M. (2006). Prospective teachers' misconceptions of vaporization and vapor pressure. *Journal of Chemical Education, 83*(8), 1237-1242.

Carlisle, D., Tyson, J., & Nieswandt, M. (2015). Fostering spatial skill acquisition by general chemistry students. *Chemistry Education Research and Practice, 16*(3), 478-517.

Carlsen, W. S. (1999). Domains of teacher knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining Pedagogical Content Knowledge* (pp. 133-144). Dordrecht: Kluwer Academics Publishers.

Champagne, A. B., Klopfer, L. E., & Anderson, J. H. (1980). Factors influencing the learning of classical mechanics. *American Journal of Physics, 48*(12), 1074-1079.

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2008). An evaluation of a teaching intervention to promote students’ ability to use multiple levels of representation when describing and explaining chemical reactions. *Research in Science Education*, *38*(2), 237-248.

Chang, A. M., Chau, J. P. C., & Holroyd, E. (1999). Translation of questionnaires and issues of equivalence. *Journal of Advanced Nursing, 29*(2), 316-322.

Chang, J. L., Chen, C. C., Tsai, C. H., Chen, Y. C., Chou, M. H., & Chang, L. C. (2013). Probing and fostering students' reasoning abilities with a cyclic Predict-Observe-Explain strategy. In M. H. Chiu, H. L. Tuan, H. K. Wu, J. W. Lin & C. C. Chou (Eds.), *Chemistry education and sustainability in the global age* (pp. 49-57). Dordrecht: Springer.

Chang, J. Y. (1999). Teachers college students' conceptions about evaporation, condensation, and boiling. *Science Education, 83*(5), 511-526.

Chang, M. C., Shaeffer, S., Al-Samarrai, S., Ragatz, A. B., de Ree, J., & Stevenson, R. (2014). *Teacher reform in Indonesia: The role of politics and evidence in policy making.* Washington DC: doi:10.1596/978-0-8213-9829-6

Chen, H. Y., & Boore, J. R. (2010). Translation and back-translation in qualitative nursing research: Methodological review. *Journal of Clinical Nursing, 19*(1-2), 234-239.

Cheung, D. (2009). Using think-aloud protocols to investigate secondary school chemistry teachers' misconceptions about chemical equilibrium. *Chemistry Education Research and Practice, 10*(2), 97-108.

Chiu, M. H. (2007). A national survey of students’ conceptions of chemistry in Taiwan. *International Journal of Science Education*, *29*(4), 421-452.

Clements, D. H., & Battista, M. T. (1990). Constructivist learning and teaching. *The Arithmetic Teacher, 38*(1), 34-35.

Corrigan, D. (2009). Chemistry teacher education to promote understanding of learning through effective reflective practice. *Chemistry Education Research and Practice, 10*(2), 121-131.

Coştu, B., Ayas, A., & Niaz, M. (2010). Promoting conceptual change in first year students’ understanding of evaporation. *Chemistry Education Research and Practice, 11*(1), 5-16.

Creswell, J. W. (2012). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (4th ed.). Boston: Pearson.

Davis, E. A., & Krajcik, J. S. (2005). Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34*(3), 3-14.

De Jong, O. (2002). Developing teachers and chemical education. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust & J. H. van Driel (Eds.), *Chemical Education: Towards Research-based Practice* (pp. 365-367). Netherlands: Kluwer Academic Publishers.

De Jong, O., Veal, W. R., & Van Driel, J. H. (2002). Exploring chemistry teachers' knowledge base. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust & J. H. van Driel (Eds.), *Chemical education: Towards research-based practice* (pp. 369-390). Netherlands: Kluwer Academic Publishers.

Diez, M. E. (2010). It is complicated: Unpacking the flow of teacher education's impact on student learning. *Journal of Teacher Education, 61*(5), 441-450.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.

Duit, R., Treagust, D. F., & Mansfield, H. (1996). Investigating student understanding as a prerequisite to improving teaching and learning in science and mathematics. In D. F. Treagust, R. Duit & B. J. Fraser (Eds.), *Improving Teaching and Learning in Science and Mathematics* (pp. 17-31). New York: Teachers College Press.

Ell, F., Hill, M., & Grudnoff, L. (2012). Finding out more about teacher candidates' prior knowledge: Implications for teacher educators. *Asia-Pacific Journal of Teacher Education, 40*(1), 55-65.

Epstein, J., Osborne, R. H., Elsworth, G. R., Beaton, D. E., & Guillemin, F. (2015). Cross-cultural adaptation of the Health Education Impact Questionnaire: Experimental study showed expert committee, not back-translation, added value. *Journal of Clinical Epidemiology, 68*(4), 360-369.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. C. Wittrock (Ed.), *Handbook of Research on Teaching* (3rd ed., pp. 119-161). New York: Simon & Schuster Macmillan.

Ferk, V., Vrtacnik, M., Blejec, A., & Gril, A. (2003). Students' understanding of molecular structure representations. *International Journal of Science Education, 25*(10), 1227-1245.

Friedel, J. M., & Treagust, D. F. (2005). Learning bioscience in nursing education: Perceptions of the intended and the prescribed curriculum. *Learning in Health and Social Care, 4*(4), 203-216.

Gabel, D. L. (1993). Use of the particle nature of matter in developing conceptual understanding. *Journal of Chemical Education, 70*(3), 193-194.

Gabel, D. L., Samuel, K. V., & Hunn, D. (1987). Understanding the particulate nature of matter. *Journal of Chemical Education, 64*(8), 695-697.

Gardner, H. (1983). *Frames of mind: The theory of multiple intelligences*. New York: Basic Books.

Garnett, P. J., Garnett, P. J., & Hackling, M. W. (1995). Students' alternative conceptions in chemistry: A review of research and implications for teaching and learning. *Studies in Science Education, 25*(1), 69-95.

Gess-Newsome, J. (1999a). Pedagogical content knowledge: An introduction and orientation. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 3-17). Dordrecht: Kluwer Academic.

Gess-Newsome, J. (1999b). Secondary teachers' knowledge and beliefs about subject matter and their impact on instruction. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 51-94). Dordrecht: Kluwer Academic.

Gess-Newsome, J., & Lederman, N. G. (1999). *Examining pedagogical content knowledge: the construct and its implications for science education*. Dordrecht: Kluwer Academic.

Gilbert, J. K. (2005). Visualization: A metacognitive skill in science and science education. In J. K. Gilbert (Ed.), *Visualization in Science Education* (pp. 9-27). Netherland: Springer.

Gilbert, J. K., & Treagust, D. F. (2009). Introduction: Macro, submicro and symbolic representations and the relationship between them: Key models in chemical education. In J. K. Gilbert & D. F. Treagust (Eds.), *Multiple representations in chemical education* (Vol. 4, pp. 1-8). Dordrecht: Springer Netherlands.

Goodlad, J. I., Klein, M. F., & Tye, K. A. (1979). The domains of curriculum and their study. In J. I. Goodlad (Ed.), *Curriculum inquiry: The study of curriculum practice* (pp. 43-76). New York: McGraw-Hill.

Griffiths, A. K., & Preston, K. R. (1992). Grade-12 students' misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching, 29*(6), 611-628.

Groundwater-Smith, S. (2007). *Teaching: Challenges and dilemmas* (3rd ed.). South Melbourne: Thomson Learning.

Gunstone, R. F., & White, R. T. (1981). Understanding of gravity. *Science Education, 65*(3), 291-299.

Guo, Y., Connor, C. M., Yang, Y., Roehrig, A. D., & Morrison, F. J. (2012). The effects of teachers qualification, teacher self-efficacy, and classroom practices on fifth graders' literary outcomes. *The Elementary School Journal, 113*(1), 3-24.

Guo, Y., Piasta, S. B., Justice, L. M., & Kaderavek, J. N. (2010). Relations among preschool teachers' self-efficacy, classroom quality, and children's language and literacy gains. *Teaching and Teacher Education, 26*(4), 1094-1103.

Gustafson, B. J., Shanahan, M. C., & Gentilini, S. (2010). Elementary children's shifting views of models and the nature of matter. *Canadian Journal of Science, Mathematics and Technology Education, 10*(2), 103-122.

Haidar, A. H. (1997). Prospective chemistry teachers' conceptions of the conservation of matter and related concepts. *Journal of Research in Science Teaching, 34*(2), 181-197.

Harrison, A. G., & Treagust, D. F. (2000). Learning about atoms, molecules, and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education, 84*(3), 352-381.

Harrison, A. G., & Treagust, D. F. (2003). The particulate nature of matter: Challenges in understanding the submicroscopic world. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust & J. H. Van Driel (Eds.), *Chemical Education: Towards Research-Based Practice* (Vol. 17, pp. 189-212). Dordrecht: Kluwer Academic Publishers.

Hofstein, A., & Kesner, M. (2006). Industrial chemistry and school chemistry: Making chemistry studies more relevant. *International Journal of Science Education, 28*(9), 1017-1039.

İpek, H., Kala, N., Yaman, F., & Ayas, A. (2010). Using POE strategy to investigate student teachers’ understanding about the effect of substance type on solubility. *Procedia - Social and Behavioral Sciences, 2*(2), 648-653.

Jeanpierre, B., Oberhauser, K., & Freeman, C. (2005). Characteristics of professional development that effect change in secondary science teachers' classroom practices. *Journal of Research in Science Teaching, 42*(6), 668-690.

Johnson, P., & Papageorgiou, G. (2010). Rethinking the introduction of particle theory: A substance-based framework. *Journal of Research in Science Teaching, 47*(2), 130-150.

Johnston, J., & Ahtee, M. (2006). Comparing primary student teachers' attitudes, subject knowledge and pedagogical content knowledge needs in a physics activity. *Teaching & Teacher Education: An International Journal of Research and Studies, 22*(4), 503-512.

Johnston, K., & Scott, P. (1991). Diagnostic teaching in the science classroom: Teaching/learning strategies to promote development in understanding about conservation of mass on dissolving. *Research in Science & Technological Education, 9*(2), 193-212.

Johnstone, A. H. (1993). The development of chemistry teaching: A changing response to a changing demand. *Journal of Chemical Education, 70*(9), 701-705.

Kala, N., Yaman, F., & Ayas, A. (2013). The effectiveness of predict-observe-explain technique in probing students' understanding about acid-base chemistry: A case for the concepts of pH, pOH, and strength. *International Journal of Science and Mathematics Education, 11*(3), 555-574.

Karacop, A., & Doymus, K. (2013). Effects of jigsaw cooperative learning and animation techniques on students' understanding of chemical bonding and their conceptions of the particulate nature of matter. *Journal of Science Education and Technology, 22*(2), 186-203.

Kearney, M. (2004). Classroom use of multimedia-supported predict-observe-explain tasks in a social constructivist learning environment. *Research in Science Education, 34*(4), 427-453.

Kearney, M., Treagust, D. F., Yeo, S., & Zadnik, M. G. (2001). Student and teacher perceptions of the use of multimedia supported predict-observe-explain tasks to probe understanding. *Research in Science Education, 31*(4), 589-615.

Kibirige, I., Osodo, J., & Tlala, K. M. (2014). The effect of predict-observe-explain strategy on learners' misconceptions about dissolved salts. *Mediterranean Journal of Social Sciences*, *5*(4), 300-310.

Koballa, T., Gräber, W., Coleman, D. C., & Kemp, A. C. (2000). Prospective gymnasium teachers' conceptions of chemistry learning and teaching. *International Journal of Science Education, 22*(2), 209-224.

Kosnik, C., & Beck, C. (2009). *Priorities in teacher education: The 7 key elements of pre-service preparation*. New York: Routledge.

Lederman, N. G., & Gess-Newsome, J. (1999). Reconceptualizing secondary science teacher education. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 199-213). Dordrecht: Kluwer Academic.

Leyendecker, R., Ottevanger, W., & van den Akker, J. J. H. (2007). *Curricula, examinations, and assessment in Sub-Saharan secondary education*. Washington, DC: World Bank.

Liang, J. C., Chou, C. C., & Chiu, M. H. (2011). Student test performances on behavior of gas particles and mismatch of teacher predictions. *Chemistry Education Research and Practice, 12*(2), 238-250.

Liew, C. W. (2009). *Effectiveness of predict-observe-explain technique: The effectiveness of predict-observe-explain technique in diagnosing students' understanding of science and identifying their level of achievement*. Köln, Germany: Lambert Academic Publishing.

Lin, H. S., Cheng, H. J., & Lawrenz, F. (2000). The assessment of students and teachers' understanding of gas laws. *Journal of Chemical Education, 77*(2), 235-238.

Loughran, J. (2005). Knowledge construction and learning to teach about teaching. In D. Beijaard, P. C. Meijer, G. Morine-Dershimer & H. Tillema (Eds.), *Teacher Professional Development in Changing Conditions* (pp. 27-41). Netherland: Springer.

Magnusson, S., Krajcik, J. S., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Dordrecht: Kluwer Academic.

Merriam, S. B. (1988). *Case study research in education: A qualitative approach*. San Francisco: Jossey-Bass.

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation*. San Francisco: Jossey-Bass.

Morine-Dershimer, G., & Kent, T. (1999). The complex nature and sources of teachers' pedagogical knowledge. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 21-50). Dordrecht: Kluwer Academic.

Naah, B. M., & Sanger, M. J. (2013). Investigating students' understanding of the dissolving process. *Journal of Science Education and Technology, 22*(2), 103-112.

Nakhleh, M. B. (1994). Chemical education research in the laboratory environment: How can research uncover what students are learning? *Journal of Chemical Education, 71*(3), 201-205.

Nakhleh, M. B., & Samarapungavan, A. (1999). Elementary school children's beliefs about matter. *Journal of Research in Science Teaching, 36*(7), 777-805.

Nakhleh, M. B., Samarapungavan, A., & Saglam, Y. (2005). Middle school students' beliefs about matter. *Journal of Research in Science Teaching, 42*(5), 581-612.

Niess, M. L., & Scholz, J. (1999). *Incorporating subject matter specific teaching strategies into secondary science teacher preparation*. Dordrecht: Kluwer Academic.

Novick, S., & Nussbaum, J. (1978). Junior high school pupils' understanding of the particulate nature of matter: An interview study. *Science Education, 62*(3), 273-281.

Novick, S., & Nussbaum, J. (1981). Pupils' understanding of the particulate nature of matter: A cross-age study. *Science Education, 65*(2), 187-196.

Nurrenbern, S. C. (2001). Piaget's theory of intellectual development revisited. *Journal of Chemical Education, 78*(8), 1107-1110.

Osborne, R. J., & Cosgrove, M. M. (1983). Children's conceptions of the changes of state of water. *Journal of Research in Science Teaching, 20*(9), 825-838.

Othman, J., Treagust, D. F., & Chandrasegaran, A. L. (2008). An Investigation into the relationship between students' conceptions of the particulate nature of matter and their understanding of chemical bonding. *International Journal of Science Education, 30*(11), 1531-1550.

Özalp, D., & Kahveci, A. (2015). Diagnostic assessment of student misconceptions about the particulate nature of matter from ontological perspective. *Chemistry Education Research and Practice, 16*(3), 619-639.

Rahayu, S., & Kita, M. (2010). An analysis of Indonesian and Japanese students' understandings of macroscopic and submicroscopic levels of representing matter and its changes. *International Journal of Science and Mathematics Education, 8*(4), 667-688.

Rahmawati, Y. (2012). *Revealing and reconceptualising teaching identity through the landscapes of culture, religion, transformative learning, and sustainability education: A transformation journey of a science educator.* Thesis (Ph.D.)--Curtin University.

Raihani, & Sumintono, B. (2010). Teacher education in Indonesia: Development and challenges. In K. G. Karras & C. C. Wolhuter (Eds.), *International Handbook of Teacher Education World-wide* (Vol. 2, pp. 181-197). Athens: Atrapos.

Ross, J. A. (1992). Teacher efficacy and the effects of coaching on student achievement. *Canadian Journal of Education / Revue canadienne de l'éducation, 17*(1), 51-65.

Russell, T. (1997). Teaching teachers: How I teach is the message. In J. J. Loughran & T. Russell (Eds.), *Teaching about teaching: Purpose, passion, and pedagogy in teacher education* (pp. 32-47). London: Falmer Press.

Sanford, J. P. (1988). Learning on the job: Conditions for professional development of beginning science teachers. *Science Education, 72*(5), 615-624.

Sarason, S. B. (1990). *The predictable failure of educational reform: Can we change course before it's too late?* San Francisco: Jossey-Bass.

Schoon, K. J., & Boone, W. J. (1998). Self-efficacy and alternative conceptions of science of preservice elementary teachers. *Science Education, 82*(5), 553-568.

Schwartz, A. T. (2006). Contextualized chemistry education: The American experience. *International Journal of Science Education, 28*(9), 977-998.

Sesen, B. A. (2013). Diagnosing pre-service science teachers' understanding of chemistry concepts by using computer-mediated predict-observe-explain tasks. *Chemistry Education Research and Practice, 14*(3), 239-246.

Severiens, S., Wolff, R., & van Herpen, S. (2013). Teaching for diversity: A literature overview and an analysis of the curriculum of a teacher training college. *European Journal of Teacher Education*, 1-17.

Shepherd, D. L., & Renner, J. W. (1982). Student understandings and misunderstandings of states of matter and density changes. *School Science and Mathematics, 82*(8), 650-665.

Sherin, B. L., Krakowski, M., & Lee, V. R. (2012). Some assembly required: How scientific explanations are constructed during clinical interviews. *Journal of Research in Science Teaching, 49*(2), 166-198.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-23.

Shwartz, Y., Dori, Y. J., & Treagust, D. F. (2013). How to outline objectives for chemistry education and how to assess them. In I. Eilks & A. Hofstein (Eds.), *Teaching chemistry – A studybook: A practical guide and textbook for student teachers, teacher trainees and teachers* (pp. 37-65). Rotterdam: SensePublishers.

Sia, D. T., Treagust, D. F., & Chandrasegaran, A. L. (2012). High school students' proficiency and confidence levels in displaying their understanding of basic electrolysis concepts. *International Journal of Science and Mathematics Education, 10*(6), 1325-1345.

Smith, K. C., & Nakhleh, M. B. (2011). University students' conceptions of bonding in melting and dissolving phenomena. *Chemistry Education Research and Practice, 12*(4), 398-408.

Taber, K. S. (1996). Chlorine is an oxide, heat causes molecules to melt, and sodium reacts badly in chlorine: A survey of the background knowledge of one A-level chemistry class. *School Science Review, 78*(282), 39-48.

Tamir, P. (1971). An alternative approach to the construction of multiple choice test items. *Journal of Biological Education, 5*(6), 305-307.

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education, 4*(2), 99-110.

Tan, K. C. D. (2005). Pre-service teachers' conceptions of basic inorganic qualitative analysis. *Canadian Journal of Science, Mathematics and Technology Education, 5*(1), 7-20.

Tan, K. C. D., & Taber, K. S. (2009). Ionization energy: Implications of preservice teachers' conceptions. *Journal of Chemical Education, 86*(5), 623-629.

Tan, K. C. D., & Treagust, D. F. (1999). Evaluating students' understanding of chemical bonding. *School Science Review, 81*(294), 75-83.

Tekkaya, C., Cakiroglu, J., & Ozkan, O. (2004). Turkish pre-service science teachers' understanding of science and their confidence in teaching it. *International research and pedagogy, 30*(1), 57-68.

Teo, T. W., Goh, M. T., & Yeo, L. W. (2014). Chemistry education research trends: 2004-2013. *Chemistry Education Research and Practice, 15,* 470-487.

Treagust, D. F. (1986). Evaluating students' misconceptions by means of diagnostic multiple choice items. *Research in Science Education, 16*(1), 199-207.

Treagust, D. F. (1987). Exemplary practice in high-school biology classes. In K. G. Tobin & B. J. Fraser (Eds.), *Exemplary practice in science and mathematics education* (pp. 29-44). Perth: Science and Mathematics Education Centre, Curtin University of Technology.

Treagust, D. F. (1988). Development and use of diagnostic tests to evaluate students' misconceptions in science. *International Journal of Science Education, 10*(2), 159-169.

Treagust, D. F. (2002). Teaching and learning about chemical compounds. In J. K. Gilbert, O. De Jong, R. Justi, D. F. Treagust & J. H. Van Driel (Eds.), *Chemical Education: Towards Research-based Practice* (Vol. 17, pp. 187-188). Netherlands: Kluwer Academics Publishers.

Treagust, D. F., & Chandrasegaran, A. L. (2007). The Taiwan national science concept learning study in an international perspective. *International Journal of Science Education, 29*(4), 391-403.

Treagust, D. F., Chandrasegaran, A. L., Crowley, J., Yung, B. H. W., Cheong, I. P. A., & Othman, J. (2010). Evaluating students' understanding of kinetic particle theory concepts relating to the states of matter, changes of state and diffusion: A cross-national study. *International Journal of Science and Mathematics Education, 8*(1), 141-164.

Treagust, D. F., Chandrasegaran, A. L., Zain, A. N. M., Ong, E. T., Karpudewan, M., & Halim, L. (2011). Evaluation of an intervention instructional program to facilitate understanding of basic particle concepts among students enrolled in several levels of study. *Chemistry Education Research and Practice, 12*(2), 251-261.

Treagust, D. F., & Chittleborough, G. (2001). Chemistry: A matter of understanding representations. In J. Brophy (Ed.), *Subject-Specific Instructional Methods and Activities* (Vol. 8, pp. 239-267). Amsterdam: Emerald Group Publishing Limited.

Treagust, D. F., Harrison, A. G., & Venville, G. J. (1998). Teaching science effectively with analogies: An approach for preservice and inservice teacher education. *Journal of Science Teacher Education, 9*(2), 85-101.

Treagust, D. F., Mthembu, Z., & Chandrasegaran, A. L. (2014). Evaluation of the Predict-Observe-Explain instructional strategy to enhance students' understanding of redox reactions. In I. Devetak & S. A. Glažar (Eds.), *Learning with Understanding in the Chemistry Classroom* (pp. 265-286). Dordrecht: Springer

Valanides, N. (2000). Primary student teachers' understanding of the particulate nature of matter and its transformations during dissolving. *Chemistry Education Research and Practice, 1*(2), 249-262.

van den Akker, J. J. H. (1998). The science curriculum: Between ideals and outcomes. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 421-447). Dordrecht: Kluwer Academic Publishers.

van den Akker, J. J. H. (2003). Curriculum perspectives: An introduction. In J. J. H. van den Akker, W. Kuiper & U. Hameyer (Eds.), *Curriculum landscapes and trends* (pp. 1-10). Netherland: Springer.

van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.

White, R. T., & Gunstone, R. F. (1992). *Probing understanding.* London: Falmer.

Williamson, V. M., & Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching, 32*(5), 521-534.

Wu, H. K., & Shah, P. (2004). Exploring visuospatial thinking in chemistry learning. *Science Education, 88*(3), 465-492.

Yezierski, E. J., & Herrington, D. G. (2011). Improving practice with target inquiry: High school chemistry teacher professional development that works. *Chemistry Education Research and Practice, 12*(3), 344-354.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, CA: Sage Publications.

APPENDICES

Appendix A

Curtin University

Memorandum

To	Tuszie Widhiyanti, SMEC
From	Pauline Howat, Administrator, Human Research Ethics Science and Mathematics Education Centre
Subject	Protocol Approval **SMEC-20-12**
Date	27 April 2012
Copy	David Treagust, SMEC

Office of Research and Development

Human Research Ethics Committee

Telephone 9266 2784
Facsimile 9266 3793
Email hrec@curtin.edu.au

Thank you for your "Form C Application for Approval of Research with Low Risk (Ethical Requirements)" for the project titled *"A curriculum inquiry of preservice chemistry teachers' content knowledge of the particulate nature of matter"*. On behalf of the Human Research Ethics Committee, I am authorised to inform you that the project is approved.

Approval of this project is for a period of twelve months **26th April 2012** to **25th April 2013**.

The approval number for your project is **SMEC-20-12**. *Please quote this number in any future correspondence*. If at any time during the twelve months changes/amendments occur, or if a serious or unexpected adverse event occurs, please advise me immediately.

Pauline

PAULINE HOWAT
Administrator
Human Research Ethics
Science and Mathematics Education Centre

Please Note: The following standard statement must be included in the information sheet to participants:
This study has been approved under Curtin University's process for lower-risk Studies (Approval Number SMEC-20-12). This process complies with the National Statement on Ethical Conduct in Human Research (Chapter 5.1.7 and Chapters 5.1.18-5.1.21).
For further information on this study contact the researchers named above or the Curtin University Human Research Ethics Committee. c/- Office of Research and Development, Curtin University, GPO Box U1987, Perth 6845 or by telephoning 9266 9223 or by emailing hrec@curtin.edu.au.

J:\SAE\SMEC\office\Pauline\ETHICS\Ethics Approval Letter 2012\Widhiyanti.docx CRICOS Provider Code 00301J

Curtin University

Memorandum

To	Tuszie Widhiyanti, SMEC
From	Mun Yin Cheong, Form C Ethics Co-ordinator, Faculty of Science and Engineering
Subject	Protocol Extension Approval **SMEC-20-12**
Date	7 May 2014
Copy	David Treagust, SMEC

Office of Research and Development
Human Research Ethics Committee

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Thank you for keeping us informed of the progress of your research. The Human Research Ethics Committee acknowledges receipt of your progress report for the project *"A curriculum inquiry of preservice chemistry teachers' content knowledge of the particulate nature of matter"*.

Approval for this project is extended to **25th April 2016.**

Your approval has the following conditions:

(i) Annual progress reports on the project must be submitted to the Ethics Office.

Your approval number remains **SMEC-20-12**. Please quote this number in any further correspondence regarding this project.

Yours sincerely

Mun Yin

MUN YIN CHEONG
Form C Ethics Co-ordinator
Faculty of Science and Engineering

Appendix B

Interview protocol for the interview with the lecturer

What is the objective of the LS-Chem unit?

What are the topics that should be discussed in the LS-Chem unit?

How do you usually conduct the lesson?

What strategy that you usually use for this unit?

Why do you think that strategy is good for the pre-service teachers?

Why do you think the unit is important for the pre-service teachers?

What are the aspects of pre-service teachers that need to be strengthened during this unit?

Is there any laboratory work for this unit?

Interview protocol for the interview with the pre-service teacher

a. Personal background

Which high school that you studied?

Do you intend to be a teacher?

What makes you doubt to be a teacher?

b. Learning experience

How was your experience of learning chemistry in the school?

How did you feel?

How did you usually learn chemistry?

How did your chemistry teacher usually teach you?

Did you have any difficulties in learning chemistry?

How do you usually overcome those difficulties?

Do you think that the chemistry content knowledge that you have learned from school is sufficient for you to be a teacher?

c. Perception about the LS-Chem unit

What are the reasons that make you decide to enrol in this elective unit?

What is your expectation of this unit?

Did the lesson fulfil your expectation?

What expectation has not been reached by this lesson?

What did you think about the method of the lesson?

How did you do the task?

What kind of sources did you use for the task?

Interview protocol for the follow-up interview of PTDI

a. PTDI No 1

What molecules are present in the container?

What does the arrow represent?

What did the smoke particles collide with?

b. PTDI No 2

What molecules are present in the first container (normal condition)?

What molecules are present in the vacuum container?

How could the bromine molecules diffuse faster/slower in vacuum condition?

c. PTDI No 3

Is there any volume change when we pour the orange juice from a tin container into a glass?

Is the volume of the tin container different to the volume of the glass container?

What about the volume of the juice?

What makes the volume differ?

What about number of molecules? Did they change?

d. PTDI No 4

In the post-test you answered that the mass would not increase, how could you explain that?

How could the mass change while the volume has changed?

How would you explain that process at the molecular level?

What happens to the particles inside the tube during the compression process?

e. PTDI No 5

You mentioned that the volume of gas decreased, why did it decrease?

What happened to the gas particles inside the tube during the compression process?

What happens if the tube contains coloured liquid?

What makes the colour of liquid become darker?

Do you think the liquid can be compressed?

What happened to the particles of liquid inside the tube during the compression process?

f. PTDI No 6

Would the red dye diffuse throughout the water?

Why does it happen?

What happens to the dye particles during the process?

g. PTDI No 7

How could the balloon become smaller?

Does the number of air molecules remain the same? How could that happen?

h. PTDI No 8

What exists in the condition shown in graphic part a, part b, and part c?

How could the temperature increase in the condition shown in graphic part a and part c?

Where did the heat go at the condition in part b?

i. PTDI No 9

What does exist below 0°C?

What does exist between 0°C - 100°C?

What does exist above 100°C?

What does exist at 0°C?

Could you explain the process that happens at 0°C?

What does exist at 100°C?

Could you explain the process that happens at 100°C?

What do the flat graphs mean?

Where did the heat go at the flat graphs?

j. PTDI No 10

What changes would absorb the heat energy?

What is the energy absorbed for?

k. PTDI No 11

How could you explain that the total volume of the liquid is decreasing?

Could you explain the situation of the mixture in the molecular level?

Appendix C

Particle **T**heory **D**iagnostic **I**nstruments

Adopted from:
Treagust, D. F., Chandrasegaran, A. L., Crowley, J., Yung, B. H. W., Cheong, I. P. A., & Othman, J. (2010). Evaluating pre-service teachers' understanding of kinetic particle theory concepts relating to the states of matter, changes of states and diffusion: A cross-national study. *International Journal of Science and Mathematics Education, 8*(1), 141-164.

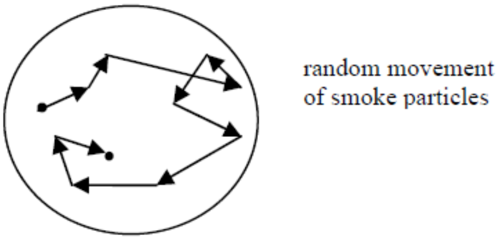
Direction

This booklet consists of 11 items of two-tier test related to the concepts of particulate nature of matter. In answering each question, go through the following:

1. Read the question carefully
2. Take time to consider the answer
3. Record your answer by putting cross on the initial of the chosen answer
4. Read the set of possible reason for your answer
5. Select one reason that best describe the reason of your answer
6. Record your choice by putting cross on the number of the chosen reason
7. If there are no choices of reason matched with your thinking, you may write the explanation using your own word in the space provided

Item No 1

The diagram represents the random zigzag movement of a smoke particle (referred to as Brownian motion) when smoke in a glass container of air is viewed under a microscope.



What conclusion can you make from this observation??

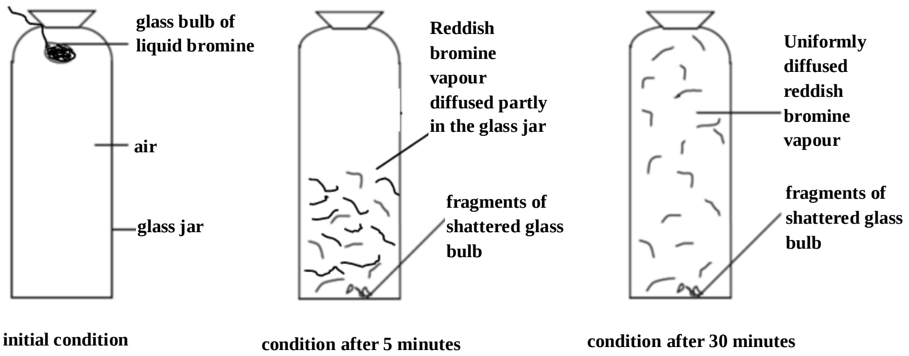
A Smoke particles are floating in air.
B Air consists mainly of empty space.
C Air is made up of tiny particles moving randomly.
D Smoke particles are larger than air particles.

The reason for my choice of answer is:

1 Smoke particles are large.
2 There are large spaces between the smoke particles.
3 Colliding smoke particles move in a random zigzag manner.
4 Air particles are constantly colliding with smoke particles.
5 *Other*: ....
....
....

Item No 2

A small glass bulb containing liquid bromine was dropped into a tall jar of air and the jar was immediately stoppered. The bulb shattered on hitting the bottom of the jar, releasing bromine vapour. After several hours, reddish bromine vapour had diffused uniformly throughout the jar.



If the experiment is repeated after pumping out most of the air from the jar, we would expect the reddish bromine vapour to diffuse and fill the jar within a few seconds.

A True B False

The reason for my choice of answer is:

1 The heavier bromine molecules will sink to the bottom of the jar.
2 Fewer collisions occur between the bromine molecules in the absence of air particles.
3 Bromine molecules can now occupy the extra space that was previously taken up by the air particles.
4 Bromine molecules diffuse slowly in a random zigzag manner to fill the jar.
5 Bromine diffuses faster because fewer collisions occur between bromine and air particles.
6 Other: ……………………………………………………………………………… ………………………………………………………………………………

Item No 3

When orange juice from a soft drink can is carefully poured into a tall wide glass without any spillage, the volume of the liquid remains approximately the same.

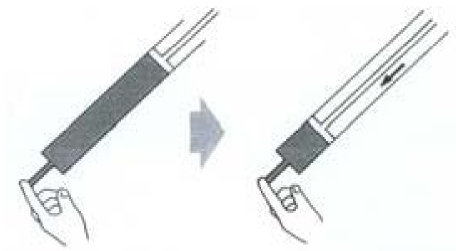
A True B False

The reason for my choice of answer is:

1 The particles are able to move about freely.
2 The particles are able to move within a fixed volume.
3 Some of the particles may have escaped as the liquid evaporated.
4 *Alasan lain*: ....
....

Item no 4

The diagram shows a pump containing a coloured gas that is compressed by pushing the plunger down.

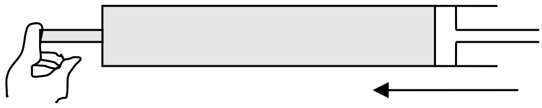


We can conclude that
A. the volume and mass of gas have decreased
B. the volume of gas has decreased while the mass has increased
C. the volume of gas has decreased while the mass remains constant

The reason for my choice of answer is:
1. Gas particles can be readily compressed and pushed closer together
2. The widely-spaced gas particles have been pushed closer together
3. The number of gas particles has decreased.
4. Other: ....

Item 5
The diagram shows a coloured gas being compressed in a gas syringe until the plunger could not be pushed any further.

The experiment was repeated using the same volume of a coloured liquid.



It was found that the final volume of the gas was
A much less than that of the liquid.
B much greater than that of the liquid.

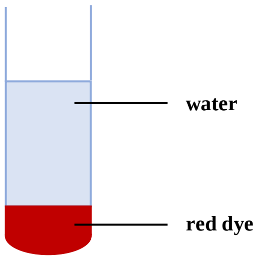
The reason for my choice of answer is:
1. The particles in the gas are more widely spaced.
2. The particles in the gas move more freely.
3. The particles in the gas move randomly in all directions.
4. Other: ……………………………………………………………

Item No 6

A small amount of red dye was carefully placed at the bottom of a test-tube containing some water as shown in the diagram.

After several hours, the particles of red dye would have diffused throughout the water producing a uniformly red solution.

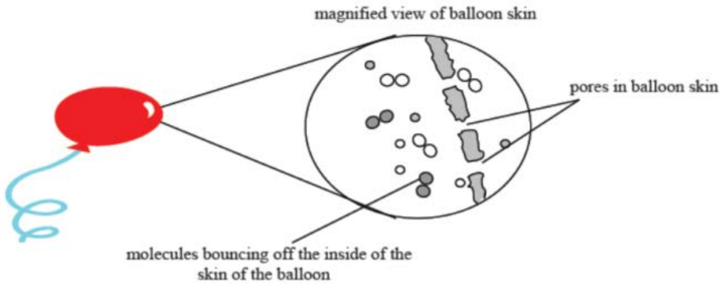
A. True B. False



test-tube containing separate red dye and water layers

The reason for my choice of answer is:
1. The particles of the red dye readily dissolve in water
2. The heavier particles of red dye sink to the bottom of the test-tube
3. The particles of the red dye are in constant random motion.
4. The red dye and water particles do not mix.
5. Other: ....
....

Item 7
A balloon is inflated and tied at the neck to prevent it from deflating.
The diagram shows a magnified view of the skin of the balloon and the particles in the inflated balloon.



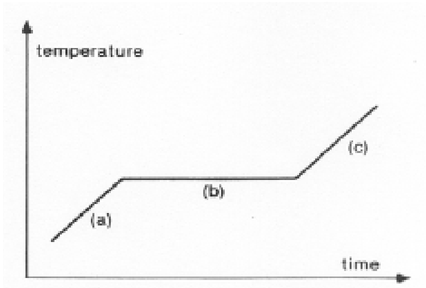
After several hours, the balloon would be found to remain the same size.

A. True B. False

The reason for my choice of answer is:

1 Air molecules bounce off the skin of the balloon, increasing its volume.
2 Air molecules diffuse through the pores in the skin of the balloon.
3 Air molecules are larger than the holes in the balloon skin, so do not escape.
4 Air molecules from the outside enter the balloon through the pores in the balloon skin.
5 Other: …………………………………………………………………………
…………………………………………………………………………………

Item No **8**



The diagram shows how the temperature changes when a solid like ice is heated gently until it melts.

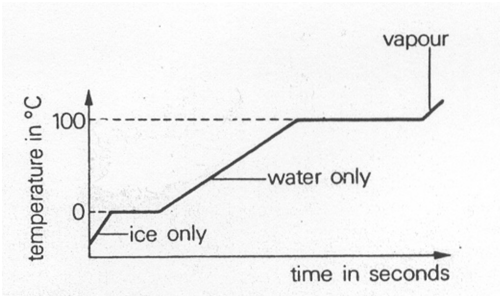
In which section of the curve is the heat energy that is absorbed not heating up the ice?

A. (a) B. (b) C. (c)

The reason for my choice of answer is:
1. Heat energy absorbed is used to break the bonds in the ice molecules.
2. Heat energy absorbed is used to weaken the forces between the ice molecules
3. Heat energy is absorbed to increase the kinetic energy of the ice molecules
4. *Other*: ....
....

Item No 9

The diagram shows how the temperature changes when some ice at a temperature below 0ºC is heated to above 100ºC.



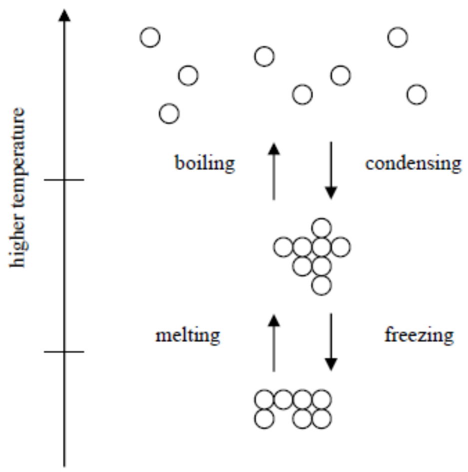
We may deduce that liquid water can exist at its boiling point of 100ºC.

A True B False

The reason for my choice of answer is:

1 At the boiling point water molecules change immediately into steam.
2 The molecules are moving fast enough to change completely into steam.
3 The attractive forces between all the water molecules have to be weakened.
4 Other:……………………………………………………………………………
………………………………………………………………………………

Item No **10**



The diagram shows the arrangement of particles in different states of matter

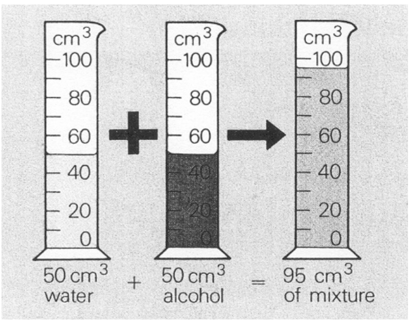
In which of the changes of state will heat energy be absorbed?

A. solid → liquid → gas
B. gas → liquid → solid

The reason for my choice of answer is:

1. The H_2O molecules are moved further away from each other.
2. The bonds in the H_2O molecules are broken.
3. The attractive forces between the H_2O molecules are weakened.
4. *Other*: ....
....
....

Item 11



The diagram shows that the total volume of liquid decreases when water and alcohol are mixed together.

We can conclude that some of the alcohol has evaporated.

A True B False

The reason for my choice of answer is:

1. The molecules of the two liquids occupy the spaces between each other.
2. The alcohol molecules have dissolved in water thus reducing the total volume.
3. Collisions between the molecules cause some molecules to escape.
4. Molecules of the two liquids repel each together.
5. Other: ………………………………………………………………………………

Particle Theory Diagnostic Instruments

Diadopsi dari:
Treagust, D. F., Chandrasegaran, A. L., Crowley, J., Yung, B. H. W., Cheong, I. P. A., & Othman, J. (2010). Evaluating pre-service teachers' understanding of kinetic particle theory concepts relating to the states of matter, changes of states and diffusion: A cross-national study. *International Journal of Science and Mathematics Education, 8*(1), 141-164.

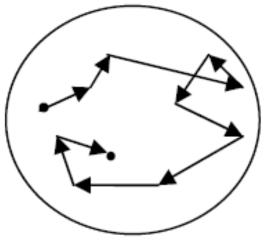
Petunjuk

Buku soal ini berisi 11 butir soal dengan bentuk two-tier mengenai konsep partikel materi. Dalam mengerjakan soal ini, langkah-langkah yang perlu dilakukan adalah:

1. Baca soal dengan teliti
2. Pikirkan dengan cermat jawabannya
3. Beri tanda silang pada jawaban yang anda pilih.
4. Baca dengan cermat beberapa pilihan alasan yang tersedia
5. Pilih alasan yang paling sesuai untuk menjelaskan jawaban anda.
6. Beri tanda silang pada nomor di depan alasan yang anda pilih
7. Jika tidak ada alasan yang sesuai, maka anda diperkenankan untuk memberikan penjelasan dengan kalimat sendiri pada tempat yang telah disediakan.

Soal No 1

Diagram berikut ini menggambarkan gerak zigzag dari partikel asap (disebut sebagai Gerak Brown) ketika asap dalam suatu wadah kaca diamati dengan menggunakan mikroskop.



Gerakan partikel asap yang tidak beraturan

Apa yang dapat anda disimpulkan dari pengamatan ini?

A. Partikel asap mengapung di udara.
B. Udara sebagian besar terdiri dari ruang kosong
C. Udara tersusun atas partikel-partikel kecil yang bergerak secara acak
D. Partikel asap lebih besar dari partikel udara

Alasan dari pilihan jawaban saya adalah:

1. Partikel-partikel asap berukuran besar
2. Terdapat ruang yang luas di antara partikel-partikel asap
3. Partikel-partikel asap saling bertumbukan dan bergerak dalam pola zigzag yang acak
4. Partikel asap terus-menerus bertumbukan dengan partikel udara di sekitarnya sehingga membentuk pola zigzag yang acak
5. *Alasan lain*: ....
   ....
   ....

Soal No 2

Sebuah bola kaca yang kecil berisi bromin cair dijatuhkan ke dalam suatu bejana tinggi yang berisi udara dan langsung ditutup. Ketika menyentuh alas bejana, bola kaca tersebut pecah dan mengeluarkan uap bromin. Setelah 1 jam, uap bromin yang kemerahan tersebar merata di dalam bejana.

Jika percobaan tersebut **diulang** dengan **bejana yang hampa udara** (udara dari dalam bejana tersebut dipompa keluar terlebih dahulu), maka dapat diharapkan uap bromin yang kemerahan tersebut dapat tersebar dan mengisi seluruh bejana **dalam hitungan detik**.

A. Benar B. Salah

Alasan dari pilihan jawaban saya adalah:

1. Molekul bromin yang lebih berat akan mengendap di dasar bejana
2. Jumlah tumbukan antara molekul bromin berkurang ketika tidak ada partikel udara
3. Molekul bromin dapat menempati ruang yang sebelumnya telah ditempati oleh partikel udara
4. Molekul bromin menyebar secara perlahan dengan pola zigzag yang acak untuk mengisi seluruh bagian dalam bejana
5. Bromin menyebar lebih cepat karena lebih sedikit tumbukan yang terjadi antara partikel bromin dengan partikel udara.
6. *Alasan lain* : ....
   ....
   ....

Soal No 3

Ketika suatu jus jeruk dituangkan dari kaleng kemasan minuman ringan ke dalam suatu gelas yang lebar tanpa ada yang tumpah, maka volume dari cairan tersebut tetap sama.

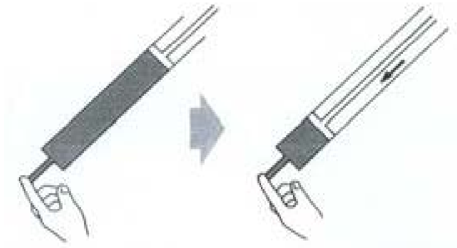
A. Benar B. Salah

Alasan dari pilihan jawaban saya adalah:

1. Partikel-partikelnya dapat bergerak dengan bebas
2. Partikel-partikelnya dapat bergerak dalam suatu volume yang tetap
3. Sejumlah partikel dapat lolos keluar karena cairan tersebut menguap
4. *Alasan lain*: ....
   ....
   ....

Soal No 4

Gambar berikut menunjukkan *syringe* yang berisi suatu **gas** berwarna dengan massa tertentu yang dimampatkan dengan menekan batang *plunger* ke bawah.



Menurut pendapat saya...

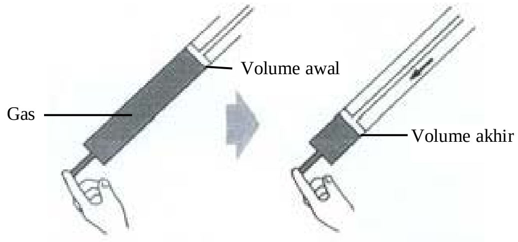
A. Volume dan massa gas tersebut berkurang
B. Volume gas berkurang sedangkan massa gas bertambah
C. Volume gas berkurang sedangkan massa gas tetap konstan

Alasan dari pilihan jawaban saya adalah:

1. Partikel-partikel gas mudah ditekan untuk menjadi lebih kecil dari ukuran partikel semula, sehingga volumenya berkurang.
2. Partikel gas yang semula saling berjauhan dapat ditekan untuk saling berdekatan satu sama lain.
3. Jumlah partikel gas menjadi berkurang.
4. *Alasan lain*: ....
   ....
   ....

Soal No 5

Gambar berikut ini menunjukkan suatu gas berwarna yang dimampatkan dalam suatu *syringe* gas sampai batang *plunger* tidak dapat ditekan lagi.



Percobaan tersebut **diulangi** dengan menggunakan **zat cair** berwarna dengan **volume awal yang sama**.

Berdasarkan kedua percobaan tersebut, ditemukan bahwa volume akhir gas setelah dimampatkan…

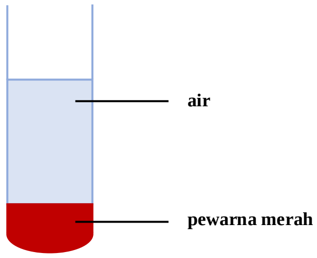
A. jauh lebih kecil dari volume akhir zat cair
B. jauh lebih besar dari volume akhir zat cair

Alasan dari pilihan jawaban saya adalah:

1. Jarak antar partikel dalam gas lebih besar dibandingkan dengan jarak antar partikel dalam zat cair
2. Partikel-partikel dalam gas bergerak lebih bebas dibandingkan dengan partikel-partikel dalam zat cair
3. Partikel-partikel gas bergerak secara acak ke semua arah
4. *Alasan lain*: ....
....
....

Soal No 6

Sedikit zat pewarna merah dimasukkan dengan hati-hati ke dalam bagian dasar tabung reaksi yang telah berisi air seperti yang ditunjukkan pada diagram di bawah ini.



tabung reaksi berisi lapisan zat pewarna dan air yang terpisah

Setelah beberapa jam, zat pewarna tersebut akan terdifusi (tersebar) merata di dalam air, membentuk larutan yang berwana merah.

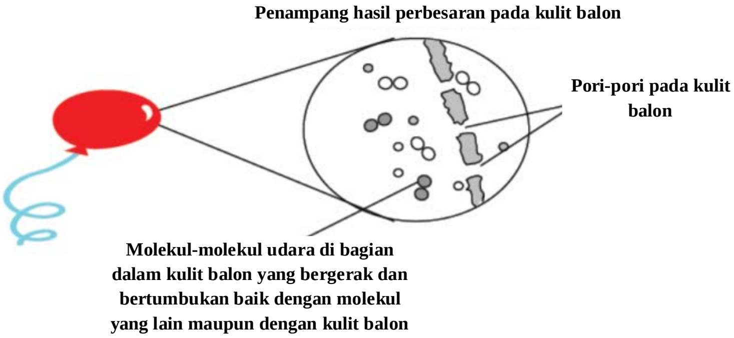
A. Benar B. Salah

Alasan dari pilihan jawaban saya adalah:

1. Partikel-partikel zat pewarna mudah melarut di dalam air
2. Partikel-partikel zat pewarna yang lebih berat mengendap di dasar tabung reaksi
3. Partikel-partikel zat pewarna bergerak terus-menerus secara acak.
4. Partikel-partikel zat pewarna dan air tidak dapat bercampur.
5. *Alasan lain*: ....
   ....
   ....

Soal No 7

Sebuah balon ditiup dan diikat agar tidak kempes. Gambar di bawah ini menunjukkan perbesaran dari kulit balon dan partikel yang berada di dalam balon tadi.



Setelah beberapa hari, ukuran balon tersebut akan tetap sama.

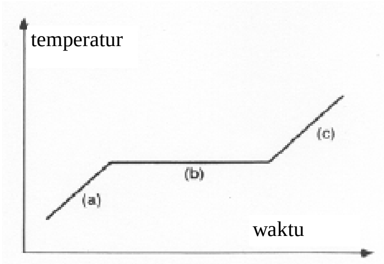
A. Benar   B. Salah

Alasan dari pilihan jawaban saya adalah:

1. Molekul udara menumbuk dan memantul pada kulit balon sehingga volumenya membesar
2. Molekul udara lolos keluar melewati pori-pori pada kulit balon
3. Molekul udara lebih besar dari pori-pori pada kulit balon sehingga tidak dapat keluar
4. Molekul udara dari luar masuk ke dalam balon melalui pori pada kulit balon
5. *Alasan lain*: ....
   ....
   ....

Soal No 8

Diagram berikut menunjukkan bagaimana temperatur berubah ketika suatu padatan seperti es dipanaskan dengan perlahan hingga meleleh.



Pada bagian mana dari kurva tersebut yang menunjukkan bahwa energi panas yang diserap tidak lagi digunakan untuk memanaskan es.

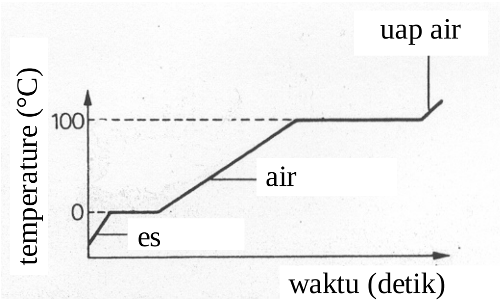
A. (a) B. (b) C. (c)

Alasan dari pilihan jawaban saya adalah:

1. Energi yang diserap digunakan untuk memutuskan ikatan pada molekul es.
2. Energi panas yang diserap digunakan untuk melemahkan gaya antar molekul
3. Energi panas diserap untuk meningkatkan energi kinetik molekul
4. *Alasan lain*: ....
   ....
   ....

Soal No 9

Diagram berikut menunjukkan bagaimana temperatur berubah ketika sejumlah es pada temperatur di bawah 0°C dipanaskan hingga lebih dari 100°C. (P = 1 atm)



Dapat disimpulkan bahwa pada titik didih air, 100°C, masih terdapat air dalam fasa cairnya.

A. Benar B. Salah

Alasan dari pilihan jawaban saya adalah:

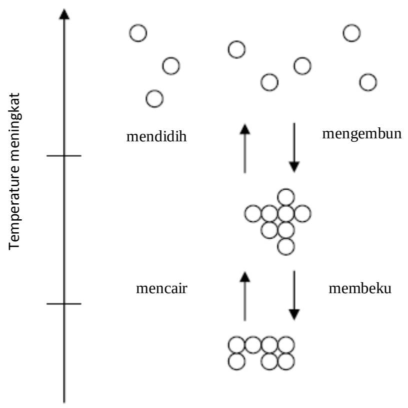
1. Pada titik didihnya, seluruh molekul-molekul air langsung berubah menjadi uap.
2. Pergerakan molekul-molekul air cukup cepat untuk dapat mengubah seluruh molekulnya menjadi uap.
3. Gaya tarik-menarik di antara semua molekul air harus dilemahkan.
4. *Alasan lain*: ....

Soal No 10

Gambar berikut menunjukkan rangkaian partikel air dalam wujud yang berbeda.

Pada perubahan wujud yang manakah energi panas akan diserap?

A. padat → cair → gas
B. gas → cair → padat

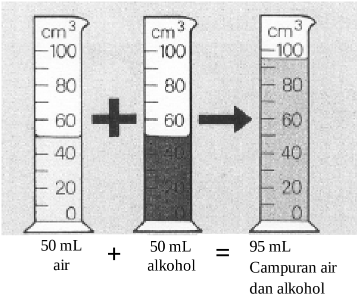


Alasan dari pilihan jawaban saya adalah:

1. Molekul H_2O bergerak saling menjauh satu sama lain.
2. Ikatan pada molekul H_2O putus.
3. Gaya tarik-menarik di antara molekul-molekul H_2O melemah.
4. *Alasan lain*: ....
....
....

Soal No 11

Gambar berikut ini menunjukkan berkurangnya volume total ketika air dan alkohol dicampurkan.



Berdasarkan gambar tersebut, dapat disimpulkan bahwa sebagian alkohol telah menguap.

A. Benar B. Salah

Alasan dari pilihan jawaban saya adalah:

1. Molekul-molekul dari kedua zat cair tersebut menempati ruang kosong yang tersedia di antara keduanya.
2. Molekul alkohol terlarut di dalam air sehingga volume total berkurang
3. Terjadi tumbukan antar molekul yang menyebabkan sejumlah molekul menguap.
4. Molekul-molekul dari kedua zat cair tersebut saling tolak menolak.
5. *Alasan lain*: ....
   ....
   ....

Appendix D

Solid, liquid, and gases in syringes

Name:

____

Group

____

Date

____

Direction

1. Make sure that you understand the experiment that will be performed
2. Make a prediction of what will be observed during the experiment
3. Write down your prediction on a space provided
4. Give explanation of your prediction in a space provided
5. Follow the instruction to do the experiment, carefully observe the phenomena and write your observation in a provided space
6. Describe your personal explanation about phenomena in a provided space
7. Discuss with other group members about the observation and your explanation
8. Write the result of group discussion.
9. Share the result of group discussion with other groups in a class discussion.

Solid, liquid and gas in syringes

In this activity, we are trying to push the plunger of three syringes that contain of three different phases (ice, water, and air). Make a prediction of what would happen with those three syringes?

Prediction

Reason

Observation

Explanation

Group discussion

Gas Law

Boyle's, Charles', and Avogadro's Law

Name:

____

Group

____

Date

____

Direction

1. Make sure that you understand the experiment that will be performed
2. Make a prediction of what will be observed during the experiment
3. Write down your prediction on a space provided
4. Give explanation of your prediction in a space provided
5. Follow the instruction to do the experiment, carefully observe the phenomena and write your observation in a provided space
6. Describe your personal explanation about phenomena in a provided space
7. Discuss with other group members about the observation and your explanation
8. Write the result of group discussion.
9. Share the result of group discussion with other groups in a class discussion.

Gas Law

The experiment is about changing some variables of ideal gas using an interactive multimedia. If one variable is changed, predict what happen to the other three variables?

Prediction and Explanation

Condition	P	V	n	T	Explanation
I	↑			constant	
II	constant			↑	
III		constant		↑	
IV	constant		↑		

Observation and Explanation

Condition	P	V	n	T	Explanation
I	↑			Constant	
II	Constant			↑	
III		Constant		↑	
IV	Constant		↑		

Group discussion result

Liquid and Gas Diffusion

Name:

____

Group

____

Date

____

Direction

1. Make sure that you understand the experiment that will be performed
2. Make a prediction of what will be observed during the experiment
3. Write down your prediction on a space provided
4. Give explanation of your prediction in a space provided
5. Follow the instruction to do the experiment, carefully observe the phenomena and write your observation in a provided space
6. Describe your personal explanation about phenomena in a provided space
7. Discuss with other group members about the observation and your explanation
8. Write the result of group discussion.
9. Share the result of group discussion with other groups in a class discussion.

Liquid and Gas Diffusion

This activity consist of a group experiment using laboratory apparatus and an observation of the experiment shown in the video.

Liquid diffusion

The first experiment is dropping the solution of food colouring into two glasses which contain water in different temperature. Make a prediction of what would happen with the food colouring in those two glasses?

Prediction

Reason

Observation

Explanation

Gas Diffusion

This second activity is observing the experiment shown in a short film. The film shown the experiment using bromine which exists as a liquid in room temperature but it is very volatile. Observe carefully the process of the experiment, and make a prediction what would happen if we repeat the same experiment using a vacuum tube.

Prediction

Reason

Observation

Explanation

Group discussion

The Changing of Phase

Name:

____

Group

____

Date

____

Direction

1. Make sure that you understand the experiment that will be performed
2. Make a prediction of what will be observed during the experiment
3. Write down your prediction on a space provided
4. Give explanation of your prediction in a space provided
5. Follow the instruction to do the experiment, carefully observe the phenomena and write your observation in a provided space
6. Describe your personal explanation about phenomena in a provided space
7. Discuss with other group members about the observation and your explanation
8. Write the result of group discussion.
9. Share the result of group discussion with other groups in a class discussion.

The Changing of Phase

Percobaan kali ini merupakan percobaan yang tampak sederhana dan merupakan fenomena yang sering dijumpai dalam kehidupan sehari-hari, yakni memanaskan es hingga mencair dan kemudian mendidih. Namun kali ini kita akan mengamati dengan lebih cermat hal apa saja yang terjadi pada proses tersebut.

Prediction

Scetch of the Graphic

Reason

Observation

Graphic from observation data

Explanation

Group discussion

Appendix E

Curtin University

Curtin University
Science and Mathematics Education Centre

Dean Information Sheet

Faculty of Science and Mathematics Education
Indonesia University of Education
Jl. Dr. Setiabudhi 229 Bandung 40154
West Java Indonesia

Dear Mr Asep Kadarohman,

My name is Tuszie Widhiyanti. I am currently completing a piece of research for my Doctor of Philosophy at Curtin University.

Purpose of Research
I am investigating the research topic:"A curriculum inquiry of preservice chemistry teachers' content knowledge of the particulate nature of matter"

Your Role
I am seeking your permission to conduct research by asking for preservice teacher to take part in short diagnostic test(s) on chemistry that will complement their learning. Preservice teacher involved will undertake a number of short tests. The results of the tests will be given back to them after the completion of the test. I may also ask for the preservice teachers' participation in a short interview (group) about their attitudes and opinions about the program of development of content knowledge in Chemistry Education Department. Again this participation will be voluntary and of short duration (10-15 mins)

Consent to Participate
The preservice teachers and your school's involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use the preservice teachers' data in this research.

Confidentiality
The information provided will be kept separate from the preservice teachers' personal details, and only I and my supervisor will only have access to this. The interview transcripts will not have student names or any other identifying information on them and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether they should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-20-21). If you would like further information about the study, please feel free to contact me on +61 416 450 383 or by email tuszie.widhiyanti@postgard.curtin.edu.au. Alternatively, you can contact my supervisor Prof. David F. Treagust on +61 8 9266 7924 or email d.f.treagust@curtin.edu.au

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

Curtin University

Curtin University
Science and Mathematics Education Centre

Head of Department Information Sheet

Chemistry Education Department
Faculty of Science and Mathematics Education
Indonesia University of Education
Jl. Dr. Setiabudhi 229 Bandung 40154
West Java Indonesia

Dear Mr Ahmad Mudzakir,

My name is Tuszie Widhiyanti. I am currently completing a piece of research for my Doctor of Philosophy at Curtin University.

Purpose of Research
I am investigating the research topic :"A curriculum inquiry of preservice chemistry teachers' content knowledge of the particulate nature of matter"

Your Role
I am seeking your permission to conduct research by asking for preservice teacher to take part in short diagnostic test(s) on chemistry that will complement their learning. Preservice teacher involved will undertake a number of short tests. The results of the tests will be given back to them after the completion of the test. I may also ask for the preservice teachers' participation in a short interview (group) about their attitudes and opinions about the program of development of content knowledge in Chemistry Education Department. Again this participation will be voluntary and of short duration (10-15 mins)

Consent to Participate
The preservice teachers and your school's involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use the preservice teachers' data in this research.

Confidentiality
The information provided will be kept separate from the preservice teachers' personal details, and only myself and my supervisor will only have access to this. The interview transcripts will not have student names or any other identifying information on them and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether they should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-20-12). If you would like further information about the study, please feel free to contact me on +61 416 450 383 or by email tuszie.widhiyanti@postgard.curtin.edu.au. Alternatively, you can contact my supervisor Prof. David F. Treagust on +61 8 9266 7924 or email d.f.treagust@curtin.edu.au

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

Curtin University

Curtin University
Science and Mathematics Education Centre

STUDENT Information Sheet

My name is Tuszie Widhiyanti I am currently completing a piece of research for my Doctor of Philosophy at Curtin University of Technology.

Purpose of Research
I am investigating the research topic: "A curriculum inquiry of preservice chemistry teachers' content knowledge of the particulate nature of matter"

Your Role
I will conduct research by asking for you to take part in short diagnostic test on chemistry that will complement your learning. Your teachers and the College principal have already been contacted and have agreed in principle to the project. Pre-service teachers involved will undertake a number of short tests. The results of the tests will be given back to you after the completion of the test. The tests will not in any way affect your reported grades. I may also ask for your participation in a short interview (group) about your attitudes and opinions about the program of development of content knowledge in Chemistry Education Department. Again this participation will be voluntary and of short duration (10-15 mins)

Consent to Participate
Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript will not have your name or any other identifying information on it and in adherence to university policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University of Technology Human Research Ethics Committee (Approval Number SMEC-20-12). If you would like further information about the study, please feel free to contact me on +61 416 450 383 or by email tuszie.widhiyanti@postgard.curtin.edu.au. Alternatively, you can contact my supervisor Prof. David F. Treagust on +61 8 9266 7924 or email d.f.treagust@curtin.edu.au.

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

Curtin University

Curtin University

Science and Mathematics Education Centre

Participant Information Sheet

My name is Tuszie Widhiyanti. I am currently completing a piece of research for my Doctor of Philosophy of Science Education at Curtin University.

Purpose of Research
I am investigating the development of preservice teachers' understanding about particulate nature of matter using a curriculum inquiry framework.

Your Role
I am interested in finding out your attitude and opinion about the program of development of content knowledge in Chemistry Education Department
The interview process will take approximately 15 minutes.

Consent to Participate
Your involvement in the research is entirely voluntary. You have the right to withdraw at any stage without it affecting your rights or my responsibilities. When you have signed the consent form I will assume that you have agreed to participate and allow me to use your data in this research.

Confidentiality
The information you provide will be kept separate from your personal details, and only myself and my supervisor will only have access to this. The interview transcript will not have your name or any other identifying information on it and in adherence to university's policy, the interview tapes and transcribed information will be kept in a locked cabinet for at least five years, before a decision is made as to whether it should be destroyed.

Further Information
This research has been reviewed and given approval by Curtin University Human Research Ethics Committee (Approval Number SMEC-20-12). If you would like further information about the study, please feel free to contact me on +61 416 450 383 or by email tuszie.widhiyanti@postgard.curtin.edu.au. Alternatively, you can contact my supervisor Prof. David F. Treagust on +61 8 9266 7924 or d.f.treagust@curtin.edu.au.

Thank you very much for your involvement in this research.
Your participation is greatly appreciated.

Appendix F

This is the transcription during the microteaching process (session by pre-service teachers) which discussed about the topic of physical and chemical properties of matter. PST-H and PST-K presented their lesson plan and pretended to be teachers while the rest of the pre-service teachers pretended to be students.

PST H: *Now we are going to discuss about the properties of matter. Does anyone remember the topic that we have discussed in last session? We discussed about phase of matter, right? Does anyone want to mention the kind of phase of matter?*

PSTs: *There are three kinds of it*

PST H: *What are they?*

PSTs: *Solid, liquid and gas*

PST-H: *Alright, beside the phases of matter, there are also phase changes, right? Does anyone know the kinds of phase changes?*

PSTs: *Freezing, melting, condensing, and evaporating.*

PST-H: *Alright, today we are going to discuss about physical properties. Does anyone has read the meaning of the physical properties? The physical properties are the properties that can be observed without changing the constituent substances. For example, the substance of water is* H_2O*. When the water freeze and become ice, it still has the properties of water. Another example of physical properties are: phase of matter, colour, solubility, electrical conductivity, magnetic properties, melting point and boiling point. These seven physical properties are only several example. There are some other physical properties.*

Then the presenter (PST-H) described the details of each examples of physical properties using the picture displayed in a projector screen. She presented book, syrup, and chlorine gas as examples of solid, liquid and gas. She also presented white milk, black metal, and the transparent water as example of different colour of matters. For solubility, she used salt and sugar as an example of soluble substances and coffee for the insoluble substances.

PST-H: *Does anyone know what actually the solubility is? The solubility is the ability of a substance to get dissolved in a solvent. What is the solute substance in a salt solution? What about coffee? What is the solvent?*

Now [I'm going to present about] electrical conductivity. This is the picture of aluminium and wood. As we know that aluminium is conductor, right? What does it mean?

PSTs: *It can flow electric current*

PST-H: *What about wood?*

PSTs: *It could not flow electric current*

PST-H: *So, what is the meaning of electrical conductivity? Conductivity is the ability of a substance to flow the electric current. For metal, such as iron and aluminium, they have conductive properties because they can flow the electric current. Whereas wood and table are the isolator because they cannot flow the electric current.*

Next, the magnetic properties. The objects can be grouped as magnetic objects and non-magnetic objects. Do you know the meaning of magnetic properties? What about non-magnetic? What are the examples? Here is a picture of a mixture of sand and iron powder. If we put the magnet near the sand mixture, only the iron powder will stick to the magnet because it has magnetic properties.

[Regarding] the melting point, melting point is a temperature when liquid phase and solid phase are in the equilibrium condition. The process happen in the pressure 1 atm. How many mmHg is 1 atm?

PSTs: *760*

PST-H: *The example of melting point is iron. Iron is melting at 1800°C. Whereas boiling point is a temperature when the saturated vapour pressure is the same as the pressure on the liquid surface. For example, water. Water can be boiled at?*

PSTs: *100°C*

PST-H: *Well, now we are going to discuss about chemical properties. The meaning of chemical properties is the opposite of the meaning of physical properties. Chemical properties are the properties that can be observed with the changing of constituent substance. So, when the [chemical] reaction occurs, the initial properties of the substance cannot be seen anymore. The first example is flammable. When an object get burnt, it changes into a different substance, right? And it cannot transform back into the initial condition. The second example is degradable, the third is rusting, the fourth is explosive and the fifth is toxic. What is an example of flammable object?*

PST: *Gasoline*

PST-H: *What about the degradable object?*

PST: *Rice or banana*

PST-H: *Well, banana and rice can be rotten, especially if we put it in the humid place. The example of rusting is iron. Iron can react with oxygen to produce iron (III) oxide. This is the rusting iron. Now, could you mention the example of explosive objects?*

PST: *[silent]*

PST-H: *What is the example of explosive object?*

PST: *LPG*

PST-H: *LPG, right? And also firecracker. Why does LPG easily get explode? LPG explode if there is a leaking in the tube. While firecracker will explode while it reacts.*

Toxic. What is the example of toxic object?

PST: *Pesticide*

PST-H: *Yes, pesticide. It is a toxic substance for insect and pest.*

The presentation by PST-H was ended up with a video of a summary about physical and chemical properties. Then PST-K took her turn to present the lesson plan about physical and chemical properties.

PST-K: *Now we are going to discuss about physical change. Does anyone know the meaning of physical change?*

PST: *the changing process which cannot produce new substance*

PST-K: *Is there any other opinion?*

What has been mentioned is correct, right? Physical change is the changing of substance which did not produce new substance. What are the characteristics [of physical change]?

First, it did not produce new substance. Second, the substance that is changed can be back to the initial condition. Third, only followed by the changing of physical properties. It is not followed by chemical properties.

Well, these are the examples of physical change in everyday life. First, ice blocks which can melt to be water. When the ice blocks become water, could do the water transform back to be the ice?

PSTs: *Yes, it could be.*

PST-K: *Yes, it could be. Isn't it? This is the example of physical change.*

The second example is water heated become water vapour. When the water vapour is chilled it will turns back to be water. The third example is the melting candle. The fourth example is salt and sugar that can be dissolved in the water. The dissolved salt and sugar can be back into the [solid] salt and sugar through the evaporation process. So, when the water is evaporated, the salt and sugar will remaining.

Well, now we are going to discuss about chemical change. We have been discussed about physical change, what is the definition of physical change?

PST: *The change that did not produce new substance.*

PST-K: *The chemical change is the opposite way around. It is a change that can produce new substance. The characteristics are also the opposites. It produces new substance, cannot transform back into the initial phase, and is followed by the chemical change. For example, a burnt paper is changing become an ash which cannot transform back to be a paper. The second example is a rotten rice which cannot transform back to be a rice.*

Appendix G

LESSON PLAN

Unit Title : Teaching and Learning Chemistry for Lower Secondary School (LS-Chem)
Topic : Solid, liquid and gases in a syringe
Length : 110 minutes
Outcomes : After completing this unit, the pre-service teachers will be able to:
- Collect and interpret data about compressibility of gas and liquid
- Demonstrate an understanding of compressibility and its relation to intermolecular spacing.

Skills : observe, communicate, make an inference, makes a prediction

Pre-service teachers Will Learn to	**Lesson Sequence**	**Teaching and Learning Strategies**	**Key Teaching Points**
- use and challenge their scientific knowledge to predict and explain a phenomena - observe thoroughly and precisely - interpret the data - explain the phenomena according to the data gained during the experiment	**Introduction** - Pre-service teachers were introduced to the POE method and what will they do in this lesson - Pre-service teachers are told that they are going to do some experiments but beforehand they need to make a prediction of what will happen with the experiment. In this part, pre-service teachers have to write down their prediction in a piece of paper. While the experiments is taken place, pre-service teachers need to observe and write down their observation - Pre-service teachers then are required to make an explanation of the fact that have been observed and later they will have a discussion in a class about the experiments **Main Activities** The Predict Stage	Strategy POE Class Organization: Pre-service teachers will do the prediction by themselves. Although the pre-service teachers will do the experiments in groups of 2 or 3, they need to write down their observation by themselves. Later, in the explain stage, they will have a discussion in a group and followed by classroom discussion. Rule: Pre-service teachers need to write down their prediction, observation, and explanation in a journal provided. Additional:	The focuses of the prediction stage are: - What will happen? - What will be observed? - Will we have any different data from pushing those syringes? Several questions for the pre-service teachers in the explain stage are: - What is inside these three syringes? - How is the appearence of those three syringes? - How would you draw the particles inside these two syringes? - Why we can push the syringe of a gas while we cannot push the liquid one?

Pre-service teachers Will Learn to	Lesson Sequence	Teaching and Learning Strategies	Key Teaching Points
	- Lecturer gives guidance about what aspect to be predicted. <u>The Observe Stage</u> - Lecturer gives a guidance about observing every single thing happen during the experiment <u>The Explain Stage</u> Pre-service teachers discuss in group of two or three to discuss about their prediction, observation and their explanation of the fact. **Conclusion**	Lecturer will prepare two different size of nuts (cashew nut and mung bean) with the same volume in two measuring glass. Then, the lecturer will mix those two nuts and show the final volume of the mixture. This experiment will give emphasize and analogy of the existence of space between molecules.	- What happens with the volume of liquid and gas inside the syringe if we pushed the plunger? - What happens with the particles when we push the plunger? - How would you draw the particles inside the syringes after you pushed in the maximum force? - What is the main difference of liquid and gas? - Do you think that there are small space between the molecules of the liquid? - If so, why did it can’t be pushed?
Resources Set of apparatus : syringe			
Assessment Particulate Theory Diagnostic Instrument			

LESSON PLAN

Unit Title : Teaching and Learning Chemistry for Lower Secondary School (LS-Chem)
Topic : Liquid and gas diffusion
Length : 110 minutes
Outcomes : After completing this unit, the pre-service teachers will be able to:
- Collect, and interpret data from the experiment
- Demonstrate an understanding of diffusion process and what happen during the process in a molecular view.

Skills : observe, communicate, make a conclusion, make a prediction

Pre-service teachers Will Learn to	Lesson Sequence	Teaching and Learning Strategies	Key Teaching Points
- use and challenge their scientific knowledge to predict and explain a phenomena - observe thoroughly and precisely - interpret the data - explain the data	**Introduction** - Lecturer gives a guidance that this lesson will also use POE like what they have in a previous lesson. - There are two kinds of POE activites in this lesson. The first POE is conducted by watching experiment from video (downloaded from youtube, link: ***www.youtube.com/watch?v=ZAGloLXO9L0***). And the second POE is the experiment of comparing the diffusion of ink in the two glass of water with different temperature. - Teacher gives a brief explanation about the video of bromine diffusion and also the experiment of comparing ink diffusion in cold and hot water. **Main Activities (First POE: Bromine Diffusion)** The Predict Stage - Lecturer play the vidoe of diffusion of liquid bromine in the tube that contains air.	Strategy: POE Class Organization: Pre-service teachers will do the prediction by themselves. Although students will do the experiments in groups of 2 or 3, they need to write down their observation by themselves. Later, in the stage of explanation, students will have a discussion in a group and followed by classroom discussion. Rule: Pre-service teachers need to write down their prediction, observation, and explanation in a journal provided.	**(First POE)** The focuses of the prediction stage are: - What happens with the liquid bromine in the first experiment? - Why liquid bromine change into gas? - How long it takes time for bromine gas to fill the whole tube? - What will happen if we repeat the experiment with a vacuum tube? - What will be observed? - Will it take longer or shorter time for bromine to fill the entire tube? Several questions for the pre-service teachers in the explain stage are: - What is inside the tube at the begining? - How could you draw the particles inside the tube?

Pre-service teachers Will Learn to	Lesson Sequence	Teaching and Learning Strategies	Key Teaching Points
	- Lecturer asked the student to watch the video carefully. - Since the language in the video is in English, the lecturer need to provide explanation in Bahasa while the video is running. - Then the video is paused when the actor in a video start to do the second experiment with the vacuum tube. - The student were asked to predict what happen with the bromine if we repeat the experiment using a vacuum tube. - Lecturer gives a guidance about what aspect to be predicted. <u>The Observe Stage</u> - Lecturer gives a guidance about observing every single thing happen on the video <u>The Explain Stage</u> Pre-service teachers discuss in group of two or three to discuss about their prediction, observation and their explanation of the fact. **(Second POE: Ink diffusion)** <u>The Predict Stage</u> - Lecturer prepare two glass of water with different temperature. - Lecturer then ask the pre-service teachers to measure the temperature of water in those two glasses. - Lecturer ask the pre-service teachers to drop the ink into the cold water and ask the student to observe.		- What happens with the bromine particles when they were transformed to gases? - What happen with the particles inside the tube when there are bromine gases present in the tube? - Why did it take longer for the bromine to be able to diffuse and fill the entire tube during the first experiment? - What is inside the tube after all bromine has diffuse in entire tube? - How could you draw the particles inside the tube on three different condition? **(Second POE)** The focus of prediction stage are: - What is the water temperature in those two glasses? - What happen when we drop the ink into the water? - Why does the ink spread in the water?

Pre-service teachers Will Learn to	Lesson Sequence	Teaching and Learning Strategies	Key Teaching Points
	- Then, the pre-service teachers are required to predict what will happen if they repeat the experiment using the hot water. - Lecturer gives guidance about what aspect to be predicted. The Observe Stage - Lecturer gives a guidance about observing every single thing happen during the experiment The Explain Stage Pre-service teachers discuss in group of two or three to discuss about their prediction, observation and their explanation of the fact. **Conclusion**		- What will happen if we drop the same amount of the ink into the hot water - What will be observe? Several question for the pre-service teachers in the explain stage are: - What is inside the glass? - Are the particles inside the glass moving? - What are the differences of the particles inside the cold and the hot water? - What happen with the particles of the ink when it dropped into the water? - Why it can be differ?

Resources
Set of apparatus : beaker glass, termometer,

Assessment
Particulate Theory Diagnostic Instrument

LESSON PLAN

Unit Title : Teaching and Learning Chemistry for Lower Secondary School (LS-Chem)
Topic : Phase Change
Length : 110 minutes
Outcomes : After completing this unit, the pre-service teachers will be able to:

- Collect, organize, display, and interpret data about phase change of matter
- Demonstrate an understanding of phase change of matter in terms of the influence of heat to the intermolecular force.

Skills : observe, communicate, measure, make an inference, makes a prediction

Pre-service teachers Will Learn About:
The process of changing of phase and what happen during the process in a molecular view and the influence of heat in intermolecular force

Pre-service teachers Will Learn to	**Lesson Sequence**	**Teaching and Learning Strategies**	**Key Teaching Points**
- use and challenge their scientific knowledge to predict and explain a phenomena - observe thoroughly and precisely - measure the temperature - record the data - make a plot of the data - interpret the data - use the molecular view to explain the data	**Introduction** - Lecturer gives a guidance that this lesson will also use POE like what they have in a previous lesson - Lecturer gives an explanation about the experiment of heating some amount of ice until it is melting and boiling **Body** The Predict Stage - Lecturer gives guidance about what aspect to be predicted. The Observe Stage - Lecturer gives a guidance about observing every single thing happen during the experiment	Strategy : POE Class Organization: Pre-service teachers will do the Prediction by themselves. Although the pre-service teachers will do the experiments in group of 2 or 3, they need to write down their observation by themselves. Later, in the stage of explanation, student will have a discussion in a group and followed by classroom discussion. Rule: Pre-service teachers need to write down their prediction, observation, and explanation in a journal provided.	The focus of prediction stage are: - What will happen - What will be observe - What kind of data will be gathered? - If we take the data of temperature over time, is there any pattern of those data? - How is the possible pattern? Several question for the pre-service teachers in the explain stage are: - Why the temperature is rise? - Why the ice melts? - What happen with the particle in an ice during the melting process? - What happen with the particle in the water during heating process?

Pre-service teachers Will Learn About: The process of changing of phase and what happen during the process in a molecular view and the influence of heat in intermolecular force			
Pre-service teachers Will Learn to	**Lesson Sequence**	**Teaching and Learning Strategies**	**Key Teaching Points**
	<u>The Explain Stage</u> Pre-service teachers discuss in group of two or three to discuss about their prediction, observation and their explanation of the fact. **Conclusion**		- What happen in the bottom, middle, and in a surface of the water? - Why did the water boil? - What is inside the bubble? - Why did the temperature stay in a same value for some time until all the ice is melting? - Why did the temperature stay in a same value for some time during boiling process? - What happen with the intermolecular force on those processes? - Which variable that influenced the intermolecular force? - How can this variable influence the intermolecular force?
Resources Set of apparatus : tripod, bunsen burner, beaker glasses, termometers,			
Assessment Particulate Theory Diagnostic Instrument			