

UNIVERSITY OF THE PHILIPPINES  
OPEN UNIVERSITY

Doctor of Philosophy in Education  
(Chemistry Education)  
Faculty of Education

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COLLABORATIVE TEACHING: EFFECTS ON SCIENCE TEACHERS'  
PEDAGOGICAL CONTENT KNOWLEDGE AND STUDENTS' UNDERSTANDING  
OF PARTICULATE NATURE OF MATTER

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August 2018

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Reynaldo R. Ibasco

Date: August 2018

## **APPROVAL SHEET**

The dissertation attached hereto entitled **COLLABORATIVE TEACHING: EFFECTS ON SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND STUDENTS' UNDERSTANDING OF PARTICULATE NATURE OF MATTER** in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Education (major in Chemistry Education), is hereby accepted

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### **Dedication**

I dedicate this dissertation to my wife, Terry, for her love, patience and support and to my four sons, Joniel, Jerahmeel, Jehezkel and Joshuel for their understanding and help. Thank you, I could let loose and enjoy being at home as I wrote my paper.

## Acknowledgement

*I praise and thank the Lord, the Author and Perfecter of my faith. He carried me during the difficult moments of my journey through the program. I praise Him, the source of my wisdom and provider of all I needed throughout my studies.*

I am very grateful to my adviser, Dr. Marlene Ferido, for taking me as advisee after my original adviser, Dr. Amy Punzalan, passed away suddenly during my preparations for my outline defense. Dr. Ferido guided me despite her many responsibilities at the National Institute for Science and Mathematics Education Development (NISMED), the Assessment, Curriculum & Technology Research Centre (a partnership between UP and the University of Melbourne), the sub-TWG on Classroom Assessment for the Department of Education and as consultant for the Department of Education in the implementation of the K-12 curriculum. Thank you for your sacrifices, encouragement and prayers.

I thank the members of the panel of my outline and oral defense, Dr. Ricardo Bagarinao, Dr. Maria Helen de Hitta-Catalan, Dr. Maria Ana Quimbo, and Dr. Irene Villasenor, for sharing their wisdom and expertise. Their scholarly input guided me as I conducted the research and wrote my paper.

I especially thank Dr. Bagarinao, for being my critic reader. He patiently guided and encouraged me in reviewing and finalizing the write-up especially during those times I was tempted to quit. His expert and scholarly advice, corrections and criticism taught me a lot and led to the tremendous improvement and polishing of the paper to what it is now.

I thank the staff of UP Open University and the National Institute for Science

and Mathematics Education Development for assisting me as I used their library resources. Thank you, Ma'am Lota Yoinco and Ma'am Myleen Argel of the UP Open University Diliman Center for your assistance and encouragement most especially during my topic proposal and oral defense. To Ma'am Rhonna Verena of the UP Open University Main Office, thank you so much for guiding and facilitating the communications between the Main Office and us students. Your commitment and service to us students are greatly appreciated. Your prompt reply to my many questions particularly during my proposal and oral defense was a huge help and made things smoother and less stressful.

I am grateful to all my UPOU teachers: Dr. Amy Punzalan, Dr. Soledad Ulep, Dr. Maria Ana Quimbo, Dr. Ester Ogena, Dr. Leon Payawan, Dr. Florentino Sumera, Dr. Irene Villasenor, Dr. Evangeline Amor, Dr. Guillermo Nuesca, Dr. Jose Solis, Dr. Mildred Ganaden, and Dr. Evangeline Zalamea. Thank you for molding me into a better teacher.

I thank the Science teachers from San Francisco High School, Tandang Sora National High School, Ernesto Rondon National High School, Juan Sumulong High School, Quirino High School, Ramon Magsaysay High School, Commonwealth High School, Batasan Hills National High School, Roxas High School, and Culiati High School. Thank you for participating in the PCK survey despite your busy schedules.

I appreciate the principals and school administrators of the schools where I conducted my study for allowing me to have access to their teachers and students. I appreciate the Science Department Head of School CT along with the other teachers and staff for their wholehearted help during my study.

I am indebted to Teacher A, Teacher B, Teacher C, Teacher D, Teacher E, Teacher F, Teacher G, Teacher H, Teacher I, Teacher J, Teacher K, and Teacher L for taking part in the study. Thank you for investing your time and expertise to contribute to the success of the study. I especially thank, Ma'am A, the Grade 8 Science coordinator, for her all-out support. Her excellent administrative skills made my data gathering easier. I also thank Elliot, Terry and Jerahmeel, for assisting me at various stages of the study.

I thank my fellow Chemistry majors: Sir Rey, Ma'am Marie, Ma'am Lanie, Sir Senor, Ma'am Jean, and Ma'am Tina. Your support, encouragement, and camaraderie made the doctoral journey, fun and easier. Thank you Sir Rey and Ma'am Lanie, for your specific comments, feedback and advice.

I am blessed to have colleagues and friends who supported me as I completed my dissertation. Thank you, Alex, Efi, Albert, Raymond, Leeboy, Tony, Geoff, Jason, Cip, Boots, and Joy for your prayers and support. I could work on my dissertation because you took my load and responsibilities many times.

Lastly, I thank and dedicate this dissertation, to the late Dr. Amy Punzalan. She encouraged, inspired and mentored me through the doctoral program. She encouraged me to have the attitude that I have what it takes to succeed. She taught me that teaching is about targeting the heart of the students not just their heads. She modeled that to us. She instilled in us that we are the next generation leaders in Science education. She reminded us that we should do whatever we can to contribute towards elevating Science Education in this country. Rest assured Ma'am Amy, that your words, labor and example will not be in vain.

## Abstract

IBASCO, REYNALDO R. University of the Philippines Open University, August 2018.  
Collaborative Teaching: Effects on Science Teachers' Pedagogical Content  
Knowledge and Students' Understanding of Particulate Nature of Matter.

This study is about an alternative school-based model of professional development for Science teachers and sought to help address the research gap about improving the Science teachers' pedagogical content knowledge to improve science teaching and student learning. It is a qualitative case study that analyzed the changes in the pedagogical content knowledge (PCK) of Particulate Nature of Matter (PNM) of teachers who underwent Collaborative Teaching (CT), and how these changes affected the conceptual understanding of PNM of their students. The study involved six Grade 8 Science teachers, the Collaborative Teaching group who underwent CT for almost eight weeks and six other Science teachers who were assigned to the Conventional Teaching group. The changes in the PCK of PNM of the teachers and their students' conceptual understanding of PNM were monitored using multiple sources of data: classroom observations, semi-structured interviews, focus group discussions, lesson plans, pre-lesson reflection guides, and questionnaires. Analysis of data from these various sources using the constant comparative method shows that the PCK of the six teachers from the Collaborative Teaching group improved. Their knowledge of science content (KSC) about PNM improved as demonstrated by their corrected misconceptions about PNM and ability to explain phase changes using macroscopic, sub-microscopic and symbolic representations. Their knowledge of students' understanding (KSU) improved as they reflected awareness of students' misconceptions and learning difficulties in their

lesson plans and adjusted teaching strategies to address these misconceptions and learning difficulties. Their knowledge of teaching strategies (KTS) also improved as they shifted from more lecture-based teaching to using interactive strategies, models and higher order thinking skills (HOTS) questioning. These PCK improvements were supported by data from the PCK-PNM Observation Rubric which showed that the PCK of teachers from the Collaborative Teaching group improved from “Emergent” to “Proficient” whereas that of the Conventional Teaching group remained as “Emergent”. Data from the PCK-PNM Questionnaire also showed a 40% increase in the PCK of Collaborative Teaching group from 26.8 out of 48 in the pretest scores to 37.5 in the posttest. The KSC mean score of the group increased by 52%, the KTS by 28% and the KSC by 40% in the posttest scores. The posttest scores in the PCK-PNM Questionnaire of the Conventional Teaching group showed their PCK of PNM increased by 26%. The posttest scores of the Conventional Teaching group increased by 26% in KSC, 33% in KTS, and 7% in the KSU. In terms of the posttest Particulate Nature of Matter Assessment (ParNoMA) mean scores of students, the Collaborative Teaching group increased by 95 percent while that of the Conventional Teaching group increased by 50.7 percent. The Wilcoxon Signed Ranks Test shows that the ParNoMA posttest scores of students from the Collaborative Teaching Group are statistically higher than their pretest scores ( $p = 0.000$  at  $\alpha = 0.05$  and 1-tailed test). Furthermore, the Wilcoxon-Mann Whitney Test shows that the gain scores of the Collaborative Teaching Group students are statistically higher than that of the Conventional Teaching Group ( $p = 0.000$  at  $\alpha = 0.05$  and 1-tailed test). The empirical data also shows that the observed improvement in the teachers’ knowledge of

science content, knowledge of students' misconceptions and knowledge of teaching strategies helped students (a) correct various misconceptions about phase changes of matter such as particle size of water molecules during evaporation and freezing; (b) shift from the continuous view of matter to the particle view and (c) develop their ability to visualize and to represent the particles of matter during various phase changes. The results of the study showed evidence that Collaborative Teaching is an effective mode of developing science teachers' PCK of PNM and of improving their students' conceptual understanding of PNM. It is thus recommended that Collaborative Teaching be used as a framework for designing professional development programs of Science teachers with emphasis on the different components of PCK in order to help improve students' conceptual understanding of essential science concepts.

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### List of Acronyms

CT	Collaborative Teaching
PCK	Pedagogical Content Knowledge
PNM	Particulate Nature of Matter
KSC	Knowledge of Science Content
KSU	Knowledge of Student Understanding
KTS	Knowledge of Teaching Strategies
ParNoMA	Particulate Nature of Matter Assessment
PCK-PNMQ	Pedagogical Content Knowledge of PNM Questionnaire
PCK-PNMOR	Pedagogical Content Knowledge of PNM Observation Rubric
FGD	Focus Group Discussion
FGDQ	Focus Group Discussion Questions
PLRF	Pre-Lesson Revision Form
PLRG	Pre-Lesson Reflection Guide
TPLIQ	Teacher Post Lesson Interview Questions
SPLIQ	Student Post Lesson Interview Questions
PPLDG	Pre-Post Lesson Discussion Guide
TIQ	Teacher Interview Questions

## Chapter 1

### INTRODUCTION

#### Background of the Study

*As I sat on a plane from East Asia to the Philippines for a vacation after two-years of teaching Math and Science in an international school, it broke my heart to hear about teachers being blamed about the downward trend in the science achievement scores in our country. In my heart, I wanted to do something about it. In fact, I decided that once I completed the remaining time of my contract I would go back to the Philippines to do what I could as an educator. Doing this study is a baby step towards fulfilling my heart's desire.*

The task of improving the quality of science teaching in our country remains daunting. The National Achievement Test (NAT) scores of high school students over the last few years (Batomaquaque, 2009; DepEd Factsheets, 2009 & 2013) show a downward trend. The DepEd reports that the NAT mean percentage score (MPS) for high school in school year 2012-2013 was 51.41 percent. This is 23.59 percentage points away from the target. The MPS in science was 41.35 percent, and 46.83 percent in mathematics. A study shows that Filipino students have low scientific literacy and difficulty applying scientific ideas to real life (UP NISMED Study, 2005). Two key questions to ask are: Do schools provide the necessary inputs for students to attain higher achievement in science? What teaching and learning practices could help improve achievement in science (ADB Country Analysis Profile, 2006)? While it is common knowledge that there are several factors that affect student learning, the teacher and how he or she teaches certainly contribute significantly. Research

shows that quality of teacher instruction may be associated with teachers' participation in professional development programs (Fishman, Marx, Best, & Tal, 2003). Borko (2004) and Fullan (2007) cite that teachers have the most direct impact on student performance because of their regular and sustained contact with them. Therefore, improving teacher practice through professional development is a key aspect of school reforms that can lead to improved student performance.

One area that must be addressed in the professional development of science teachers is their *pedagogical content knowledge* (PCK). Research shows that PCK affects teacher practice (Appleton, 2008). Some science teachers are not confident in teaching science or teach unsatisfactorily because of limited PCK (Goodrum et al., 2001). It was Shulman who advanced the concept of PCK (Shulman, 1986). *PCK is a teacher's ability to create and represent content to make it comprehensible to others to ensure student understanding of concepts.* The knowledge bases of teachers generally focus on content knowledge and pedagogical knowledge. PCK is topic-specific and formed by blending content and pedagogy (Shulman, 1987). The PCK of the expert teacher includes his or her understanding of what makes learning of specific topics easy or difficult (Shulman, 1986, p.9). Therefore, professional development of teachers must include the development of their PCK.

Shulman (1987) pointed out that teaching effectively goes beyond knowing the content and knowing teaching strategies. Teacher professional development needs to focus also on the PCK of teachers. PCK is an academic construct that is rooted in the belief that teaching requires more than delivering subject content knowledge to students (Loughran et al., 2006). PCK describes both the content and

pedagogical knowledge that teachers must have in order to provide students with rich experiences in science. No matter how capable a teacher might be when teaching his or her subject, both skills and ability are immediately challenged when he or she is teaching content which he has little familiarity (Loughran et al., 2006).

The current study focused on developing the science teachers' PCK of Particulate Nature of Matter (PNM) using Collaborative Teaching intervention. The study examined both content and pedagogy wherein the science teachers used their PCK to develop deeper understanding of science content, represent content in a variety of ways that is meaningful to their students and translating science content to their students in the unique situations of their classes. There are still few studies in the Philippines that sought to understand the role of teacher education programs in the development of science teachers' pedagogical content knowledge. Most of these have been spearheaded by National Institute for Science and Mathematics Education Development (NISMED). This current study seeks to contribute to this endeavor.

School-based professional development like lesson study, professional learning communities (PLC's) and collaborative action research have contributed significantly towards the continuing development of teachers (Lin, 2001; Hollins et al., 2004; Ulep, 2008; Poekert, 2012; de la Cruz, Magno & Punzalan, 2013). In general, collaborative action among teachers such as those aforementioned has been recognized as contributing to the professional development of teachers (Levine & Marcus, 2010). While conventional modes of teacher professional development provide equipping and development, teachers do not always have access to such.

Moreover, some may not have the monetary means to afford such trainings.

### **Rationale of the Study**

Due to various collaborative initiatives by different entities, there is a general improvement in NAT scores in science since the downward trend observed about five years ago. The 2014-2015 National NAT Mean Percentage Score (MPS) for Grade 10 in Science and Mathematics rose to about 47% each (BEST Independent report, 2018). There is minimal increase for Mathematics but a huge increase in Science from the MPS in 2013 (almost 6 percentage points). The Collaborative Lesson Research and Development (CLRD) Project by NISMED and the Learning Action Cell (LAC) Program by the Department of Education (DepEd Order 35, 2016) are some of these effective initiatives that are bearing fruit. However, there is still much room for improvement, especially in light of the thrust to support the K to 12 Program. One area of continuing improvement is the quality of teaching. The quality of learning is greatly influenced by the quality of teaching (Borko, 2004; Fullan, 2007). Different methods of teacher professional development are implemented throughout the DepEd system to improve teaching-learning processes. The usual way of teacher professional development is through in-service trainings and seminars. However, most of these are top-down processes wherein expert knowledge is shared or transferred. Examples of these are lectures or workshops during teacher training and short-term courses. Due to financial constraints, only a few teachers can avail these trainings. The few and chosen to attend these trainings are expected to echo to their fellow teachers what they learned. Ulep and Reyes

(2013) pointed out that this model may often lead to dilution effects and lessen effectiveness of teacher training. They point out also the generic nature of top-down teacher development, which do not always address the unique problems encountered by participant teachers. In contrast, there are fewer instances of bottom-up teacher professional development programs where teachers study content and pedagogies together, plan lessons collaboratively, and conduct action research as a group. Examples of these are school-based learning action cells, teaching circles, communities of practice, and lesson study.

This current study describes the use of *Collaborative Teaching*, as a viable school-based teacher professional development mode. Being school-based, *Collaborative Teaching* is more accessible to and affordable for teachers. A good educational system of teacher development ensures that opportunities for professional development programs are *readily available* and *accessible* to teachers (Whitehouse, 2011). Research has shown that effective professional development should involve teachers and be ongoing in order to provide *continuing* and *sustainable* improvement of teacher practice (Gutierrez, 2015; Loucks-Horsley et al., 2003; Smith, 2001; Darling-Hammond & Sykes, 1999). Collaborative Teaching addresses these needs and can therefore be adopted as an on-going school-based teacher professional development strategy.

### **Statement of the Problem**

The study investigated the effects of Collaborative Teaching on Science teachers' PCK and their students' conceptual understanding of Particulate Nature of

Matter. Specifically, the study sought to answer the following questions:

1. What changes occurred in the PCK of PNM of science teachers after Collaborative Teaching?
2. What changes occurred in the conceptual understanding of PNM among students whose teachers underwent Collaborative Teaching?
3. To what extent did changes in teachers' PCK facilitate student conceptual understanding of PNM?

### **Objective of the Study**

This study sought to find the effect of collaborative teaching as a mode of professional development on science teachers' PCK and students' understanding of Particulate Nature of Matter. More specifically, the study aimed to:

- a. Determine the changes in the teachers' knowledge of PNM concepts after Collaborative Teaching.
- b. Determine the changes in teachers' knowledge of their students' misconceptions after Collaborative Teaching.
- c. Determine the changes in the teachers' teaching strategies after Collaborative Teaching.
- d. Identify students' understanding of PNM concepts before and after Collaborative Teaching.
- e. Identify the extent changes in teachers' PCK facilitate student conceptual understanding of PNM.

## **Significance of the Study**

**Teacher development.** Developing the pedagogical content knowledge of science teachers through collaborative teaching is one way to help science teachers improve their practice. This research presented an alternative model of collaborative teacher development that is characterized by three elements: social, situated and teacher-directed. Schools or communities of teachers can benefit from the professional development framework presented in this study as a guide when they design professional development programs for their teachers. Thus, following these tenets, those that design professional developments of science teachers should intentionally incorporate these three elements of Collaborative Teaching framework into the training curriculum and training materials used. In fact, this framework can be applied to other disciplines as well. In addition, Collaborative Teaching can be a sustainable teacher development alternative for schools since it is school-based and require less expense on the part of the school and the individual teachers. For the Department of Education supervisors and school administrators who conduct regular assessments of teachers, the PCK-PNM Questionnaire (PCK-PNMQ) and the PCK-PNM Observation Rubric (PCK-PNMOR) may be used as assessment tools in the development of science teachers. Furthermore, the pre and post lesson reflection guides may be used to help teachers develop a habit of reflecting on their teaching.

**Student achievement.** The study showed the extent that PCK development facilitate students' understanding. Science teachers can benefit from the results of this study of using their PCK to address students' misconceptions and their various difficulties in understanding science concepts. Thus, for example, the increase of

usage of models by teachers helps students gain fluency in explaining macroscopic phenomena using microscopic representation. An assessment tool like the Particulate Nature of Matter Assessment (ParNoMA) may be helpful to anticipate students' misconception and learning difficulties. The Particle Model and other teaching tools can be valuable resources for science teachers to improve student learning of PNM concepts

**Theoretical significance.** The Collaborative Teaching Model –*social, situated and teacher-directed*, may be a valuable addition to existing professional development frameworks and theoretical models for teacher development. The Department of Education and private curriculum developers and designers can make use of the findings of the study particularly in how the development of PCK can be integrated intentionally into curricular materials used in teacher professional development. As presented in the study, curriculum developers and planners can specifically target the three components, Knowledge of Science Content (KSC), Knowledge of Student Understanding (KSU) and Knowledge of Teaching Strategies (KTS) when crafting trainings and seminars for science teachers. PCK can be viewed as both an inner construct affecting teacher knowledge and an external construct impacting teacher practice.

**Resources for future studies.** Because many consider measuring PCK difficult and challenging, there is limited work done in developing assessment instruments to measure science teachers' PCK (Lange et al., 2009; Rohaan et al., 2009). This study sought to develop assessment instruments to measure science teachers' PCK and contribute to locally developed assessment instruments. Finally,

the qualitative methods, findings and instruments developed and used in this research can be used in other studies on PCK. There is still limited research linking Collaborative Teaching and PCK development (Evens, 2015). Overall, the study sought to contribute to the existing conversation on PCK in the scientific community.

### **Scope and Delimitation**

The study was limited to twelve Grade 8 science teachers and their students from a public high school during the third quarter of the school year 2015-2016. The teachers went through six cycles of Collaborative Teaching. The cycles matched the six lessons on Particulate Nature of Matter of the new K to 12 curriculum for Grade 8 Science. This section of the study took six weeks to complete.

The researcher observed only one intact class per teacher. This was a necessary consequence of the Collaborative Teaching cycle. Each cycle consists of planning, implementing, evaluating and revising the lesson. One class for each teacher gave the researcher enough time to set up class observations and interviews.

The study only attempted to measure the PCK of science teachers teaching the chemistry portion of the Grade 8 curriculum. The author focused only on Particulate Nature of Matter, a topic commonly found to have misconceptions among students (Punzalan & Marasigan, 2009; Agas, 2003).

The research design of the study is a case study. Ideally, a longer period of time is needed to collect data (Creswell, 2003). However, the new K to 12 curriculum is such that the Chemistry portion is taken up for only one quarter. The topic about

the Particulate Nature of Matter is just one of three modules under the unit of matter. Thus, the researcher had to pack the six Collaborative Teaching cycles in 18 actual days (spread in six weeks). This limited the time for the pre and post lesson reflection and discussions, interviews, processing of videos and pictures needed for discussions and focus group discussions. There was also a one-week cancellation of classes in the middle of the study due to APEC week. The researcher planned to give the pretest during the last week of the second quarter. However, due to changes in the schedule of second quarter examinations, the pretest was moved to first week of third quarter.

The original intent was to use a quantitative design as well. However, there were just exactly 12 science teachers assigned to the Grade 8 level. Two teachers from the Conventional Teaching group were not able to complete the duration of the study. The small sample size brought about by the limitations of the study made inferential analysis of quantitative data on teachers' PCK not feasible.

## Chapter 2

### REVIEW OF RELATED LITERATURE

*This chapter describes theories and studies on PCK and the role of PCK development on student understanding. The review also covers students' misconceptions and understanding of PNM. Lastly, it discusses collaborative teaching as it relates to improving teachers' PCK and student understanding. The chapter opens with an introductory paragraph that highlights the researcher's view of how critical professional development of teachers is in improving science education in our country. The current study is a response to this view.*

While there are several factors that influence student learning, teachers have the most direct impact on student performance because of their regular and sustained contact with them (Borko, 2004; Fullan, 2007). Therefore, improving teacher practice through professional development is a key aspect of school reforms that can lead to improved student performance. Professional development of teachers should be central to improving science education in our country. Studies show that improving teacher quality will improve student achievement (Darling-Hammond, 1998; Vescio, Ross, & Adams, 2008). Deliverers of professional development must strive for teacher learning whatever mode of professional development is used. They must ensure that there will be changes in knowledge, beliefs, and attitudes of teachers that lead to acquisition of new ideas and practices (Fishman et al., 2003).

## **Pedagogical Content Knowledge (PCK)**

### **Definition of PCK**

It was Shulman who advanced the concept of pedagogical content knowledge or PCK (Shulman, 1986). According to him, PCK is a teacher's ability to formulate and represent content in a manner that students understand the concepts. The knowledge bases of teachers generally focus on content knowledge and pedagogical knowledge. PCK is topic-specific and formed by blending content and pedagogy (Shulman, 1987). To teach effectively goes beyond knowing the content and teaching strategies. PCK is the expert teacher's understanding of what makes the learning of specific topics easy or difficult (Shulman, 1986, p. 9). Park and Oliver (2008) defined PCK as "teachers' understanding and enactment of how to help students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment." Loucks-Horsley et al. (2003) further emphasized the complex, integrated nature of PCK when they described it as "more than knowing content or how to teach in a generic way." PCK is about understanding what aspects of the content students can learn at a particular developmental stage. It is how to represent content to them and lead them into different conceptual understandings. Wilson, Shulman and Richert (1987) defined teacher knowledge base as "the body of understanding, knowledge, skills, and dispositions that a teacher needs to perform effectively in a given teaching situation" (p.106). Teacher knowledge base then includes knowledge domains required for effective teaching. In subsequent years, researchers have included PCK in their descriptions of knowledge base of a teacher (see for example, Carlsen, 1999; Grossman, 1990;

Turner-Bisset, 1999). These definitions imply that "PCK is both an external and internal construct, as it is constituted by what a teacher knows, what a teacher does, and the reasons for the teacher's actions" (Park & Oliver, 2008). Hence, PCK encompasses both teachers' understanding and their enactment.

Shulman (1987) suggested that teachers' content knowledge and their pedagogy were being treated as mutually exclusive domains. Such dichotomy produces teacher education programs focused on content or pedagogy, not both. This dichotomy occurred when prospective teachers learned pedagogy apart from subject matter (Hewson and Hewson, 1988). Efforts are already being done to bridge the gap between the pedagogical and content aspects of science teacher preparation that lead to development of a cohesive and integrated knowledge base (Doster, Jackson, & Smith, 1994). PCK has been suggested as one knowledge base for science teacher preparation (Anderson & Mitchener, 1994). Anderson and Mitchener (1994) suggested that PCK could be an alternative perspective from which science educators could view secondary science teacher preparation. The epistemological concept of PCK offers the potential for linking the traditionally separated knowledge bases of content and pedagogy. Science education students typically take separate courses on pedagogy and separate courses on science content but not an integrated course that covers both knowledge bases. Typical pre-service trainings and workshops and even in-service ones also treat science content and pedagogy separately. Linking these two using PCK as a guiding framework can offer an alternative to science education courses and designing pre-service and in-service trainings and workshops (de Jong et al., 2005).

## Nature of PCK

There have been a number of researches that explored the nature of PCK (Shulman, 1986; Grossman, 1990; Cochran et al. 1993; Mellado et al. 1998; Magnusson et al. 1999; Appleton, 2006). PCK, as conceptualized by Pamela Grossman (1990), subsumes three knowledge domains that influence a teacher's PCK. These knowledge domains include the following: (1) subject matter knowledge and beliefs, (2) pedagogical knowledge and beliefs, and (3) knowledge and beliefs about context. According to Grossman (1990), PCK is a type of knowledge transformed by these three knowledge domains. He also states PCK is more powerful than its constituent parts. Accordingly, PCK includes a) knowledge and beliefs about purpose, (b) knowledge of students' conceptions, (c) curricular knowledge, and (d) knowledge of instructional strategies. Some referred to science PCK as including (a) teacher's orientation to teaching science, (b) knowledge of science curricula, (c) knowledge of assessment, (d) knowledge of scientific literacy, (e) knowledge of students' understanding of science, and (f) knowledge of instructional strategies. Others further characterized PCK as (a) knowledge of students, (b) knowledge of environmental contexts, (c) knowledge of pedagogy, and (d) knowledge of subject matter.

One useful way of unpacking the nature of PCK as a construct is through the General Taxonomy of PCK by Veal and Makinster (1999). They described a so called General PCK, Domain-Specific PCK and a Topic-Specific PCK (Figure 2.1). General PCK is the first level within this taxonomy. The expert teacher with general PCK would have a sound understanding of pedagogical concepts and the concepts

and strategies employed specific to the disciplines of science, art, history, math, or English. General PCK in science for instance, will refer to subject-specific PCK strategies. Subject meant the content area of science or subject-specific PCK

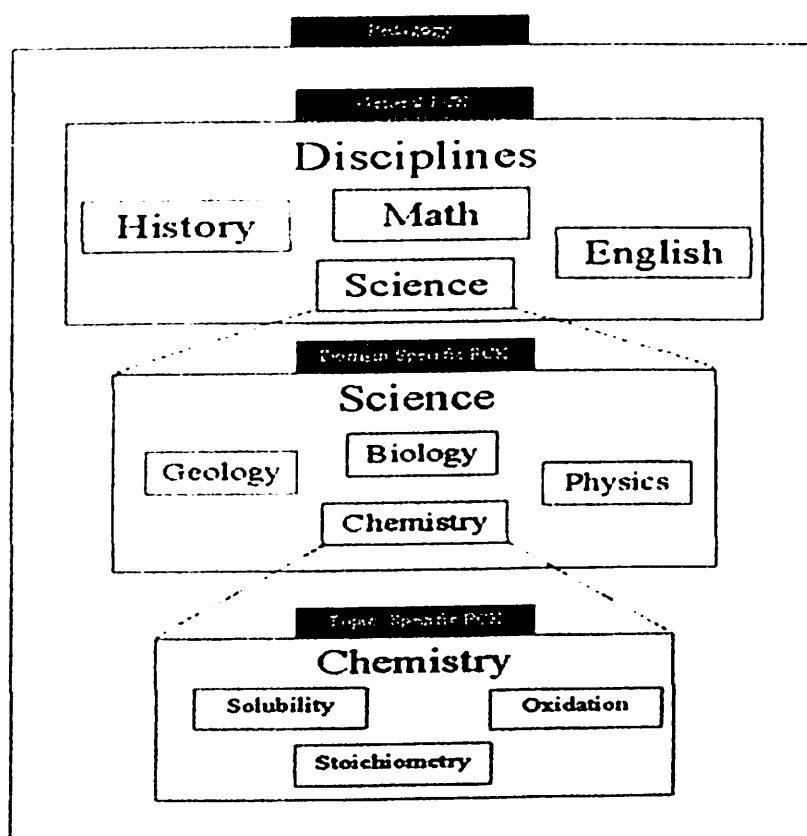
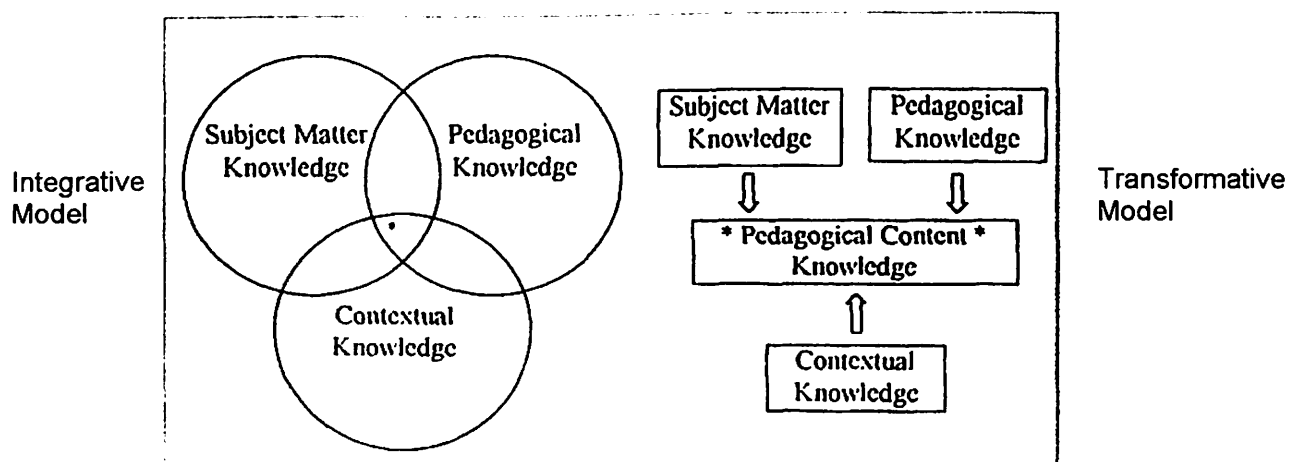


Figure 2.1. General Taxonomy of PCK (Veal & Makinster, 1999).

strategies for teaching science such as activity-driven, discovery, project-based science, and guided inquiry. These orientations represented "a general way of viewing or conceptualizing science teaching" (Magnusson, Krajcik, & Borko, 1999). The second level is domain-specific PCK. *Domain-specific PCK* focuses on one of the different domains or subject matters within a particular discipline. A chemistry teacher for instance, who possess a developed domain-specific PCK has understanding of how to teach chemical concepts to students. Domain-specific PCK is positioned between disciplines and domains of science to represent a different

level and specificity of subject matter and pedagogy. *Topic-specific PCK* is the most specific and novel level of the general taxonomy. In this level of PCK a chemistry teacher would have knowledge of skills and abilities in the previous two levels. In addition he or she has knowledge of the skills and abilities to teach a specific chemistry concept such as Particulate Nature of Matter.

Models also provide another way of unpacking the nature of PCK. Gess-Newsome (1999) summarized the different representations of PCK by different researchers and presented two models: Integrative Model and Transformative Model. In the integrative model, PCK is formed by integration of other knowledge domains. In the transformative model, PCK is a transformation of other knowledge domains into a unique form for effective teaching. According to a transformative model, other knowledge domains are only useful when they are transformed into PCK (Gess-Newsome, 1999). Figure 2.2 shows the representations of these two types of models.



\* Knowledge needed for classroom teaching.

Figure 2.2. Representations of PCK Models. Adapted from Gess-Newsome (1999).

Cochran, DeRuiter and King (1993) described PCK with constructivist perspective as pedagogical content knowing (PCKg). PCKg has four components: knowledge of pedagogy, knowledge of subject matter content, knowledge of students, and knowledge of environmental contexts (Figure 2.3).

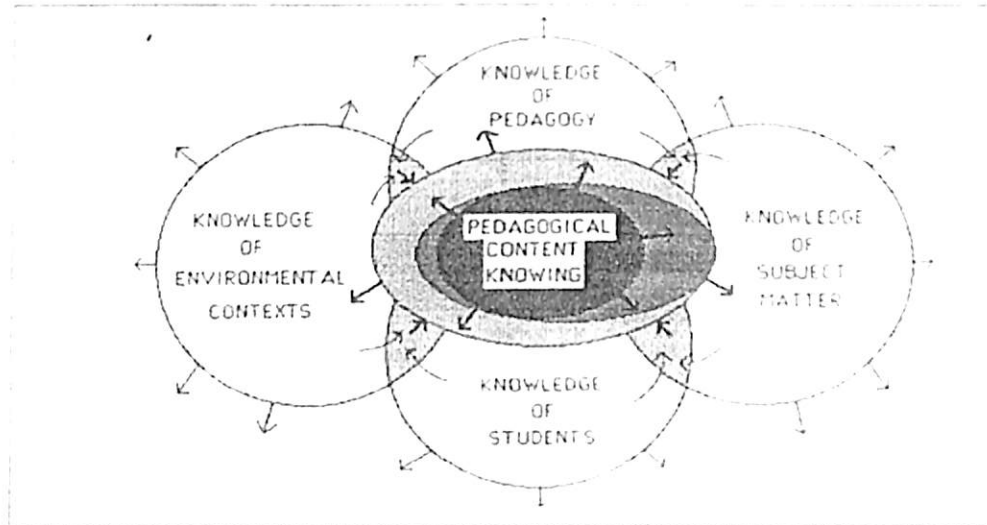


Figure 2.3. PCKg Model of Cochran et al. (1993).

Magnusson et al. (1999) developed a transformative PCK model for science teachers, by building upon the studies of Grossman (1990) and Tamir (1988) (see Figure 2.4). According to this model, PCK emerges from transformation of five components: orientations toward teaching science, knowledge of science curriculum, knowledge of students' understanding of science, knowledge of assessment in science, and knowledge of instructional strategies. The first component includes beliefs and knowledge of science teachers about goals and objectives of science teaching. This component shapes all the other components, since it serves as a 'conceptual map' for instructional decisions. The second component contains teachers' knowledge about curricular goals and objectives, and applicable materials

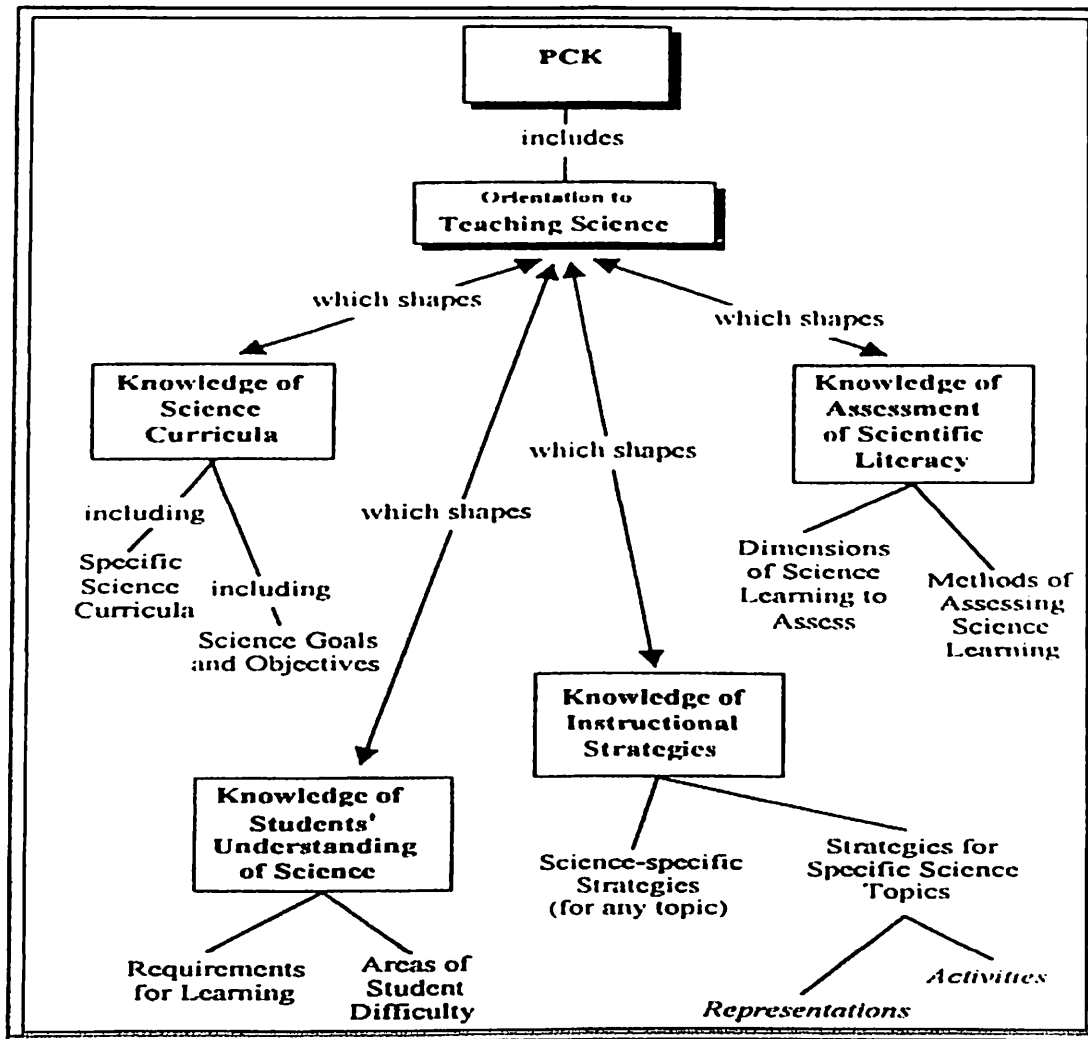


Figure 2.4. PCK Model Developed by Magnusson et al. (1999).

to achieve these goals and objectives. According to Magnusson et al. (1999), knowledge of science curriculum should be especially included in a PCK model since this type of knowledge distinguishes a content specialist from a pedagogue. Third component includes teachers' knowledge about students' requirements for effective learning and their learning difficulties. The fourth component, knowledge of assessment in science, refers to teachers' knowledge of student learning and scientific literacy that is important to assess and assessment procedures appropriate for different aspects of student learning. The last component of the model includes teachers' knowledge of subject-specific and topic-specific strategies. Scope of

subject-specific strategies (such as conceptual change strategies and learning cycle) is wider than topic-specific strategies (such as illustrations and analogies).

### **PCK Development**

PCK is a dynamic, rather than static, teacher knowledge construct that gets molded and may be developed through various ways. A number of researches focus about the development of PCK (van Driel et al. 1998; Appleton, 2008; 1999; Grotzer et. al., 2011; Turner, 2012; Lucenario, 2013; Han, 2014; Nillsson, 2014). These studies cited that contributing sources to PCK include classroom observation during times as student and pre-service teacher education. Another contributing source of PCK is teacher education programs. Science class and classroom teaching experience are also sources of PCK. Other studies point that recommendations from trusted mentors have also been found to contribute. The role of personal beliefs and perceptions of teaching and learning also help develop and shape science PCK as these determine how experiences are viewed and understood. The PCK of 12 pre-service chemistry teachers were found to improve as a result of attending workshops (twice a week for one semester) and the influence of their mentors (van Driel et al., 1998). Appleton (2008) reports the result of two case studies that showed mentoring supports the development of PCK. This is consistent with a similar study of nine teachers by Koch and Appleton (2007). The mentoring described in these case studies involved cooperative planning of lessons by mentor and mentee with occasional visits and observation with feedback during teaching times. The mentoring also involved modeling and constructive inputs and suggestions by

mentor. A longitudinal study by Turner (2012) involving 35 faculty instructors revealed significant pedagogical differences between faculty who participated in the NASA/NOVA professional development project and those who did not. Moreover, the following characteristics regarding the pedagogical content knowledge of faculty instructors who participated in the project emerged: (1) content knowledge about science concept taught and observed during instruction; (2) orientations consistent with reform instruction advocated by the National Science Education Standards for effective science teaching; (3) purposeful selection of activities that best engender student understanding of specific science concepts; and (4) reflective practitioner. In a related study by Turner (2011) of 91 in-service elementary teachers who experienced the undergraduate reformed science courses, it showed statistically significant difference in PCK prior and after the reformed program. A study of four high school chemistry teachers involved in PCK-guided lesson study showed improved PCK competencies about solutions (Lucenario, 2013). This resulted in enhanced student achievement in terms of conceptual understanding and problem-solving skills involving molarity and percentage by volume of solutions. In a study involving 14 middle school science teachers, intervention by providing web-based curriculum materials resulted improvement of PCK of the teachers as shown by pre-post testing (Grotzer et al., 2011). The PCK improvement of the teachers showed in terms of their understanding of the need for appropriate classroom activities and for focusing on structural information as part of pedagogy. The researchers also found an appreciation for the deep understanding that the unit on density and density-related topics encouraged. A qualitative study involving three high school science

teachers indicates teacher efficacy plays a pivotal role in developing PCK through a system of validation and evaluation of the teacher's cognitive belief structure (Han, 2014). Furthermore, it was determined that as teachers gain classroom teaching experience, their sustained PCK growth is the result of increasing their knowledge of student understanding. Nillsson (2014) presented in a study of three secondary science teachers that PCK is enhanced through their participation in a learning study. The results provided an insight into how the teachers developed their self-understanding in which they questioned their own epistemological beliefs, aims and objectives of teaching and taken-for-granted assumptions about science teaching and learning.

### **Particulate Nature of Matter and Student Misconception**

The Particulate Nature of Matter is a fundamental topic in science education. There has been several research studies carried out about students' and prospective teachers' misconceptions regarding particulate nature of matter (Kokkotas et al. 1998; Nakhleh & Samarapungavan 1999; Kelly et. al., 2010; Bruck et. al., 2010; Stains et. al., 2011; Fang et. al., 2014; Agas, 2003; Punzalan & Marasigan, 2008). One component of teachers' PCK is Knowledge About Students' Conceptions. This refers to knowledge about students' specific conceptions and ways they reason about a specific topic. From research findings, Filipino students find it difficult to understand the meaning of the term "particles" and the nature of space between particles. Filipino students also find it difficult to understand behavior of particles across different states of matter. They find it difficult to understand

changes in the arrangement of particles during the chemical processes (Agas, 2003; Punzalan & Marasigan, 2009; Gutierrez, 2009; Campo, 2009; de Hitta-Catalan & Treyes, 2013).

Punzalan and Marasigan (2009) detail several PNM misconceptions of high school students such as distinguishing between atoms and molecules and difficulty accepting the notion of space between particles of matter. Gutierrez (2009) cites the difficulty of students and even teachers distinguishing between elements and compounds. Distinction is typically based on the number of atoms in the particle unit rather than on the kind of atoms present. De Hitta-Catalan and Treyes (2013) noted in their study among high school students that students find it difficult to understand and represent how diffusion and osmosis occur at the molecular level.

The expert teacher fully understands the challenge posed by the inherent nature of chemical representations that consists of the macroscopic, the microscopic such as molecules and atoms and the symbolic (Johnstone, 2010). Johnstone (2010) noted that the practice of teachers moving from one representation to another in the course of teaching overloads the working memory of the student. The student can easily get lost in the midst of complex jargon of chemistry. The triangle he refers to is a triangle diagram (Figure 2.5) representing the three aspects of chemical representation (Johnstone, 1991). The challenge for teachers lies more specifically in the inability of students to distinguish between macroscopic and microscopic properties of matter (Bucat, 2004; Chandrasegaran, Treagust, & Mocerino, 2009).

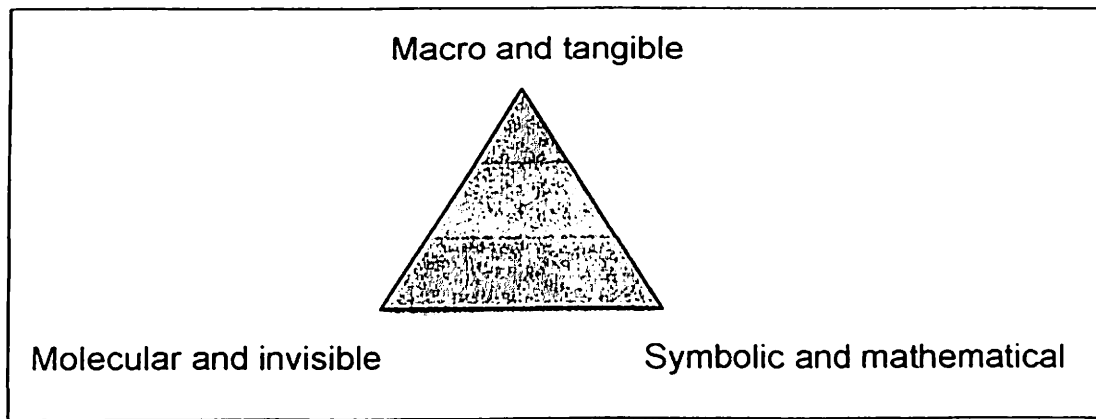


Figure 2.5. Representation in the physical sciences (Johnstone, 2010).

### Teachers' PCK and Student Understanding

The expert teacher is one who recognizes that students do not come to class with empty minds. They come with their prior knowledge, both correct and incorrect, picked up from various sources (Bodner, 1991; Sirhan, 2007; Stojanovska, 2012). It has been known that misconceptions are powerful, extremely persistent and hard to change, creating obstacles to further learning (Canpolat, 2006; Pabuccu & Geban, 2006). Research shows that students must undergo conceptual change in order to do away with their misconceptions and replace the misconceptions with the correct and complete ideas. The process of conceptual change can look upon misconceptions as ideas that interfere with students learning (Smith, di Sessa, & Roschelle, 1993). The teacher's ability to address students' misconceptions is critical to conceptual change. The conceptual change students must undergo to understand PNM involves moving from a continuous view of matter to a particle view (Nussbaum & Novick, 1982; Lee et al, 1993; Vosniadou, 1994; Harrison & Treagust, 2002; Niaz et al, 2002). Students' conceptions are constantly changing due to both their experiences and instruction (Strike & Posner, 1992). Thus teachers must be

intentional in addressing the students' misconceptions so they learn and develop conceptual understanding. Teachers' knowledge of how to address such misconceptions plays a vital role in ensuring that students understand clearly and correctly these concepts. A well-developed PCK of Particulate Nature of Matter will enable the teacher to address properly the students' misconceptions.

Research also shows that knowledge of subject matter influences the development of teachers' PCK. Various reasons, such as teachers' beliefs about teaching or learning science and their subject matter knowledge, may influence differences of PCK among teachers. For example, it was found that differences between the subject matter knowledge of the pre-service teachers led to different PCK (Grossman 1990; Van Driel et al. 2002). Similarly, Smith and Neale (1989) reported the influence of subject matter knowledge on teachers' knowledge about instructional strategies, one component of PCK.

The influence of teachers' analysis of students' conceptions and types of reasoning on the improvement of teachers' PCK has been mentioned in the literature (Geddis 1993; Lederman et al. 1994). Some studies have been carried out about prospective teachers' pedagogical content knowledge in various chemistry topics, such as combustion (De Jong et al. 1999) and chemical equilibrium (Van Driel et al. 1998). Van Driel et al. examined the effect of an in-service workshop on the development of their PCK attended by chemistry teachers. The workshop done for two afternoons per week for a month, provided chemistry teachers with opportunities to gain understanding of students' misconceptions and reasoning about the topic of "chemical equilibrium." It was found that chemistry teachers'

ability to analyze students' conceptions and reasoning helped some of the in-service chemistry teachers develop their PCK about chemical equilibrium.

There are still a few studies on topic-specific pedagogical content such as particulate nature of matter (Magnusson et al. 1999; Boz & Boz, 2007). This indicates the need for more research in this area. The purpose of this study is to investigate how collaborative teaching can improve the science teachers' topic specific, PCK of Particulate Nature of Matter and students' conceptual understanding of Particulate Nature of Matter.

### **Collaborative Professional Development (CPD)**

Teachers generally teach in isolation away from scrutiny of fellow teachers. They are left alone to practice their craft unless they encounter some problems or they have to be evaluated. Schools are traditionally structured such that teachers work alone, do not plan lessons together or share teaching strategies and materials (Darling-Hammond et al., 2009). Research shows, however, that collaboration among teachers is a powerful learning and change agent among teachers (Fullan, 2001; Lin, 2001). Collaborative professional development therefore is seen as an effective means to improve teaching and learning (Alozie, 2010; Prytulla & Weimann, 2012).

### **Nature of CPD**

A comparison of the more common collaborative professional development modes such as PLC's, lesson study and collaborative action research point to some commonalities:

1. There is open practice in ways that encourage sharing, reflecting, and taking the risks necessary to change. The very nature of collaborative professional development modes is collegial and having a sense of community among teachers who participate.
2. There is focus on student learning. The driving force of CPD is to improve student learning. The participating teachers collaborate to improve their classroom practice that result in students learning better.
3. *They are characterized by a development cycle that includes three basic elements: planning the lesson together; implementation of the lesson; post-lesson reflection and discussion to improve the lesson shown in Figure 2.6.*

### CPD on Teacher Development

A challenge of teaching is bridging the gap between what the teacher teaches and what the students learn (McDermont, 1991). Approaching the issue from the teacher side makes sense since teachers have the most direct impact on students because of their regular and sustained contact with them. Improving

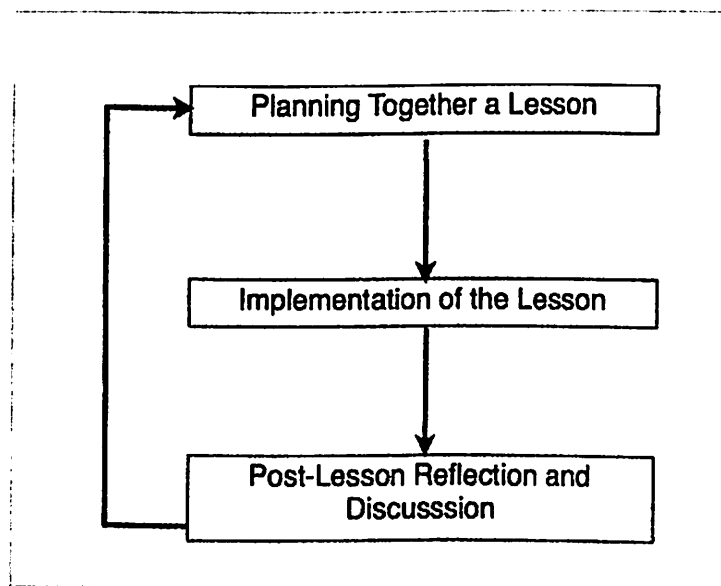


Figure 2.6. Development Cycle in CPD. Adapted from Ulep et al. (2013).

instructional practice through professional development (PD) of teachers must therefore be central to any effort to improve school teaching and learning (Borko, 2004; Fullan, 2007). Some teachers consider some modes of professional development, as inadequate, having poor quality, fragmented and more frustrating than inspiring (Nieto, 2009). This kind of professional development encourages isolation among teachers who view teaching as “personal” (Hiebert, et al., 2002). This isolation limits improvement of teaching in a broader scale since improvement of teaching of individual teachers is in a form that cannot be easily accessed by colleagues. Knowledge of practice should be made public, one that can be shared with other teachers. Knowledge of practice should be verified so it becomes professional knowledge (Hiebert et al., 2002). These are effectively accomplished through professional development modes characterized by powerful and highly effective collaboration. Collaborative professional development involves a systematic process in which teachers work together to analyze and improve their classroom practice (Dufour, 2005). This collaboration involves teachers working toward common learning goals, addressing common research questions, and determining if instruction is meeting the needs of all learners.

Collaborative professional development has been shown to facilitate development of preservice teachers (Thies-Sprinthall, 1986; Rock & Levin, 2002; Serrano, Garcia & Alfaya, 2012). Collaborative professional development of pre-service teachers improved teaching skills such as using innovative classroom practices and ways of working inside the classroom (Serrano, Garcia & Alfaya, 2012). Among in-service teachers, collaborative professional development was

shown to develop a more positive teacher identity (Prytulla & Weimann, 2012), improve teacher efficacy (Perry, 2008; Shepard, 2008) and enhance teacher practice (Lin, 2001; Hollins et al., 2004; Ulep, 2008; Poekert, 2012; de la Cruz, Magno & Punzalan, 2013; Shuilleabhain, 2013). Lin (2001) reports that a collaborative action research of seven teachers showed teachers shifting from non-constructivist to constructivist classroom practice. The teachers showed improved reflection on their classroom planning and improvement of classroom climate. In a study by Hollins et al. (2004), twelve teachers in a professional learning community developed a shift toward a more strategic focus as they designed a new approach to teaching language arts. Furthermore, the teachers began using strategies that included “visualization techniques” to help children read and communicate better (p. 259). However, initial teaching practices were not specified in these studies. Nevertheless, the studies mentioned show that CPD impacts teacher practice and classroom learning.

Goerner (1998) claims collaboration is a vehicle for achieving “evolutionary leaps” with “commitment to the greater good” (p. 4), even though such achievements are difficult to measure. Briscoe and Peters (1997) reference several researchers who claim that collaboration is instrumental for the process of facilitating change because “change occurs in a social context” and is “influenced by interactive processes” (p. 52). They concluded “collaboration is essential to support the change process, lessen the fear of risk taking, and provide a forum for analysis of what works and what does not” (p. 63).

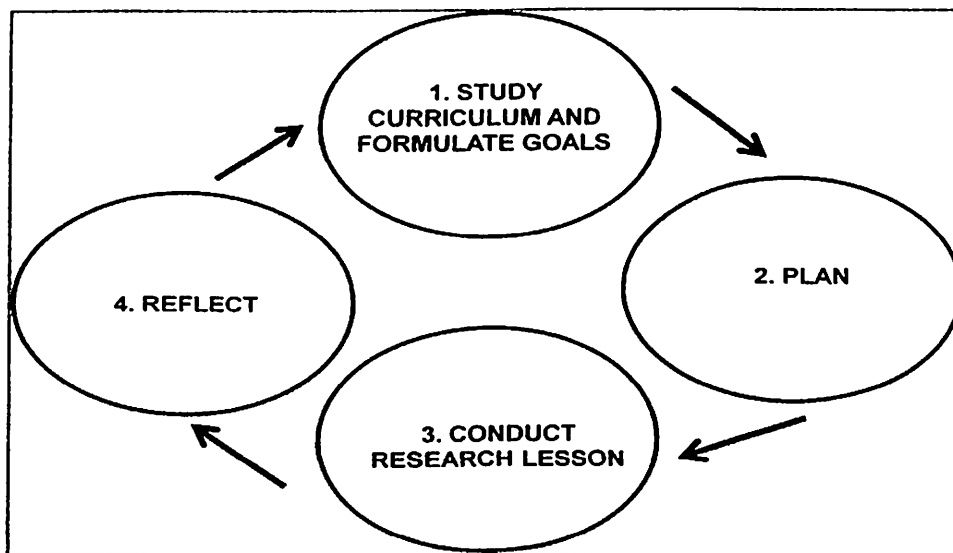
## **CPD on Student Understanding**

There is a growing body of research that shows collaboration among teachers improves student learning (Levine & Marcus, 2010; Vescio, Ross, & Adams, 2008; Cordingley et al. 2003; Bolam et al., 2005). This is because collaboration can lead whole departments or even whole schools to develop shared norms, values, practices, and orientations towards colleagues and students (Achinstein, 2002; McLaughlin, 1993; McLaughlin & Talbert, 2001; Westheimer, 1998). In the middle school case study of teachers by Phillips (2003), the goal of teachers collaborating to create innovative curriculum, was to improve learning for low and underachieving students. The teachers in studies by Strahan (2003), Hollins et al. (2004), and Englert and Tarrant (1995) all had an underlying focus of improving student literacy. Bolam et al. (2005) found that in effective professional learning communities (PLC), the “pupil learning was the foremost concern” (p. 146). PLCs at higher levels of development had stronger linkages between student achievement and teachers’ professional learning.

## **Lesson Study – Example of Teacher Collaboration**

One example of collaboration is the Japanese Lesson Study described by Chokshi and Fernandez (2004). Through this process, teachers work as a team to identify a problem and alter their teaching practices to address it. The strength of the collaborative effort ultimately determines the success of the group. Lesson study is a way of improving knowledge and practice of teachers to improve student learning. It is a Japanese form of professional development consisting of the study or

examination of teaching practice (Fernandez & Yoshida, 2004). In Japanese Lesson Study, teachers work in small teams to plan, teach, observe, analyze, and refine individual class lessons, called research lessons. In Lesson Study, the practice of teachers can be improved by collaborating with fellow teachers to plan, observe, and reflect on lessons (Lewis, 2002b; Stigler & Hiebert, 1999). The steps to Lesson Study include identifying learning goals, and planning instruction together. One teacher teaches the research lesson while others observe followed by reflecting on the research lesson, and possibly re-teaching the lesson (Lewis, 2002b; Stigler & Hiebert, 1999; Perry, Lewis, & Akiba, 2002). Although a typical Lesson Study follows a basic format, there can be nuances in how it is done. Figure 2.7 and Figure 2.8 below are some examples:



*Figure 2.7.* Lesson Study Cycle. Adapted from Lewis et al. (2009).

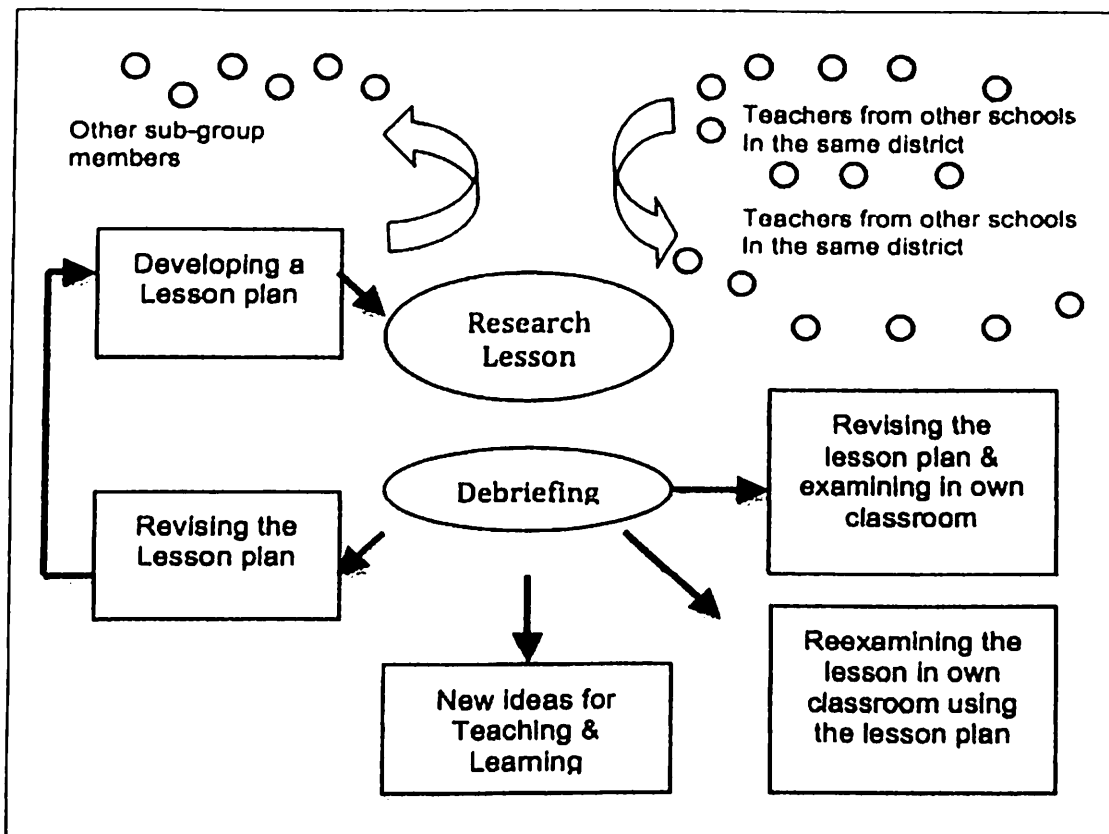


Figure 2.8. Typical Lesson Study process. Adapted from Takahashi & Yoshida (2004).

In this research, the Collaborative Teaching intervention followed the lesson study format being adapted by the National Institute for Science and Mathematics Education Development (NISMED). The following steps consists one cycle or iteration of Lesson Study:

1. Unit Planning. The group of teachers plans the unit by formulating the unit goal which will be anchored on the Lesson Study goals. The group also decides what research lessons to be included.
2. Preparation of the draft lesson plan. The first teacher who teaches writes the first draft of the research lesson.

3. Pre-implementation discussion. The first teacher presents the first draft of the lesson to the group. The group discusses, critiques and together thinks of ways how to improve further the lesson plan.
4. First revision of the lesson plan. The first teacher revises the lesson according to the input coming from the discussion of the Lesson Study group. All suggestions for improvement should be incorporated.
5. First implementation of the lesson plan. The first teacher teaches the revised lesson to his or her class while the other members of the group observe.
6. Post-implementation reflection and discussion. The observers give feedback about how the lesson was conducted covering all aspects of the classroom teaching. The group reflects on what they learned and how the lesson can be improved further.
7. Second revision of the lesson plan. The second teacher does the second revision to further improve the lesson plan based on the input from the post implementation discussion.
8. Second implementation. The second teacher implements the revised lesson plan while the rest of the group observes.
9. Second post-implementation reflection and discussion. The group discusses the observations and reflections and think of other ways to improve the lesson even further.
10. Finalizing of the lesson plan. The lesson plan is finalized based on the discussion.

Research shows that Lesson Study leads to improved student understanding

and develop pedagogical knowledge and practices (Briscoe & Wells, 2002; Meyer, 2005; Rock & Wilson, 2005; Lewis et al., 2009; de la Cruz et al., 2013; Lucenario, 2009; Barrett, Riggs & Ray, 2013). In a study of 13 middle school mathematics teachers, Lesson Study impacts teachers' pedagogical knowledge in the areas of self-reflection and incorporating problem-solving activities. Lesson Study also encouraged cooperative learning and improved teachers' content knowledge (Meyer, 2005). In addition, Lesson Study had positive impact on students' understanding, achievement and engagement in mathematics. Rock and Wilson (2005) conducted a study of the impact of Lesson Study on teaching practice of six intermediate level elementary teachers. The study showed Lesson Study enabled participants to have focused and sustained work to stimulate their growth as teachers. The participants experienced an increase in their professional confidence and stressed that the peer collaboration was valuable to their professional development. They also found reading and sharing of professional literature and the consultations with experts were very beneficial to the process. Furthermore, they expressed that peer coaching and mediation training would improve their abilities to engage in Lesson Study more effectively (Rock & Wilson, 2005). De la Cruz et al. (2013) reported the positive impact of Lesson Study on six chemistry teachers in five areas: their knowledge content and pedagogy, teaching strategies and lesson planning, communication skills, classroom management and confidence in teaching. A study among four Filipino high school chemistry teachers involved in PCK-guided Lesson Study showed improved PCK competencies resulting in enhanced student achievement in terms of conceptual understanding and problem-solving skills

(Lucenario, 2009). A study on the impact of collaboration of high school teachers who used Lesson Study showed that through their efforts, student engagement and achievement in geometry were improved (Barrett, Riggs & Ray, 2013). The mean scores in geometry of the students of the teachers in Lesson Study groups increased from 51 percent to 72 percent.

While the researcher adopted the Lesson Study format, Collaborative Teaching is not designed to be exactly like Lesson Study. The primary focus of Lesson Study is how students are learning, their thinking processes in response to a particular lesson so that there is maximum student learning (Ulep, 2013). The Lesson Study participants focus on collecting evidence that the instructional strategies used in the lesson promote the desired student learning. It is based upon logic that the best place to begin to improve teaching is in a classroom context where the *student and student learning* occupy the heart of the process (Lewis, 2002; Stigler & Hiebert, 1999). Another mode of teacher collaboration is Learning Study which originated in Hong Kong and is used in such countries as Brunei and Sweden (Cheng, 2009). In Learning Study, the focus is on the *object of learning or the content of the lesson* to be taught to the students. Collaborative Teaching in contrast to Lesson Study and Learning Study focuses on the *teachers and how they are working effectively to improve teachers' knowledge and practice*. CT was neither limited to follow exactly the typical Lesson Study nor was it bound by Lesson Study protocols. It has its own set of protocols described under the chapter on Methodology. The last section describes the theories that support the perspective that collaborative teaching as a mode of professional development impacts teachers'

PCK development and student understanding.

### **Theoretical Framework for Collaborative Teaching**

A paradigm shift about professional development of teachers is gathering momentum. This new paradigm is calling for professional development to move beyond acquisition of new knowledge and skills for teachers (Vescio, Ross, & Adams, 2008). Darling-Hammond and McLaughlin (1995) called teachers to rethink their own practice, construct new classroom roles and expectations about student outcomes and to teach in ways they have never taught before. These words remind us that there is a necessity to move beyond traditional methods of professional development. Teachers must shift from being passive receptacles to active members and contributors of a discourse community. In a discourse community, teachers assume dual capacities of both teaching and learning and “create new visions of what, when, and how teachers should learn” (McLaughlin & Talbert, 1993; Darling-Hammond and McLaughlin, 1995; Putnam and Borko, 2000). A discourse community of teachers is collaborative, critical and reflective. It allows participants to generate knowledge and new ways of teaching practice. Also, it allows participants to sustain their efforts for inquiry, reflection and experimentation. Teachers come out of the interaction and exchange with new insights about teaching and learning. Collaborative Teaching fits this paradigm shift. A growing body of research confirms there is impact on teaching practice and student learning when teachers take part in collaborative professional communities (Vescio, Ross, & Adams, 2008).

This research on Collaborative Teaching is grounded on three major learning theories: the **socio-cultural theory**, the **constructivism theory**, and the **situated learning theory**. The *socio-cultural theory* implies that professional development is social (Vygotsky, 1978; Soltis, 1981). It takes place in a social environment where learning takes place as teachers interact and learn with and from one another. Vygotsky (1978), the first advocates of the socio-cultural view of knowledge and learning, considered interactions among learners as a way to develop ideas and theories. He believed that the learner's thoughts and reasons begin as interactions with others. It then becomes internalized as individual forms of thought. As learners interact with others, new and different ideas and theories are developed and formed (Vygotsky, 1978). The *constructivism theory* emphasizes the active role of the learner (Driver & Oldham, 1986; von Glaserfeld, 1995; Howe & Stubbs, 1997)). Constructivism affirms that individuals construct meaning in their attempt to make sense of the world (Driver & Oldham, 1986). This view is also the core of the 'genetic epistemology' of Piaget (Fung, 2000). The teachers themselves construct the knowledge through interactions with others; thus professional development is *teacher-directed* rather than focused on the expert lecturer such as those commonly found in many in-service training. The *situated learning theory* (Lave & Wenger, 1991; Andersen et al., 1996; Greeno, 1997; Greeno, Collins & Resnick, 1997) posits that professional development should be tied to the *situation* of the learners. The skills and knowledge learned by the teachers should be relevant and close to the realities they encounter in their classroom and school settings. Collaborative Teaching as a form of teacher development as proposed in this study is **social**,

***teacher-directed and situated.***

### **Collaborative Teaching is Social**

For Vygotsky, knowledge is socially constructed and the way a person thinks and reasons is largely shaped by their interactions with others (Vygotsky, 1978). Thus, as learners interact with other members of the learning community, new and different ideas are developed and formed. In Collaborative Teaching, the teachers participating form the community of learners working together to improve the knowledge and practice of everyone in the learning community. From literature, the common characteristics of learning communities are collaboration, collective responsibility and shared values and vision. Learning communities show concern for individual and minority views. They also involve meaningful relationships, reflective personal inquiry, collaboration and promotion of group and individual learning (Grossman et al., 2001; Stoll et al., 2006; Wenger et al., 2002). Lave and Wenger (1991) describe such a community which they call *communities of practice* where participants share common actions, procedures and goals. In addition, those in this community share a common concern or passion about a topic and deepen their knowledge and expertise by interacting on an ongoing basis (Wenger et al., 2002). Resnick (1991) describes a type of collaborative professional development called *discourse community*, where groups of people share common interests. Here, teachers can avail of cognitive tools, such as ideas, theories, and concepts about teaching and learning which they can use to make sense of their instructional experiences. As teachers talk and interact they can consider ideas that they may not

have thought of before, potentially, incorporating them with existing ideas, or replacing former ideas (Hammond & McLaughlin, 1995).

### **Collaborative Teaching is Teacher-directed**

The framework of this study was also guided by the constructivism theory in which knowledge and meaning are not transmitted passively but are actively constructed by individuals in their attempt to understand the world around them (Driver & Oldham, 1986; Howe & Stubbs, 1997). Traditional professional development, which some describe as “transmissional,” “passive,” or “trickle-down,” is focused on professional development facilitators or “experts” delivering content to recipient teachers (Howe & Stubbs, 1997; Darling-Hammond, 1994). Professional development, in the constructivist approach, empowers teachers to construct their own knowledge in a supportive environment. They become *self-directed* learners who experience development through their actions and experiences influenced by each one’s existing knowledge and beliefs (Borko & Putman, 1996; Howe & Stubbs, 1997). Teachers themselves, and not so much the “experts” or system-generated in-service programs drive the development. This model can be done school-wide or even in one department such as the science department. Howe and Stubbs (1997) for instance proposed a model which is a continuing process that begins with an extended workshop initiated and facilitated by teachers. In this “empowered environment”, the teachers developed curriculum materials which they can apply in their classrooms, share with colleagues and form an encouraging and supportive community. As a result of these experiences, the teachers grow professionally and

are “empowered to become effective leaders and advocates for science education”.

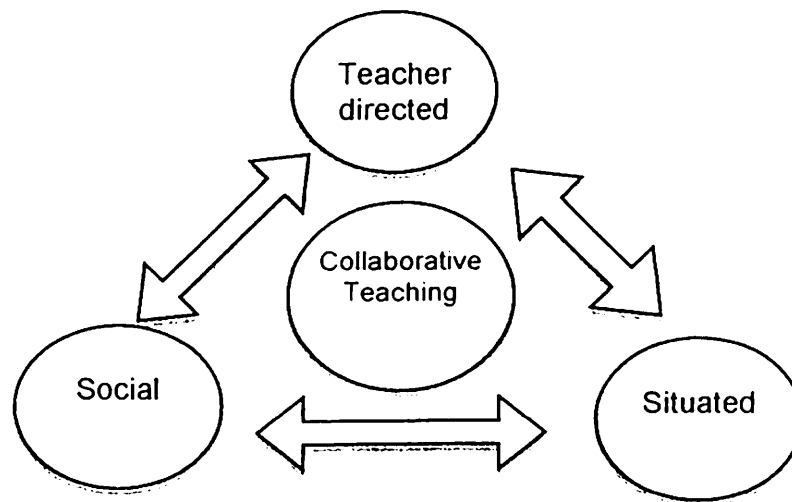
The teacher-directedness (constructivist nature) of Collaborative Teaching and the fact that it is social (socio-cultural nature) imply a dynamic environment. In this dynamic environment, teachers are active contributors in the learning-development process. At one time they act as recipient and at other times as the expert contributing his or her expertise and experience. A necessary consequence in this constructivist-socio-cultural framework is activities such as teachers planning together, discussions, reflection, and feedback. There is interdependence that serves the community of learners. These activities become foundations that sustain the development of the community. The individual teachers contribute to the knowledge and learning of the community of teachers. This process of growing the collective knowledge and learning constitute the professional development (PD) which impact the development of the individual members.

### **Collaborative Teaching is Situated**

The Situated Learning Theory completes the framework used in this study. At the most basic level, situated learning emphasizes context or the situation of the learners in which knowledge is being learned (Andersen, Reder, & Simon, 1996). Thus, the realities and activities teachers engage in inside their classrooms become powerful contexts for their learning (Greeno, Collins, & Resnick, 1996; Ball & Cohen, 1999; Putnam & Borko, 2000). It is possible that professional development programs may not match the current realities faced by the recipient teachers and so the impact of such programs may be less than desired. Learning theories remind us that

learners respond to stimuli that makes sense or relevant to them. Various studies (Lave and Wenger, 1991; Wilson and Berne, 1999; Dufour, 2004; Vescio, Ross & Adams, 2008) report that when teachers are in a community of learning, teachers change. As they talk about their teaching experience and the challenges their students face in learning, they rethink their ideas about how students learn, moving to higher levels of theoretical understandings. Sherin and van Es (2009) for example, showed in their study of teachers participating in video clubs that a teacher learning within personal practice has the potential to influence professional discourse about teaching and learning. As these teachers engaged in a cycle of experimentation and reflection they shifted their focus from general pedagogy to one that is particularly connected to their own students.

All the three elements - ***Collaborative Teaching as social, situated and teacher-directed***, work together to make Collaborative Teaching effective as an approach or mode of professional development impacting teacher knowledge and practice. Teachers participating in Collaborative Teaching form a community of interdependent learners (social). Through discussion, feedback, and reflection of their individual and collective classroom experiences (situated), they construct their own learning (teacher-directed) for the collective development of the group in terms of knowledge, practice and student learning. This framework, shown in Figure 2.9 gives us a way to design *collaborative professional development* programs that can be adapted to the context of any group of teachers.



*Figure 2.9. Theoretical Framework of Collaborative Teaching as a mode of PD*

### **The Case Study Approach**

The case study approach was used in this study. Case study is an in-depth exploration or detailed investigation of the unit of study such as a program, an event, an activity, a process, or one or more individuals within the context or environment unique to that unit of study (Merriam, 1998; Patton, 2002; Creswell, 2003). Case study method is used when a holistic, in-depth investigation is needed in order to explain, describe or explore events or phenomena in the everyday contexts in which they occur (Feagin, Orum & Sioberg, 1991; Yin, 2009; Crowe et al., 2011). In this study, the focus is a group of six Science teachers who underwent Collaborative Teaching intervention during the 2<sup>nd</sup> quarter of the 2015-2016 school year. Case studies are designed to bring out the details from the viewpoint of the participants by using multiple sources of data. In a case study approach the researcher explores a bounded system over time, gathering detailed, in-depth data from multiple information sources. Case study is an honored method that has multiple research applications across social science disciplines (Creswell, 2007; Hatch, 2002). Hatch

(2002) reports that case studies and rich narratives account for the acceptable work products generated from constructivists work in qualitative research. In this study for instance, the researcher chose case study because it is aligned with constructivism, one of the theories on which CT is based. Getting a holistic picture of teachers' PCK and students' conception of PNM through the various sources is a constructivist perspective that involved construction of multiple realities which could only be studied holistically (Lincoln & Guba, 1985; Lankford, 2010; Turner, 2011). Each data source such as classroom observation and teacher interview gives a separate picture or reality of teachers' PCK. Turner (2011) calls these multiple realities "snapshots" which depict the PCK of the teacher. Lankford (2010) calls these multiple realities "vignettes" which describe a teacher's PCK derived from various data sources. The researcher developed two important realities about the teachers' PCK: one as described by the teachers and another one as described by their students (Lankford, 2010; Turner, 2011).

There are at least three situations for applying the case study method as a research method. First and most important, case studies are pertinent when the research addresses either a descriptive question—"What is happening or has happened?" or an explanatory question—"How or why did something happen?" (Crowe et al., 2011; Yin, 2009). For instance, Han (2014) used case study to study the role of efficacy on the development of PCK of experienced science teachers. This is similar in the current study, which seeks to study the effect of Collaborative Teaching on the development of science teachers' PCK of PNM. Second, by emphasizing the study of a phenomenon within its real-world context, the case study

method favors the collection of data in natural settings, compared with relying on “derived” data (Bromley, 1986, p. 23), for example, responses to a researcher’s instruments in an experiment or responses to questionnaires in a survey. For instance, Lankford (2010) used case study to examine the PCK of science teachers for teaching osmosis and diffusion. Campo (2012) used case study to study how teachers integrate pedagogy and content into chemistry instruction. In this current study, data about the teachers PCK of PNM was collected as teachers taught Module 1 (Chemistry) of Unit 3 in the Grade 8 Science class. Third, the case study method is now commonly used in conducting evaluations. Case studies are used to examine, evaluate and compare the effect of processes, e.g. interventions and programs on the unit of study or case (Balbach, 1999; Meyer, 2005; Yin & Davis, 2006; Pinnock et al., 2008; Robertson et al., 2010; Barlett & Vavrus, 2017). For instance, Meyer (2005) used case study to examine the effects lesson study had on middle school mathematics teachers and students in a large urban school district. Authoritative sources such as the U.S. Government Accountability Office (1990) and others (e.g., Yin, 1992, 1994, 1997) have documented the many evaluation applications of the case study method. Balbach (1999) and Yin and Davis (2006) point out that this evaluative type of case study are designed to determine what happened during the implementation of the intervention and its impact.

Although the case study is an excellent choice for a qualitative study, consideration must be given to construct validity, internal validity, external validity, and reliability (Yin, 1989). In the current study the researcher established construct validity by using multiple sources of data, having experts evaluate the instruments

used and regular consultation with the adviser. The researcher established internal validity by member checking, having a comparison group (the Conventional Teaching group) and triangulation. External validity is more difficult to attain in case studies. Yin (1994) provided the assertion that external validity could be achieved from theoretical relationships and from these generalizations could be made. Reliability was addressed in the study by using high Cronbach alpha for the two main instruments, PCK-PNM Questionnaire and ParNoMA. Peer and experts' review of methodology and instruments used also helped increased reliability. In addition, the use of documentation in the form of videos, photos and field notes, contributed to reliability.

### **Conceptual Framework for the Study**

Teaching provides the social context where teachers can work together to help improve their teaching. Thus, it is possible PCK of teachers can improve through collaborative actions. The transformative view of PCK supports PCK change. Teacher knowledge bases are transformed and combined through experience into a new form of knowledge base (Shulman, 1986; Grossman, 1990; Cochran et al. 1993; Gess-Newsome, 1999). The changes in teacher's PCK influence his or her teaching and consequently students' learning (Shulman (1986). The knowledge about students' understanding, instructional strategies and representations and knowledge of content point to how PCK influence the practice of teachers (Park & Oliver, 2008; Schmelzing et al., 2010). Magnusson's PCK model

shown by Figure 2.4 further guides the specific components of science PCK highlighted in the study.

Figure 3.1 shows the conceptual framework that guided the research. This study used the input-process-output model. The model shows the teachers' PCK of PNM before (INPUT) and after (OUTPUT) Collaborative teaching (PROCESS) in terms of the teachers' knowledge of science content, knowledge of teaching strategies and knowledge of student understanding. Collaborative teaching involves an iterative process of planning the lesson together, implementing the lesson and

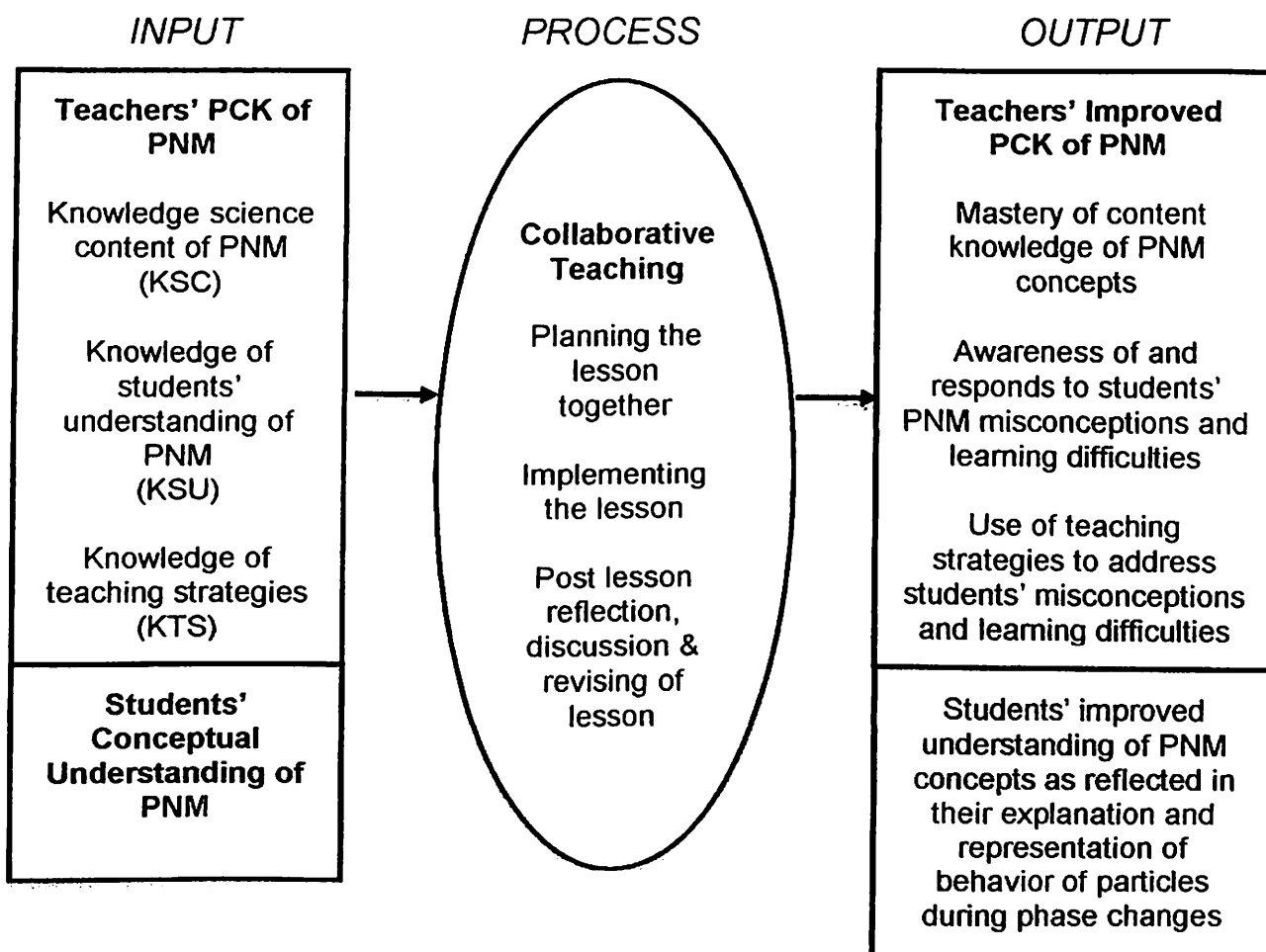


Figure 2.10. Conceptual Framework for the effect of Collaborative Teaching on teachers' PCK and students' understanding.

doing post lesson reflection, discussion and revision. The three main variables are *Collaborative Teaching (CT)*, *PCK of Particulate Nature of Matter (PCK-PNM)* and *Students' Conceptual Understanding of PNM*. The Collaborative Teaching process impacts the teachers' PCK of PNM improving their content knowledge about PNM, their awareness and understanding of students misconceptions and learning difficulties and knowledge of teaching strategies to address students' misconceptions and learning difficulties. The CT process also impacts students' Conceptual Understanding of PNM in terms of how they explain and represent behavior of particles of matter during phase changes. A similar model was adopted in two Philippine studies, which investigated the impact of Lesson Study on teacher effectiveness in high school chemistry (de la Cruz et al., 2013; Lucenario, 2013). As teachers engage in Collaborative teaching (process), their PCK is developed. The improved PCK is seen in what they do to teach effectively. Ultimately, the effect of improved PCK is seen in improved conceptual understanding of PNM of the students.

## **Operational Definition of Terms**

### **Collaborative Teaching (CT)**

Collaborative teaching is a concerted effort of teachers to plan, implement and improve lessons. The common goal is to increase teacher effectiveness in order to improve student learning. In this study, Collaborative Teaching was an intervention used to improve the PCK of PNM of six high school science teachers. The teachers *prepared* a Grade 8 lesson plan about Particulate Nature of Matter,

*implemented* the lesson plan, *discussed and reflected* on the teaching experience in order to *improve the teaching* of the lesson. CT in this study used Lesson Study format wherein one of the participant teacher taught the lesson prepared by the group. After discussion, reflection and revision of the lesson taught, a second teacher taught the revised lesson. The teachers met again for a final discussion, reflection and revision to improve further the lesson. The researcher adopted the Lesson Study format based on a research conducted by de la Cruz et al. in a public high school, SY 2003-2004 (de la Cruz, Magno, & Punzalan, 2013). The collaborative teaching of the six teachers involved six iterations or cycles corresponding to six research lessons based on Module 1 of the unit on matter in DepEd's Learner's Material, Grade 8 Science (2013).

### **Pedagogical Content Knowledge (PCK)**

PCK is a teacher's ability to formulate and represent content to make it comprehensible to students to ensure student understanding of concepts (Shulman, 1986). In addition, PCK is teachers' understanding and enactment of how to help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment (Park & Oliver, 2008). In this study, PCK referred to the knowledge and practice of the teachers to transform their knowledge of science content (KCS) about Particulate Nature of Matter, knowledge of teaching strategies (KTS), knowledge of students understanding (KSU), to improve students' conceptual understanding of PNM. The PCK of PNM

was measured using the researcher developed 15-Item PCK-PNM Questionnaire before and after the Collaborative Teaching intervention. The PCK of the participants was also measured through the PCK-PNM Observation Rubric. The researcher also used data from lesson plans, interviews, lesson plan reflection guide, classroom observations (videos, photos, notes) and focus group discussions to capture the teachers' PCK of PNM.

### **Knowledge of Science Content (KSC) of PNM**

The teachers' Knowledge of Science Content (KSC) refers to their grasp and understanding that matter is made up of discrete particles and that there are spaces in between the particles. The KSC of PNM also refers to the teachers' understanding that particles of matter are in constant motion and there are forces of attraction between particles. During the CT process, the teachers demonstrated their KSC with respect to their ability to teach effectively the PNM concepts as assessed by the PCK-PNM Observation Rubric. Their KSC was also reflected in their answers and explanations in the PCK-PNM Questionnaire. Furthermore, the researcher also used data from lesson plans, interviews, lesson plan reflection guide, classroom observations (videos, photos, notes) and focus group discussions to capture the teachers' KSC of PNM.

### **Knowledge of Student Understanding (KSU) of PNM**

The Knowledge of Student Understanding (KSU) of PNM refers to the teachers' awareness and understanding of their students' misconceptions and

learning difficulties about PNM concepts. In the study, the teachers' KSU of PNM was demonstrated in their anticipation of students' potential misconceptions and learning difficulties during lesson planning. In addition, the teachers' KSU was assessed based on their answers and explanations in the PCK-PNM Questionnaire. Their KSC was also assessed during instruction through the PCK-PNM Observation Rubric, noting particularly if they addressed students' misconceptions and learning difficulties. Furthermore, the researcher also used data from lesson plans, interviews, lesson plan reflection guide, classroom observations (videos, photos, notes) and focus group discussions to capture the teachers' KSU of PNM.

### **Knowledge of Teaching Strategies (KTS)**

The Knowledge of Teaching Strategies (KTS) of teachers refer to the instructional strategies and activities the teachers used to teach PNM concepts to their students. This includes those that they used to address students' misconceptions and learning difficulties about PNM concepts. The teachers' KTS was assessed during classroom observation using the PCK-PNM Observation Rubric. The teachers' KTS was also reflected in their responses to PCK-PNM Questionnaire. The researcher also used data from lesson plans, interviews, lesson plan reflection guide, classroom observations (videos, photos, notes) and focus group discussions to capture the teachers' KTS of PNM.

### **Students' Conceptual Understanding (SCU)**

The student's conceptual understanding is his or her ability to connect new

knowledge with prior knowledge. It also refers to his or her ability to apply the new knowledge in varying and new context. Conceptual understanding is more than just knowing isolated facts and information. The Student Conceptual Understanding in the study referred to the student's understanding of PNM concepts. The students' conceptual understanding was measured before and after Collaborative Teaching intervention using the 20-Item ParNoMA Questionnaire. Data from interviews and classroom observations (videos, pictures, notes) were also used to capture students' conceptual understanding of PNM.

### **Collaborative Teaching Cycle or CT Cycle**

The CT Cycle referred to the iterative process used by the participant teachers of the Collaborative Teaching group. Each cycle involves planning the research lesson to be taught, teaching the lesson by one teacher to be observed by the other participants, a post-lesson reflection and discussion and then a final revision of the research lesson. The Collaborative Teaching group did six cycles corresponding to the 6 Activity Lessons of the new Grade 8 Science K-12 curriculum.

## Chapter 3

### METHODOLOGY

*This chapter describes the research perspective and design, the sampling employed, the procedure used to gather data and the method used to analyze the data. This chapter also describes the different stages of the research. Furthermore, this chapter tries to detail the context, realities and challenges the researcher faced during data gathering.*

#### **Research Design and Perspective**

This study used a qualitative approach to determine the effect of Collaborative Teaching as a mode of professional development, on science teachers' PCK and students' understanding of Particulate Nature of Matter. In order to accomplish these, the researcher collected data from various sources about the effect of a six-week Collaborative Teaching intervention, on the PCK of six teachers and the conceptual understanding of PNM of their students. The data sources include classroom observations, semi-structured interviews, focus group discussions, lesson plans, pre-lesson reflection guides and questionnaires. A mix-method design was intended, recognizing that PCK is a construct that is not easily captured (Loughran et al., 2006; Turner, 2011). A quantitative and qualitative design would afford this research more ways to capture how Collaborative Teaching impacts the PCK of science teachers. However, the small sample size ( $N=12$ ) brought about by the limitations of the study made inferential statistics not feasible. The researcher then focused more on using the qualitative approach that employed

a case study design. Nevertheless, descriptive statistics was retained to help triangulate results about the effects of CT on the teachers' PCK and students' understanding of PNM. A non-parametric statistical analysis using Wilcoxon Sign Test and Wilcoxon-Mann-Whitney Test was also used to help triangulate results about the effect of CT on students' conceptual understanding of PNM.

Case study is particularly useful to employ when there is a need to obtain an in-depth appreciation of a unit of study such as an issue, event or phenomenon of interest (Merriam, 1998; Patton, 2002; Creswell, 2003). In this study, the focus is a group of six Science teachers who underwent Collaborative Teaching intervention during the 2<sup>nd</sup> quarter of the 2015-2016 school year. The case study approach also lends itself well to capturing information on more explanatory 'how', 'what' and 'why' questions (Crowe et al., 2011). The researcher sought to find WHAT changes occurred in the science teachers' PCK of PNM and the conceptual understanding of PNM of their students during Collaborative Teaching intervention. The researcher also sought to find out HOW the changes in the teachers' PCK facilitate changes in the students' conceptual understanding of PNM concepts. Case studies are also used to examine, evaluate and compare the effect of processes, e.g. interventions and programs on the unit of study or case (Balbach, 1999; Meyer, 2005; Yin & Davis, 2006; Pinnock et al., 2008). Balbach (1999) and Yin and Davis (2006) for instance point out that this evaluative type of case study are designed to determine what happened during the implementation of the intervention and its impact.

The researcher also found case study applicable to this research because it is aligned with constructivism (Guba & Lincoln, 1989; Driver et al., 1994), one of the

theories on which Collaborative Teaching is based. In constructivism, knowledge and meaningful reality are connected with the actions of individuals and constructed within the context of the interaction between individuals and their world (Crotty, 2003; Carlson, 2007). The constructivist perspective in this study provided an understanding about the nature of the teachers' PCK of PNM possessed by the teachers and how it impacted the students' understanding of PNM concepts. The participants in this study varied in their backgrounds, experiences, and the context in which they taught. By maintaining a constructivist perspective, the researcher was able to get a holistic picture of the teachers' topic-specific knowledge for teaching within the context of their experiences and the unique environment of their school and science department. The researcher documented the experiences of six Grade 8 Science teachers and their students as the teachers underwent Collaborative Teaching intervention for 6 weeks covering six Activity lessons on the Particulate Nature of Matter. The complex and multi-dimensional nature of the PCK construct makes it challenging to measure and to capture into words. The case study was chosen in order to get a holistic picture of the selected science teachers' PCK (Crowe et al., 2011). To do that, the researcher had to use multiple sources of data such as classroom observations, semi-structured interviews, focus group discussions, lesson plans, pre-lesson reflection guides and questionnaires.

A case study method was also appropriate because the study was about the PCK of science teachers for which the researcher had little or no control of (Yin, 2009; Crowe et al., 2011). Through their reflection of their own classroom teaching and student learning of PNM, the participants were constructing their own PCK of

PNM (Guba & Lincoln, 1989; Carlson, 2007; Ferguson, 2007). While the researcher was the one who conducted interviews and discussions with the participants, the teachers were the ones doing the reflections, interpretation of their experience and decision-making that informed the changes in their thinking and practice (Hatch, 2002; Carlson, 2007). Thus, teachers were constructing their own knowledge and practice (PCK) during the course of Collaborative Teaching. The researcher merely recorded their experience. This follows from the constructivist perspective that the learning experience of teachers and students in this study were situated (Andersen, Reder, & Simon, 1996). The participants' experiences during the Collaborative Teaching intervention were unique in the specific context and conditions they were at. The teachers also shared this same unique experience as they collaborated to improve their teaching. The realities and activities that the teachers engaged in inside their classrooms were powerful contexts for developing their PCK of PNM and facilitating learning of their students (Greeno, Collins, & Resnick, 1996; Ball & Cohen, 1999; Putnam & Borko, 2000). The set of conditions and factors of the study was unique and pre-existent for the group of Grade 8 science teachers selected from School CT. The research focused on PCK of Particulate Nature of Matter of Grade 8 science teachers who taught Module 1 of the Unit III on Matter in the DepEd's Learner's Material, Grade 8 Science. The researcher monitored the teachers' PCK as the teachers went through six cycles of Collaborative Teaching intervention. The intervention covered research lessons based on Module 1 of Unit III on matter. Changes in the PCK of the teachers and students' understanding were monitored and gathered as evidence of the effect of Collaborative Teaching on

teachers' PCK of PNM and students' understanding of PNM concepts during the six weeks of Collaborative Teaching.

## **Sampling**

**Selection of the school.** The choice of school was limited by the fact that in Quezon City, there were only three out of 45 high schools that have at least 12 Grade 8 Science teachers. Twelve was a minimum number needed to form two groups of six members each - one group as the comparison group and the other as the group that underwent the 6 cycles of Collaborative Teaching. This minimum number also gave room for attrition inherent in a case study design. The choice of school was further limited because there were only two schools where the Grade 8 Science teachers teach all the Science Units to the same class for the entire 2015-2016 school year. This made it possible for the researcher to make continuous observation of the teachers and their students from second quarter to third quarter. This would not have been possible in the other schools. The final choice of the school, School CT, was influenced further by the previous working relationship of the researcher with the principal of School CT, which was seen as advantageous for the implementation of Collaborative Teaching.

**Selection of teachers.** There were only twelve Grade 8 Science teachers in School CT. Hence, all were selected for the study. They were assigned equally to the Collaborative Teaching and Conventional Teaching groups for the schedule of the six CT cycles. Assigning the twelve teachers to control and experimental groups was not random. The schedule of the teachers that accommodated the Collaborative

Teaching cycles became the determining factor. The participant teachers have varied backgrounds. Although all have a background in Science, there is variability as to their area of specialization: 10 have education background, 2 have Agriculture background. Of those with education background, four are Biology majors, three are Physics majors, two are General Science majors, and one Agriculture Education major. The teaching experience ranged between 3 years to 34 years. Science teaching experience ranged from 3 to 34 years as well. Of the twelve teachers, three are male. One participant worked in another government office for many years before shifting career as a teacher. Three participants taught in a private school before joining School CT. The Conventional Teaching group consisted of 5 female and one male teacher. Teacher L, Teacher G Teacher H, Teacher I, Teacher J, and Teacher K teach Section 5, 6, 9, 13, 35 and 41, respectively. The Collaborative Teaching group consisted of 4 female and 2 male teachers. Teacher A is Master Teacher I, the current Grade 8 Science Coordinator and handles Section 1. Teacher B, Teacher C, Teacher D, Teacher E, and Teacher F handle Sections, 15, 18, 20, 21 and 43, respectively. Table 3.1 is a summary of information about the teacher-participants.

The following additional criteria were also prescribed on the participants:

- (1) Participant has taught Grade 7 or 8 Science for at least one year using the new K to 12 curriculum so they are familiar with the science curriculum and its content.
- (2) Participant must have been teaching high school science for at least 3 years so their science PCK has gained minimum development (Clotfelter, Ladd & Vigdor, 2007; Kane, Rockoff, & Staiger, 2006). However, the participants from CT group must

have not taught more than 10 years so that experience will not be an extraneous or intervening variable. This criterion is more critical for CT group so that any improvement in PCK is really due to CT and not because the teacher has an expert PCK already. Although studies show that number of years is not determinant of PCK (Meyer, 2005; Clotfelter, Ladd & Vigdor, 2007; Kane, Rockoff, & Staiger, 2006;

Table 3.1

*Teachers' background information*

Teacher	Major	Years of teaching	Years teaching HS Science	Previous professional development	Post-undergraduate studies
Collaborative Group					
A	BSE Biology	12	11	School-based, division, regional, national seminars	MAEd Biology 9 units MAEd Mgt
B	BSE Physics	3	3	School-based, division seminars	MST Physics 6 units
C	BSE Biology	10	10	School-based, division, regional seminars	MAEd Biology 12 units
D	BSE Physics	4	3	School-based, division seminars	MAEd Physics 18 units
E	BSE Physics	3	3	School-based, division, regional seminars	MST Physics 18 units
F	BSE Biology	7	7	School-based, division seminars	MAEd Biology 6 units
Conventional Group					
G	BSE General Science	11	11	School-based, division, regional seminars	MAEd Biology 6 units
H	BS Agriculture	20	20	School-based, regional, national seminars	MAEd Biology 18 units
I	BSE General Science	20	20	School-based, regional, national seminars	MAEd Biology 24 units
J	BSE Biology	34	34	School-based, regional, national seminars	MAEd Biology 24 units
K	BS Agriculture	15	15	School-based, division, regional seminars	MAEd Biology 6 units
L	Agricultural Education	17	17	School-based, division, regional seminars	MAEd Biology 9 units

Turner, 2011) level nevertheless, the researcher wanted to ensure this variable will not affect the validity of the results. The pretest data on teachers' PCK of PNM actually confirmed that the teachers have the same PCK level (Emergent) at the beginning of the study. Therefore, the above concern was ruled out.

(3) Participant had not been part of a lesson study research group before.

All the members of the Collaborative Teaching group satisfied these additional criteria except Teacher CT who has been teaching high school science for 11 years by the time of the data gathering. This entire process of selecting participants was done in collaboration with the Science Department Head and the Grade 8 Science Coordinator.

**Selection of students.** Intact classes of students corresponding to the classes handled by the participant teachers were used. The researcher needed intact classes to find out the effect of Collaborative Teaching on the students' Conceptual Understanding of Particulate Nature of Matter. Each teacher handles up to four classes and one class was chosen whose schedule accommodated the Collaborative Teaching cycle. The students of the participating teachers came from different sections: Three sections (Sections 1, 5 and 6) belong to homogeneous classes where all students have relatively high general average the previous school year. The rest (Sections 9, 13, 15, 18, 20, 21, 35, 41, and 43) belong to heterogeneous sections where students are randomly assigned. The practice of assigning higher sections as homogenous while the rest as heterogeneous is a common practice in the Philippine public school system, homogeneous student

sectioning (ability grouping) is done since it is easier to teach a group of like-ability students (Ballantine, 1997). Following the Collaborative Teaching schedule limitations mentioned in the previous section, Section 1, 15, 18, 20, 21 and 43 were assigned to the Collaborative Teaching group while the rest to Collaborative Teaching Group (Table 3.2). Ages of students range from 14 to 20. The few older students (less than 10 in two classes) are SPED students who are integrated into the regular classes.

Table 3.2

*Group Assignment of students*

<b>Group</b>	<b>Class Section of Students</b>
Collaborative Teaching Group	Section 1, 15, 18, 20, 21 and 43
Conventional Teaching Group	Section 5, 6, 9, 13, 35, and 41

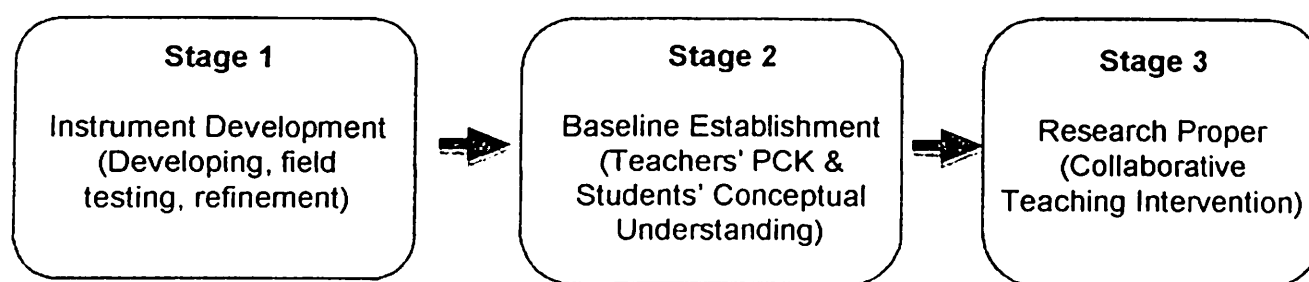
### **Data Collection Procedure**

There were three stages to this research (Figure 3.1). Stage 1 is Instrument Development. Stage 2 is Baseline Establishment. Stage 3 is the Research Proper.

### **STAGE 1: Instrument Development**

*Stage 1, the Instrument Development Stage* began June 2015. This stage involved developing, field-testing and refining the following instruments used to gather data about the teachers' PCK of Particulate Nature of Matter (PCK-PNM) and the students' understanding before and after CT.

1. *PCK of PARTICULATE NATURE OF MATTER QUESTIONNAIRE (PCK-PNMQ; See Appendix A)*. This questionnaire assessed the PCK of science teachers on the



*Figure 3.1. Stages of the research.*

Particulate Nature of Matter. It was used at the beginning (pretest) and towards the end of the study (posttest). A preliminary exploration towards developing the instrument was done using data from literature (Rowan et al., 2001; Birk and Yeziarski, 2006; Schuster, Cobern et al., 2007; de la Cruz, 2009; Gutierrez, 2009; Punzalan & Marasigan, 2009; Grotzer et al., 2011; Bacihvan, E. 2012).

Originally 2-3 weeks were allotted for field-testing and refinement through factor analysis excluding the initial development and initial refinement that were already done earlier. However, field-testing took longer due to a few unanticipated events. First, the processing of permit for the study from the Department of Education Quezon City Division Office took longer than one week. The researcher was bound ethically not to start anything without the official permit. Second, the original plan to conduct group testing did not happen. The principals and Science coordinators of the schools who allowed the PNM-PCK survey would not agree to group testing citing the schedules of the teachers as the main reason. Group testing would have been preferred for expediency, time and objectivity (Borg and Gall, 1989). Instead the researcher was asked to leave the survey forms with the Science

coordinators to distribute and was asked to come back after. For some schools it was only a week after; for others, it took additional 2-3 weeks.

The researcher initially developed a 20-item questionnaire. The questionnaire had seven items about Knowledge of Science Content (KSC) regarding Particulate Nature of Matter. It also had seven items about Knowledge of Student Understanding (KSU) of Particulate Nature of Matter. It also had six items about Knowledge of Teaching Strategies (KTS) of how the teacher addresses student misconceptions. For greater content validity, three science education experts were consulted to review the draft questionnaire. This resulted in a *second version* that consisted of ten items about KSC, five items about KTS and five items about KSU. As a result of this consultation, various items were adjusted for easier reading, greater clarity of meaning and literature linkages to improve unclear survey items (Neuman, 2000). The PCK-PNM Questionnaire assumed its *third version* before being administered, after feedback from a panel of experts (2 Science Education specialists, 2 Research specialists, and one Chemistry Education specialist). From the feedback, the number of items was reduced to fifteen: 5 items corresponding to each PCK component, KSC (Items 1 to 5), KSU (Items 6 to 10) and KTS (Items 11 to 15).

The researcher pilot tested the PCK-PNM Questionnaire to 59 randomly selected public school science teachers. A factor analysis using SPSS 23 was then conducted to refine the instrument for greater validity and reliability (Hair et al., 1995; Kline, 1998) before implementing it during the research proper. After securing permit from the Department of Education Division Office of Quezon City, about 150

questionnaires were distributed to science teachers from 10 public schools. Only 59 surveys were completed and collected. Despite the extension given by the researcher, many of the schools were not able to complete the survey due to schedule limitations and busyness of the teachers. The researcher wanted to complete the factor analysis before the start of the Collaborative Teaching intervention. Thus there were limitations in the schedule. With only a small sample ( $N = 59$ ) used for the factor analysis, the following values were adopted to ensure high internal reliability (Zhao, 2009; Costelo & Costelo, 2005): Cronbach alpha set at 0.70 ((Shum, O’Gorman, & Myers, 2006); eigen values at least 1.0; measure of sampling adequacy (MSA) at 0.50 (Hair et al., 1995), communality set at a minimum of 0.40 (Costelo & Costelo, 2005) and factor loading set at 0.50 (Hair et al., 1995). Using SPSS 23, Cronbach alpha was found to have an acceptable value at 0.883 and MSA at 0.773. Communalities were higher than 0.40 for all the items except for Item 11 (0.395). Three factors whose eigen values are higher than 1 (Hair et al., 1995) were retained - Factor 1 (5.962), Factor 2 (1.985) and Factor 3 (1.172) which account for 60.8% of the variance. Factor loading for the 15 items are higher than 0.50 except for Item 6, Item 8 and Item 10, which were dropped (Table 3.3). Items 1 to 5 form the first factor, Items 11 to 15 form the second factor and Items 7 and 9 form the third factor. This confirms the intended PCK components of KSC, KTS and KSU based on literature. The final items included are indicated in Table 3.3. The researcher decided to retain item 11 since its factor loading is still within the acceptable level 0.5 (Hair et al., 1995) and when rounded off, has a communality of 0.40 (Costelo & Costelo, 2005).

Table 3.3

*Factor loading results of factor analysis*

<b>PCK-PNMQ Items</b>	<b>Factor 1</b>	<b>Factor 2</b>	<b>Factor 3</b>
<b>Item 1</b>	0.700		
<b>Item 2</b>	0.863		
<b>Item 3</b>	0.755		
<b>Item 4</b>	0.728		
<b>Item 5</b>	0.560		0.655
<b>Item 6</b>			-
<b>Item 7</b>			0.812
<b>Item 8</b>			-
<b>Item 9</b>			0.593
<b>Item 10</b>			-
<b>Item 11</b>		0.556	
<b>Item 12</b>		0.537	
<b>Item 13</b>		0.716	
<b>Item 14</b>		0.833	
<b>Item 15</b>		0.716	

## *2. PCK about PARTICULATE NATURE OF MATTER OBSERVATION RUBRIC*

*(PCK-PNMOR; See Appendix C)*. The researcher developed a PCK Rubric to help assess the PCK of the participants while they are teaching. This rubric based from literature (Marshall & Smart, 2010; Turner, 2011; Gardner & Gess-Newsome, 2011; Aydeniz & Kirbulut, 2012), is designed to complement the PNM-PCK Questionnaire. Three Science education specialists, two research experts and one Chemistry education expert reviewed and critiqued the instrument. Based on their comments the instrument was revised accordingly. A formal pilot testing was not done but the researcher showed versions of the instrument to at least three colleagues for their inputs. While PCK-PNMQ is based on written responses from the teachers, PCK-

PNMOR is based on observing the teachers in a real classroom situation as they teach PNM lessons.

PCK-PNMOR rates the teacher's PCK components of Knowledge of Science Content, Knowledge of Student Understanding and Knowledge of Teaching Strategies as "Novice", "Emergent", "Proficient" and "Advanced". The teachers are evaluated along twelve items in each category rating. Thus, the maximum score is 48 while the minimum score is 12.

3. *TEACHER INTERVIEW QUESTIONNAIRE (TIQ; See Appendix B)*. Interview questions were used at the beginning of the study to gather information about the participants. The information about the participants helped establish the similarity or equivalence of the two groups of teachers - Conventional and Collaborative Teaching groups. The data from TIQ also served as a second source of baseline PCK of the teachers. The interview was planned to be semi-structured and audio/video recorded that lasted 15-20 minutes. To ensure high reliability and validity, three Science education specialists, two research experts and a Chemistry Education expert reviewed and assessed the questionnaire. The final version was refined for greater clarity and easy understanding.

4. *PARTICULATE NATURE OF MATTER ASSESSMENT (ParNoMA; See Appendix D)*. This instrument assessed students' conceptual understanding of the Particulate Nature of Matter principles before (pretest) and after Collaborative Teaching (posttest). Birk and Yeziarski (2006) developed this instrument. The instrument has a reliability with Cronbach  $\alpha = 0.78$  has been found to have no ceiling effect. The originators, Dr. Birk and Dr. Yeziarski gave permission for the researcher to use

ParNoMA. This 20-item test is scored 1 point per item.

5. *PRE LESSON REFLECTION GUIDE (PLRG; Appendix E)*. This instrument is used to determine the thinking of the teacher about the different parts of his or her lesson plan. This instrument also seeks to get snapshots of the teacher's PCK-PNM. As a tool for teacher development, it can help teachers reflect more on his or her planned actions of how best to teach the material and make appropriate changes. Three Education specialists, 2 research experts and one Chemistry education expert reviewed and assessed the questions and appropriate changes were made to improve clarity and ease of reading.

6. *FOCUS GROUP DISCUSSION QUESTIONS (FGDQ; See Appendix F)*. The FGDQ is a set of questions designed to capture the experience of teachers as they went through Collaborative Teaching. It is also meant to get snapshots of the PCK development of the teachers. It also afforded the teachers to reflect on their thinking and practice as they taught PNM concepts. The questionnaire was reviewed and assessed by three Science education specialists, two research experts and one Chemistry education expert for consistency and clarity.

7. *TEACHER POST LESSON INTERVIEW QUESTIONS (TPLIQ; See Appendix G)*. This instrument is designed to get feedback of the teacher right after teaching about how the lesson went. This gave another source of data about the teacher's PCK through self-reflection. The interview focuses on how they address misconceptions of students. It also shows how they ask questions and respond to students' questions. The instrument particularly points if the teacher uses higher order thinking skills (HOTS) type questions to assess students' conceptual understanding

of PNM. The interview also highlighted how the teachers make decisions to change aspects of the lesson plan in response to unforeseen and unique classroom situations. The interview is semi-structured and audio/video recorded that lasted up to 30 minutes. Three Science education specialists, two research experts and one Chemistry education expert reviewed and assessed the instrument for reliability and validity.

8. *STUDENT POST LESSON INTERVIEW QUESTIONS (SPLIQ; See Appendix H).*

This instrument is designed to get the comments and feedback of students about the lesson they just had. This is another source of data about the teachers' PCK and how they interacted with the students during the lesson from the point of view of students. The instrument is designed to document what students learned from the lesson, particularly their conceptual understanding of PNM from that lesson or class. The interview is semi-structured and audio/video recorded that may last up to 30 minutes. Three Science education specialists, two research experts and one Chemistry education expert reviewed and assessed the instrument for reliability and validity.

9. *PRE-POST LESSON DISCUSSION GUIDE (PPLDG; See Appendix I).* This instrument is designed as a guide when the Collaborative Teaching group met for pre and post-lesson discussion, feedback, reflection and revisions after one teacher implements a research lesson. The researcher recorded the responses from the group.

All these instruments were deemed necessary for triangulation in order to ensure more sources of data to capture the teachers' PCK and the students'

conceptual understanding of PNM during the study (Bloor, 1997; Mays & Pope, 2000). For instance, the observations from PCK-PNM Questionnaire were compared with the observations about teachers' PCK from the PCK-PNM Observation Rubric. These two data sources were further corroborated by data from FGD, Teacher Post-Lesson Interview Questions, and Post-Lesson Discussion Guide. Additional observations about their PCK were also derived from the lesson plans submitted by teachers before they taught a class, such as how they were aware about students' possible misconceptions and learning difficulties. The descriptive statistics on teachers' over-all PCK and PCK components (from PCK-PNMQ and PCK-PNMOR) were also used to validate the qualitative data derived from the different sources. The results of ParNoMA, which assessed students' understanding of PNM concepts, were compared with comments of teachers from Post-Lesson Interview Questions, and the Post-Lesson Discussion Guide. Data from these were also corroborated by responses of students from the Student Post-Lesson Interview Questions. The descriptive statistics on students' conceptual understanding of PNM (from ParNoMA) were also used to validate the qualitative data derived from the different sources.

The different instruments were used at appropriate stages of collaborative teaching as shown in Figure 3.2.

## **STAGE 2: Baseline Establishment**

*Stage 2 was the Baseline Establishment Stage.* The goal was to begin to assess and measure the teachers' PCK-PNM and the students' understanding prior to the intervention using the instruments developed in Stage 1. It was also during

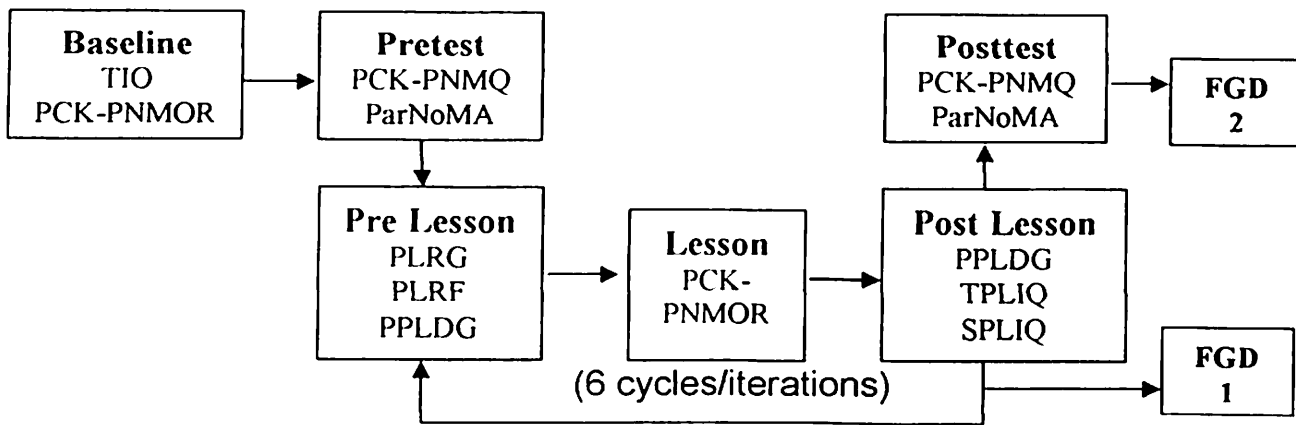


Figure 3.2. A flow diagram indicating when instruments were used.

this stage that the participants were oriented about the research and the CT Process was set-up. Stage 2 took place during the 2nd and 3rd week of October of the 2nd Quarter of the 2015-2016 school year. The pretest using the PCK-PNMQ for teachers and the ParNoMA for students, were done also in Stage 2.

### Gathering Baseline Data

After obtaining a permit to conduct the research from the Department of Education Division Office of Quezon City, the researcher sought the permission from principal of School CT who then tasked the Science Department Head to assist me in my study. He then coordinated with the Science Department Head and Grade 8 Science coordinator to arrange for teacher interviews and classroom observation of the classes. Thus the Grade 8 Science teachers and their students were required to participate in the study based on the principal's memo to the Science Department Head. Pretesting was also done during this time.

1. *Pre-Collaborative Teaching Classroom Observation.* The researcher observed

each of the twelve Science teachers as they taught during the last two weeks of the Second Quarter of School Year 2015-2016. Pictures and videos were taken throughout the class. The PCK-PNMOR developed in Stage 1 was used to evaluate the teachers taking note they were still teaching topics in Unit 3 of Earth Science. The researcher conducted pre-CT classroom observation to become familiar with classroom set-up, locations of the classrooms and the schedule. This also helped the teachers and students to begin getting used to someone coming to their class to observe, take pictures and videos.

2. *Pre-Collaborative Teaching teacher interview.* Each of the twelve participants went through a semi-structured interview using the TIQ developed in Stage 1 which lasted between 15 to 20 minutes. Most of the teachers were interviewed immediately after the class observation. The rest were interviewed at a later time. The researcher recorded the teachers' responses to the interview questions. The interview was done in both Filipino and English.

3. *Pretest of PCK of PNM of teachers.* The teachers' initial PCK about the Particulate Nature of Matter was assessed using the PCK-PNM QUESTIONNAIRE. The Collaborative Teaching group and Conventional Teaching group took the survey together in one room. It took up to an hour for the teachers to complete the questionnaire.

4. *Pretest of the Conceptual Understanding of the students.* The pretest was conducted on the first week of classes of the third Quarter among the students of the participant teachers using the ParNoMA instrument. The researcher planned to conduct the pretesting. However, the teachers preferred to do it in order to complete

the pretesting faster. This way they could start with their discussion of Unit 3 earlier. The researcher acceded to their preference. He pointed out though that they should not help students in answering the questionnaire except when students ask them to translate. The students were given up to 30 minutes to complete the test. The test was marked immediately after the test. The results of the test and the item analysis were submitted to the researcher.

### **Conducting the Research Orientation**

The researcher gave an orientation to the participants in the Conventional and Collaborative Teaching groups. The researcher formally introduced himself to the group. He gave an overview of the research study, which included the title of the research, background, research questions, a brief explanation of the research design, assessment instruments and general methodology. He also presented the suggested timeline (Appendix J) for questions and clarifications. From the input of the Science Department Head, Grade 8 Science coordinator and the teachers, the schedule was finalized. The researcher also gave an overview of what Collaborative Teaching is. This orientation lasted for two hours.

The researcher met the Collaborative Teaching group for another one hour. He discussed in detail the Collaborative Teaching Schedule, the significant roles of participants and researcher in the lesson study (Table 3.4), and guidelines. The guidelines were as follows:

Table 3.4

*Roles and responsibilities of researcher and teachers during the Collaborative**Teaching*

	Researcher	Teachers/Time required
Orientation and Planning the Research Lessons	<p>Facilitates the planning and discussions</p> <p>Act as Knowledgeable Other/ Chemistry expert on PNM</p> <p>Give pretest of PCK-PNMQ</p> <p>Provide ParNoMA pretest forms to teachers</p>	<p>Draft lesson plans assigned to them and give copies to participants (one day; twice during the study)</p> <p>Improve the lesson plan promptly after group discussions and give copies of improved lesson plan to participants (one day; twice during the study)</p> <p>Give ParNoMA pretest to students and submit to researcher with item analysis (one day)</p> <p>Take pretest of PCK-PNM Questionnaire and submit to researcher (one hour)</p>
Pre and Post Discussions	<p>Facilitate the discussion</p> <p>Act as the Knowledgeable Other/Chemistry expert on PNM</p> <p>Provide Pre-Lesson Revision Form (PLRF)</p> <p>Provide Pre-Post Lesson Discussion Questions (PPLDQ)</p>	<p>Attends all pre and post lesson discussions (14 meetings; 2 hours each meeting)</p> <p>Provide feedback and suggestions to improve the research lesson plan and implementation (during meetings)</p>
Pre Lesson	<p>Confirm class schedule and room (laboratory room or regular classroom)</p> <p>Provide copy of Pre-Lesson Reflection Guide (PLRG)</p>	<p>Inform/remind researcher which classroom to be used (2-3 times during the study)</p> <p>Submit completed PLR Guide and PLPR Form (one day; twice during the study)</p> <p>Provide copies of improved lesson plan to participants/observers (one day; twice during the study)</p>
Lesson Implementation	<p>One of the observers</p> <p>Provide copies of PCK-PNMO Rubric to observers</p> <p>Take videos and pictures</p>	<p>Implement improved lesson plan (2-3 class sessions; 1 hour each)</p> <p>Observe; evaluate the PCK of teacher using PCK-PNMO Rubric (2 class sessions; 1 hour each)</p> <p>Make additional notes about the teacher, students and implementation (during observation)</p>
Post Lesson	<p>Interview teachers and selected students</p>	<p>Randomly select 3 students for interview (twice during the study)</p> <p>An interviewee (2 times; 20 minutes each)</p>
Focus Group Discussion	<p>Facilitate the discussion and give input when needed</p> <p>Take video or audio of FGD</p> <p>Give Post-test of PCK-PNMQ</p>	<p>Attend the FGD; Contribute actively to the discussion (2 meetings; 2 hours each)</p> <p>Take Post-test of PCK-PNM Questionnaire and submit to researcher (1 hour)</p>

1. The participants from the two groups are not supposed to interact and discuss the research amongst them. This was difficult in their context considering that all twelve belong to the same Science unit under the leadership of Teacher CT, the Grade 8 Science Level coordinator.
2. The schedule should be followed strictly. The teachers should inform and discuss with the researcher any changes in the schedule for greater coordination. Teacher CT, the Grade 8 Science Level coordinator, was a key person identified who will coordinate directly with the researcher regarding schedule matters.
3. The students of the participating classes will be reminded to refrain from discussing their lesson experiences with those of other students from the other classes.
4. Teachers should not discuss the questions covered by ParNoMA prior to the posttest.

### **STAGE 3: Collaborative Teaching Intervention**

*Stage 3 was the Research Proper Stage.* During this stage, the Collaborative Teaching group went through Collaborative Teaching. This took up to 6 weeks (4 weeks of actual Collaborative Teaching with some interruptions). Data about the effect of CT on teachers' PCK and students' understanding of PNM was gathered and monitored.

#### **Unit Planning**

The Collaborative Group teachers met to come up with a unit plan and

decided on six research lesson plans corresponding to the six activity lessons from the DepEd's Learner's Material, Grade 8 Science (2013). They also reviewed the unit and module goals stated in the new K-12 curriculum. These goals were clarified and reworded to make them easier for students (and teachers as well) to understand. They also discussed how the goals connect to the purposes of the research. Highlighted in the unit planning (unit on Matter of Grade 8, K to 12 curriculum) were the following guidelines:

1. The unit and module goals should be clear to teachers and for students. They should be able to explain the properties of solids, liquids and gases based on the particle nature of matter. They should be able to explain physical changes in terms of the arrangement and motion of atoms and molecules. They should be able to demonstrate understanding of the particle nature of matter as basis for explaining properties, physical changes, and structure of substances and mixtures.
2. Lesson plans should address the misconceptions of the students about Particulate Nature of Matter
3. Lesson plans should be patterned after Activity 1 to Activity 6 of DepEd's Learner's Material, Grade 8 Science (2013).
4. Competencies specified in the new K to 12 Grade 8 Science curriculum should be included.

### **Collaborative Teaching Proper**

The six teachers worked together to plan the lessons, implement, revise for

better implementation and then repeated the process one more time. Each research lesson went through three revisions. Revision 1 was when the group discussed the lesson plan before Implementation 1. Revision 2 happened when the group did post lesson discussion after Implementation 1. Revision 3, which is the final one, happened when the group did another post lesson discussion after Implementation 2. The format used was based on a Lesson Study conducted by de la Cruz et al. in a public high school, SY 2003-2004 (de la Cruz, Magno, & Punzalan, 2013):

*CT Cycle 1:* Teacher A prepared Learning Activity 1 lesson plan, improved it after group discussion and then taught it to her Section 1 class. Teacher F improved Learning Activity 1 lesson plan after post lesson discussion by the group and then taught it to her Section 43 class. A final version was done after another post lesson discussion.

*CT Cycle 2:* Teacher C prepared Learning Activity 2 lesson plan, improved it after group discussion and taught it to her Section 18 class. Teacher D improved Learning Activity 2 lesson plan after post lesson discussion by the group and then taught it to his Section 20 class. A final version was done after another post lesson discussion.

*CT Cycle 3:* Teacher E prepared Learning Activity 3 lesson plan, improved it after group discussion and then taught it to his Section 21 class. Teacher B improved Learning Activity 3 lesson plan after post lesson discussion by the group and then taught it to her Section 18 class. A final version was done after another post lesson discussion.

*CT Cycle 4:* Teacher F prepared Learning Activity 4 lesson plan, improved it after group discussion and then taught it to her Section 43 class. Teacher A improved Learning Activity 4 lesson plan after post lesson discussion by the group and then taught it to her Section 1 class. A final version was developed after another post lesson discussion.

*CT Cycle 5:* Teacher D prepared Learning Activity 5 lesson plan, improved it after group discussion and then taught it to his Section 20 class. Teacher C improved Learning Activity 5 lesson plan after post lesson discussion by the group and then taught it to her Section 18 class. A final version was developed after another post lesson discussion.

*CT Cycle 6:* Teacher B prepared Learning Activity 6 lesson plan, improved it after group discussion, and then taught it to her Section 15 class. Teacher E improved Learning Activity 6 lesson plan after post lesson discussion by the group and then taught it to his Section 21 class. A final version was done after another post lesson discussion.

The classes selected for the purpose of the CT were morning classes. This enabled the researcher to observe each class in the morning and then schedule a post lesson discussion in the afternoon. The researcher planned for the other teachers to observe the class with him. However, at the most, only two teachers were available to observe due to schedule conflicts. The Science Department head

was invited to be one of the observers but declined due to her very busy schedule. A master teacher joined once to observe one participant teacher.

Each teacher was observed two times as shown in Table 3.5. At least two observers evaluated the PCK-PNM of the teacher using the PCK-PNM Observation Rubric. Right after the class, three randomly selected students were

Table 3.5

*Implementation Assignments of the Collaborative Teaching Group*

CT Cycle	Topic	Implementation 1		Implementation 2	
		Teacher & Section	Observers	Teacher & Section	Observers
1	Activity 1 <i>Which is matter, which is not?</i>	Teacher A Section 1	Teacher B Teacher N Researcher	Teacher F Section 43	Teacher E Teacher A Researcher
2	Activity 2 <i>What is matter made of?</i>	Teacher C Section 18	Teacher A Teacher O Researcher	Teacher D Section 20	Teacher B Teacher A Researcher
3	Activity 3 <i>Are particles of matter moving? What is between them?</i>	Teacher E Section 21	Teacher F Teacher A Researcher	Teacher B Section 15	Teacher A Teacher D Researcher
4	Activity 4 <i>What changes take place when water is left in an open container? in a closed container?</i>	Teacher F Section 43	Teacher E Teacher A Researcher	Teacher A Section 1	Teacher B Researcher
5	Activity 5 <i>What changes take place when water is heated or cooled?</i>	Teacher D Section 20	Teacher B Teacher A Researcher	Teacher C Section 18	Teacher A Researcher
6	Activity 6 <i>What changes take place when ice turns into water?</i>	Teacher B Section 15	Teacher A Teacher D Researcher	Teacher E Section 20	Teacher F Teacher A Researcher

interviewed using the SPLIQ. This semi-structured interview was video/audio

recorded and lasted for 10-15 minutes. After the students, the researcher interviewed the teacher using the TPLIQ. The semi-structured interview was video/audio recorded and lasted for 20-30 minutes. The researcher conducted a mid-Focus Group discussion to get feedback from the Collaborative Teaching group. He wanted to find out how the collaborative teaching was for them so far. He also wanted to ask their suggestions and give room for necessary adjustments. The FGD was audio/video recorded. The Science coordinator and principal were invited to observe the meetings and classes. However, their busy schedules did not permit them to attend the FGD.

### **Summative Data Gathering**

1. *Final Focus Group Discussion (FGD)*. Two days after the last research lesson was taught and reached a final revision, the researcher conducted a final focus group discussion of the Collaborative Teaching group participants. The discussion focused on what the participants perceived to have been the value of Collaborative Teaching for them, what challenges they encountered and how specifically Collaborative Teaching helped develop their PCK. The FGD also focused on the impact of CT on the conceptual understanding of the students. The discussion was video/audio recorded and lasted one hour.

2. *Posttest of PCK-PNM*. All 12 teacher-participants took the PCK-PNM Questionnaire at the same time, two days after the last research lesson was completed. The teacher-participants took up to 70 minutes to complete the questionnaire.

3. *Posttest of ParNoMA*. The students who participated in the pretest of each of the 12 teachers took the ParNoMA test after they completed all the six Learning Activity lessons of Module 1 of Unit III on Matter. Four teachers from Conventional Teaching group completed all six Learning Activity lessons ahead and so had their post-test earlier by three days (1st week of December). The rest of the group along with the Collaborative Teaching group members did the post-test about the same time (early 2nd week of December).

4. *Participant-Teacher Portfolio*. To keep track of and to document the results, the researcher kept a portfolio for each of the twelve teachers. This included interview results using TIQ and post lesson interviews of teachers and their students. The portfolio also included results of Pretest and Posttest PCK-PNM Questionnaire and the results of observation using PCK-PNM Observation Rubric. Lesson plans, Pre Lesson Plan reflections, audio/video recordings, pictures and field notes were also part of the portfolio.

### **Reliability and Validity**

The reliability and validity of the results were established through the following:

1. *Use of comparison group*. The focus of the study was the six teachers of the Collaborative Teaching group and their students. However, the researcher set up a comparison group, the Conventional Teaching group of six teachers and their students. As the Collaborative Teaching group was going through the intervention, the Conventional Teaching group was also teaching their respective classes. The

researcher also used the same multiple sources of data such as classroom observations, semi-structured interviews, focus group discussions, lesson plans, pre-lesson reflection guides and questionnaires to study the Conventional Teaching group teachers' PCK of PNM and their students' understanding of PNM concepts. The changes in the PCK of PNM of the teachers from the Collaborative Teaching group were compared with those of the teachers from the Conventional Teaching group. In a case study, comparing two cases such as the Collaborative Teaching and the Conventional Teaching groups is done in order to develop more complete descriptions and more powerful explanations of the results found for the main case or the Collaborative Teaching group (Merriam, 1998; Meyer, 2005; Turner, 2011). Turner (2011) for instance used a comparison group to establish the impact of *faculty-created undergraduate science reform* courses on the pedagogical content knowledge of in-service teachers. Thus, the PCK of those teachers who underwent the reformed course was compared with the PCK of the comparison group. Comparing the results for the case in study with a comparison group deepens understanding of the data as similarities and differences between the two are identified (Patton, 2002; Lankford, 2010). Thus, using a comparison group is another way to triangulate the findings from analysis of the PCK of PNM of the Collaborative Teaching group. Through the various data sources such as, pre- lesson discussion sessions, lesson plans, observation notes, and FGD's, the researcher was able to validate findings by comparing the data between the two groups (Creswell, 2003).

2. *Triangulation*. The use of multiple sources of data to compare and corroborate results is also known as data triangulation. Triangulation is a technique used to

accurately increase fidelity of interpretation of data by using multiple methods of data collection (Glesne & Peshkin, 1992). Triangulation also includes the strategies of multi-researchers and multi-theoretical approaches (Banning, n.d.). The researcher used triangulation to increase the internal validity of the study (Bloor, 1997; Mays & Pope, 2000). In employing triangulation, the researcher looks for patterns of convergence to develop or corroborate an overall interpretation and picture of the teachers' PCK of PNM (Mays & Pope, 2000). The qualitative data such as classroom observations and semi-structured interviews were cross-referenced with quantitative data from various instruments such as the PCK-PNM Questionnaire and ParNoMA Test. For instance, the rating of teachers' PCK from the PCK-PNM Observation Rubric were corroborated by and compared with teachers' answers and explanations of particular items from the PCK-PNM Questionnaire. Data from PCK-PNMQ about changes in teachers' content knowledge about PNM and changes in teachers' classroom teaching practice were compared with data from the comments of teachers from FGD, Post-Lesson Interview Questions, and Post Lesson discussions. Thus, the consistency of the data sources could be checked through a comparative analysis as case profiles were being developed. The source of data about teachers PCK involved the students as well. Their feedback about the teachers and their classes were used to converge and confirm conclusions being developed by the researcher from teacher data. In the same manner the teachers were another source of data about students' conceptual understanding.

*3. Experts', Specialists' and Peer Review:* Four Science education specialists, two research experts and two Chemistry education experts reviewed and critiqued the

methodology and the different instruments used in this study. The researcher also consulted three peers and colleagues to review and critique the PCK-PNM Questionnaire and PCK-PNM Observation Rubric to further minimize bias.

4. *Member Checking*: The researcher employed member checking. He asked the participants to check, verify and give feedback about the following sources of data that the researcher gathered from each of the participants:

- a. The transcripts from the audio/video interviews and focus group discussions;
- b. The PCK-PNMOR ratings of the teachers.
- c. The PCK-PNMQ Pretest and Posttest scores

The Science Department head and Grade 8 Science level coordinator were consistently being consulted regarding the data being derived from the participants. Copies of the data and results were submitted to the Science Department head and principal for their perusal and feedback as well.

5. *Inter-rater or inter-observer reliability*: Observing the teachers using PCK-PNM Observation Rubric utilized at least two observers. To establish reliability, the ratings were compared and where there were differences, the observers and the researcher validated their respective data and agreed to a common rating. This was done to address the common ratings errors: *error of leniency*, *error of central tendency* and *halo effect* (Borg & Gall, 1989).

6. *Internal Reliability and Validity of Instruments*: The Cronbach alpha were used as a basis to establish the internal reliability of PCK-PNM Questionnaire and ParNoMA. The values were 0.773 and 0.780, respectively. Factor analysis was used also to refine and increase the validity and reliability of PCK-PNM Questionnaire.

## Chapter 4

### RESULTS AND DISCUSSION

*This chapter presents the results of the Collaborative Teaching intervention. It details the impact of Collaborative Teaching on the teachers' PCK and students' understanding of particulate nature of matter. The themes follow the results of constant comparison method employed in analyzing the data. The themes also reflect the components of PCK.*

#### **Data Analysis**

#### **PCK Scoring Rubrics**

The Pretest and Posttest Scores of teachers in the PCK-PNM Questionnaire and the PCK-PNM Observation Rubrics were obtained using a Scoring Rubric. The researcher scored the participants in the pretest and posttest of the PCK-PNM Questionnaire and the PCK-PNM Observation Rubric. The Grade 8 Unit head and another research assistant helped validate the checking and scoring of the PCK-PNM Questionnaire. A teacher who is doing an Activity lesson was rated by two participant teachers, a non-participant teachers and the researcher for the PCK-PNM Observation Rubric.

So far, there is no universally accepted means by which PCK is measured (Friedrichsen et al., 2011). Thus, the researcher developed a rating scale which is only a relative way of differentiating the PCK of teachers. The development of the rating scale was derived from and guided by some examples and models in literature (Marshal et al., 2010; Turner, 2011; Gardner & Gess-Newsome, 2011;

Bahcivan, 2012; Aydeniz & Kirbulut, 2012). The researcher used *holistic scoring* in evaluating open-ended items of the PCK-PNM Questionnaire. The researcher used *analytic scoring* in rating the teachers' PCK of PNM using the PCK-PNM Observation Rubric. Analytical scoring view performance as being made up of many components, provide separate scores for each component. It focuses on several identifiable qualities and more detailed information that may be useful when providing feedback. The analytical approach minimizes bias, allowing for all activities or answers to be remembered and documented as they occurred (Linn, & Miller, 2005; Airasian & Russell, 2008; Issacson, & Stacy, 2008). Holistic scoring and recording reflect an overall impression of performance and results in a single score or grade (Linn & Miller, 2005).

#### 1. PCK-PNM Questionnaire

For the PCK-PNM Questionnaire the scoring rubric is as follow: For Items 1-5, teachers got 4 points for a correct choice and explanation; 3 points for a correct choice but an incomplete explanation; 2 points for a correct answer but explanation has some misconceptions; 1 point for incorrect or no answer with or without explanation will get. For Items 6-10, teachers got 4 points for a complete and correct assessment and explanation of student misconceptions; 3 points for a correct but incomplete assessment and explanation of student misconception; 2 points for an assessment that contain some errors; 1 point for no answer. For items 11-15, the following scoring scheme was used to guide those who corrected the questionnaire,

- a. Response that reflects effective and appropriate teaching strategies about how to address student misconceptions gets 4 points;

- b. Response that reflects sound but insufficient teaching strategies about how to address student misconceptions will get 3 points;
- c. Response that reflects inappropriate teaching strategies will get 2 points;
- d. No appropriate response will get 1 point.

The maximum score is 60 and the minimum score is 15. The scoring is meant to relatively differentiate the responses of the respondents. The researcher adopted the suggestions of Miller et al., (2008) most particularly the use of a holistic scoring rubric and method to increase the reliability. The researcher also adopted the holistic scoring of PCK items used by Bahcivan (2012) in scoring the teachers in the open-ended items of the Pedagogical Electricity Content Knowledge Instrument (PECKI). The instrument by Bahcivan (2012) focused on measuring teachers' Knowledge of Students' Understanding of Electricity (KSUE) and Knowledge of Instructional Strategies (KIS). The choice of using 1 as the lowest score was arbitrary and practical (Marshall, 2010; Aydeniz & Kirbulut, 2011; Gardner & Gess-Newsome, 2011; Bahcivan, 2012). For instance, Gardner & Gess-Newsome (2011) used 0 to 4 in their PCK scoring rubric. Marshall et al. (2010) used a scoring scale of 1 to 4. The choice was practical so that factor analysis is less complicated (Bahcivan, 2012).

## 2. PCK-PNM Observation Rubric .

In the PCK-PNM Observation Rubric, the teacher is evaluated using twelve statements or descriptors for each rating, three for KSC five for KTS and four for KSU (Refer to Appendix 3). The researcher adopted analytical scoring used by Marshall et al (2010) and Aydeniz & Kirbulut (2012) as opposed to holistic scoring used by Turner (2011). This scoring also follows the example of Marshall et al.

(2010) and Aydeniz & Kirbulut (2012). The PCK-PNMOR format and scoring was also influenced largely by the Electronic Quality of Inquiry Protocol (EQUIP), which was developed by Marshall et al. (2010). It is a valid and highly reliable instrument designed to measure the quantity and quality of inquiry-based instruction. This observational protocol consists of 19 indicators forming five constructs (Time, Instruction, Discourse, Curriculum, and Assessment). The EQUIP Discourse scale is comprised of the following factors: questioning level, complexity of questions, questioning ecology, communication pattern, and classroom interactions. In addition to receiving scores on each of these factors, an overall summative score was also assigned for the Discourse scale. The EQUIP is scored using a descriptive rubric. A detailed description is provided on the instrument for each factor for the following levels: (1) pre-inquiry, (2) developing inquiry, (3) proficient inquiry, and (4) exemplary inquiry. With permission from the authors, the researcher patterned the PCK-PNMOR format after the EQUIP instrument. Furthermore, the PCK instruments developed by Turner (2011), Gardner & Gess-Newsome (2011) and Aydeniz & Kirbulut (2012) influenced the use of PCK levels. Turner used holistic scoring in assessing the PCK of the teachers using a PCK rubric. Based on this rubric teachers are rated as having PCK that is: *Novice, Emergent, Proficient* and *Advanced*. Gardner & Gess-Newsome (2011) developed a PCK rubric with the following ratings: *Limited, Basic, Proficient* and *Advanced*. Aydeniz & Kirbulut (2012) developed a PCK instrument called Secondary Teachers' Scientific Pedagogical Content Knowledge (STSPCK). The STSPCK has three categories: curriculum, instruction, and assessment. The participants' responses in each category were rated in each

category based on a scale that ranged from 1-10 with 1 representing the lower level of PCK knowledge and 10 highest level of PCK. The participant gets a cumulative score for each category: curriculum, instruction, and assessment and their PCK are categorized into 1) *Naive PCK*, 2) *Developing PCK*, and 3) *Sophisticated PCK*.

Thus, based on the work of Aydeniz & Kirbulut (2012), Gardner & Gess-Newsome (2011), Marshall et al. (2010) and Turner (2011), the researcher decided to finally adopt the categories, "Novice", "Emergent", "Proficient" and "Advanced." As indicated in the PCK-PNMOR instrument (See Appendix 3), **Novice PCK** rating suggests limited knowledge and understanding of PNM content, no awareness of students' prior knowledge, misconceptions and learning difficulties, and lack of knowledge and usage of appropriate teaching strategies to address students' misconceptions and learning difficulties. **Emergent PCK** rating suggests partial knowledge and understanding of PNM concepts, some awareness of students' prior knowledge, misconceptions and learning difficulties, and limited knowledge and use of appropriate teaching strategies to address students' misconceptions and learning difficulties. **Proficient PCK** rating suggests solid knowledge and understanding of PNM concepts, adequate grasp of students' prior knowledge, misconceptions and learning difficulties, and adequate knowledge and usage of appropriate teaching strategies to address students' misconceptions and learning difficulties. **Advanced PCK** rating suggests in-depth and complete mastery of PNM concepts, solid and in-depth grasp and understanding of students' prior knowledge, misconceptions and learning difficulties, and deep knowledge and excellent usage of appropriate teaching strategies to address students' misconceptions and learning difficulties.

In the PCK-PNMOR, *Advanced* rating was scored "4", *Proficient* was scored "3", *Emergent*, "2", and *Novice*, "1". For instance, if a statement under "Novice" applies to a teacher, he or she gets 1 point for that. If a statement under "Proficient" applies to a teacher, he or she gets 3 points for that. Hence the maximum score is 48 and the minimum score is 12. The over-all rating is as follows:

<b>Cumulative Score</b>	<b>PCK Rating</b>
12-20	Novice
21-29	Emergent
30-38	Proficient
39-48	Advanced

The range is found by subtracting the lowest possible score from the maximum possible score. The difference (36) is divided by the number of PCK ratings (4); thus giving an interval of 8 or 9.

### **Scoring for the ParNoMA Test**

Each item is scored 1 point. Thus, the minimum score is 0 and the maximum is 20 points. The students' scores are evaluated further using the DepEd NAT Achievement Level Description Equivalent that uses the percentage of correct answers:

96% - 100%	Mastered
86% - 95%	Closely Approximating Mastery
66% - 85%	Moving Towards Mastery
35% - 65%	Average Mastery

16% - 34%	Low Mastery
5% - 15%	Very Low Mastery
0% - 4%	Absolutely No Mastery

High School students' competence in science is assessed annually by the Department of Education using the scale above. The researcher used the DepEd scale (Department of Education Memo No. 160, 2012) to assess quantitatively the students' understanding of PNM concepts as shown by their ParNoMA scores.

### **Coding Process**

The data from the interviews, classroom observations, focus group discussions were coded and subjected to horizontal and vertical data analysis. Horizontal analysis refers to instances when teachers and students from the same group were being analyzed for specific aspect of the research question. For instance, the pre and post CT construct of elements and compounds of teachers from Collaborative Teaching group were compared. Vertical analysis refers to instances when teachers and students from the Collaborative Teaching group and those from the Conventional Teaching group were being compared. For instance, changes in the classroom practices of teachers from the Collaborative Teaching group and those from the Conventional Teaching group were compared (Meyer, 2005). The coding process employed the help of NVIVO Software to organize and code the various data sources. The researcher used open coding at the initial stage of coding followed by axial coding utilizing the categories from PCK-PNM components: knowledge of content, knowledge of student

misconceptions/difficulties, knowledge of teaching strategies and methodologies. In axial coding data are pieced together in new ways after initial attempt to organize data. By the continuation of asking question and making comparisons, the inductive and deductive thinking process of relating subcategories to a category is the main emphasis of the axial coding (Kolb, 2012). Axial coding facilitates building connections within categories, both between categories and sub-categories, and thus served to deepen the theoretical framework underpinning the analysis (Fielding & Lee, 1991). From these general concepts or categories, sub-categories or sub-codes were developed, e.g., under teaching strategies are usage of visuals and models. The researcher also used axial coding using categories based on the three elements of the Collaborative Teaching: social, situated and teacher-centered.

### **Comparative Analysis**

The scores of teachers were computed from the PCK-PNM Questionnaire, PCK-PNM Observation Rubric, and ParNoMA Questionnaire. The qualitative analysis consists of documenting the teachers' change in PCK of PNM by analyzing their responses to various instruments like PCK-PNMQ and Pre-lesson Reflection Guide, transcripts of FGD's and interviews, videos and observations using PCK-PNMOR and field notes. These data sources helped capture and illustrate the teachers' PCK of PNM and students' conceptual understanding of PNM. Cross-case analysis was done to compare teachers from the two groups - Collaborative Teaching Group and Conventional Teaching Group. Qualitative analysis of students' conceptual understanding of PNM was done by analyzing and comparing interview

transcripts, and classroom observations (video and field notes) of students and answers to ParNoMA test.

The constant comparative method of analysis was used to code and analyze the various data to establish patterns across the Collaborative Teaching and the Conventional Teaching groups. The Constant Comparative Analysis method is an iterative and inductive process of reducing the data through constant recoding (Glaser & Strauss, 1967). Incidents or data are compared to other incidents or data during the process of coding. This process begins with open coding to develop categories from the first round of data reduction and further reducing and recoding allows possible core categories to emerge (Charmaz, 2001; Glaser, 1978; Glaser & Strauss, 1967; Strauss, 1987). As implied in the use of the term "constant comparison", the researcher initially began coding data for one teacher using the various data sources such as FGD's and interviews. He then compared it with another teacher and produce initial categories as patterns began to emerge. This process of comparing cases was done until final categories or themes were formed that best captured the patterns about the PCK of teachers before and after Collaborative Teaching. The themes that emerged were used to compare the PCK of PNM of teachers from the Collaborative Teaching group with those from the Conventional Teaching group. The same process was done for students as the researcher went through various data sources to capture patterns or themes about the students' understanding of PNM concepts (Creswell, 1998; Kim, 2004).

## **Research Question #1: What changes occurred in the Science teachers' PCK of PNM as a result of Collaborative Teaching?**

### **Changes in the teachers' content knowledge about the particulate nature of matter**

The researcher used the PCK-PNM questionnaire and the PCK-PNM Observation Rubric to assess the content knowledge about PNM of the participant teachers. The themes and topics covered below are the result of constant comparative analysis of data sources notably, the interviews, classroom observations, PCK-PNM Questionnaire and PCK-PNM Observation Rubric. Reducing and recoding of initial codes developed resulted in the final themes and categories used to analyze the teachers' content knowledge about PNM. At the Baseline Stage, the mean PCK-PNM rating of the teachers from Collaborative and Conventional Teaching groups was "Emergent". This means that though they possess basic knowledge and understanding of PNM concepts, they hold misconceptions on a number of Particulate Nature of Matter concepts which includes:

- a. Construct of elements and compounds based on the number of atoms
- b. Water breaks into hydrogen gas and oxygen gas during evaporation and/or melting
- c. Particles of matter stop moving during freezing
- d. Molecular structure changes during phase change

## Teachers' construct of elements and compounds

The dominant teachers' construct of elements and compounds prior to Collaborative Teaching is based on the number of atoms. Data from the PCK-PNM questionnaire, classroom observations and responses in the interview, show that the teachers had perceived elements as monoatomic (only one atom) while compounds as polyatomic (two or more similar or different atoms). This was true for both groups of teacher participants. The following statements were observed to be prevalent among teachers in both Collaborative and Conventional Teaching groups:

*"Examples of element is H and O; H<sub>2</sub> and O<sub>2</sub> are compounds..."*

*"F<sub>2</sub>, H<sub>2</sub>, Cl<sub>2</sub>, Br<sub>2</sub>, I<sub>2</sub> and N<sub>2</sub> are compounds."*

*"Akala ko (I thought...) ozone is compound kasi (because...) O<sub>3</sub>."*

*"Examples of compounds are NaCl, sugar, carbon dioxide and hydrogen gas."*

The results of the PCK-PNM Questionnaire corroborated this observation. Of the ten teacher participants, only one (1) had correctly distinguished an element from a compound. Item 10 (Figure 4.1) gave an indication of the teachers' conception of how to distinguish between elements and compounds. Only this teacher gave a correct and clear distinction between elements and compounds. It is a common conception that teachers associate a single atom to elements while two or more atoms to compounds (Kruse & Roehrig, 2005; Stains & Talanquer, 2007; Gutierrez, 2009).

10. Comment on the student's response to the following questions:

Classify whether the drawing shown in cards below represent only elements, only compounds, or both (elements and compounds) and give a short explanation.

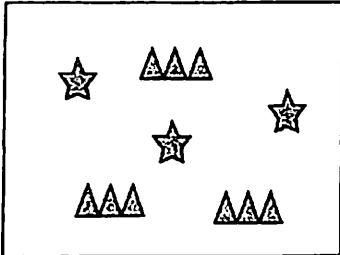


Figure A.  
"Elements and compounds because some are single, others are triple."

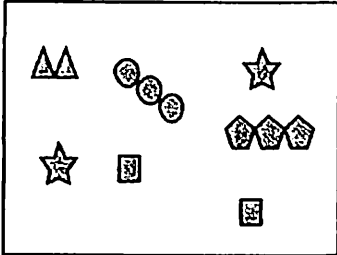


Figure B.  
"Elements and compounds because some are single, others are connected."

Figure 4.1. Item 10 of PCK-PNM Questionnaire.

The following were taken from the responses of teachers from both groups on Item 10 of PCK-PNM Questionnaire:

*"Elements are single and compound are triple, double, etc."*

*"Elements are composed of a single atom while compound is composed of two or more elements."*

*"Elements are in single unit; compound because of 2 or more elements."*

*"Element, monatomic; compound made up of 2 or more elements chemically combined."*

As indicated in their responses to Item 10 of PCK-PNM questionnaire, teacher participants wrongfully constructed an element as a substance that is made up of only one atom while a compound as a substance that contains two or more atoms. This is different from the accepted theoretical construct of element and compound. Distinguishing between an element and a compound is based on whether they can

be decomposed into simpler substances (Gutierrez, 2009). An element is a substance that cannot be simplified to its component substances while a compound is a substance that can be broken down into its simpler substances by chemical means (Silberberg, 2010).

Several studies (e.g. Kruse & Roehrig, 2005; Stains & Talanquer, 2007; Gutierrez, 2009; Sheehan et al., 2015) had also observed similar misconceptions among teachers. They reported that teachers could not recognize molecules that are made up of two or more identical atoms as elements. In the study of Gutierrez (2009), a teacher when asked about her idea of molecule responded “...*if an element then atom and if it is a compound then molecule.*” When asked about molecules being associated with elements, the teacher responded that it could not be since atoms are the ones associated with elements. Stains and Talanquer (2007) report of teachers stating that “*an element cannot be diatomic; it would be a compound*” and “*we call sulfur ( $S_8$ ) an element but it is really a compound.*” Sheehan et al. (2015) reports that about 30% of teachers they studied ( $N=212$ ) could not properly identify substances as compounds or elements.

The teachers' conception of elements and compounds could be attributed to their lack of content knowledge in Chemistry. Some authors point out that teachers who teach outside their discipline have limited or fragmented understanding of the subject (Kruse & Roehrig, 2005; Gess-Newsome & Lederman, 1993; Brickhouse & Bodner, 1992). As indicated in the pre-Collaborative Teaching Interview, the teacher participants were non-Chemistry majors. Most of them are education majors while some of them have pre-service training in Physics and Biology. With a lack of

content knowledge in Chemistry, they find teaching atoms and molecules challenging since they considered both concepts as abstract or invisible to the unaided eye. However, the teachers who are Physics majors expressed relative ease teaching about atoms and molecules because they usually deal with these elementary particles in their discipline more often than in Biology and in Education courses. Like most of the other teachers though, they find teaching chemistry challenging because it is not their major.

It is also possible that the teachers' wrong construct about elements and compounds are ideas they had tenaciously when they were still students. Some authors point out that misconceptions are powerful, extremely persistent and hard to change, creating obstacles to further learning (Canpolat, 2006; Pabuccu & Geban, 2006). Hence, the same misconceptions from elementary and high school may still be carried all the way to the undergraduate and graduate levels (Mulford & Robinson, 2002) and even with those already teaching (Kruger & Summers, 1989; Goodwin, 2000).

Interestingly, the rest of the teachers in the Collaborative Teaching group had corrected their construct of element and compound after implementing the Collaborative Teaching activities. After Collaborative Teaching, the teachers differentiated element from compound based on the kind instead of the number of atoms that they have. Thus, they define element as a matter made up of only one kind of atom, and compound as matter made up of two or more kinds of atoms. Below are some of the changes in the responses of teachers for Item 10 in the posttest of the PCK-PNM questionnaire:

*“They (referring to Figure A and B of Item 10) are elements and compounds because elements are single and compound are triple, double, etc.”(Pretest)*

*“They are all elements because single or bonded, they have the same kind of atom.” (Posttest)*

*“Atoms are for elements while molecules are for compounds.” (Pretest);*

*“Figure A, Figure B represent elements of single atoms, diatomic molecules and triatomic molecules.” (Posttest)*

After post-lesson discussions for Activity 1 and first focus group discussion, teachers from the Collaborative Teaching group had expressed a corrected conception about elements and compounds:

*“Akalako (I thought...) ozone is compound kasi (because...) O<sub>3</sub> so element also even if three atoms.”*

*“Our misconceptions are corrected; not only single atoms are elements also diatomic molecules such as O<sub>2</sub> and H<sub>2</sub> are also elements.”*

It is possible that the series of discussions during Collaborative Teaching helped them clarify the distinction between elements and compounds. In the post-lesson discussion for Activity 1, one teacher stated that her tendency in the past to refer to H and O as elements but not H<sub>2</sub> and O<sub>2</sub> had been corrected:

*“In the past, I refer to H and O as elements. Our misconceptions are*

*corrected. O<sub>2</sub> and H<sub>2</sub> are also elements."*

Thus, she was able to correctly classify hydrogen and oxygen molecules as "elements". The other teachers did similar corrections when asked about molecular elements such as ozone (O<sub>3</sub>), nitrogen (N<sub>2</sub>) and even sulfur (S<sub>8</sub>). After the teachers discussed these concepts during Collaborative Teaching, they correctly identified them as elements despite the number of atoms that these elements contain. The teachers' corrected conception is reflected in their posttest responses for Item 10 of PCK-PNM Questionnaire. One teacher for instance stated during pretest that the students' responses were correct:

*"Both elements and compounds. The 2 figures has a single shape while others are connected to one another."*

In the posttest, she stated,

*"The students are both wrong based on the definition of elements and compounds. Elements are composed of a single kind of element while compound is composed of two or more kinds of elements."*

Conventionally, teaching is a solitary academic endeavor where a teacher prepares, teaches, and makes improvements on his/her lessons alone (Darling-Hammond et al., 2009). However, in Collaborative Teaching, each individual teacher benefits from the collegial collaboration and discussion as to what and how to teach the content (Fullan, 2001; Lin, 2001; de la Cruz et al, 2013; Lucenario, 2013). During

the focus group discussion (FGD) the teachers under the Collaborative Teaching group recognized these benefits when they said:

*"It is because misconceptions are corrected. I am not really a [chemistry] major. Like that of an element; molecule even if three atoms such as O<sub>3</sub> but classified as element not compound"*

*"We share, we help each other how to analyze and understand the given concept if there are misconceptions. What I like about this group the collaboration is we share the ideas, what we have, what our weaknesses, what our strong points."*

These comments reflect the social dimension of Collaborative Teaching where teachers could openly discuss their teaching difficulties and ask their colleagues questions on what and how they taught their lessons. The collegial environment in Collaborative Teaching created a safe environment for mutual learning. Teachers were willing to take the risk of being embarrassed:

*"Gustung-gusto kong matuto sa kanila (I really want to learn from them). May room for improvement, nobody's perfect; natuto ako sa kanila kasi magkakaiba kaming ideas, (I learn from them because we each have different ideas) tulungan talaga, cooperation yung pinakavalue ng collaboration, sharing...(we help each other, cooperation is the value of collaboration, sharing.)"*

In the current study, such collegial and collaborative environment developed a sense of greater freedom among the teachers to admit their lack of understanding about the difference between elements and compounds. According to Lewis (2002), collaborative work shifts the direction from hierarchical or top down to the grassroots level. Learning and training emanates from the teachers themselves. Thus, the comment, “*we can correct each other...*” or “*we help each other...to analyze and understand...concepts*” reflect this collegiality and collaborative environment. The teachers found the post-lesson discussions very helpful instead of fearing to be embarrassed. Feedback, observations and suggestions offered by the group helped them identify their mistakes and areas of improvement.

*“Inoobserve tayo so natitingnan yung strengths and weaknesses natin so yung weaknesses natin naiicorrect ba; naggrogrow tayo naicocorrect natin sa next demo. (We are observed so our strengths and weaknesses can be seen so our weaknesses can be corrected; we grow, we are corrected for the next demo.)”*

Having a context of discussion on how to improve their understanding about the concepts of elements and compounds for the benefit of the students motivated the teachers to correct their misconceptions. As Olson, White, and Sparrow (2011) indicated, having this goal in Collaborative Teaching fuels and motivates the participants to move towards improving and deepening their understanding on what they were teaching. This is evident on what this teacher participant commented:

*“Advantage sa learning ng bata; nagbebenefit yung mga bata. Yung mga*

*concepts pinag-uusapan namin para lalong maimprove the way we teach. May impact sa mga bata; iba talaga yung result kung may collaboration.”*  
*(It is an advantage on the learning of the students; it is the students who could benefit from this. We discussed the concepts to improve the way we teach. This would have an impact on students. The result is something else if there is collaboration.)”*

In contrast, three of the teachers from the Conventional Teaching group retained their construct of elements and compounds (NOTE: Two teachers did not do the posttest of PCK-PNM questionnaire, thus, conclusions drawn during posttest pertain to four teachers only). At the PCK-PNM posttest for instance, the following responses for Item 10 (Figure 4.1) persisted. Their explanation of Figure A and Figure B of Item 10 still referred to drawings with two units or more combined as compounds. Those with one unit were referred to as element.

*“The element is the simplest form of substances while compounds are made up of two or more elements chemically combined”.*

*“Compounds are combination of two or more elements that are connected by bonds.”*

*“Figure B [of Item 10 shown in Figure 4.1] represents both compounds and elements. “*

The foregoing quotes indicate that a few of the teachers still classified diatomic and triatomic molecules as compounds. Canpolat (2006) and Pabuccu and Geban (2006) reported similar observations thus they concluded that misconceptions are powerful, extremely persistent and hard to change (Canpolat, 2006; Pabuccu & Geban, 2006). Canpolat (2006) noted the various misconceptions of undergraduate students about evaporation which many developed when they were younger students. These misconceptions remain as part of the student's thinking about science unless activated and exposed. Pabuccu & Geban (2006) reports similarly about students' misconceptions in relation to chemical bonding. They pointed out the need for students' to be made aware of their inaccurate preconceptions and help them change their non-scientific conceptions toward more scientific ones through the use of explanations and examples. Consequently, the persistence of these misconceptions could create obstacles to further student learning.

### **Teachers' construct on molecular behavior of water during phase changes**

Before Collaborative Teaching, majority of the teachers from both the Collaborative and Conventional groups who completed the PCK-PNM questionnaire held some misconceptions about the behavior of molecules during phase changes. Only three teachers (from Collaborative Teaching group) had a correct construct about molecular behavior during phase changes.

## Water breaks into hydrogen gas and oxygen gas during evaporation and/or melting

Four teachers (one from Collaborative group and three from Conventional group) wrongly thought that liquid water breaks down to hydrogen gas and oxygen gas during evaporation and/or melting. Items 4 and 5 of the PCK of PNM Questionnaire pertain to this construct directly. Items 8 and 12 also pertain to this construct indirectly since the items assess the teachers' pedagogical content knowledge about PNM. Figure 4.2 shows Item 4 where the said teachers chose letter A; implying the breaking of water into hydrogen gas and oxygen gas during evaporation:

4. When water is vaporized, it is changed to
- A. hydrogen and oxygen
  - B. hydrogen only
  - C. gaseous water
  - D. air, hydrogen, and oxygen
  - E. oxygen only

Figure 4.2. Item 4 of PCK-PNM Questionnaire.

One of the teachers' explanation for choosing letter A is as follows:


*"When water is vaporized, it is changed to hydrogen and oxygen. Since heat is involved, the composition of water is changed."*

This explanation shows a lack of understanding of the effect of heat on the molecules during evaporation of water. The Kinetic Molecular Theory states that


heat increases the kinetic energy of particles of liquid causing them to move more rapidly and farther apart. When the energy of the particles is great enough and overcomes the force of attraction holding them in the liquid state, the particles then exists in the gaseous state (Silberberg, 2010). Heat then only affects the intermolecular force of attraction. It does not cause breaking of covalent bonds between hydrogen and oxygen atoms. The responses of teachers to these two sets of items (Items 4 & 5 and Items 8 & 12 of PCK-PNMQ) may corroborate each other. For instance the explanation of the teacher mentioned above for Item 8 (Figure 4.3) reflects the same misconception about phase change:

*“The answer is B. The composition of the particle will be changed after undergoing melting process.”*

A diagram representing water molecules in the solid phase (ice) is shown below.



Which of these diagrams best shows what water would look like after it melts (changes to a liquid)?



A.      B.      C.      D.      E.

*Student 1: B;    Student 2: A    Student 3: E*

Figure 4.3. Item 8 of the PCK-PNM Questionnaire.

Figure 4.4 below shows Item 12 where teachers' explanation may give a clue of their

construct about evaporation of water and particle nature of matter in general.

12. A teacher asked the following questions to her Grade 8 Science class. To her dismay all except five students gave the correct answer. Many answered (d) and a few others (c). Comments on the students' understanding of phase change. How will you help the students develop the right conceptual understanding?

**Key**  
 △ Water  
 ○ Oxygen  
 • Hydrogen

Liquid Water      Evaporated Water

(a)   (b)   (c)   (d)   (e)

Figure 4.4. Item 12 of the PCK-PNM Questionnaire.

One of the teachers' explanation in Item 12 states:

*"D is not the correct answer because it represents elements oxygen and hydrogen alone...The correct answer is A – a mixture of hydrogen gas ( $H_2$ ) and oxygen gas ( $O_2$ )."*

The above observations are a common misconception mentioned in previous studies (Osborne & Freyberg, 1985; Ferido, 1995; Kruse & Roehrig, 2005; Senocak, 2009; Sheehan et al., 2011). Kruse and Roehrig (2005) reported in their study that more than half of chemistry teachers ( $N=45$ ) they tested thought water breaks into its element components during evaporation. Sheehan et al. (2011) reports that at least 30% of pre-service teachers ( $N=212$ ) believed that there is breaking of water into its

elements during evaporation. In these studies, the teachers thought that heat destroys or breaks the covalent bond between hydrogen and oxygen.

The teachers' wrong construct or misconception on water breaking into its elements during phase change may be traced from their lack of a deeper understanding that matter is made of discrete particles (Cosgrove & Osborne, 1983; Kruse and Roehrig, 2005; Merritt, 2010; Tuysuz et al., 2011; Sopandi et al., 2017). Cosgrove and Osborne (1983) concluded in their study that the naïve or undeveloped view that matter is made of discrete particles, lead to other observed misconceptions about phase changes. Tuysuz et al. (2011) reported in their study ( $N=7$ ) that teachers had difficulties in using and explaining both the symbolic and the sub-microscopic levels of representation for phase changes and dissolution while being able to explain these changes at the macroscopic level. This could explain the misconception that teachers hold about evaporation and melting and explanation of these changes. Sopandi et al. (2017) corroborates this in their study of 37 primary teachers where about 80% of teachers had difficulties explaining phenomena verbally and visually at the sub-microscopic level.

It is also possible that the teachers with the wrong construct attributed bulk properties of substances to particles of the substance (Brook et al., 1984; Griffiths & Preston, 1992; Stojanovska et al., 2012). Bulk properties are those that characterize the substance such as size, shape, mass, volume, color and hardness. Thus, the teachers may have also thought that when ice (solid water) melts, its particles are also broken apart like ice breaking apart during melting. Similarly, teachers may think that water splits into hydrogen gas and oxygen gas much like water "split into

millions of tiny micro bits and floated up" (Russel and Watt, 1990). Association with the known fact that water is composed of oxygen and hydrogen can lead to the misconception that water breaks into  $H_2$  and  $O_2$  during evaporation (Osborne & Freyberg, 1985; Ferido, 1995). The misconception can also be attributed to erroneous textbooks. Stojanovska et al., (2012) cited the following erroneous statements from some textbooks:

*"The atom is the smallest particle of a chemical element that retains its physico-chemical properties."*

*"All substances are composed of small invisible particles that possess the same properties as the parent material. These particles are called molecules."*

### **Water molecules stop moving during freezing**

Four teachers (two from Collaborative group and two from Conventional group) held a wrong construct that water molecules stop moving during freezing. This contradicts the Kinetic Molecular Theory of matter which states that particles of matter are constantly moving (Silberberg, 2010).

Data from PCK-PNM questionnaire illustrates the above misconceptions of the said teachers. Item 2 of the PCK-PNM questionnaire asked the question, "*When water at  $24^{\circ}C$  is cooled to  $0^{\circ}C$  and freezes, the water molecules \_\_\_\_\_*". From the ten teachers who completed the PCK-PNM questionnaire, only four teachers (from the Collaborative group) answered correctly letter E, "move much more slowly". Of

the six who answered wrongly, two teachers from the Collaborative group and two teachers from the Conventional group answered letter C, “stop moving”, one teacher from the Conventional group answered letter A, “become less organized” and one teacher from the Conventional group answered letter B, “move much faster”. Studies show that students and teachers alike share this misconception (Kruse & Roehrig, 2005; Senocak, 2009; Nuic & Glazar, 2015; Ozalp & Kahveci, 2015). There is a lack of understanding among these teachers that particles are always in motion even under freezing condition.

It is possible that when the teachers visualize the atoms of solids as maintaining fixed positions, they understand it to mean that these atoms are stationary. While the atoms of solids are in fixed position, they vibrate and hence are still moving. The Kinetic Molecular Theory states that molecules are in constant motion even at freezing point. Their speed is dependent on their average kinetic energy. The average kinetic energy is dependent in turn on temperature (Silberberg, 2010). The misconception may also be attributed to teachers’ ascribing bulk properties to the particles (Stojanovska et al., 2012; Merritt, 2010; Brook et al., 1984) as stated by the teachers’ explanation below.

*“The answer is C. Since it (water) freezes, the molecules will stop moving.”*

*“The water molecules start to crystallize.”*

Ice is observed as solid compact and not “moving,” thus the teachers concluded its

molecules must not be moving, too. The teachers may have some knowledge of crystallization where solids form from solution; hence, the association that the water molecules will cease moving once crystallization takes place. According to Nussbaum and Novick (1981) misconceptions that occur at the sub-microscopic level can also be due to everyday experiences which may not necessarily be consistent with scientific concepts. Barke et al. (2009) pointed out that learners use what they observe in the world around them to “form intelligent ideas about the world.” Thus, it may be easier for teachers to conclude that liquid water particles are constantly moving since from everyday experience liquid water flows; and hence moving. It may also be easier for teachers to think that water vapor particles are constantly moving since gases such as smoke or steam can be seen moving. However, solid water is seen as compact and does not show apparent movement; thus, they conclude water particles in a solid do not move.

After Collaborative Teaching, the three teachers from the Collaborative Teaching group corrected their misconceptions about the behavior of particles during phase change. For instance, in the PCK-PNM posttest, Teacher D described evaporation as a change of liquid water to gaseous water that does not alter the molecular structure of water. In the posttest, Teacher D changed his answer to letter C, “gaseous water” instead of letter A, “hydrogen and oxygen”. The following typified their description of evaporation such as found in Items 4, 8 and 12:

*“There is no re-arrangement of atoms nor creation of new atom that took place in evaporation. The particles just changed their arrangement only or the space they occupied. There is no chemical nor nuclear change that took*

*place.”*

Teacher E corrected his misconception that water molecules undergo molecular change during evaporation:

*“The liquid particles change to gas particles. The K.E. of the particles is increasing as temperature increases. The particles of water are apart and remains as water in gas form we call water vapor.”*

There is marked improvement in the teacher’s explanation of what evaporation is; that it is a physical change (“remains as water in gas form”) and not a chemical change (change in molecular structure). Teacher D and Teacher F corrected their misconception that water molecules stop moving during freezing. Teacher F’s explanation at posttest also changed:

In the Pretest: *“As molecules freeze, the molecules stop moving.”*

In the Posttest: *“When water is cooled, the heat energy is removed from the water molecules as a result of which they have less kinetic energy and move more slowly.”*

The Collaborative Teaching group may have benefitted from collegial discussions about possible confusion and misconceptions among students (Hammond & McLaughlin, 1995; Meyer, 2005). As pointed earlier, the teachers from the Collaborative group stated that their discussions such as FGD help them gain better conceptions of what they were supposed to teach:

*"It is because **misconceptions** are **corrected**."*

*"We share, we **help each other** how to **analyze and understand the given concept** if there are **misconceptions**."*

Through the iterative pre-lesson and post lesson discussions on PNM concepts, the teachers were able to correct their wrong constructs about the behavior of particles during phase change. Cognitive theories describe learning as changes in an individual's schema as they make their own ideas visible (for example, PNM concepts) and experience conflict between one's own ideas and ideas from colleagues, students, the curriculum, or other sources (Doerr and English 2006; Remillard and Bryans 2004; Hashweh 2003). The teachers improved their content knowledge as they anticipate and examine student conception (of PNM, in this instance). This is consistent with previous studies that show how teachers improve in their understanding of content as they collaborate in order to ensure that the lesson plan addresses students' misconception (Austria et al., 2013; de la Cruz et al., 2013). Moreover, as the teachers reflected together on their teaching, they were able to surface ideas about PNM concepts and use these as a vantage point to examine and revise their individual thinking (e.g., Chazan et al. 1998; Jacobs et al. 2007; Sherin 2002; Warfield et al. 2005).

After Collaborative teaching, they understood the following: (1) that water molecules do not change in size or separate into hydrogen and oxygen and (2) that molecules continue to move even during freezing. More importantly, these enabled them to guide students in correcting similar misconceptions. Table 4.1 summarizes

the change in the teachers' misconceptions.

Table 4.1

*Teachers' corrected misconceptions about phase changes of water*

PRIOR MISCONCEPTIONS	CORRECTED CONCEPTIONS
1. Water breaks into H <sub>2</sub> and O <sub>2</sub> during evaporation and/or melting.	1. Water does not break down into its elements during evaporation. Evaporation is only a physical change.
2. Particles stop moving during freezing.	2. Particles do not stop at freezing; particles of matter are in constant motion.
3. Molecular structure changes during phase change	3. Molecular structure does not change during phase change; phase change is a physical change.

The improvement in the teachers' construct regarding the molecular behavior during phase change, demonstrated that they have undergone conceptual change. It is not sufficient for learners to hear the correct scientific conception in order to change long-held misconceptions or so-called the naïve view of scientific concepts (Ferido, 1995). Posner et al. (1982) stated four conditions that need to be met for conceptual change to happen illustrated in Figure 4.5:

(1) Dissatisfaction – the individual must realize that there are inconsistencies and that his or her way of thinking does not solve the problem at hand. The individual cannot explain phenomena using his or her current conception.

(2) Intelligibility – the individual must find the new concept intelligible and making sense to him that he or she is able to explain it to others.

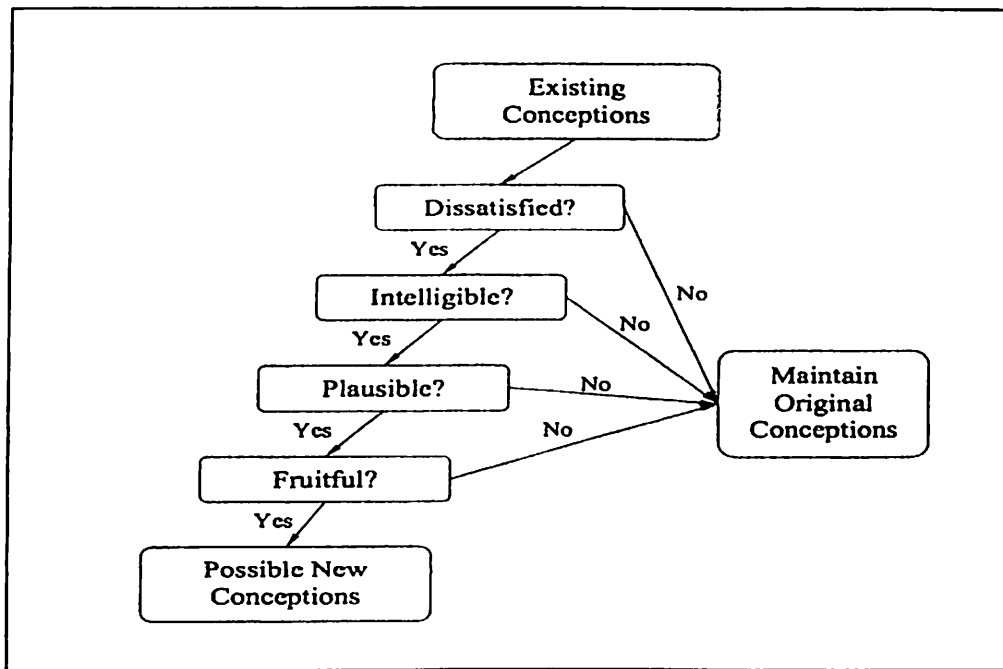


Figure 4.5. An illustration of Posner et al.'s Model of Conceptual Change (adapted from Dole & Sinatra (1998).

(3) Plausibility - the individual must find the new concept plausible in that it makes more sense than the former concept. The individual must be able to see how the new concept fits into his current understanding and conception.

(4) Fruitfulness – the individual must find the new concept fruitful in that it can be extended to other context and open up new areas of inquiry.

Figure 4.5 illustrates how conceptual change could have happened to the teachers. The regular feedback of fellow teachers throughout the Collaborative Teaching intervention caused the teachers with misconception about PNM to realize inconsistencies in his or her understanding of PNM conception (dissatisfaction). As they also observed other teachers teach PNM concepts, the teachers were afforded time to reflect on their own construct about PNM. Through group discussions, the

teachers made sense of the collective corrections and suggestions towards more accurate constructs about the behavior of particles during phase changes (intelligibility). During classroom observations, the teachers were also able to observe fellow teachers apply the improved conceptions in addressing students' misconceptions (plausibility). Finally, the teachers saw how their corrected conceptions and constructs helped the students to gain better understanding of PNM concepts (fruitfulness).

These results and observations are consistent with previous studies (de la Cruz et al., 2013; Lucenario, 2013; Poekert, 2012; Meyer, 2005). The studies done by de la Cruz et al. (2013) and Lucenario (2013) show that teachers improved in their conceptual understanding of chemistry following Lesson Study. The study of Lucenario (2013) focused on concentrations of solution. Cruz et al. focused on elements and compounds, acids and bases, organic and inorganic compounds and homogenous and heterogenous mixtures. In his study, Poekert (2012) showed that teachers improve their teaching when they undergo collaborative professional development. He reports that teachers improved their ability to provide instructional support and foster student engagement. His study also provides evidence of specific changes in teacher practice by documenting the shift in teacher abilities to facilitate higher-order thinking, provide feedback, and stimulate language development. Meyer (2005) showed in her study that teachers improve their content knowledge of mathematics after they have undergone Lesson Study.

The teachers from the Conventional Teaching group also demonstrated improvement in their PCK-PNM Questionnaire results. Teacher G, Teacher H and

Teacher I improved their understanding of evaporation. In the posttest of the PCK-PNM Questionnaire, they answered C (gaseous water) instead of A (hydrogen and oxygen) or B (hydrogen only) for Item 4. They also improved in how they explained their answer. Below is a typical posttest explanation:

*“When water is vaporized, the molecules of water is [are] changed to gaseous water; molecules of water is [are] still the same.”*

Teacher H answered B instead of D in Item 5. She also corrected her explanation for Item 5 (*“A pot of water on a hot stove begins to boil rapidly. A glass lid is placed on the pot and water droplets begin forming on the inside of the lid. What happened?”*) as follows:

*In the Pretest: “The answer is D. Hydrogen and oxygen combined to form water. During evaporation, the water is separated into hydrogen and oxygen and during condensation, they are combined.”*

*In the Posttest: “During boiling process, water absorbed heat so it changes from liquid to gas. These gas molecules (steam) condenses on the lid during the cooling process which make the water molecules to move close to other water molecules.”*

While the explanation of Teacher H can still be refined, it reflects a more accurate conception of condensation of water. It is possible that the teachers benefitted from the instructional material used that emphasized activity-based, learner-centered and

inquiry-based learning. Studies show that instructional materials have a positive effect on teachers' practice (Singer et al., 2000; Eya, 2004; Eya, 2006; Usman & Adewumi, 2006). Usman and Adewumi (2006) stated that instructional materials, particularly, activity-based and learner-centered, help the teacher overcome physical limitation during presentation of subject matter. Eya (2004) states further that instructional materials enable the teacher to have an "air of guidance, coordination, supervision and more time for correction, brighten the classroom and bring variety in the class lesson". Eya (2006) further noted that effective activity-based instructional materials include such things as experimentation, demonstration, task instruction and project method. Singer et al. (2000) state that instructional materials are educative for teachers. They added that instructional materials that are inquiry-based and learner-centered help teachers engage students and increase student learning.

However, the misconception of Teacher H and Teacher I about the molecules stopping their motion during freezing persisted. As pointed out earlier, misconceptions could be extremely persistent and difficult to change (Canpolat, 2006; Pabuccu & Geban, 2006). To change long-held misconceptions require more than just the learning about the correct scientific conception (Ferido, 1995). Without the benefit of feedback by fellow teachers, group discussion among colleagues, and an affirming environment afforded by Collaborative Teaching, Teacher H and Teacher I from the Conventional Teaching group, retained their misconception about the motion of particles. There was no feedback of fellow teachers that could have led someone to realize inconsistencies in his or her PNM conception (dissatisfaction).

They did not have the benefit of group discussions and collective corrections and suggestions more accurate constructs about the behavior of particles during phase changes (intelligibility). These teachers did not also observe fellow teachers apply the improved conceptions especially in addressing students' misconceptions (plausibility). Finally, these teachers did not experience how the corrected conceptions and constructs helped students gain better understanding of PNM concepts (fruitfulness).

These results with the Conventional Teaching group are consistent with earlier studies in which teachers who did not participate in collaborative professional development showed less improvement in their teaching compared to those who participated in collaborative professional development (Lucenario, 2013; Poekert, 2012). For instance, while Teacher D and Teacher F from Collaborative Teaching group corrected their misconception about movement of water particles during freezing, Teacher H and Teacher I from the Conventional Teaching group retained their misconception. The posttest results of the PCK-PNM Observation Rubric of the Collaborative Teaching group improved from "*Emergent*" to "*Proficient*". The rating of the Conventional Teaching group remained as "*Emergent*" in the posttest. Table 4.2 shows a portion of the PCK-PNM Observation Rubric illustrating how the teachers from the Collaborative Teaching group improved in their content knowledge about PNM concepts.

Table 4.2.

*A Portion of the PCK-PNM Observation Rubric*

Advanced	Proficient	Emergent
<input type="checkbox"/> Responses and actions showed COMPLETE MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes	<input type="checkbox"/> Responses and actions showed AVERAGE MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes	<input type="checkbox"/> Responses and actions showed LOW MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes
<input type="checkbox"/> Used language that is COMPLETELY ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Used language that is MOSTLY ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Uses language that is SOMEWHAT ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes
<input type="checkbox"/> Used AT LEAST THREE appropriate, accurate examples of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase	<input type="checkbox"/> Used TWO appropriate, accurate examples of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Uses ONE POTENTIALLY appropriate, accurate example of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes

**Teachers' level of explanation about phase changes of matter**

Items 1 to 5 of the PCK-PNM Questionnaire (Appendix 1) are multiple-choice questions that measure Knowledge of Science content about PNM. The teachers were asked to give a short explanation for their answers to know the depth of the teachers' understanding of PNM concepts. For items 6-10, they were also asked to comment on students understanding of PNM concepts. For Item 11-15, the teachers

were asked what they would do in the given situation to help students gain understanding of PNM concepts.

To determine the level of explanation of the teachers about phase changes, their explanations for Item 1 (on evaporation), Item 2 (on freezing) and Item 5 (on condensation) were analyzed for consistency with the Kinetic Molecular Theory (KMT). KMT explains the relationship of temperature, heat, kinetic energy of particles to the forces of attraction between particles, the movement of particles and the space between particles during phase change (Silberberg, 2010). Their explanations were also analyzed according to levels of representation in chemistry – macroscopic, sub-microscopic and symbolic. Evidences of connections between these levels in their explanation were also noted. Studies show that acquisition of chemical concepts is enhanced when learners are able to use all three levels of representation and make meaningful connections between the levels (Adadan, 2006; Tuysuz et al., 2011; Thadisson, 2011; Milencovic et al., 2014). Johnstone (1993) pointed out that chemistry concepts such as PNM could be described at three levels – macroscopic, sub-microscopic and symbolic. At the macroscopic level, learners describe scientific concepts and phenomena based on that which is observable such as the melting of ice, change in color or liquid water changing to steam (Hinton & Nakhleh, 1999; Silberberg, 2010; Tuysuz et al., 2011). At the sub-microscopic level, learners describe scientific concepts and phenomena based on the behavior of particles such as molecules and atoms. Stating that water molecules move faster than the molecules of solid water is a sub-microscopic representation. At the symbolic level learners describe scientific concepts and phenomena using

pictures, numbers, symbols and mathematical manipulations such as using “H<sub>2</sub>O” to represent water (Hinton & Nakhleh, 1999; Treagust, Chittleborough & Mamila, 2003; Wu, 2003).

## Evaporation

In Item 1 (Figure 4.6), the teachers were supposed to explain why the water molecules move farther apart during evaporation. Before Collaborative

Item 1: When water at 25°C is heated and changes to a gas at 110°C, the water molecules

- A. become more organized.
- B. move farther apart.
- C. stop moving.
- D. move closer together.
- E. move more slowly.

Figure 4.6. Item 1 of the PCK-PNM Questionnaire.

Teaching, all ten teachers from both groups, chose the correct answer, letter B. One teacher from the Collaborative Teaching group explained at the macroscopic only. Four teachers (two from each group) used the sub-microscopic level in their explanation. Five teachers (three from Collaborative Teaching group and two from the Conventional Teaching group) used both macroscopic and sub-microscopic levels of representation in their explanation. Five teachers (three from the Conventional Teaching group and two from the Collaborative Teaching group) used the KMT in their explanation. Below were some of the teachers' explanations:

Macroscopic:

*“At temperature of 100°C or higher, liquid water changes to steam (or gas).”*

Sub-microscopic:

*"The water molecules became excited and moved rapidly."*

*"The molecules of water move farther apart when it reached the gaseous state."*

Macroscopic, Sub-microscopic

*"Liquid water changes to gas molecules that move apart at 100°C."*

Sub-microscopic; with KMT aspect

*"The molecules became excited when heated."*

*"When water undergoes boiling process, the kinetic energy increases, therefore the molecules will move farther apart."*

Macroscopic, Sub-microscopic; with KMT aspect

*"Molecules of water disorganized, increase in entropy because of increased KE and increased heat. Water changed from liquid to gas."*

*"Once liquid water is heated it changes to gas. Gas molecules are far apart compare to liquid. When particles gain energy it tends to move."*

The first sample explanation is at macroscopic level since it deals with what is observable to the senses (Hinton & Nakhleh, 1999; Silberberg, 2010; Tuyuz et al., 2011) – liquid water turning to steam or gaseous water. The second sample explanations are at sub-microscopic level because the teachers described the

behavior (excited, moved rapidly) of the molecules of water. The third sample explanation was at macroscopic and sub-microscopic level. However, a closer look though at this explanation shows a misconception. **Liquid water** (substance; macroscopic) is referred to as turning to **gas molecules** (particle; sub-microscopic). Some studies have shown that this is a common PNM misconception where learners confuse the macroscopic substance with that of the sub-microscopic particle such as molecules and atoms (Griffiths & Preston, 1992; Chittleborough et al., 2002; Stojanovska et al., 2012). This kind of misconception may arise as learners associate common everyday experience to scientific phenomena (Griffiths & Preston, 1992; Stojanovska et al., 2012) such as boiling water in a pan and seeing steam or liquid water turning to ice in a freezer. The fourth and fifth sample explanation also used both macroscopic (e.g. "water changed from liquid to gas") and sub-microscopic ("molecules ... disorganized") levels. Some studies point out that the use of all three levels of representation is needed for a full understanding of chemical concepts (Johnstone, 1993; Hinton & Nakhleh, 1999; Tuysuz et al., 2011; Milenkovic et al., 2014). Moreover, they pointed out that it is important to establish conceptual relationships among these levels for deeper understanding of chemical concepts. Only five of the ten teachers (three from the Collaborative Teaching group and two from the Conventional Teaching group) used both macroscopic and sub-microscopic levels of representation and thus are moving towards what is ideal. However, looking closely at these explanations, shows that there is no conceptual connection between the levels (Hinton & Nakhleh, 1999; Tuysuz et al., 2011). For instance, the relationship of the statement "*Water changed from liquid to gas*"

(macroscopic) with the statement, "*Molecules of water disorganized, increase in entropy because of increased KE and increased heat*" (sub-microscopic) is not clear. The other statement, "*Once liquid water is heated it changes to gas*" (macroscopic) shows some conceptual link with the sub-microscopic part of the explanation, "*Gas molecules are far apart compare[d] to liquid...*" The first statement emphasizes the change of state, i.e. liquid to gas. The next statement compares the distance between molecules of gas and molecules of water. Still, these explanations can be improved by particularly applying the KMT. For teaching and learning chemical concepts the integration between levels is important to facilitate understanding of chemical concepts (Milenkovic et al., 2014). The study of Milenkovic et al. (2014) demonstrates that a teaching strategy which emphasizes the interplay between the three levels of representation, leads to an increase in students' performance. In addition, their study shows that the integration among the levels makes it easier for students to handle the cognitive load.

Only five teachers reflected reference to KMT. Analysis of the teachers' statements that included KMT aspects shows the following understanding of KMT in relation to evaporation:

- (1) Increased heat causes evaporation to take place ("*Once liquid water is heated it changes to gas*").
- (2) The increase in the movement of particles was associated with increased heat and kinetic energy ("*The molecules became excited when heated; When particles gain energy it tends to move*").
- (3) Increased KE and increased heat causes molecules in liquids to become

disorganized (*"Molecules of water disorganized...because of increased KE and increased heat"*).

(4) Increased kinetic energy causes the particles to move farther apart (*"...the kinetic energy increases, therefore the molecules will move farther apart"*).

(5) The distance between particles of gases are larger (or farther) compared to those in liquids (*"Gas molecules are far apart compare to liquid; When water undergoes boiling process...the molecules will move farther apart"*).

Interestingly, none of the teachers described the forces of attraction between particles and how they are affected when the water molecules are heated. This is a key aspect of the KMT. Their explanations are also not very clear that increased heat causes the average kinetic energy of the molecules to increase which eventually leads to the breaking of the liquid particles into the gaseous phase. The relationship between increased temperature, heat, and kinetic energy are not clearly presented. There could also be some misconception here about the organization of particles in liquids when the teacher stated, *"Molecules of water disorganized...because of increased KE and increased heat"*. The particles of liquid already possess some degree of disorganization unlike those of solids. These indicate that while teachers possess some knowledge about KMT they could not explain conceptually what happens during evaporation.

These aforementioned responses of teachers are consistent with what previous studies (Chang, 1999; Valanides, 2000; Goodwin 2003; Senocak, 2009; Govender et al., 2016) have indicated that teachers could not accurately and fully explain evaporation. Chang (1999) for instance reported that more than 50% of

participant teachers from Taiwan thought that bubbles during boiling of water contained air. Valanides (2000), in his study of 30 pre-service teachers, showed that more than half had difficulty explaining evaporation accurately. Only five of these teachers were able to explain evaporation in terms of molecules “moving faster and bouncing farther apart”. Ten of the teachers even thought that during evaporation, the molecules themselves expand. Eight believed that evaporation leads to breaking the covalent bonds between hydrogen and oxygen. Govender et al. (2016) analyzed in their study the conceptual maps about gas behavior generated by 27 pre-service teachers preparing to teach Physical Science. They concluded that the teachers have superficial understanding of gases and KMT. Representations were mostly at the macroscopic level. Tuysuz et al. (2011) reported in their study ( $N=7$ ) that teachers had difficulties in using and explaining both symbolic and sub-microscopic levels for phase changes and dissolution even though they could make explanations at the macroscopic level. However, even if the teachers in the current study could make sub-microscopic representations, these contain some incorrect constructs. Moreover, the sub-microscopic and macroscopic representations are not connected showing that although the teachers have some awareness of these representations, they are unable to hold them in their focal awareness simultaneously (Govender et al., 2016). Some authors point out that the difficulty of teachers to use and integrate the different levels correctly may be linked to their misconceptions about the particulate nature of matter (Stojanovska et al., 2012; Ben-Zavi & Gai, 1994). Some studies also show that teachers educators and researchers may have retained many chemical misconceptions that may not necessarily been corrected despite years of

studying science and teaching preparation (Kruger & Summers, 1988; Kokkotas & Hatzinikita, 1994; Sheehan et al., 2011; Stojanovska et al., 2012). Teachers' difficulty using the different levels and making connections between them may also be due to their limited understanding of KMT (Sande, 2010; Govender et al., 2016).

After Collaborative Teaching, teachers from the Collaborative Teaching group improved in their level of explanation of evaporation in terms of the levels of representations and KMT. Explanations moved more towards the sub-microscopic level incorporating more KMT concepts. Thus, the number of teachers that included KMT into their explanation increased from two to five teachers. The following are some of their explanations:

*"The molecules of water will gain more kinetic energy that at some point will break the attractive force between them causing them to move farther from each other."*

*"Heat causes the rise in the kinetic energy of the water molecules making them move faster and farther apart."*

*"The liquid particles changes to gas particles...the kinetic energy of the particles is increasing as temperature changes".*

The explanations focused more on the sub-microscopic level of representation. This is important since this level is crucial for a meaningful understanding of chemical phenomena and processes. Neglecting it represents the basis for the formation of

various students' alternative conceptions (Stojanovska et al., 2012; Milenkovic et al., 2014). There is now mention about the force of attraction between particles. The relationship between temperature, heat, and kinetic energy, movement of particles and distance between particles are logically and sequentially clearer. Various authors point out that deeper understanding of chemical concepts means that learners are able to relate macroscopic representation to the sub-microscopic and symbolic (Chittleborough & Treagust, 2008; Al-Balushi, 2012; Milenkovic, 2014). The starting point towards learning chemical concepts starts with the macroscopic level wherein students describe evaporation as liquid water turns to steam. Learners eventually should be able to move towards the sub-microscopic such as explaining evaporation in terms of the particles of water. Chittleborough (2014) used the "rising iceberg" to represent this process. The visible part of the iceberg diagram represents the domain of learner's understanding of the concepts being learned. It grows, as the learner's understanding is moving towards sub-microscopic and symbolic representations. In the case of the teachers in this study, their explanations moved towards microscopic level after Collaborative Teaching intervention. The two misconceptions earlier identified with the teachers' explanation were also corrected. Thus, the teacher who mentioned that heat causes molecular structure to change corrected his misconception. The tendency to confuse the macroscopic substance with the sub-microscopic particle is also gone.

The teachers from the Conventional Teaching group also showed improvement. All four teachers moved towards a more sub-microscopic level of representation in their explanations. All incorporated the KMT into their explanations.

The following were their explanations:

Macroscopic, Sub-microscopic; with KMT aspects:

*"When water is heated, the water molecules vibrate faster which separate them from other molecules. The kinetic energy increases when liquid water is changed to gaseous water."*

Sub-microscopic; with KMT aspects:

*"When water molecules are heated or absorbed heat, its particles move farther apart because they move faster."*

*"Molecules of water gained more kinetic energy when heated."*

*"If there is an increase in the temperature, particles of water move faster and have more energy. Since it is in gaseous form the particles are apart."*

Though they incorporated KMT, a closer look at their explanations shows however the following in the posttest of the PCK-PNM Questionnaire:

(1) The logical relationship between increased temperature, heat, kinetic energy of particles and their movement is still not clearly demonstrated. For instance, in the statement, *"If there is an increase in the temperature, particles of water move faster and have more energy"* the increase in the speed of the movement of particles and their energy are not clearly stated. The concept that the movement of the particles is influenced by their kinetic energy is not explicitly stated. It is possible that the explanation could lead to the misconception that increased energy of particles is the result of particles moving faster.

(2) There is still no mention of forces of attraction between molecules.

(3) Some portions of the explanation may lead to potential misconception. For instance, the statement, "*The kinetic energy increases when liquid water is changed to gaseous water*" may be interpreted that kinetic energy increases only when the particles become gaseous. According to KMT, kinetic energy of particles increase due to increase in temperature. The statement, "*Since it is in gaseous form the particles are apart*" may show a misconception that particles are only apart in gaseous state. The particles are apart in all states since there are spaces in between particles for all states.

### Freezing

In Item 2 (Figure 4.7), the teachers were supposed to explain why water molecules move much more slowly when cooled to its freezing point. Only six of the ten teachers chose the correct answer, letter E (move much more slowly).

- Item 2: When water at 24°C is cooled to 0°C and freezes, the water molecules
- A. become less organized.
  - B. move much faster.
  - C. stop moving.
  - D. break apart.
  - E. move much more slowly.

Figure 4.7. Item 2 of the PCK-PNM Questionnaire.

Four teachers (two from the Collaborative Teaching group and two from the Conventional Teaching group) answered letter C (stop moving). One teacher from the Collaborative Teaching group explained freezing at the macroscopic level only. Nine teachers incorporated sub-microscopic level in their explanations. Three

teachers from the Collaborative Teaching group used both macroscopic and sub-microscopic levels in their explanations. Below are the groups' explanations:

Macroscopic:

*"When water hits 0°C...it will just release energy until it freezes. During that time the temperature remains at 0°C."*

Sub-microscopic:

*"The molecules of solid are compact and very close to each other that's why they move much more slowly."*

Macroscopic, Sub-microscopic:

*"When the water freezes it will change from liquid to solid. Solid has molecules that are close to each other and moves slowly."*

*"The water molecules are closer and formed the ice crystal formation."*

Sub-microscopic; with KMT aspects:

*"Molecules of water organized because of increased enthalpy, decreased entropy, because of decreased KE and decreased heat."*

*"When water freezes the molecules move more slowly because heat energy is decreased and transferred to the environment."*

It is noteworthy that almost all the teachers were able to explain freezing at the sub-microscopic level. As was pointed above, the ability to explain concepts at the sub-microscopic level is critical for teaching and learning chemical concepts

(Stojanovska et al., 2012; Milenkovic et al., 2014). It is also an indicator of deepening understanding of chemical concepts (Chittleborough & Treagust, 2008; Al-Balushi, 2012; Milenkovic, 2014). The teachers exhibited generally a good grasp of the sub-microscopic level of representation as they described the behavior of particles of water during freezing. There is also indication that they know freezing of water as a change from liquid water to solid water or ice, which is simply a macroscopic description of freezing. However, only two teachers (one from the Collaborative Teaching group and one from the Conventional Teaching group) explained freezing in terms of using KMT concepts. However, even if their explanations use macroscopic and sub-microscopic levels of representation, there is no integration between levels. For instance, the following statement at the sub-microscopic level, *“When the water freezes it will change from liquid to solid. Solid has molecules that are close to each other and moves slowly”* does not really explain how liquid water changes to solid (macroscopic level). The same can be said of the statement, *“The water molecules are closer and formed the ice crystal formation”*. It does not clearly show how the water molecules moving closer (sub-microscopic level) results in the formation of ice crystals (macroscopic level). Some authors point out that integration between levels is challenging for students and even teachers (Hinton & Nakhleh, 1999; Tuysuz et al., 2011; Thadison, 2011; Govender et al., 2016). The teachers’ explanations also show their limited knowledge of KMT:

- (1) There is no mention about forces of attraction between particles and how they are affected when the temperature goes down which is a key aspect of KMT.
- (2) Their explanations that decreased heat causes the average kinetic energy of the

molecules to decrease and eventually leads to the liquid particles to move into the solid phase is not very clear. For instance, in the statement, "*When water freezes the molecules move more slowly because heat energy is decreased and transferred to the environment*" the effect of decreased heat on the kinetic energy of the water molecules was absent.

(3) The conceptual relationship among the following is not very clear: of the decrease in temperature, heat, and kinetic energy of particles, forces of attraction and distance between particles. For instance, in the statement, "*Molecules of water organized because of increased enthalpy, decreased entropy, because of decreased KE and decreased heat*" the relationship between decreased heat and kinetic energy is not specified.

(4) There could also be some misconceptions about the spaces between the particles in solids when the teacher stated, "*molecules of solid are compact*". This is a misconception among students and teachers mentioned in past studies (Cosgrove & Osborne, 1983; Kruse and Roehrig, 2005; Sopandi et al., 2017). There is also the misconception that molecules stop moving at freezing. These were discussed more fully in the previous section. The other possible misconception is the use of the term "crystallization" and "crystal." While freezing of water is classified as crystallization, not all crystallization is due to freezing. Crystallization is a more general term referring to the formation of crystals from a uniform liquid or solution, typically a supersaturated solution (Silberberg, 2010). Crystallization does not necessarily happen at low temperature or freezing temperatures such as those during precipitation reactions.

The above observations show that the teachers from both groups possess some knowledge about KMT. However, it is not yet fully extensive to give a conceptually correct explanation of freezing. This observation is supported by a previous study by Senocak (2009) where about 40% of a group of teachers ( $N=60$ ) could not explain fully and accurately the freezing of water. Sopandi et al. (2017) reports that more than 50% of the pre-service teachers ( $N=37$ ) are not able to explain freezing at the submicroscopic level verbally. These teachers were categorized as having partial understanding only, or have misconceptions or do not understand freezing at all.

After Collaborative Teaching, the teachers from the Collaborative Teaching group improved in the level of explaining freezing. All six teachers reflected the sub-microscopic level in their explanations. Before Collaborative Teaching, three teachers explained in a more macroscopic level. The ability to use sub-microscopic level of representation is an indicator of deepening understanding of freezing (Chittleborough & Treagust, 2008; Al-Balushi, 2012; Milenkovic, 2014). After Collaborative Teaching all teachers incorporated the KMT in their explanations. Before CT, only one teacher used KMT in explaining or describing freezing. Using KMT to explain freezing may further indicate that the teachers improved in their conceptual explanation of freezing (Milenkovic, 2014; Govender et al., 2016). Below are representative explanations of teachers:

*“When water...cooled to 0°C, the kinetic energy of the molecules decreases making them move much more slowly but not to the point that they stop moving because particles of matter is[are] always in motion.”*

*“When water is **cooled** the **heat energy** removed from the water molecules as [a] result of which they have **less kinetic energy** and **move more slowly**.”*

*“Since **cooling** is a process of **releasing heat**, the **kinetic energy** becomes **lower** causing them to **move closer** and **slower**.”*

The misconception about the particles of water as not moving at freezing was corrected as discussed above. Moreover, the relationship between temperature, heat, kinetic energy, movement of particles and distance between particles are more clearly and logically described. For instance the following statement, *“Since **cooling** is a process of **releasing heat**, the **kinetic energy** becomes **lower** causing them to **move closer** and **slower**”* describe the temperature (*cooling*), heat energy (*releasing heat*), kinetic energy (*kinetic energy...lower*), distance between particles (*move closer*) and movement of particles (*slower*). One thing not included in the statement is about the forces of attraction between particles.

The teachers from the Conventional Teaching group explained freezing at the sub-microscopic level of representation just as how they did it before Collaborative Teaching. The big change is the use of KMT in explaining freezing. From only one teacher in the pretest, all four teachers used KMT in the posttest. Below are their explanations:

Macroscopic; with sub-microscopic; KMT aspects:

*“Since the **temperature is decreased**, water is changed from liquid to solid, and since it reached its **freezing point**, the molecules will **move much more**”*

*slowly.*"

Sub-microscopic; with KMT aspects:

*"Particles with less energy will stop moving when it reaches 0°C/freezes."*

*"Removal of heat makes the water molecules to move slowly until it reaches freezing point."*

*"When water molecules cooled, it releases heat and its particles move slowly."*

The use of KMT to explain freezing could indicate that the teachers have improved in the level of explaining freezing (Milenkovic, 2014; Govender et al., 2016). A closer look at their explanations that there are pieces of evidence that they could use Kinetic Molecular Theory in explaining freezing:

- (1) Decrease in temperature causes molecules to move slower. For instance, this is clear from the statement, *"Removal of heat (or decrease in temperature) makes the molecules to move slowly..."*
- (2) Decrease in temperature and release or removal of heat are related (*When water molecules cooled, it releases heat...*).
- (3) Lower kinetic energy affects the movement of particles (...less energy... stop moving...).

However, there is still no mention about the forces of attraction between particles just like in the pretest. There is also no mention regarding the distance between particles. The relationships between temperature, heat, kinetic energy,

movement of particles, force of attraction between particles and distance between them are not clearly described just like in the pretest. The misconception about the particles not moving during freezing is still not corrected. The statement, "**Removal of heat makes the water molecules to move slowly until it reaches freezing point**" may imply that the particles stop moving eventually once freezing point is reached. These are indicators that the teachers' knowledge of KMT is still not fully developed (Govender et al., 2016).

### Condensation

In Item 5 (Figure 4.8), the teachers were expected to explain the formation of water droplets on the inside of the lid of a pot. Essentially, they need to explain what condensation is about in the context of the situation given. Seven teachers from both groups answered correctly, letter B. Two teachers from the Conventional Teaching group answered D. One teacher from the Collaborative Teaching group had no answer. Two teachers from the Collaborative Teaching group had no explanations. Three teachers (One from the Collaborative Teaching group) used macroscopic level in their explanation. Five teachers (two from Collaborative Teaching group

5. A pot of water on a hot stove begins to boil rapidly. A glass lid is placed on the pot and water droplets begin forming on the inside of the lid. What happened?
- A. The lid became sweaty.
  - B. Steam cools and water molecules moved close together.
  - C. Water from outside leaked into the pot.
  - D. Hydrogen and oxygen combined to form water.
  - E. Steam combined with the air to wet the inside of the lid.

Figure 4.8. Item 5 of the PCK-PNM Questionnaire.

and three from the Collaborative Teaching group) gave their explanation at the sub-microscopic level in their explanation. Below are some of their explanations:

Macroscopic:

*“Evaporation is the process where the water turns to vapor or gas.”*

*“Gaseous water condenses.”*

Sub-microscopic:

*“The molecules become less excited and **move much more slowly.**”*

*“As steam **cools**, water molecules **move slowly** and **form into liquid molecules.**”*

Sub-microscopic; *with KMT aspects:*

*“Condensation took place where gas water molecules **cooled** due to **decreased temperature** and **decreased heat** turned molecules to be organized **decreased in KE** molecules **more closer.**”*

*“**Removal of heat** makes the gas molecules to **move slowly.**”*

Most of the teachers focused their explanations on condensation. Three of these also incorporated the assumptions of KMT. Only two teachers focused on evaporation such as, *“Evaporation is the process where the water turns to vapor or gas.”* Perhaps they referred to the initial part where water boils and produces the steam that condenses on the lid. However, these two teachers failed to give a complete explanation since Item 5 is more about condensation (*“Steam cools and*

*water molecules moved close together*"). It is noteworthy though that most of the teachers (six of the eight with explanations) were able to explain freezing at the sub-microscopic level. As was pointed above, this can be an indicator of a deepening understanding of chemical concepts (Chittleborough & Treagust, 2008; Al-Balushi, 2012; Milenkovic, 2014). The teachers demonstrated their general knowledge that condensation of water is a change from gaseous water to liquid water, a macroscopic description of condensation such as the statement, "As **steam cools**,  $H_2O$  molecules move slowly and **form into liquid molecules**." The explanations at the sub-microscopic level generally describe particle behavior correctly that during condensation (1) particles are cooled (2) particles move slowly or closer. These observations are consistent with studies that teachers are generally able to explain many chemical concepts such as phase changes at both the macroscopic and sub-microscopic level (Hinton & Nakhleh, 1999; Treagust, Chittleborough & Mamila, 2003; Wu, 2003; Tuysuz et al., 2011). However, the explanations do not describe clearly why the water molecules moved closer to each other. There is a need to use the KMT to explain further what happened. However, only two teachers (one from the Collaborative Teaching group and one from the Conventional Teaching group) incorporated KMT concepts. Of these, only one teacher specified about kinetic energy and distance between particles. There is no mention about force of attraction between particles. Thus over-all the teachers' explanations were inadequate to account why the particles moved closer. These observations are consistent with studies on teachers' difficulty to explain at the sub-microscopic level, and particularly use the KMT to explain phase changes such as condensation (Govender et al.,

2016; Stojanovska et al., 2012; Guzel & Adadan, 2012; Valanides, 2000; Chang, 1999). Chang (1999) for instance reported that among pre-service teachers more than 50% held various misconceptions about condensation such as white “smoke” rising from the water kettle is gaseous water or air condenses into water when cooled. The teachers’ explanations about condensation in this current study contained misconceptions. The primary one was about their understanding that condensed water is the result of hydrogen and oxygen combining (*“Hydrogen and oxygen combined to form water. During evaporation, the water is separated into hydrogen and oxygen and during condensation, they are combined”*). This may be a consequence of the misconception that water breaks into its component elements during evaporation (Brook et al., 1984; Griffiths & Preston, 1992; Stojanovska et al., 2012). This was discussed in the previous section above.

After Collaborative Teaching, all six teachers from the Collaborative Teaching group indicated the correct answer (letter B; “Steam cools and water molecules moved closer together”). This time all these teachers gave their respective explanations unlike in the pretest, where two teachers failed to give their explanations. Two teachers explained at the macroscopic level. Three teachers explained at the macroscopic and sub-microscopic levels. More teachers (three teachers compared to only one before CT) incorporated KMT aspects in their explanation. One teacher explained at the sub- microscopic level only. Below are their explanations:

Macroscopic:

*“The process is **condensation**. The **vapor/steam** coming from boiling water*

*cools down and changes to liquid phase."*

*"When the glass lid is placed on the pot and water droplets begin forming, steam cools because it is undergoing the process of condensation."*

Sub-microscopic:

*"Evaporation is cooling effect so the molecules are being condensed."*

Macroscopic, Sub-microscopic; with KMT aspects:

*"The steam undergoes condensation. The gaseous water turned into liquid.*

*The vapor released heat which cause the particles to move closer forming the liquid."*

*"...molecules moved closer together...When steam touches the glass lid, the water vapor interacts with the glass lid which is at a lower temperature making the water vapor to condense and moved closer together."*

*"The glass is cooler than the boiling water so some of the heat energy of the vapor molecules are transferred to the glass, in effect, cooling the water vapor."*

The teachers were able to describe and explain condensation in greater detail.

Using KMT the teachers attempted to explain further the following:

(1) The reason steam cools was that because the glass lid was cooler or at a lower temperature (*"When steam touches the glass lid, the water vapor interacts with the glass lid which is at a lower temperature..."*)

(2) Condensation of water involves cooling the water vapor ("**vapor/steam** coming from boiling water **cools** down...").

(3) Particles moved closer together after water vapor is cooled or because of the decrease in temperature (*water vapor interacts with the glass lid which is at a **lower temperature** making the water vapor to condense and **moved closer together**...*).

(4) When gaseous particles (water vapor) are cooled, they lose heat energy ("*The glass is **cooler** than the boiling water so some of the **heat energy** of the **vapor molecules** are transferred to the glass...*").

(5) The relationship among temperature, heat, and distance between particles are conceptually connected.

Overall then, the teachers' explanation about condensation improved especially as they incorporated aspects of KMT. However, there is no mention about kinetic energy and movement of the particles. There is still no mention about the force of attraction between particles. One teacher has a misconception that the cooling that caused water vapor to condense was due to evaporation. During evaporation, the particles at the surface of the liquid with enough kinetic energy escape as water vapor particles. By removing these higher energy particles, the average energy of all the remaining water particles reduces; hence the cooling effect (Silberberg, 2010). Clearly, the teacher confused this endothermic process that is taking place at or near the surface of the boiling water with the cooling due to the colder glass lid.

After Collaborative Teaching, the teachers from the Conventional Teaching group also showed improvement in their level of explanation for condensation. All

indicated the correct answer (letter B). Two teachers explained at the macroscopic level. One explained at the sub-microscopic level. Another teacher gave explanations at both levels. Two explanations incorporated different aspects of KMT.

Macroscopic:

*“Gaseous water cannot escape on the pot its tendency is to cool forming water droplets.”*

*“Water in gaseous phase condensed and turns to liquid water again.”*

Sub-microscopic: with KMT aspects:

*“When gaseous water cools down its movement become slower, molecules move closer together forming liquid water.”*

Macroscopic, Sub-microscopic; with KMT aspects:

*“During boiling process, water absorbed heat so it changes from liquid to gas. These gas molecules (steam) condenses on the lid during the cooling process which releases heat and make the water molecules to move closer to other water molecules.”*

The explanations reflect a proper understanding of condensation at the macroscopic level. Gaseous water cools down and turns into liquid water. Two teachers were able to explain further what happens during condensation at the sub-microscopic level and used some aspects of KMT aspects. They included the following detail:

(1) Particles move closer to other particles due to the cooling down of gaseous water

or when particles lose heat.

(2) Particles slow down due to the cooling down of gaseous water or when particles lose heat.

(3) The relationship among temperature, heat, movement of particles and distance between particles are conceptually connected.

As in the Collaborative Teaching group, there is no mention about kinetic energy and about the force of attraction between particles. There is also no mention about the kinetic energy of the particles. The misconception about hydrogen and oxygen combining to form the water droplets was corrected.

The above observations and results indicate that the teachers' level of understanding of phase changes were initially limited, sometimes inaccurate or fragmented. Thus, their description and explanation of evaporation, freezing and condensation were inadequate and contain misconceptions. These are consistent with earlier studies indicating that teachers who are non-majors in science demonstrated a more limited and fragmented understanding of the science concepts they teach (Gess-Newsome & Lederman, 1993; Kruse & Roehrig, 2005). Kruse & Roehrig, (2005) highlight for instance that the lack of science background among such teachers (such as the case of those in this study) could lead to superficial teaching of concepts or to a lack of depth in explaining science concepts. One teacher involved in their study sums up this issue:

*"I just don't have the conceptual framework of chemistry enough at this point. I feel I am just building the kind of content knowledge that I need. It's not even really the content knowledge, I mean I know chemistry, but knowing and*

*teaching are two different things.”*

Some of the participant teachers expressed the same sentiment:

*“I am not really a Chemistry major. I thought ozone or hydrogen are compounds.”*

*“Among the topics in Grade 8 Science, I find Chemistry difficult because it is abstract. It is hard to imagine molecules and atoms. Chemistry is not my major.”*

The positive impact of Collaborative Teaching are consistent with previous studies that show that teachers' knowledge of representation of phase changes improved after going through collaborative teacher development (Kokkotas et al., 1998; Van Driel & De Jong, 1999; Ulep et al., 2013; Govender et al., 2016). In the study of Van Driel and De Jong (1999), teachers (N=12) improved their PCK particularly the knowledge of integrating macroscopic and sub-microscopic representations related to PNM as a result of mentoring, discussion with other teachers and classroom experience. The study by Kokkotas et al. (1998) showed that teachers (N=70) corrected their conceptions and gained deeper understanding of PNM concepts by discussing, reflecting and learning with fellow teachers. In the study by Govender et al. (2016), teachers (N=27) improved their understanding of behavior of gases and KMT by working with fellow teachers in developing their concept maps about behavior of gases and KMT.

The improvement of the teachers' level of explanation of phase changes, are supported by other sources of data. For instance, one of the teachers' comments about students' understanding of phase changes reflects better knowledge of sub-microscopic representation of phase change along KMT:

*"They do not know that particles are continually moving even if they are packed the particles are still moving, minimal for solid, faster in liquid and fastest for gas, there are spaces in between particles. They thought solids are super compact that there are no spaces in between particles. In melting and freezing they could not explain what happens to the particles during phase changes and how they can represent the states of matter in kinetic molecular theory they could not explain initially when matter absorbs heat that it can move faster."*

Her comments show deeper grasp of PNM concepts and phase change such as about the distance between particles and their movement during freezing and melting. There is an apparent understanding of how KMT applies to phase change such as the constant motion of particles in all states and how heat affects the speed of the movement of particles. Other teachers commented about behavior of particles during melting, freezing and evaporation

*"In melting and freezing they [students] do not know how to describe what happens to the particles, how to represent each state of matter; that of the spaces in solid they thought only particles of liquid and particles of gas move. They also thought that if heat is absorbed the chemical bond is broken."*

*“Phase changes, physical change according to the students. Students initially thought particles or molecules of water, hydrogen and oxygen separate but later became clearer. They were able to correct that if water undergo phase change nothing happens to the bond between the atoms. Students said atoms of hydrogen and oxygen do not separate.”*

*“They do not know that particles are continually moving; even though they are very close to each other, they are still moving but minimal for solid, for liquid faster; another is that there are spaces in between particles. They thought that solids are super-compact and no spaces in between particles; then in melting and freezing they do not know how to describe what happens to the particles, how to represent each state of matter; that of the spaces in solid, they thought only particles of liquid and particles of gas move. They also thought that if heat is absorbed the chemical bond is broken.”*

The improvement indicates that teachers' conceptual understanding of phase changes improved. This is consistent with previous studies indicating that collaboration among teachers helps improve their conceptual understanding (de la Cruz et al., 2013; Lucenario, 2013). As teachers participated in repeated pre and post lesson discussions, their misconceptions are corrected. Their understanding of PNM concepts deepened as each lesson is discussed and reviewed. They also acquire additional inputs about the topics they teach through feedback and suggestions from other participants who observed them during classroom

observations. They further got more information as they observe how other teachers taught. Teachers commented,

*"We are continually corrected. There is continuity so learning process is improved continually. It is wonderful. We were informed and transformed."*

*"We help identify overlooked concepts. We discuss concepts."*

Hence, it is plausible that it is easier for teachers to experience conceptual change in a reflective environment (Posner et al., 1982) such as that afforded by Collaborative Teaching. The improved conceptual understanding happens also as teachers anticipate and reflect on students' conceptions and misconceptions (Meyer 2005).

The results of the PCK-PNM Observation Rubric also support the improvement of the teachers' level of explanation after Collaborative Teaching. The Collaborative Teaching Group's mean PCK-PNM rating at posttest improved from "Emergent" to "Proficient". This improvement in the PCK rating parallels that which was observed in previous studies where PCK of teachers improved after being involved in collaborative professional development (Cerbin & Kopp, 2006; Goodnough, 2010; Khan & Halai, 2011; Ulep et al., 2013). These studies demonstrate teacher improvement in many areas besides PCK and more particularly in the content knowledge of the teachers.

## Changes in teachers' classroom teaching practice

Before Collaborative Teaching intervention, the teachers from both groups used lecture, very few visuals and limited technology based on classroom observation done before the first activity lesson. At the beginning of the Collaborative Teaching intervention the teachers used **lecture** and **reporting** by students as primary teaching strategies. A few teachers used **concept mapping** to review what students know about classification of matter. However, they did not use specific strategies to help students gain deeper understanding of PNM concepts. Initially, the teachers did not use visuals, **models** or representations to help students understand PNM concepts such as spaces between particles of matter. There was limited use of **technology**. It was used only to show the procedure of the Activity Lesson. These observation was consistent with the teachers' responses to Items 11 to 15 in the PCK-PNMQ, where they were expected to propose the teaching strategy best suited to address the given classroom situation described. Practically all teachers cited a more lecture-based approach in Items 11 to 15. One teacher from the Collaborative Teaching Group mentioned the use of using model for Item 11. Another teacher from the Collaborative Teaching Group cited the use of model for Item 15.

Towards the end of Collaborative Teaching, the teachers from the Collaborative Teaching group began shifting to more use of visuals, models, technology and interactive strategies. The creative strategies and tools used by the teachers included games ("4 pics, "one word" and puzzles) and interactive group activities ("Human Particle Activity"). The teachers also used artwork, models,

Predict-Observe-Investigate, videos and slide presentations. Some teachers used colorful liquids, sweets for the freezing activity, concept mapping, think-pair-share, jigsaw puzzle, mind-splatter, and music. Figure 4.9 shows the Human Particle Activity. In this activity the teacher asked students to simulate the particles of matter in different states, solid, liquid and gas. It may also be used to demonstrate phase changes. Figure 4.10 shows students playing a game.



*Figure 4.9.* Human Particle Simulation activity to illustrate states of matter.



*Figure 4.10.* Using a game for Activity 2 to review concepts.

Table 4.3 compares the teaching strategies used during the early stage of Collaborative Teaching and towards the end. Analysis of teachers' posttest responses in the PCK-PNMQ show a general shift towards use of model, interactive activities and even HOTS questioning among teachers from the Collaborative

Table 4.3

*Teaching strategies during the early and later stage of Collaborative Teaching*

<b>Before and Early Stage of CT</b>	<b>Latter Stage of CT</b>
<ol style="list-style-type: none"> <li>1. High utilization of lecture</li> <li>2. Very limited usage of technology; one used his laptop to show a short video</li> <li>3. Very little interactive strategies; two teachers used group activity</li> <li>4. Experiments/Lab activity as dictated by the curricular materials</li> <li>5. Class demonstration of experiment/activity due to apparent lack of space and time.</li> <li>6. Discussion/ Q&amp;A</li> </ol>	<ol style="list-style-type: none"> <li>1. Minimal use of lecture</li> <li>2. High usage of models/drawings about particle nature of matter</li> <li>3. Games (e.g. 4 Picture, One Word)</li> <li>4. Use of music</li> <li>5. Simulation activity (e.g. Human Particle)</li> <li>6. Asking Higher Order Thinking Skill (HOTS) questions</li> <li>7. Arts: drawing, story, colorful liquids</li> <li>8. Predict-Observe-Investigate</li> <li>9. Use of technology e.g., videos</li> <li>10. Concept mapping</li> <li>11. Jigsaw puzzle</li> <li>12. Think-Pair-Share</li> <li>13. Mind Splatter</li> <li>14. Use of sweets to demonstrate freezing</li> <li>15. Experiments/Lab activity as recommended by curricular materials</li> <li>16. Discussion/ Q&amp;A</li> </ol>

Teaching Group. All six teachers mentioned the use of models; three mentioned the use of interactive activity such as games; one teacher mentioned the use of HOTS questioning. The four teachers from the Conventional Teaching Group retained a

lecture-based response for most of the items. One teacher mentioned the use of model for Item 14 and another mentioned the use of model in Item 13 and 15.

### Use of Models

One specific improvement of the teachers' classroom practice is the use of models or symbolic representations of matter demonstrating that matter is made up of discrete particles and there are spaces in between the particles. Model as used in this study refers to representations that focus on key features to explain and predict a scientific phenomenon and concept (Schwarz et al., 2009).

Before and during the onset of CT, the teachers from both groups did not use models. As the CT intervention went on, teachers from the Collaborative Teaching group showed apparent intentionality in using models. A picture of the model shown in Figure 4.11 became a common sight in the Grade 8 classes for the remainder of the study: Some of the teachers commented they learned to use models to explain the lesson more effectively:

*"Natutunan kong gumamit ng mga model hindi lang kung chalk chalk." ("I learned to use models not just chalk chalk.")*

*"Dati wala tayo yung particle model eh, more on videos lang so ngayon mas lalo pa nating nabibigyan ng mas deeper conception yung pagpresent natin." (Before we did not have the Particle Model, more on videos only. So now we can give deeper conception our presentation.)*

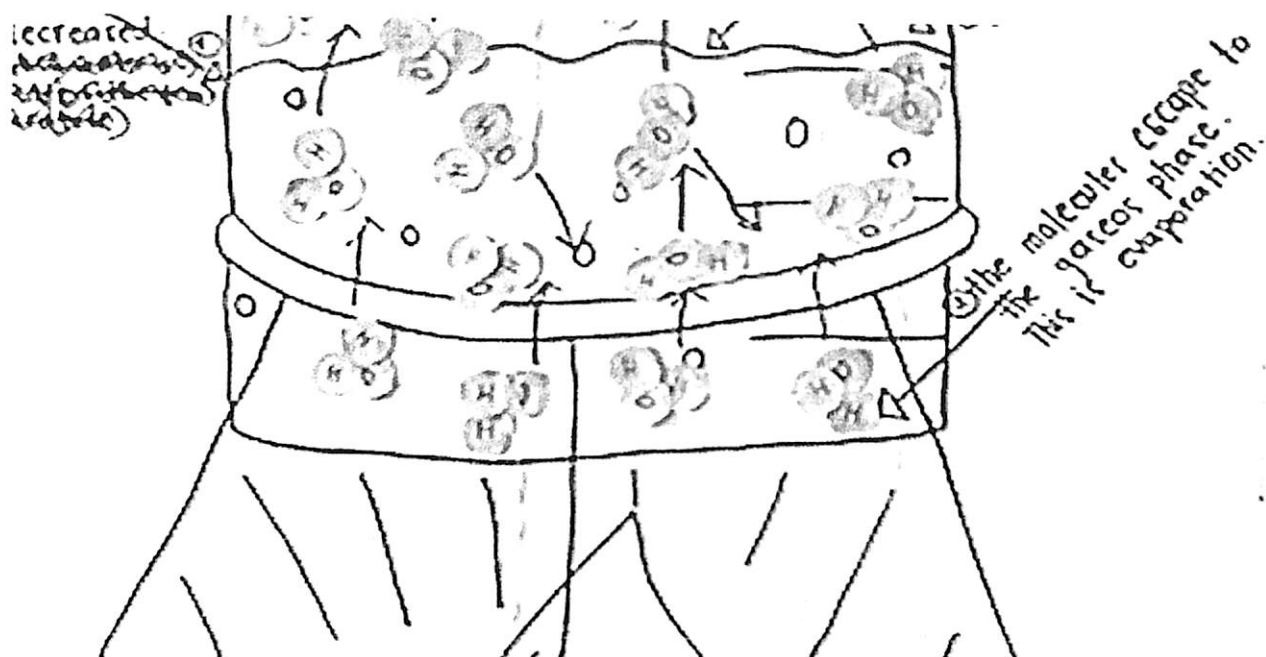


Figure 4.11. A sample of the particle model of water

Figure 4.12 below shows one of the teachers using a particle model to explain what happens when sugar dissolve in water in Learning Activity 2:

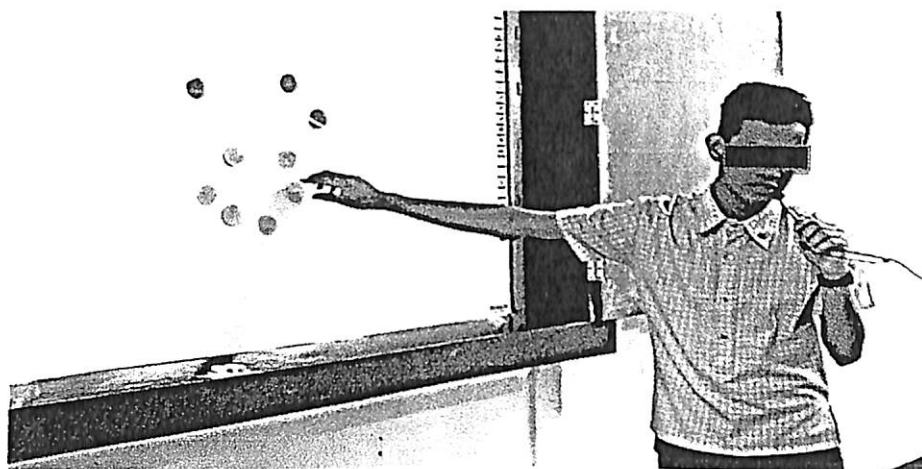
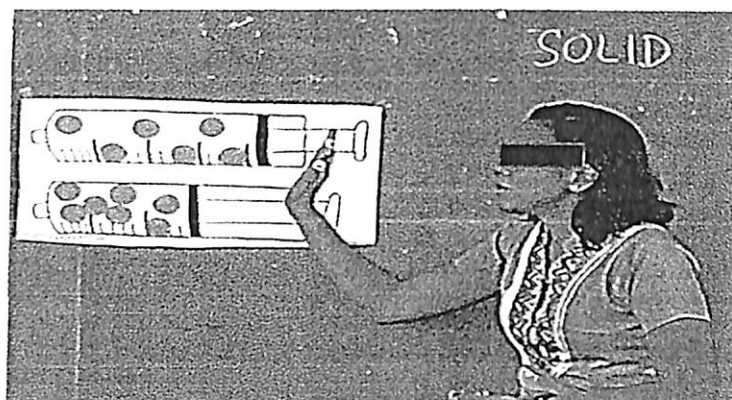


Figure 4.12. A teacher using a model to explain what happens when sugar dissolves in water.

Figure 4.13 shows a teacher from the Collaborative Teaching group using a particle model to discuss Activity 3 Lesson (Are particles of matter moving? What is

between them?). Studies show that using models helps students understand the macroscopic and sub-microscopic representation of particles of matter thereby improving performance (Hinton & Nakleh, 1999; Arda & Akaygun, 2005; de Jong et al., 2005; Onwu & Randall, 2006). Onwu and Randall (2006) conclude in their study that students are able to display consistent reasoning about the



*Figure 4.13.* Teacher discussing Learning Activity 3 using Particle Model.

particulate nature of matter if they have appropriate representational model on which to base their thinking. The early drafts of the teachers' lesson plan did not include the use of models. They reasoned that Unit III lessons were activity-based, already complete and more than adequate for students to learn the concepts of PNM. In fact, the teachers were apprehensive at first about Collaborative Teaching that they would have to do beyond the activity lessons already prepared for them to use. Their apprehensions were alleviated when they realized they are not being required to do more than what is really contained in the activity lessons. What was expected of the teachers was to process the activity results thoroughly and give opportunities for students to explain the concepts drawn from the activities done.

## Use of Higher Order Thinking Skills Questions

Another specific improvement of the teachers' classroom practice is asking higher order thinking skills or HOTS questions. One of the teachers, states,

*"You probably saw me during the first day, at my first demo (Cycle 1, Activity 1 Research Lesson) I did not know how to use HOTS questions, I did not know how to draw out answers from my students. As the study continued I began to learn how to use HOTS questions on my students."*

This teacher previously does not know how to use higher order thinking skills (HOTS) questions to help her students. Through CT she learned to use HOTS by observing other members of the CT group do it with their students. Perhaps like most teachers, this teacher is aware of developing HOTS through appropriate questioning but do not use it intentionally in class. Some studies show that even though teachers see the value of using HOTS questions, not many use it in teaching (Tobin et al., 1990; Borko & Putnam, 1996; Barak & Shakhman, 2008; Saeed et al., 2012).

Another teacher used HOTS questions because it forced students to think more critically. The following taken from video transcripts, is a snapshot of this:

*Student: "Yung plunger na may air naitutulak pa naman siya kaso bumabalik siya."* ("The plunger that has air it can still be pushed but it pushes back.")

*Teacher E: "Why?"*

*Student: "Because of air pressure inside it. It is hard to push the plunger with water than with air."*

*Teacher E: "Why?"*

*Student: "Kasi yung air pressure nga; dahil sa water hindi siya makamove."*

("Because of the air pressure; because of water it cannot move")

*Teacher E: "Bakit nga? Anong meron sa water?" ("Why really" what is it in water?")*

*Student: "Kasi may mga particles." ("Because there are particles.")*

Another teacher stated during the FGD about how CT helped her develop more in using HOTS questioning,

*"Students learn in constructivist approach; students are more visual learner. Through models, experiments, the activities, strategies, the HOTS we are able to develop their higher order thinking skills. All of this will become engaging learning at its best; when I discuss with my students I am more of higher order thinking skills so I am able to enhance the way I ask my students how to think critically."*

The value of asking HOTS questions is consistent with studies that show that quality questioning develops students' thinking and performance (Strother, 1989; King, 1994; Jiang & Ellen, 2011). It also fosters higher student engagement (Warfa et al., 2014). Warfa et al. (2014) point out in their study that teachers' efforts to ask students meaningful questions (he refers to as dialogic discourse) increases engagement and student understanding of concepts.

These changes are consistent with studies on the impact of collaboration

among teachers on the teachers' teaching strategies (Williams, 2010; Ronda, 2013; Austria et al., 2013). In the study by Austria et al. (2013), participant chemistry teachers who underwent lesson study were able to think of new strategies to suit the type of students. They were also able to choose the appropriate activities in order to address students' misconceptions successfully. The study by Williams (2010) and Ronda (2013) further show that collaborative teaching provides an avenue for teachers to reflect on their teaching and how students are responding to their teaching. Thus, changes in the teachers' practice observed in the current study may be due to the collective reflection of the group on how best to deliver PNM concepts for maximum understanding of the students. Observing and analyzing others' lesson helped the teachers from the Collaborative Teaching group to reflect more deeply about their own teaching practice. This also made them more critical in choosing the right teaching activities that help will students to understand the lesson more deeply. One of the teacher states,

*"I like to add the improvement of our instructional materials. Now we can give deeper conception when we are teaching. So now **we realize we have more and better activities** that we can do."*

They also recognize the benefit of **reflecting together** how to improve the teaching of the lessons. As teachers put it,

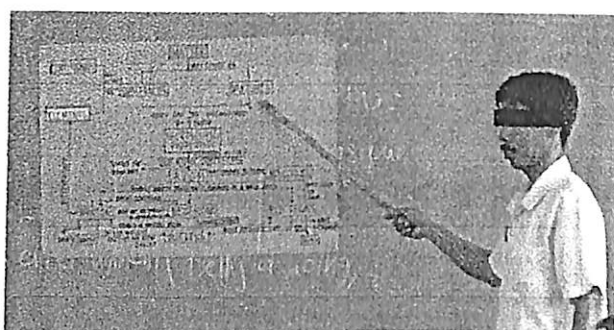
*"I really like the collaboration. We are continually updated."*

*"There is teamwork; we cooperate. This is really neat; I realized there is much*

*we can do together, isn't that great?"*

*"We can correct each other. We can deliver a better quality of education; unlike if we do not discuss we approach our lesson in many different ways at the same time we cannot correct our mistakes."*

The Conventional teaching group also used more lecture-based, chalk and board strategies at the beginning of the intervention (Figure 4.14).



*Figure 4.14.* A teacher from the Conventional group uses lecture method to teach classification of matter.

However, they continued to use more lecture-based strategies even towards the end of the study. One teacher's comment when asked about her teaching strategy is:

*"Because of lack of space, I just do the demonstration myself instead of asking my students to perform the activity."*

Indeed some of the classrooms are small and may discourage teachers to perform the activities described in the instructional material. One of the teachers also cited

that lack of time also influence the decision to do class demonstration instead of asking everyone to perform the activities in the learning material:

*“Some activities take more time to do so I just demonstrate them to be faster. It is easier to incorporate the lecture and discussion already during the demonstration.”*

The researcher noted though that this did not seem to discourage some teachers from the Collaborative Teaching group to let their students perform the activities. Also while all the teachers from the Collaborative Teaching group began using models as the CT intervention progressed, the researcher only observed one teacher from the Conventional Teaching group who used a model. She used a model to explain the different phase changes as shown in Figure 4.14 below:

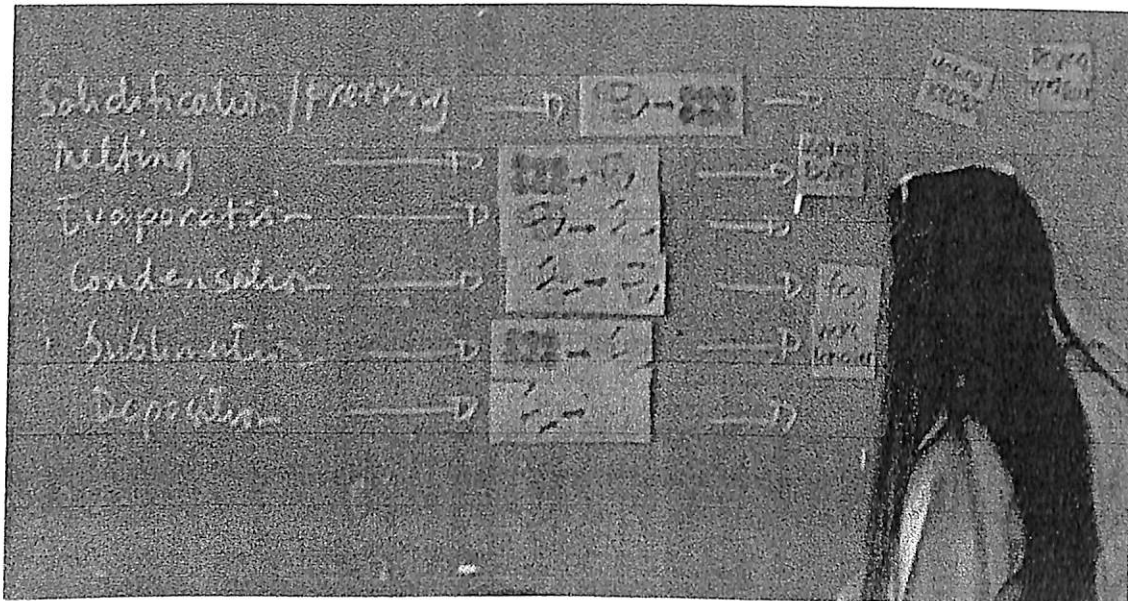


Figure 4.15. A teacher using models to explain the different phases of matter.

## **Changes in teachers' knowledge of students' misconceptions**

Before CT intervention the teachers from both groups showed little or lack of awareness of students' misconceptions about PNM. Items 7 and 9 of the PCK-PNM Questionnaire were designed to test the teachers' knowledge about students understanding of PNM. Item 7 was taken from ParNoMA of Birk and Yizierski (2006). Item 9 was taken from Punzalan and Marasigan (2009). For item 7, it is expected that teachers should point out that the students' responses show the students lack of knowledge and understanding that air, water and sugar are made up of tiny particles. They should be pointing out that the students were only describing air, water and sugar macroscopically rather than sub-microscopically.

For Item 7, nine of the ten teachers considered it correct when a student described air as something that "cannot be seen" or the water vapor as "very small drops." This indicates the teachers' lack of understanding of the student's misconception about sugar and air being made up of particles. It can also be concluded that the teachers' response indicated their lack of knowledge and understanding of the particle nature of matter. Only one teacher somehow expressed that students viewed air, water, and sugar macroscopically. She pointed out the students missed showing that air, water and sugar are made up of particles. Only one other teacher expressed that students should view air molecules as far apart, water molecules are closer together and sugar molecules are closest together.

For Item 9, it is expected that teachers should point out that Student 1 and Student 2 have very limited or no knowledge of PNM concepts. The students'

explanation of ink spreading in water and that “bagoong” smells clearly show they lack knowledge and understanding that ink and the chemical responsible for the smell of “bagoong” are made up of particles. The teachers were expected to point out that Student 1 and Student 2 also lack knowledge and understanding that there are spaces in between particles of ink, water, air and the chemical causing the odor of “bagoong.” The teachers were also expected to point out that only Student 3 has a good grasp of PNM principles. However, teachers from both groups were not able to point out the lack of knowledge and understanding of Student 1 and Student 2 of PNM concepts. They were not able to point that Student 1 and Student 2 could not explain microscopically why a drop of ink spreads evenly in water or that “bagoong” smells. They also did not point out that Student 3’s answers, “There are spaces in between molecules” and “There is evaporation and mixing in the air” reflect some knowledge and understanding of PNM concepts.

The observations from teacher responses to Items 7 and 9 are supported by observation of the teachers’ lesson plans. The researcher noticed that first drafts of the lesson plan submitted by teachers did not anticipate misconceptions of students. It was only after the pre-lesson discussion that they became aware of the importance of such. Many do not indicate anything under this category in the lesson plan. A few indicate about students’ difficulty with the English language,

*“Language barrier is one of the difficulties/limitations that I anticipate can limit the acquisition of the main concepts.”*

Most of the teachers' responses to the pre-lesson reflection guide also show their apparent lack of knowledge of how to anticipate the students' misconception or learning difficulties about PNM. One teacher's concern is simply that the students could finish the activity:

*"I think there will be a lack of time because the students need a lot of time for them to answer the guide questions."*

Only one teacher (from the Collaborative Teaching group) mentioned in her pre-lesson reflection guide that she thinks that students may not have a full grasp about the particle nature of matter. She also anticipated that students might have a hard time visualizing the particle nature of matter.

At the onset of the CT intervention, teachers came more with concerns about students not having enough time to complete activities or lacking in understanding of procedures of class activities. For instance, during the pre-lesson discussion of Activity 1 (Which is matter, which is not?), some teachers expressed their concern about the inability of some students to use the balance in measuring the mass of the samples. Although the students may have used balances before, the group agreed that it is wise to demonstrate the proper use of the balance. Another concern raised was about heat, light and smoke. From previous experience teaching Activity 1, some expressed that it may be difficult for students to classify heat, light and smoke. One teacher suggested removing smoke from the list because it may confuse students since smoke is a colloid. It was suggested to discuss it under

application about pollution. The researcher did not influence the decision even though he did not fully agree. He just encouraged the group to look more into students' thinking about smoke, heat and light during their class.

As the CT intervention progressed, the researcher noticed that teachers from the CT group began to show awareness of students' misconceptions and difficulties about PNM concepts. Post lesson discussions began to focus on how students are getting or not getting the concept that matter consist of particles. For instance, in the post lesson discussion of Activity 1 during the second implementation, the teachers shared how their students struggled on classifying heat, smoke, light and air as matter or not. Some of the teachers' comments include:

*"Hirap talaga ang mga bata mag-weigh so their results for air and smoke parang malabo for them. Most of them classify air and smoke as not matter. (The students found weighing difficult so their results for air and smoke is not clear to them. Most of them classify...).*

*"Some of the students did not readily understand the connection between the volume and weight of the object and their classification. Kahit nasa book nila parang hindi nila binasa yung explanation." (Even though it's in their book, it seemed they did not read the explanation.)"*

The post lesson interviews also exemplified teachers' growing awareness of students' misconceptions and learning difficulties. For instance, one teacher commented about the students' lack of understanding that there are spaces in

between particles of solids:

*"Hindi alam ng students ko na may space na small sa solids."*

*(My students do not know that there are small spaces in solids.)*

Another teacher noted that students have misconceptions about the movement of particles:

*"My students have misconceptions about movement of particles of matter; nacoconfuse sila." (...they get confused).*

The increase in teachers' knowledge of students' misconception after CT intervention is consistent with previous studies (Cheng & Ling, 2012; de Hitta Catalan et al., 2013; Lomibao, 2016). Lomibao (2016) reported that teachers who underwent Lesson Study became more conscious and sensitive to students' learning needs and difficulties of mathematics. Similarly, the study of de Hitta Catalan et al. (2013) showed that Biology teachers who underwent Lesson Study were able to identify alternative conceptions of students about diffusion and osmosis. Another study by Cheng and Ling (2012) showed that Mathematics teachers who underwent Learning Study, a collaborative action research approach showed increased awareness of students' misconceptions and difficulties with teaching content guiding them how to formulate their lesson plan.

It seemed that teachers' increased awareness or knowledge of students' misconceptions and learning difficulties spurred them to adjust their lesson. Thus, pre and post lesson discussions also focused on addressing the students'

misconceptions. For instance, in the post lesson discussion of Activity 1, the teachers thought of making these changes:

- a. Review and demonstrate proper weighing to help students with their confusion about the classification of air as discussed above.
- b. It was also suggested that a real-life application about pollution be added to increase students' understanding that smoke is indeed matter.
- c. Explain more clearly the concept of volume and mass as it relates to matter. Most teachers said that most students could recite the classic definition of matter, "anything that occupies space and has weight". However, they struggle using the definition to guide classifying matter.
- d. There was also the caution that going into deeper concepts about heat and light to explain why it is not matter may not be helpful for students. The teachers agreed that sticking to the learners' material about volume and mass or weight is enough.
- e. The teachers also noted that the next time they review the classification of matter, they would clarify students' construct about elements and compound. It was apparent that students were not so clear that classification should be based on the kind of atom rather than number of atoms. They noted that in the past they were content giving the textbook diagram of classification of matter. Teacher F made the adjustment in her class by asking students to use the textbook diagram to classify substances and asking them to explain their answers.

In another instance, as teachers realized students' difficulty visualizing the particles in the sub-microscopic representation and the spaces between them, one of the teachers suggested that they employ models. This discussion was triggered

as teachers observed students could not represent well sugar or food coloring dissolving in water in Learning Activity 2 ("What is matter made of?").

It is apparent that the changes in the content knowledge of PNM concepts, the teachers' classroom teaching strategies and their knowledge of students' misconceptions and learning difficulties are connected. This is consistent with the integrative model of PCK (Magnusson et al., 1999; Shulman, 1986; Grossman, 1990; Cochran et al. 1993; Gess-Newsome, 1999). Thus, teachers' increased understanding about elements and compounds (KSC) made them aware of students' similar misconception (KSU) especially those of diatomic or triatomic molecules such as  $I_2$  or  $O_3$ . This led them to adjust their use of the textbook diagram of classification of matter (KTS). Overall then, their PCK expanded or developed in this instance. In the same manner, teachers' awareness of students' difficulty of visualizing particles of matter and the spaces in between (KSU) led them to think of using models (KTS). For some teachers, the use of model deepened their knowledge and understanding of the process of sugar or food coloring dissolving in water. One teacher stated,

*"Before hirap akong iexplain what happens when sugar dissolved in water. I usually mention diffusion. Kaya lang parang lalong nacoconfuse ang mga bata kasi I used another term na medyo unfamiliar. With the Particle Model it is easier to explain." (Before I found it difficult to explain what happens when sugar...However, it seemed the students get more confused because I used another unfamiliar term...)*

For this teacher the new teaching strategy of using models developed her knowledge and understanding about PNM (KSC).

The teachers from the Conventional Teaching group did not show apparent similar improvements and adjustments done by the Collaborative Teaching group in preparing lesson plans. Perhaps the absence of collaboration and group discussions may have prevented from developing significant awareness of students' misconceptions and learning difficulties in the course of their teaching. This observation is consistent with studies that show that the average teacher, especially prior to collaborative actions show minimal or less awareness of students' misconceptions and learning difficulties (Even & Tirosh, 1995; Dickinson, 2009; Turner, 2011; Cheng & Ling, 2012). Post lesson discussions often centered on the matter about not finishing the activity or students' seeming difficulty carrying out the activity. One teacher though somehow recognized her students' difficulty with representing particles during evaporation and condensation. However, the researcher did not see adjustment in her lesson plans to do something about this.

### **Changes in the teachers' pretest scores of PCK components**

Quantitative data gathered from PCK-PNM Questionnaire and the PCK-PNM Observation Rubric support the observations that the teachers' PCK of PNM developed. Table 4.4 is the Table of Specification (TOS) for PCK-PNM Questionnaire. The over-all purpose of PCK-PNMQ is to assess the teachers knowledge of content knowledge about PNM, knowledge of students' misconceptions and learning difficulties about PNM and knowledge of teaching

strategies that can facilitate learning of PNM. These correspond to KSC, KSU and KTS which are the components of PCK.

Table 4.4

*Table of Specification for PCK-PNM Questionnaire*

Teacher knowledge	Multiple Choice with explanation	Short Essay	Items	Points	%
1. Show understanding of behavior of particles of matter during phase changes. (KSC)	5		1 - 5	20	41.7%
2. Identify students' misconceptions about PNM. (KSU)		2	7, 9*	8	16.6%
3. Knows appropriate teaching strategies to address students' misconceptions about PNM.(KTS)		5	11 - 15	20	41.7%
<b>Total</b>	<b>5</b>	<b>7</b>	<b>12</b>	<b>48</b>	<b>100%</b>

\*NOTE: Item 6, 8 and 10 were dropped after factor analysis.

Table 4.5 shows that the mean PCK-PNMQ posttest scores of the two groups increased. However, the mean score of the Collaborative Teaching group which is 37.5 is higher than that of the Conventional Teaching group which is 26.2.

Table 4.5

*PCK-PNM questionnaire mean pretest/posttest scores*

	Mean Pretest (Maximum score = 48)	Mean Posttest (Maximum score = 48)	Gain Score
<b>Collaborative Teaching Group (N= 6)</b>	26.8 SD = 4.7	37.5 SD = 4.8	+10.7
<b>Conventional Teaching Group (N=4)</b>	20.8 SD = 3.1	26.2 SD = 3.1	+5.4

This represents a 43.1% difference. Moreover, the gain score of the Collaborative Teaching group is 98% higher than the gain score of the Conventional Teaching

group. The number of participants in the Conventional group was reduced from six to four since two teachers did not complete the pre and post PCK-PNMQ. Table 4.6 further indicates that the PCK-PNM components namely, KSC, KSU and KTS, of teachers from the Collaborative Teaching Group showed greater improvement than the Conventional Teaching group. For instance, Table 4.5 shows that KSC score of Collaborative Teaching group teachers improved from 12.0 to 18.2 (out of maximum of 20), an almost 52% increase. Comparatively, the KSC score of the Conventional Teaching group teachers improved from 10.5 to 13.2 which is only a 25.7% increase. For the KSU and KTS scores of the Collaborative Teaching group, the increase is 39.5% and 27.3%, respectively. For the Conventional Teaching group, the increase is 7.1% and 33.3%, respectively.

Table 4.6

*PCK-PNM questionnaire PCK components scores*

PCK Components	Collaborative Teaching Group (N=6)		Conventional Teaching Group (N=4)	
	Mean Pretest	Mean Posttest	Mean Pretest	Mean Posttest
<b>KSC*</b>	x = 12.0 SD = 3.7 (Max. score= 20)	x = 18.2 SD = 3.0	x=10.5 SD= 2.6	x = 13.2 SD =2.4
<b>KSU</b>	x = 3.8 SD = 0.75 (Max. score= 8)	x = 5.3 SD = 1.2	x=2.8 SD=0.5	x = 3.0 SD =0.0
<b>KTS</b>	x = 11.0 SD = 1.7 (Max. score= 20)	x = 14.0 SD = 2.3	x=7.5 SD=2.1	x = 10.0 SD = 1.8
<b>TOTAL</b>	x = 26.8 SD = 4.7 (Max. score=48)	x = 37.5 SD = 4.8	x=20.8 SD=3.1	x = 26.2 SD = 3.1

\* KSC: Knowledge of Student Content; KSU: Knowledge of Student Understanding; KTS: Knowledge of Teaching Strategies

Comparison of the TOS with Table 4.6 shows that over-all teachers from both groups scored the highest in the KSC area, both in pretest and posttest. Similarly, teachers from both groups scored the lowest in the KSU area, also both in pretest and posttest. The comparison also shows that the teachers from the Collaborative Teaching group registered higher increases in all areas:

- a. KSC (31 percentage points for Collaborative Teaching Group compared to 13.5 percentage points for the Conventional Teaching group).
- b. KSU (19 percentage points for Collaborative Teaching Group compared to 2.5 percentage points for the Conventional Teaching Group).
- c. KTS (15 percentage points for the Collaborative Teaching Group compared to 12.5 percentage points for the Conventional Teaching Group).

Table 4.7 shows that the posttest KSC score, in the PCK-PNM Observation Rubric of the Collaborative Teaching group improved by almost 43% from 6.8 to 9.7 (out of a maximum 12). This score is also about 33% higher than that of the Conventional Teaching group. The over-all rating of the teachers from the Collaborative Teaching group went from "Emergent" (27.0) to "Proficient" (37.3) in the posttest. The rating of the Conventional Teaching group remained as "Emergent" (27.5) in the posttest.

Table 4.7

*PCK-PNM Observation Rubric Scores*

PCK Components	Collaborative Teaching Group (N=6)		Conventional Teaching Group (N=4)	
	Mean Observation 1* Score	Mean Observation 2 Score	Mean Observation 1 Score	Mean Observation 2 Score
KSC	x = 6.8 SD = 1.7 (Max. score=12)	x = 9.7 SD = 1.6	n/a**	x = 7.3 SD = 1.0
KSU	x = 10.0 SD = 2.2 (Max. score=16)	x = 13.3 SD = 2.3	n/a	x = 9.7 SD = 1.5
KTS	x = 10.2 SD = 2.1 (Max. score=20)	x = 14.3 SD = 2.9	n/a	x = 10.5 SD = 0.8
TOTAL	x = 27.0 SD = 5.7 (Max. score=48)	x = 37.3 SD = 6.6	n/a	x = 27.5 SD = 1.9

\* NOTE: Observation 1 refers to the first time a teacher was observed teaching a lesson at the beginning part of the CT intervention. Observation 2 refers to the second time a teacher was observed teaching towards the end of the CT intervention.

\*\* n/a means this was not measured for the Conventional Teaching Group since the researcher only intended to compare the PCK of the two groups at the end of CT process.

### Summary of Research Question #1 Discussion

Teaching is traditionally a solitary practice. The teacher prepares the lesson plan and implements it. He or she alone makes decision with respect to what eventually takes place in his or her classroom. The teachers from the Collaborative Teaching group had a totally different experience. The teachers formed a learning community where they worked with others. They were no longer isolated but functioned in a community (Darling-Hammond & McLaughlin, 1996). They were freer to discuss their own misconceptions and lack of understanding about the particulate nature of matter concepts. They were active contributors to the community of

teachers as they shared their “expertise.” For instance at the pre lesson discussion for Activity 1 the teachers helped each other understand the distinction between elements and compounds. As mentioned previously, the sharing and exchanges about the distinction between elements and compounds enabled teacher to handle correctly the review part of the lesson about classification of matter. For Learning Activity 2 the teachers also helped each other understand why the volume of the mixture of sugar and water is less than the sum total of their respective volumes. This interdependent interaction and intentional effort to help each other are further illustrations of the social element of Collaborative Teaching.

In an environment of open discussion, the teachers themselves began to teach each other, sharing what they know (Nieto, 2009). They are also able to ask questions and clarify with lesser apprehensions. The researcher acting as the Facilitator or Knowledgeable Other was not the only source of knowledge but rather the collective knowledge of the group. Hence the teachers were learners and facilitators at the same time. Even the researcher learned many things through the interactions with teachers. This is an illustration that Collaborative Teaching is teacher-centered.

The mechanics of collaboration among the teachers involved a shared desire to improve the lesson to be taught and how it is to be taught. The teachers worked as a team doing the following:

- a. Planned the lesson together.
- b. Participated in pre-lesson and post- lesson discussion.
- c. Observed each other when the lesson is taught.

d. Improved the lesson plan during pre-lesson and after post-lesson discussions.

The teachers employed active reflection during these activities. The collective reflection during pre-lesson, post-lesson and even during implementation of the research lesson facilitated the change in the teachers' knowledge and understanding of the PNM concepts (Hatch, 2007; Hindin et al., 2007). As teachers reflect together, their cognition is deepened leading them to change what and how they taught concepts (Meirini et al., 2007). The collaboration helped the teachers individually and collectively to increase their knowledge and understanding about phase changes and other PNM concepts. It also helped them as a group to grow in knowing how to work together for the common good of teachers and students in a particular school.

## Research Question #2: What changes occurred in students' understanding of PNM concepts as a result of Collaborative Teaching?

### Changes in students' view of matter from continuous to particle nature

Data from PCK-PNM Questionnaire, classroom observations, and post-lesson interviews indicate that prior to the implementation of Collaborative Teaching, students' prevalent conception of matter is more of being continuous than a particle. A *continuous view* of matter holds that matter is homogenous, indivisible with no spaces. A *particle view* holds that matter is made up of discrete particles with spaces in between them (Merritt et al., 2006). When asked which is matter and which is not in Learning Activity 1 ("*Which is matter, which is not?*"), students from the Collaborative group easily classified stone, sugar and leaves as matter. However, at least 70% of the students had difficulty classifying smoke, air, heat and light. Table 4.8 is a portion of students' output for Learning Activity 1 classifying different samples.

Table 4.8

#### *Students' classification of different objects during Activity 1*

Sample	Properties of Matter		Is the sample matter? (Yes or No)	Reason
	Has mass (√ or X) If √ indicate mass	Has Volume (√ or X) If √ indicate volume		
3. stone	√	√	Yes	It has a mass and volume
4. air inside ball	√	X	No	Because it's not occupy space
5. leaves	√	√	Yes	It has mass and volume
6. heat	X	X	No	Because it's not have a mass and volume

For the students, matter is something that they can see, touch, hold or feel. Thus, when asked about why they say the object is matter, some students replied, "dahil may timbang" ("because it has weight"). Others said, "nahahawakan po" ("can touch them"). Such conception has been reflected in their classification of air and smoke as "not matter" since they could not imagine that both could have mass, or they could hold it. But when the teachers taught them how to get the mass of air and smoke, they concluded that air or smoke is matter.

The students' apparent difficulty classifying air and smoke as matter indicate their limited understanding that matter is composed of discrete particles with spaces in between them (Abraham et al., 1992). Air is sometimes misclassified as not matter because the particles are not visible to the unaided eye. Smoke, like air, is misclassified because some students cannot comprehend that smoke is made up of tiny solid, liquid and gas particles (Silberberg, 2010). Studies show that there is tendency among young students ages 13 to 18 to hold a "naïve view" of matter (Novick & Nuusbaum, 1981; Stavy and Satchel, 1985; Stavy, 1990). For instance, according to Stavey and Satchel (1985), 12 to 13 year olds associate solids to rigid objects such as wood and metal. However, non-rigid solids such as sponge, sand or dough are considered non-solids. Sere (1986) reports the same naïve view about gases such as air. She found that 11-year olds associate gases to everyday experience such as those used in balls and tires or something that is everywhere even though it is invisible and cannot be touched. This might explain why students in Activity 1 could not easily classify air inside the ball or smoke since they cannot be touched or appear invisible to the unaided eye. The students also showed a naïve

view of matter during the first implementation of Learning Activity 2 (“*What is matter made of?*”). The setup in Learning Activity 2 involved mixing of sugar and water and food coloring and water in separate containers. Students were asked to observe and explain what would happen to sugar and food coloring when each is placed into separate graduated cylinders with water. About 75% of the students simply illustrated their observation without showing the particles of sugar and food coloring in water such as shown by the arrow in Figure 4.16.

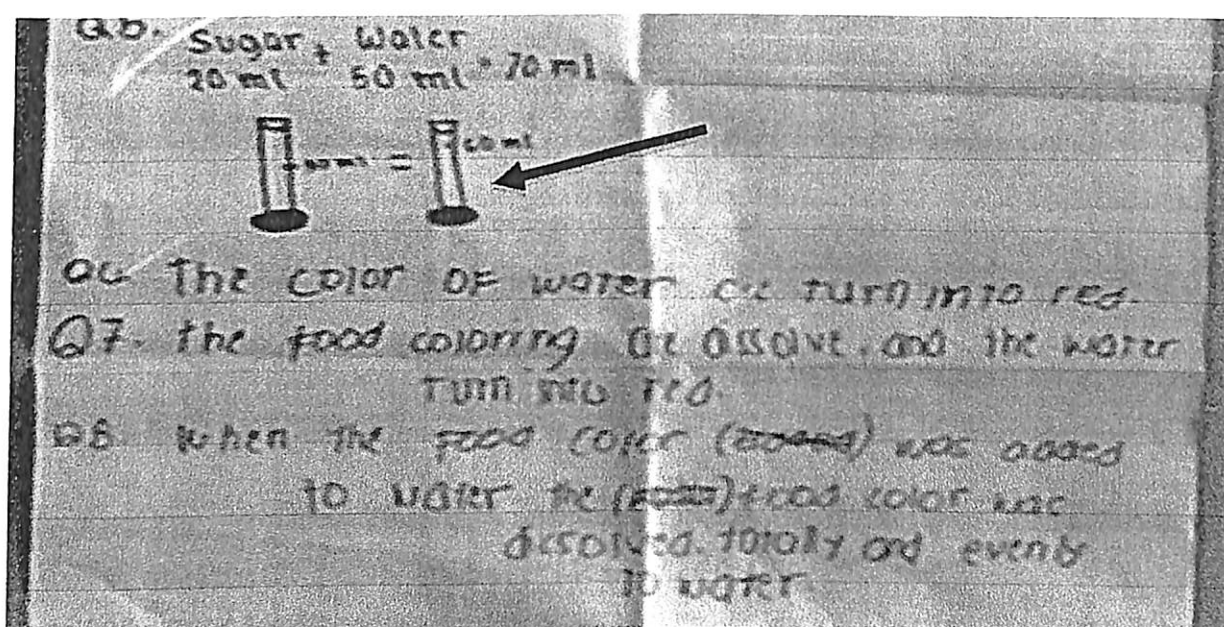


Figure 4.16. Students' explanation and illustration about when sugar and food coloring were each added to water.

In addition, the students simply described the changes in color of the water when food coloring was added to it. Below are sample responses of students to Questions 6 to 8 in Figure 4.16. The students' responses do not reflect knowledge that sugar and water are made of discrete particles:

Question #6: Describe what you observe after adding the food coloring.

Students' answers:

*"The color of water are turn into red"*

*"We observed that as we added the food coloring water slowly became colored",*

Question #7: *What happens to the food coloring dropped in the bottle containing water? Write all your observations in your notebook.*

Students' answers:

*"The food coloring are [was] dissolved, and the water turn into red."*

*"The food color is scattered into the water."*

Q #8: *Think about food coloring and water as made up of particles. With your group mates, discuss and give your reason(s) for the observations you made in Q6. You may draw illustrations to further explain your reason(s).*

Students' answers:

*"When the food color was added to water the food color was dissolved totally and evenly to [in the] water".*

*"The water have a color."*

The macroscopic explanation of the students from the Collaborative Teaching group indicates that they may have no knowledge and understanding that matter is made up of particles. For instance, none of the groups who reported their observations when sugar and food coloring were dissolved in water mentioned about particles of either sugar or food coloring. In fact, at some point the teacher asked and perhaps tried to prompt the students:

Teacher: *"Why is it you do not represent the particles of sugar or food coloring in your drawing?"*

Students: *"We used dots before dissolving but after no more because the sugar and food coloring melted completely."*

It also shows their limited conception that there are spaces in between the particles of water, sugar and food coloring. For instance, students' description of what happens when sugar is dissolved in water and when food coloring is added to water does not reflect that particles of sugar and food coloring move into the spaces between water particles:

*"The sugar is mixed in the tap water so the taste is sweet"*

*"Sugar is melt if you stir in the water."*

*"The food color dissolved to water evenly."*

*"Water turns to color red."*

The students could have inferred that sugar molecules and food coloring molecules moved into the spaces in between the water molecules. Their observations could have been taken as evidence that there are spaces in between the particles.

The apparent lack of students' understanding to represent the particles of matter is consistent with findings from studies about misconceptions on the Particulate Nature of Matter (Mulford & Robinson, 2002; Merritt et al., 2007; Stojanovska et al., 2012). Mulford and Robinson (2002) reported that less than half of students they tested were confused about properties of the macroscopic substance and its microscopic particle (81% pretest; 75% posttest). The students

could not represent the particles of liquid water after it undergoes evaporation (61% pretest; 55% posttest). Stojanovska et al., (2012) also report of students having confusion about properties of the macroscopic substances and its microscopic particles. Merritt et al. (2007) reports that over 45% of students ( $N=57$ ) in their study held a continuous view of matter in illustrating mothballs in an open jar. These studies point that students go through stages of development toward a correct particle view of matter from. Merritt et al. (2006) used the following classification of how students represent matter:

Type 1: Continuous (no space)

Type 2: Continuous with empty space

Type 3: Mixed, particles and clouds or particles and lines

Type 4: Particles, including everyday ideas (germs, water in air)

Type 5: Particle

According to Merritt et al. (2006) Type 1 views matter as continuous medium with no space, hence the absence of discrete particles making the substance. Objects are described exactly as they appear. The students' representation of dissolved sugar in water in the graduated cylinder (Figure 4.16) is a Type 1 representation. Type 2 views matter as continuous medium but is represented as having space between. Objects are usually represented as wavy lines or strokes. Type 3 represents matter as being made up of a mixture of particles and lines that are smaller pieces of the original substance. Thus, students describe solids, liquids, and gases as made up of smaller pieces of that same substance, which come together to form a whole. Type 4 represents matter as composed of particles but

may have misconceptions related to everyday ideas. Type 5 is the complete particle view of matter, which embodies the correct concepts of PNM. The students at this point of the study show a Type 1 or Type 2 view of matter. The students at this point of the study show a Type 1 or Type 2 view of matter. This might explain their illustration of sugar dissolving in water (Figure 4.17) where they drew sugar as being completely homogenous with water after dissolving thus unseen in their drawing.

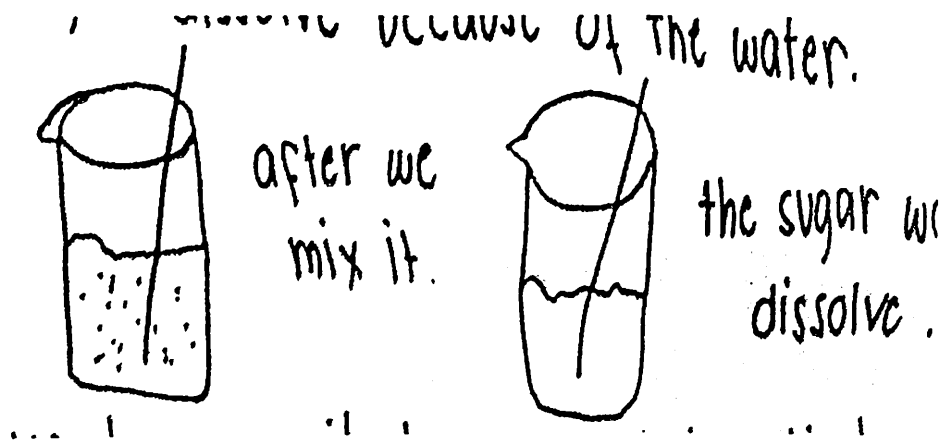


Figure 4.17. Students' representation of sugar dissolving in water reflecting a continuous view of matter (Type 1 view).

Some studies point out that it is common that students explain what they observe during experiments based on their everyday experience (Osborne & Cosgrove, 1983; Gabel, 1993). Thus, in Learning Activity 1, students classified air as non-matter since they thought it has no volume or mass thus they could not be held or touched. Concrete objects such as stone and leaves were easily classified as matter. In Learning Activity 2 for example, students (and even a few teachers) used the term "natunaw" or "melted" to describe how sugar dissolved in water. This particular misconception where students do not distinguish between melting and dissolving is mentioned in past studies (Osborne & Cosgrove, 1983; Goodwin, 2002;

de la Cruz, 2008). In this study, students used melting instead of dissolving. Perhaps this is based on the everyday experience of mixing coffee, sugar or powdered juice in water to prepare common drinks. Moreover, Filipinos commonly use the same word, "tunaw" for dissolving and melting.

The observations above are corroborated by results of the ParNoMA questionnaire. Table 4.9 indicates that more of the students in the Collaborative group (N=143) have misconceptions related to matter being composed of discrete particles.

Table 4.9

*Number of Collaborative Group students (N=143) with correct answers and with misconceptions in ParNoMA items about matter being composed of particles*

	Description of ParNoMA Item	Percentage with correct answers	Percentage with Misconceptions*
Item 1	Melting of ice	32.9	42.8
Item 4	Evaporation of ammonia	19.3	51.5
Item 6	States of matter	15.7	84.3
Item 8	Boiling of water	20.0	74.3
Item 16	Melting	44.3	21.4
Item 19	States of matter	13.6	86.4
<b>Mean</b>		<b>24.3</b>	<b>60.1</b>

\*NOTE: Misconceptions include incorrect answers by at least 20% of total number of respondents (Dhindsa & Treagust, 2009).

Items 1, 4, 6, 8, 16 and 19 of ParNoMA pertain to the concept of matter being made up of particles and the spaces between them. Almost 76% of the students did not have a clear understanding that matter is made up of particles and there are spaces in between them.

For instance, the pretest answers of the students of the Collaborative Teaching group for Item 1 (Figure 4.18) shows that they lack understanding of the microscopic representations of matter. The prevalent misconception of the group is that the atoms of oxygen and hydrogen separate during melting. Only 32.9% of students chose C, the correct answer for this item. About 13.6% chose A, 40.7% chose B, 10.7% chose D and 2.1% chose E indicating that 67.1% has misconceptions on the sub-microscopic representation of melting of water. Interestingly, students who chose B believed that atoms of oxygen and hydrogen separate during melting, an observation also reported by Osborne and Cosgrove (1983). According to them, most 17 year olds think that water can be split into its

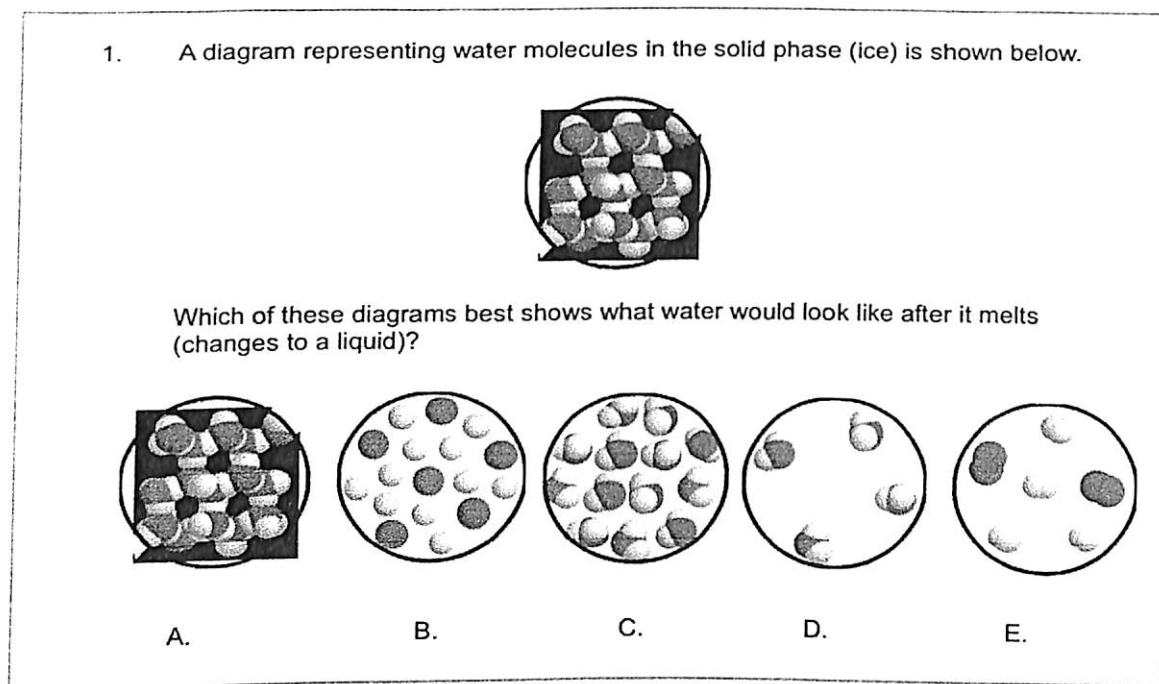


Figure 4.18. Item 1 of ParNoMA Questionnaire.

component elements by heating due to the influence of teaching. Students are taught the formula of water is  $H_2O$ , so they imagine that water molecules breakup on heating.

In Item 4 (Figure 4.19), a similar misconception was observed when students think that ammonia breaks into nitrogen and hydrogen during evaporation. Several studies also reported a similar misconception (Osborne & Cosgrove, 1983; Stojanovska et al., 2012; Mayer, 2011; Regan et al., 2011). In the ParNoMA test results, only 19.3% got the correct answer (i.e. letter A), indicating that the rest of the students (80.7%) have misconceptions. In addition, about 51.3% of the students thought ammonia breaks into hydrogen and nitrogen. This misconception may be analogous to their thought of water breaking into hydrogen and oxygen. The latter is due to their prior conception that water consists of hydrogen and oxygen that separates during electrolysis (Osborne & Cosgrove, 1983).

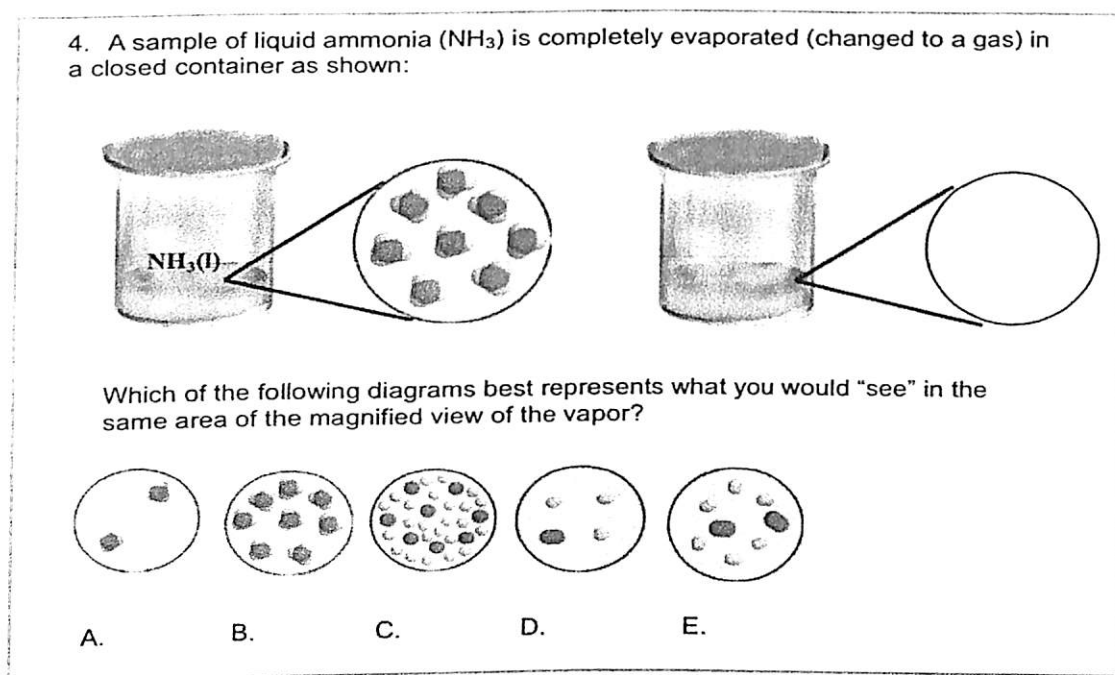


Figure 4.19. Item 4 of ParNoMA Questionnaire.

Responses of students to Item 1 and Item 4 show that they lack understanding of the particulate nature of solids, liquids and gases, and the spaces between the particles. These students do not recognize that spaces between

particles of liquid ammonia are closer than in gaseous ammonia. Similarly, some students do not recognize that the spaces between particles of solid water are closer than in liquid water. This is further indicated by students' answers to Items 6, 8, 16 and 19. Column 3 of Table 4.8 further summarizes the percentage of students with misconceptions. The teachers' reflections during the post-lesson discussions further supports the observation of students' lack of understanding that matter is composed of discrete particles and there are spaces between them. Two teachers commented that:

*"Nahirapan sila ivisualize yung particles, postulates of particulate nature of matter kasi hindi naman talaga nila nakikita." (The students have difficulty visualizing the particles, postulates of particle nature of matter because they really cannot see the particles.)*

*"The students describe the matter given to them by their naked eye. They describe it based on what they see but not on the deeper understanding. They can describe it macroscopically but not microscopically."*

As indicated in the preceding comments, students held a macroscopic view of matter at the beginning of the study. More specifically, they exhibited a Type 1 or Type 2 view of matter (Merritt et al., 2006). They lacked understanding that matter is composed of discrete particles and there are spaces between the particles. This could be a key reason why they have several misconceptions in the ParNoMA test.

However, as the Collaborative Teaching intervention progressed, students

from the Collaborative group began to exhibit the ability to represent at the submicroscopic level phenomena they observed during the activity lessons. For instance, students showed improvement in explaining sugar dissolving in water in Learning Activity 2 (“What is matter made of?”). Figure 4.20 shows the students explaining through a diagram what happened to sugar dissolved in water. This improvement occurred during the second implementation of Learning Activity 2. Students began to use dots to represent the sugar particles before and after dissolving of sugar. They also indicated that there are spaces in between the particles. Interview of selected students after Learning Activity 2 lesson confirms the students’ improved conceptual understanding that matter is made up of particles and there are spaces between them:

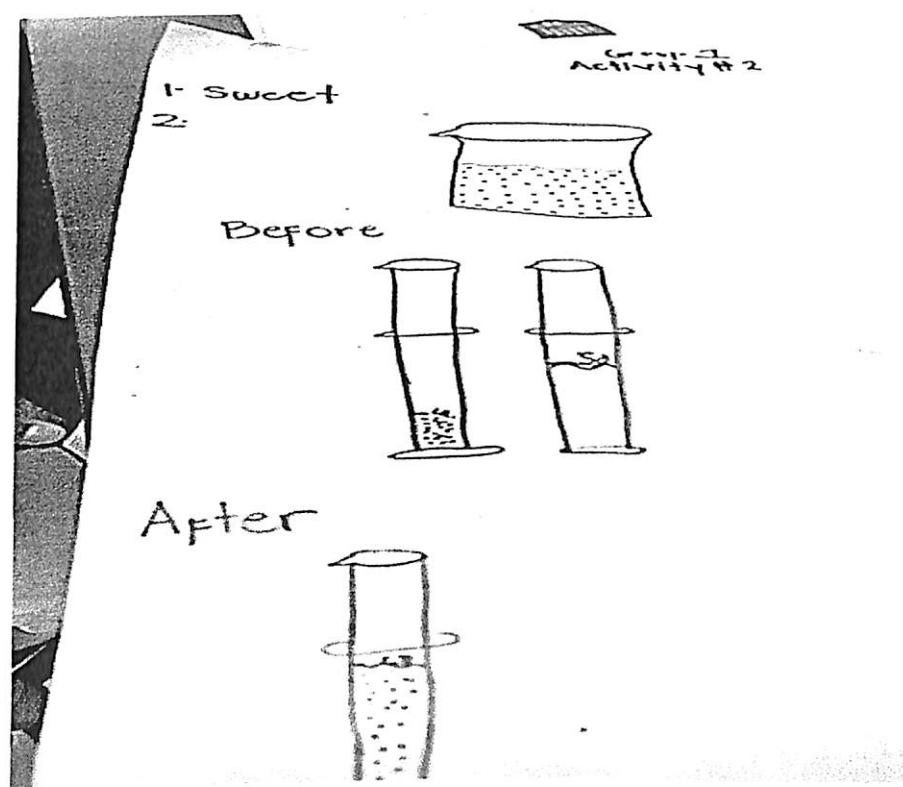


Figure 4.20. Students’ representation of sugar dissolving in water.

Student 1: *"Pag nag dissolve yung sugar sa water yung molecules ng sugar umaano sa space ng water molecules."* ("When sugar dissolves in water, the sugar molecules get in between the spaces in between water molecules.")

Student 2: *"Yung sugar na occupy nya yung space habang nasa water. Yung maliliit na particles ng sugar nag occupy siyang space sa water"* ("The sugar occupied the space while in the water. The small sugar particles occupied the space in water.")

The students recognized that there are spaces in between particles of matter. They were also beginning to represent matter at the sub-microscopic level. Figure 4.21 is another example of students' sub-microscopic representation of matter in Learning Activity 3 (*"Are the particles of matter moving? what is between them?"*). The shift from macroscopic to microscopic representation of matter indicates that the students have moved from a continuous view of matter to a particle view of matter.

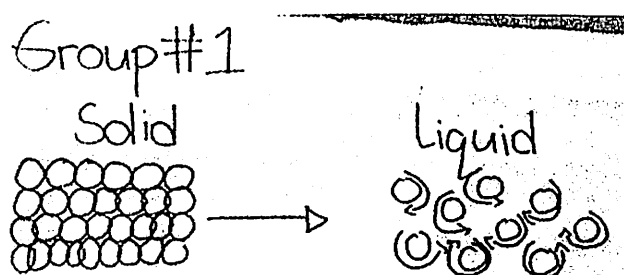


Figure 4.21. Students' representation of solid changing to liquid in Activity 3.

This conceptual change is important for students to describe chemical phenomena at a sub-microscopic level. Figure 4.22 below further shows that students of the

Collaborative Teaching group began to have a clearer understanding about the spaces between particles in gases and liquids. The illustration shows that students in this group knew what might happen to the particles of air and water as they pushed the plunger.

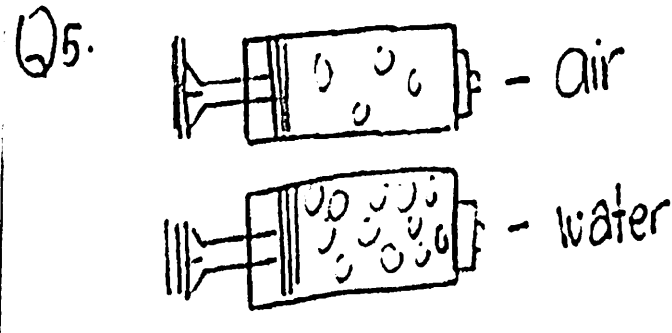


Figure 4.22. Students' illustration of their observation about the plungers in Activity 3.

This is evident in the following teacher-student conversation regarding this activity:

Question: *"Can you push the plunger all the way through the syringe while your thumb presses on the tip of the plunger? Why or why not?"*

Student's Answer: *"No, because the air do not escape to [from] the syringe."*

Question: *"What do you feel as you push the plunger?"*

Student's Answer: *"It can easily [be] pushed."*

Question: *"Compare what you felt when you pushed the plunger with air and with water?"*

Student's Answer: *"when we push the plunger with air we feel [it] so easy consequently, with the water we feel [it is] so hard or so difficult to push."*

The students explained that they could not push the plunger all the way through the syringe while their thumb presses on the tip of the plunger because of the air particles pushing against the plunger. In addition, they reported that it was more difficult to push the plunger with water because water particles are more closely packed as indicated in their drawing in Figure 4.22:

*“It was not possible to push the plunger all the way because there are air particles.”*

*“Air being gas there are large spaces between particles so it can be made to come closer. We can’t push the plunger with water because water particles are closer than in air.”*

Research indicates that students must undergo a conceptual change in order for them to move from a continuous view of matter to a particle view (Nussbaum & Novick, 1982; Vosniadou, 1994; Harrison & Treagust, 2002). According to Piaget (1977), learning happens when students experience “disequilibrium” or a conflict between their conception (or misconception) and what their teacher is presenting to them. This conflict induces them to reflect on their conception and try to resolve the conflict by integrating the new conception to their thinking and apply them to the phenomenon at hand. Hence, as students were exposed to the particle models through diagrams and other interactive activities (e. g., Human Particle activity), they began to make changes in their representation of matter. Hence, their understanding of matter changed from having a continuous view (Figure 4.16 and 4.17) to having a

complete particle view of matter (Figure 4.20 to Figure 4.22).

In the previous section, the conceptual change model by Posner et al. (1982) was presented. According to Posner et al. (1982), there are four conditions that should be met by students in order to go through conceptual change. These conditions are repeated in the context of the students' experiences during the Collaborative Teaching intervention:

1. Dissatisfaction. The learners need to realize that there is inconsistency in their way of thinking which does not explain phenomena or solve problems at hand. *In the study, students realized that their initial conclusion that smoke is not matter, were incorrect as the class discussed their output in Learning Activity 1 (Table 4.7).*
2. Intelligibility. Students should find the new conception understandable or intelligible in order for them to use the new conception to explain phenomena or solve problems. *In this study, students began to understand that solids, liquids and gases are made up of particles with spaces in between. The teachers' use of models made the particle view of matter understandable or intelligible.*
3. Plausibility. The students should see that the new conception is plausible and make more sense than the old conception. They should see that the new conception can explain the phenomena and solve the problem at hand. *In this study, as students began to understand that solids and liquids are made up of particles with spaces in between them, this helped them to explain more correctly what happens when sugar dissolves in water (Figure 4.20).*
4. Fruitfulness. The students should see that the new conception could explain other phenomena or solve the other problems. The new conception enables them to

understand and explain new areas of inquiry. *In the study, the students began to use with greater ease their particle view of matter to explain phase change in the latter Learning Activity lessons.*

The observed change in students' view of matter, is supported by the result of the ParNoMA test. Table 4.10 below shows the improvement in the mean scores of students from the Collaborative Teaching group for the items that pertain to the particle nature of matter and the spaces between them. The number of students with correct answers improved more than 90% for these particular items from 24.3% (35 students) in the pretest to 46.2% (66 students) in the posttest. Figure 4.23 shows graphically students' improvement of the mean scores in the ParNoMA test.

Table 4.10

*Percentage of Collaborative Teaching group students with correct answers at pretest and posttest on items about matter being composed of particles (N=143)*

	<b>Description of ParNoMA Item</b>	<b>Pretest</b>	<b>Posttest</b>	<b>Gain</b>
Item 1	Melting of ice	32.9	79.3	+46.5
Item 4	Evaporation of ammonia	19.3	44.3	+25.0
Item 6	State of matter	15.7	24.3	+8.6
Item 8	Boiling of water	20.0	36.4	+16.4
Item 16	Melting	44.3	55.7	+11.4
Item 19	State of matter	13.6	37.1	+23.5
<b>Mean</b>		<b>24.3</b>	<b>46.2</b>	<b>+21.9</b>

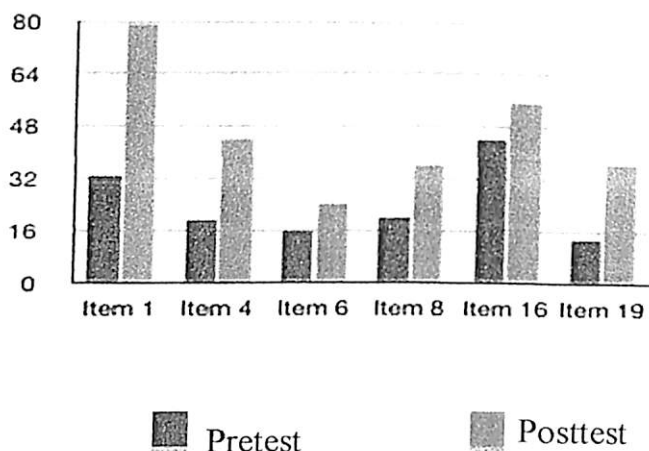


Figure 4.23. Percentage of students ( $N=143$ ) from the Collaborative Teaching group with correct answers for Items 1, 4, 6, 8, 16 and 19.

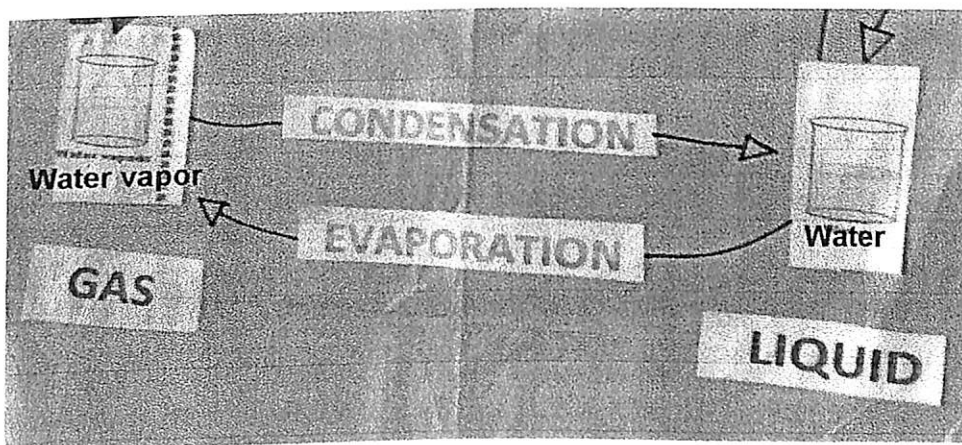
The students from the Conventional group ( $N=113$ ) also showed the same misconceptions as that of the Collaborative group. For instance, in Item 1, 40.7% of the students (or 46 students) chose B, meaning they also believed that atoms of oxygen and hydrogen separate during melting, an observation also reported by Osborne and Cosgrove (1983). In Item 4, 55.8% of the students (or 63 students) thought that particles of ammonia separate into nitrogen and hydrogen atoms during evaporation. Table 4.11 indicates that almost 70% of students lack knowledge that matter is made up of particles and there are spaces between these particles. About 56% have some misconceptions related to the particulate nature of matter than having a right conception.

Table 4.11

*Percentage of Conventional teaching group students with correct answers and with misconceptions about matter being composed of particles (N=113)*

	Description of ParNoMA Item	Percentage with correct answers	Percentage with misconceptions
Item 1	Melting of ice	44.3	40.7
Item 4	Evaporation of ammonia	26.6	55.8
Item 6	State of matter	15.0	57.5
Item 8	Boiling of water	23.0	52.2
Item 16	Melting	53.1	0.0
Item 19	State of matter	21.2	58.4
<b>Mean</b>		<b>30.5</b>	<b>44.1</b>

Like the students from the Collaborative group, students from the Conventional group also demonstrated a Type 1 or Type 2 view (continuous) of matter as can be seen in Figure 4.24. The individual particles of water molecules were not used to represent liquid and gaseous water.



*Figure 4.24. Representation of water undergoing evaporation and condensation by students from Conventional group.*

At the ParNoMA posttest there was also improvement in the mean scores of the students from the Conventional group. Table 4.12 shows the improvement in the students' mean scores for the items that pertain to the particle nature of matter and the spaces between them. The number of students with correct answers improved about 50% for these particular items from 30.5% (35 students) in the pretest to 45.8% (52 students) in the posttest.

Table 4.12

*Percentage of Conventional Teaching group students with correct answers at pretest and posttest on items about matter being composed of particles (N=113)*

	Description of ParNoMA Item	Pretest	Posttest	Gain
Item 1	Melting of ice	44.3	69.0	+24.7
Item 4	Evaporation of ammonia	26.6	41.6	+15.0
Item 6	State of matter	15.0	21.2	+6.2
Item 8	Boiling of water	23.0	45.1	+22.1
Item 16	Melting	53.1	62.8	+9.7
Item 19	State of matter	21.2	35.4	+14.2
Mean		30.5	45.8	+15.3

### **Changes in students' understanding of the phase changes of matter**

#### **Students' view of phase changes shift from chemical to physical change.**

At the beginning of the study, students from the Collaborative Teaching group showed a poor understanding of the fact that phase change of matter is only a physical process and not a chemical one. In a phase change, there is no bond-breaking or bond formation between atoms comprising the particles of matter.

For instance, in Item 5 (Figure 4.25) of the ParNoMA, only about 9% of the students (or 129 out of 143) chose the correct answer letter D. The rest of the students thought that some kind of bond breaking and/or formation of new bonds

occur. In fact, more than half of the students chose letter C thinking that oxygen and hydrogen atoms will separate during evaporation. This is consistent with their answer to Item 4 and Item 7 where about 43% and 85% of the students, respectively, concluded that some kind of bond breaking and/or bond formation occurs during evaporation.

5. When water changes from a liquid to a gas through evaporation or vaporization, energy is required to
- A. break the bonds between the hydrogen atoms.
  - B. form new bonds between the atoms.
  - C. break the bonds between the oxygen and hydrogen atoms in the molecules.
  - D. break the water molecules away from other water molecules.
  - E. form new bonds between the molecules.

Figure 4.25. Item 5 of ParNoMA Questionnaire.

Similarly, in Item 1 and Item 16 almost 43% and 23%, respectively of the students concluded that bond breaking and/or formation occur during melting. The observations regarding evaporation and melting are consistent with previous studies (Osborne & Cosgrove, 1983; Stojanovska et al., 2012; Mayer, 2011; Regan et al., 2011). These authors revealed that students think that water may split into its elements during evaporation and/or melting. Table 4.13 shows the items in ParNoMA where students show misconception about phase change being a chemical process. Only 25% got the correct answers for these items. Almost 48% of the students or 69 students held misconceptions about phase change being a chemical process.

It is possible that because of the students' initial low understanding of the particle nature of matter, they did not know the correct representation of phase

Table 4.13

*Percentage of Collaborative teaching group students with correct answers and with misconceptions about phase changes (N=143)*

	Description of ParNoMA items	Percentage with correct answers	Percentage with misconceptions
Item 1	Melting of ice	32.9	42.8
Item 4	Evaporation of ammonia	19.3	51.5
Item 5	Evaporation of water	9.3	80.7
Item 7	Vaporization of water	15.0	85.0
Item 8	Boiling of water	20.0	28.0
Item 11	Evaporation of water	34.3	32.1
Item 16	Melting	44.3	21.4
<b>Mean</b>		<b>25.0</b>	<b>47.8</b>

changes. Thus, students may have thought that when water evaporates and spreads into the surrounding air, it "splits" into its components as reported by Cosgrove and Osborne (1983) and Russel and Watt (1990) among upper elementary and middle school students. Students think that water "has split into millions of tiny micro bits and floated up" (Russel and Watt, 1990). Prior learning among students about water splitting into hydrogen and oxygen during electrolysis may also contribute to the misconception (Cosgrove & Osborne, 1983). That students attribute bulk properties of substances to particles may have also led students to think that when ice (solid water) melts, its particles are also broken apart like ice breaking apart during melting (Merritt, 2010; Brook et al., 1984). Stojanovska et al. (2012) reports, too, that students think that during evaporation the molecules themselves turn into vapor.

The data from ParNoMA are supported by the observations of the teachers from the Collaborative Teaching group. They observed the students' misconceptions

and difficulty in representing what happens to particles during phase change. Below are some of the similar comments of teachers:

*"In melting and freezing they do not know how to describe what happens to the particles, how to represent each state of matter; that of the spaces in solid they thought only particles of liquid and particles of gas move. They also thought that if heat is absorbed the chemical bond is broken."*

*"Their drawing of water particles looks like particles disband into hydrogen oxygen."*

Figure 4.26 illustrates what these teachers are talking about. The liquid water particles are shown separating into hydrogen and oxygen molecules as they escape into the gaseous state during evaporation.

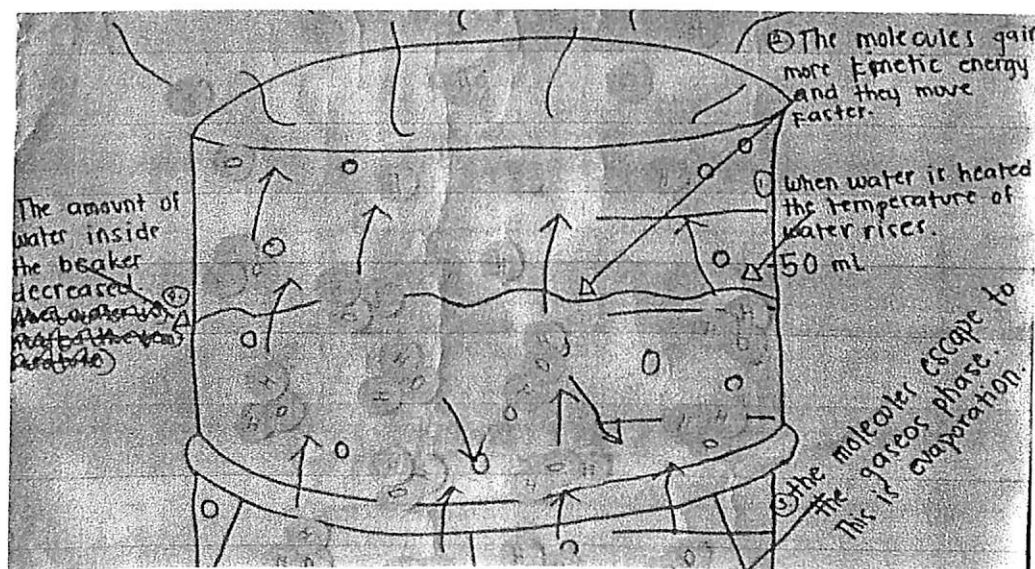


Figure 4.26. Representation of water particles separating into hydrogen and oxygen during evaporation.

The ParNoMA posttest scores of the students improved after CT intervention for their teachers as shown by Table 4.14. The number of students with correct answers increased about 103% from 25% (36 students) in the pretest to 50.7% (73 students) in the posttest. This is supported by the observation of teachers that students changed their understanding of phase changes as the study progressed.

Table 4.14

Percentage of Collaborative Teaching group students with correct answers at pretest and posttest about phase changes ( $N=143$ )

	Description of ParNoMA items	Pretest	Posttest	Gain
Item 1	Melting of ice	32.9	79.3	+46.5
Item 4	Evaporation of ammonia	19.3	44.3	+25.0
Item 5	Evaporation of water	9.3	52.1	+42.8
Item 7	Vaporization of water	15.0	39.3	+24.3
Item 8	Boiling of water	20.0	36.4	+16.4
Item 11	Evaporation of water	34.3	47.9	+13.6
Item 16	Melting	44.3	55.7	+11.4
Mean		25.0	50.7	+25.7

As a result they corrected the misconception they held that phase change is a chemical change. One teacher commented towards the end of the study,

*“Phase changes, physical change according to the students. Students initially thought particles or molecules of water, hydrogen and oxygen separate but later became clearer. They were able to correct that if water undergoes phase change nothing happens to the bond between the atoms; students said atoms of hydrogen and oxygen do not separate.”*

Another teacher observed that her students became better at representing the particles during phase change as they were doing Learning Activity 5:

*"Sabi nila alam na naman nila yung particles of gas particles of liquid; nagegets naman nila yung explanation. Tama naman yung illustration drawing nila ng evaporation and condensation. Students are able to explain and describe the process of evaporation and condensation at the submicroscopic level...(students said they know already about particles of gas and particles of liquid. They get the explanation. Their illustration drawing of evaporation and condensation is correct.)"*

Figure 4.27 is a typical illustration of students at Activity 5 showing the particles of water during evaporation and condensation. The students no longer represent particles of water separating into hydrogen and oxygen. The students from the Conventional Teaching group also hold the misconception that a phase change

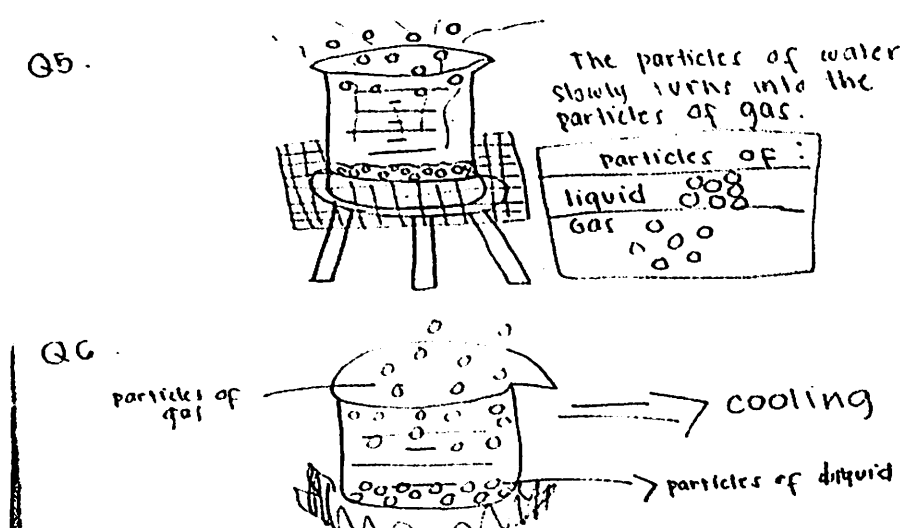


Figure 4.27. Students' correct representation of evaporation and condensation at Learning Activity 5.

involves a chemical process as shown in Table 4.15. Almost 46% of the students thought that phase change is a chemical change. This is comparable to that of the students (48%) from the Collaborative group.

Table 4.15

*Percentage of Conventional Teaching group students with correct ParNoMA pretest answers and with misconceptions about phase change (N=113)*

	<b>Description of ParNoMA items</b>	<b>Percentage with correct answers</b>	<b>Percentage with misconceptions</b>
Item 1	Melting of ice	44.3	48.7
Item 4	Evaporation of ammonia	26.6	44.3
Item 5	Evaporation of water	20.4	79.6
Item 7	Vaporization of water	28.3	71.7
Item 8	Boiling of water	23.0	23.0
Item 11	Evaporation of water	38.9	33.6
Item 16	Melting	53.1	19.5
<b>Mean</b>		<b>33.5</b>	<b>45.8</b>

Likewise, Table 4.16 shows there was improvement in the ParNoMA posttest scores of the students from the Conventional Teaching group. The number of students with correct answers rose from 33.5% (38 students) in the pretest to 46.3% (52 students) in the posttest or about 38% increase. However, this is smaller compared to the 103 percent of the Collaborative group.

Table 4.16

*Percentage of Conventional Teaching group students with correct answers at ParNoMA pretest and posttest on items about phase changes (N=113)*

	Description of ParNoMA Items	Pretest	Posttest	Gain
Item 1	Melting of ice	44.3	69.0	+24.7
Item 4	Evaporation of ammonia	26.6	41.6	+15.0
Item 5	Evaporation of water	20.4	23.0	+2.6
Item 7	Vaporization of water	28.3	34.5	+6.2
Item 8	Boiling of water	23.0	45.1	+22.1
Item 11	Evaporation of water	38.9	47.8	+8.9
Item 16	Melting	53.1	62.8	+9.7
Mean		33.5	46.3	+12.8

### **Students' realization that the size of particles of matter do not change during phase changes**

During phase change the size of particles does not change. Atoms change in size only when they are involved in a chemical reaction (Silberberg, 2010). Students from the Collaborative group ( $N=143$ ) held the misconception that particles of matter change in size during phase change. For instance, in Item 3 and Item 14 (Figure 4.28) almost 99% and 76% of the students, respectively, thought that particle size change during phase change. Table 4.17 shows the ParNoMA items where students held misconceptions about particle size during phase change. Almost 60% of the students (or 83 students) thought particles either expand or shrink during phase change. About 27% of students (or 39 students) think particles expand during melting or evaporation. Perhaps this may sound logical to students since melting and evaporation leads to matter being less compact or bigger. About 28% of students (or 40 students) think particles shrink during condensation or freezing. This

too, may sound logical to students since condensation and freezing lead to matter being more compact or smaller.

3.	Which of the following processes will make water molecules larger?
A.	freezing
B.	melting
C.	evaporation
D.	condensation
E.	none of the above
14.	Which of the following processes will make molecules smaller?
A.	freezing
B.	melting
C.	evaporation
D.	condensation
E.	none of the above

Figure 4.28. Item 3 and Item 14 of the ParNoMA Questionnaire.

Table 4.17

*Percentage of students from Collaborative group with correct ParNoMA pretest answers and those with misconceptions about particle size (N=143)*

	Description of ParNoMA Items	With Correct Answers	With Misconceptions
Item 3	Phase changes	1.4	98.6
Item 6	States of matter	15.7	38.6
Item 13	Evaporation/gas phase	31.4	39.3
Item 14	Phase changes	24.3	75.7
Item 19	States of matter	13.6	37.9
<b>Mean</b>		<b>17.3</b>	<b>58.0</b>

This misconception is consistent with those found in similar studies wherein students think water molecules can expand during evaporation and melting or shrink during condensation and freezing (Osborne & Cosgrove, 1983; Mulford & Robinson, 2002; Stojanovska et al., 2012). These studies show that the misconception about

size of particles during phase change is prevalent among middle school students (Osborne & Cosgrove, 1983), among high school students (Stojanovska et al., 2012) and college students (Mulford & Robinson, 2002). It is possible that those with misconceptions about the size of particles associate bulk properties to particles (Merritt, 2010; Brook et al., 1984). Bulk properties refer to physical properties of the substance such as volume or size, and physical characteristic of the substance such as being hard or brittle. Thus when water is heated, students may conclude that it expands since most objects expand when heated. Griffiths and Preston (1992) report in their study a similar misconception among high school students who think water molecules in steam are larger than those in ice.

Teachers shared similar observations about the students' misconception on particle size during phase change:

*“They think that phase change is chemical change, that particles or molecules of water, hydrogen and oxygen separate. When water undergo phase change the arrangement of molecules change, the size of atoms, particle size increase.”*

*“Misconceptions of students, naaalala ko about the size of particles; akala nila pagsa solid, especially sa yelo, yung liquid pagnilagay sa ice bag sa freezer lumalaki; akala nila lumaki din yung particles ng liquid kasi naoccupy nila yung plastic bag. I have to remind them that particle size donot change.”*

*(misconceptions of students, I remember about the size of particles; the students think that in solids, especially that of ice, if the liquid is placed into an*

*ice bag then into the freezer, the bag expands; they think the particles also grew bigger because the liquid is now occupying the entire plastic bag.”).*

At posttest, the ParNoMA scores of students from the Collaborative Teaching group showed improvement as shown in Table 4.18. There is a 112 percent increase in the number of students who got the correct answers for the items about particle size, from about 17% (24 students) in the pretest to almost 37% (53 students) in the posttest. This would mean that students improved in their understanding that particle size do not change during phase changes.

Table 4.18

*Percentage of students from Collaborative Teaching group with correct answers at pretest and posttest of ParNoMA for items about particle size (N=143)*

	<b>Description of ParNoMA Items</b>	<b>Pretest</b>	<b>Posttest</b>	<b>Gain</b>
Item 3	Phase changes	1.4	18.6	17.2
Item 6	States of matter	15.7	25.0	9.3
Item 13	Evaporation/gas phase	31.4	54.3	22.9
Item 14	Phase changes	24.3	48.6	24.3
Item 19	States of matter	13.6	37.1	23.5
<b>Mean</b>		<b>17.3</b>	<b>36.7</b>	<b>19.4</b>

Perhaps this is due to the progression of students' view of matter from the naïve and continuous view to the particle view. Various authors have pointed out that misconception of students in chemistry can be traced to a lack of understanding of the particle nature of matter. Improvement in their understanding of the particle nature of matter addresses their misconceptions about other PNM concepts (Adadan, 2006; Merritt, 2010; Chandrasegaran et al., 2009; Stojanovska et al., 2012;

Milenkovic et al., 2014). Merritt (2010), for instance, showed in her study that improvement in student performance parallels the shift of students' view of matter from continuous (Type 1) to the particle view (Type 5). Thus, as students from the Collaborative Teaching group learned more about the particle nature of matter, their misconception about particle size was addressed. Their teachers noted this improvement as the unit on matter progressed. One teacher commented how her students began to have a clearer picture about particles of matter:

*“Yung sa space naclarify yung meaning ng space; at least sa Activity 3 medyo nalilinawan na sila kung ano yung particle.” (about the space the meaning of space gets clearer; at least in Activity 3, the students already have a better understanding of what a particle is.)*

Another teacher noted that students are able to go beyond what they see to represent what they observe during phase change:

*“Sa pagdrawing ng sub-microscopic level ng particle dati kung ano langkasi ang nakikita nila yun na ang idradrawing nila but this time natuto sila mag-imagine ng submicroscopic level pagnagevaporate ang liquid into gas pagnagkaroon ng changes.” (In drawing sub-microscopic level of particle before, they just drew what they can see but this time they learned to imagine the sub-microscopic level when a liquid evaporates into gas when there are changes.) – in reference to Activity 4.*

Figure 4.29 shows their representation of what happens when water evaporates in

Activity 4 (“What changes take place when water is left in an open container? In a closed container?”). Students were already beginning to distinguish between macroscopic and sub-microscopic representations of phase change.

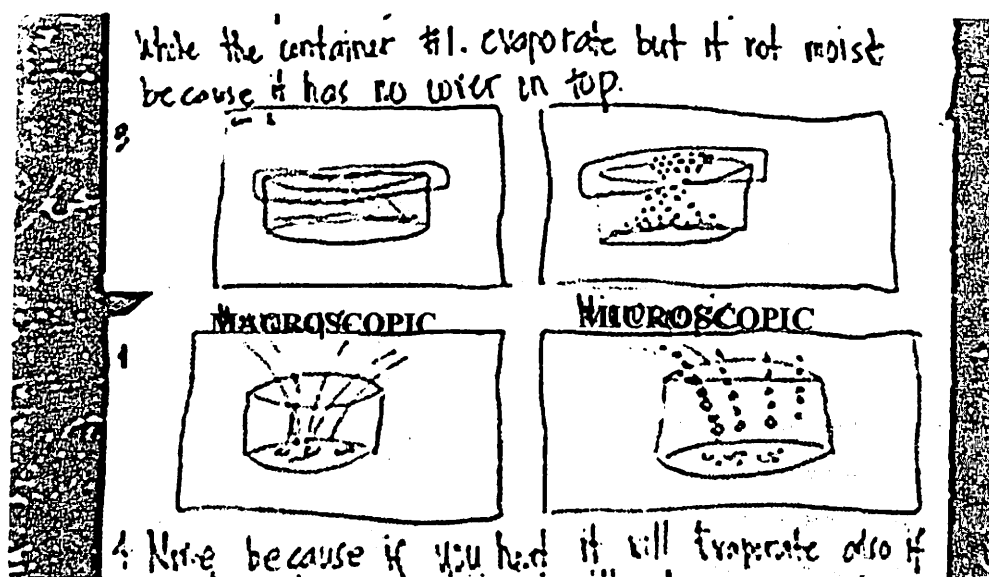


Figure 4.29. Students' macroscopic and submicroscopic representation of evaporation.

Another teacher noted that students found it easier to represent phase changes using sub-microscopic representation:

*"Students said they know already about particles of gas and particles of liquid...they get the explanation...their illustration...drawing of evaporation and condensation is correct (in reference to Learning Activity 5).*

Thus, by Learning Activity 5 (*What changes take place when water is heated and when it is cooled?*) students have shown understanding of what happens to particles of water during evaporation and condensation. The following is an excerpt from the interview of some students after their class did Learning Activity 5:

Interviewer: *“What did you learn from today’s lesson?”*

Student 1: *“Evaporation at saka boiling about molecules; kapag malamignagdidikit sila, pagmainit naghihiwalay. ” (“Evaporation and boiling about molecules; when it is cold they move closer together, when it is hot, they separate from each other.”)*

Student 2: *“Natutunan ko ano yung solid to liquid, liquid to solid tapos about molecules. Kapag mainit naghihiwalay sila, pagmalamig nagdidikit sila.” (“I learned what is solid to liquid, liquid to solid; and then about molecules. When it is hot, they separate from one another, when it is cold, they move closer together.”)*

Figure 4.30 to Figure 4.32 are samples of students’ outputs in Learning Activity 5. They show that students have improved understanding of particles of matter at the sub-microscopic level during phase change. Students are beginning to show the ability to represent water as made up of particles that move apart (“naghihiwalay”) during evaporation or move closer (“nagdidikit”) during condensation. Representation of matter shifted from Type 3 to Type 5 view of matter (Merritt et al., 2006). Figures 4.30 to 4.32 are reflections of the development of the students’ fluency of representing the particle nature of matter (Warfa et al., 2014; Merritt, Schwartz & Krajcik, 2007).

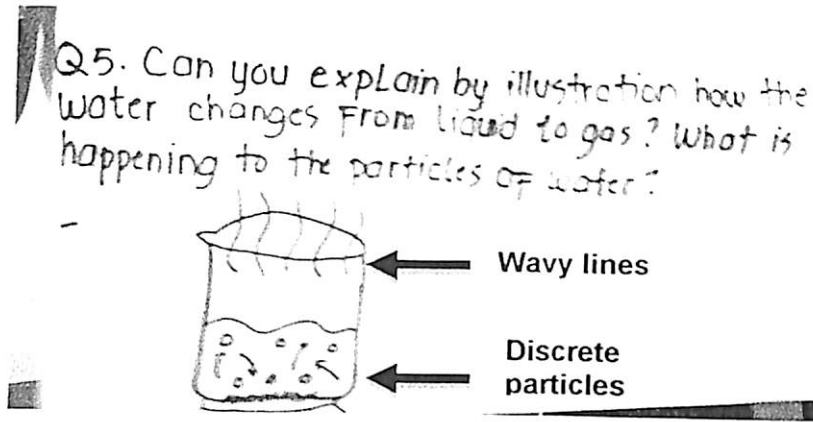


Figure 4.30. Students' Type 3 representation of water molecules as it evaporates.

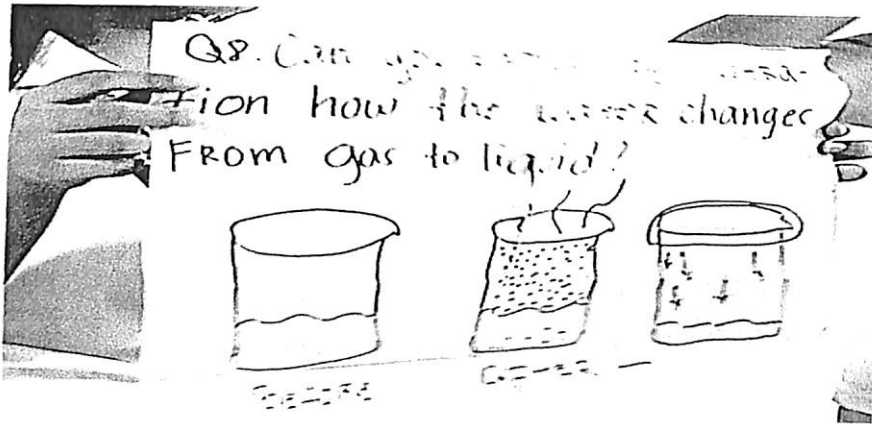


Figure 4.31. Students' Type 3 representation of water molecules as it condenses.

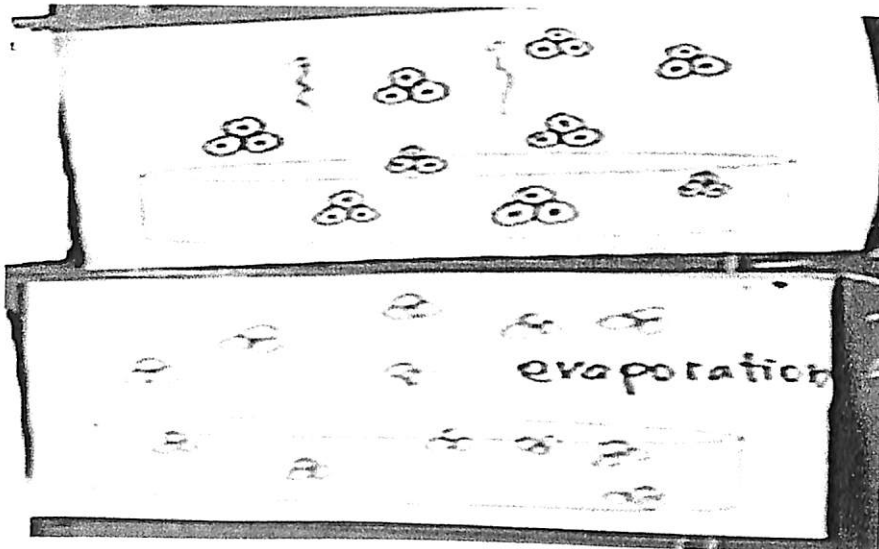


Figure 4.32. Students' Type 5 representation of water molecules as it evaporates.

The students moved from a continuous model of matter or Type 1 (Figure 4.17) to mix model or Type 3 consisting of lines and particles (Figure 4.30 and Figure 31) and then to a full particle model of matter (Figure 4.32). A mix model means that in their diagram, some parts show the particle nature of matter and other parts reflect a continuous view of matter. For instance they use small dots to illustrate the gaseous molecules and wavy lines to illustrate vapor or smoke. This important development in the students' particle view of matter served to unlock their understanding of other PNM concepts such as phase changes.

The students from the Conventional group ( $N=113$ ) showed similar misconception about the particle size of matter during phase change as shown in Table 4.19. Only about 16% of the students (or 18 students) got correct answers for the items pertaining to size of particles of matter during phase change. Almost 64% of the students (or about 72 students) hold misconceptions of particles of matter expanding or shrinking during phase change.

Table 4.19

*Percentage of students from Conventional group with correct ParNoMA pretest answers and those with misconceptions about particle size ( $N=113$ )*

	<b>Description of ParNoMA Items</b>	<b>With Correct</b>	<b>With</b>
Item 3	Phase changes	3.6	96.4
Item 6	States of matter	14.2	49.6
Item 13	Evaporation/gas phase	23.0	50.0
Item 14	Phase changes	15.0	85.0
Item 19	States of matter	21.2	38.1
<b>Mean</b>		<b>15.4</b>	<b>63.8</b>

The ParNoMA posttest scores of students from the Conventional Teaching group also improved as shown by Table 4.20. There is about 77% increase in the number of students who answered correctly the items about particle size. This is much less than the 112% increase shown by the Collaborative Teaching group.

Table 4.20

*Percentage of students from Conventional Teaching group with correct answers at pretest and posttest of ParNoMA for items about particle size (N=113)*

	Description of ParNoMA Items	Pretest	Posttest	Gain
Item 3	Phase changes	3.6	13.3	+9.7
Item 6	States of matter	14.2	19.5	+5.3
Item 13	Evaporation/gas phase	23.0	45.1	+22.1
Item 14	Phase changes	15.0	23.0	+8.0
Item 19	States of matter	21.2	35.4	+14.2
<b>Mean</b>		<b>15.4</b>	<b>27.3</b>	<b>+11.9</b>

### **Students' realization that particles are in constant motion in all states of matter**

Students from the Collaborative Teaching group exhibited difficulty in grasping the concept that particles of matter are moving constantly in all states of matter. The kinetic theory of matter states that all matter consists of many and very small particles that are constantly moving. Students from the Collaborative Teaching group showed their misconception about the movement of particles in matter. Item 2 and Item 10 are items about the motion of particles in the different states of matter shown in Figure 4.33. In Item 2, only about 27% of the students answered correctly

(i.e. option B). The rest did not know that particles of liquids move slower than particles of gas. Only about 28% answered correctly (i.e. option A) for Item 10. The rest of the students did not know that particles of liquids move faster than particles of solids. This implies that at least 70% of the students do not know that particles of gas move faster than particles of liquid and particles of liquids move faster than particles of solids.

2. Consider three samples of water in three phases. The first is solid water (ice) at  $0^{\circ}\text{C}$ , the second is liquid water at  $24^{\circ}\text{C}$ , and the third is gaseous water at  $100^{\circ}\text{C}$ . The water molecules in the liquid phase \_\_\_\_\_ the water molecules in the gaseous phase.

- A. move faster than
- B. move slower than
- C. move at the same speed as
- D. move more randomly than
- E. travel in the same direction as

10. Consider three samples of water in three phases. The first is solid water (ice) at  $0^{\circ}\text{C}$ , the second is liquid water at  $24^{\circ}\text{C}$ , and the third is gaseous water at  $100^{\circ}\text{C}$ . The water molecules in the liquid phase \_\_\_\_\_ the water molecules in the solid phase.

- A. move faster than
- B. move slower than
- C. move at the same speed as
- D. move more randomly than
- E. travel in the same direction as

Figure 4.33. Item 2 and Item 10 of ParNoMA questionnaire.

Table 4.21 shows the number of students with correct answers for the item about motion of particles of matter. Only about 29% of the students have correct understanding and about 69% who have misconceptions about the movement of particles in the different states of matter.

Table 4.21

*Percentage of students from Collaborative Teaching group with correct answers and with misconceptions for Items about motion of particles (N=143)*

	Description of ParNoMA Items	Percentage with correct answers	Percentage with misconceptions
Item 2	Phases of Matter	27.1	72.9
Item 10	Phases of matter	27.9	72.1
Item 13	Evaporation of water	30.7	57.9
Item 17	Evaporation of water	31.4	68.6
Item 20	Freezing of water	28.6	71.4
Mean		29.1	68.6

In addition to not knowing the difference in the speed of motion of particles among the different states, about 19% thought that particles of solids do not move (Item 20 in Figure 4.34).

20.	When water at 24°C is cooled and freezes, the water molecules
A.	become less organized
B.	move much faster
C.	stop moving
D.	break apart
E.	move much more slowly

Figure 4.34. Item 20 of ParNoMA Questionnaire.

The above results of pretest ParNoMA are supported by observations by the teachers. They noted early on that students have misconceptions about the movement of particles in different states:

*“How particles behave differently; particles of solid do not move because they are very close to one another.”*

*“Hindi alam ng ibang students ko na may spaces na small sa solids.” (Some of my students do not know that there are small spaces between solids.)*

*“About movement of particles, yung spaces sa solid akala nila anggumagalaw lang ay yung particles ng liquid and particles ng gas.” (...the spaces in solids they thought only particles of liquids and gases move.)*

These findings were corroborated by teachers' observations during the implementation of Activity 3 (*“Are particles of matter moving? What is between them?”*) and Activity 6 (*“What changes take place when ice turns into water?”*). Teachers reported that it was difficult for students to grasp the idea that even particles of solids are constantly moving. One teacher reported that:

*“They do not know that particles are continually moving; even though they are very close to each other, they are still moving but minimal for solid, for liquids faster. Another is that there are spaces in between particles; they thought that solids are super-compact and no spaces in between particles. Then in melting and freezing they do not know how to describe what happens to the particles; how to represent each state of matter that of the spaces in solid.*

Another teacher reported that students lack understanding about the particles' motion and forces of attraction between particles during phase changes:

*“They lack understanding about the movement of particles; that of the spaces in solid. They thought only particles of liquid and particles of gas move. They*

*also thought that if heat is absorbed the chemical bond is broken. ”*

Misconceptions about motion about particles of matter had been reported in previous studies among students (Novick & Nussbaum, 1981; Osborne & Cosgrove, 1983; Stavy, 1990; Osborne & Simon, 2006; Kirbulut & Beeth, 2013; Sopandi et al., 2017). Novick and Nussbaum (1981) reported that among 16 and above year old students, only half of those in their study have correct conception of particles of matter in constant motion. Among 13-14 year olds in their study, they found out 25% think there is no space between particles of matter. Even among 16-18 year olds, Kirbulut and Beeth (2013) reported students' misconception that particles in solids do not move. Sopandi et al. (2017) reported that even among college students there is the misconception that water particles do not move in frozen ice or when ice melts or during condensation.

However, as the implementation of Collaborative Teaching intervention progressed, students in the Collaborative Teaching group demonstrated changes in their understanding of particles being in constant motion and the impact of heat on the speed of their movement. These changes are more prominent among the students in the Collaborative Teaching group than those in the control group. Table 4.22 shows the improvement of ParNoMA scores of students from the Collaborative teaching. There is about 97% increase in the mean scores of the students for the pertinent ParNoMA items. This increase meant students who have correct conception about motion of particles of matter rose to almost 58%. The improvement is greatest with Item 20 (Figure 4.34) where about 17% thought that particles of

solids do not move or stopped moving (letter C) in the pretest. In the posttest, only about 6% of the students held on to the misconception.

Table 4.22

*Percentage of students from Collaborative Teaching group with correct answers at pretest and posttest for items about motion of particles (N=143)*

	<b>Description of ParNoMA Items</b>	<b>Pretest</b>	<b>Posttest</b>	<b>Gain</b>
Item 2	Phases of Matter	27.1	58.6	+31.5
Item 10	Phases of matter	27.9	50.7	+22.8
Item 13	Evaporation of water	30.7	54.3	+23.6
Item 17	Evaporation of water	31.4	61.4	+30.0
Item 20	Freezing of water	28.6	62.1	+33.5
<b>Mean</b>		<b>29.1</b>	<b>57.4</b>	<b>+28.3</b>

Teachers who observed improvement in their students' understanding of the motion of particles corroborate this. As Collaborative Teaching continued, students' representation of particles of solids, liquids and gases improved as pointed in the earlier sections of this chapter. One of the teachers, states:

*"Students thought particles of solid do not move because they are very close to one another. It was corrected right away. Students realized molecules of solid particles move all the time different as it shifts from solid to liquid to gas."*

The improvement may be attributed to students' improved understanding of the particle nature of matter. As studies show, students show improvement in their understanding of other PNM concepts as they gradually learn concepts that are taught and learned through submicroscopic representation, one of which is that

matter is made up of particles (Adadan, 2006; Merritt, 2010; Chandrasegaran et al., 2009; Stojanovska et al., 2012; Milenkovic et al., 2014).

Like the students from the Collaborative Teaching group, students in the Conventional Teaching group showed misconceptions about the movement of particles in different states of matter. Table 4.23 shows the number of students with correct answers and those with misconceptions about the motion of particles of matter in solids, liquids and gas. These are comparable to those of the Collaborative Teaching group students. The number of students with misconceptions (about 70%) is comparable to that of the Collaborative Teaching group students (about 70%).

Table 4.23

*Percentage of students from Conventional Teaching group with correct answers and with misconceptions for Items about motion of particles (N=113)*

	<b>Description of ParNoMA Items</b>	<b>Percentage with correct answers</b>	<b>Percentage with misconceptions</b>
Item 2	Phases of Matter	38.9	61.1
Item 10	Phases of matter	34.5	65.5
Item 13	Evaporation of water	23.0	75.6
Item 17	Evaporation of water	37.2	62.8
Item 20	Freezing of water	20.4	79.6
<b>Mean</b>		<b>30.8</b>	<b>68.9</b>

Table 4.24 shows that students from the Conventional Teaching group also showed improvement in the posttest of ParNoMA. The increase in the scores is almost 77%. The actual increase in the number of students with correct conception about the motion of particles of matter rose to about 54%.

Table 4.24

*Percentage of students from Conventional Teaching group with correct answers at pretest and posttest for items about motion of particles(N=113)*

	Description of ParNoMA Items	Pretest	Posttest	Gain
Item 2	Phases of matter	38.9	59.3	+20.4
Item 10	Phases of matter	34.5	67.2	+32.7
Item 13	Evaporation of water	23.0	45.1	+22.1
Item 17	Evaporation of water	37.2	58.4	+21.2
Item 20	Freezing of water	20.4	38.9	+18.5
<b>Mean</b>		<b>30.8</b>	<b>53.8</b>	<b>+23.0</b>

This increase is relatively lower than that of the students from the Collaborative Teaching group, which showed a 97 percentage increase, from 29% at pretest to about 58% at posttest of students with correct conception. Like the students from the Collaborative Teaching group, the students from Conventional Teaching group may have improved in their understanding of the particle nature of matter. In fact, 46% of students have correct conception of the particle nature of matter (Table 4.16) at posttest. As pointed earlier, studies have shown that improvement in students' understanding of particle nature of matter helps improve other PNM conceptions (Adadan, 2006; Merritt, 2010; Chandrasegaran et al., 2009; Stojanovska et al., 2012; Milenkovic et al., 2014).

The observed improvement in students' understanding of PNM, are consistent with other studies that show collaboration among teachers improve student learning (Lucenario et al., 2016; Austria et al., 2013; Punzalan et al., 2013; Barrett, Riggs & Ray, 2013). For instance, the study by Lucenario et al. (2016) shows that students of chemistry teachers who underwent PCK-guided Lesson Study, developed

conceptual understanding of solutions. The study by Austria et al. (2013) shows that students of teachers who underwent Lesson Study, increased their understanding of chemical change. These studies point out that collaboration of teachers in preparing and evaluating the lesson plans and implementation of the plan contribute to increased student learning. The teachers worked as a team to develop, implement and improve lessons in order to improve student learning. The teachers from this current study expressed these same aspects of CT:

*“Communication is very important especially within colleagues because there are techniques and strategies that we might not know and how to use them without the help of others. If there is sharing, we see our mistakes and how it can be improved. After discussion or after observation we can improve the specific lesson, improve ourselves, what else there is to improve. **We can improve in turn the quality of education we give our students.**”*

In this study, the Collaborative Teaching intervention also afforded teachers time to reflect about their teaching and how the students are learning. Group discussion during pre-lesson and post lesson and focus group discussions were some ways teachers could do this reflection. Observing other members of the group teach the lessons helped teachers see how they can improve their teaching of similar concepts. Teachers commented below how CT helped them:

*“We share, we help each other how to analyze and understand the given concept if there are misconceptions. What I like about this group collaboration is we share the ideas, what we have, what our weaknesses, what our strong*

*points, what we can use during the teaching.”*

*“The concepts, ideas and strategies we discuss to improve even more the way we teach which has a **huge impact on our students’ learning.**”*

*“We see our mistakes and what we should improve. After discussion or after observation we are able to improve the specific lesson; others give feedback of how we can improve then **we also improve the quality of education we give our students.**”*

The students from the Conventional Teaching group also showed improvement as pointed above. While the improvement could be attributed to student learning using conventional method such as lecture (Mbirimtengerenji et al., 2015), the increase may also be attributed to the activity-based and inquiry approach Learning Material provided by the Department of Education, called Learner’s Material, which each student has. The teachers have both the Teacher’s Guide and Learner’s Material. The activities in the Learner’s Material for Grade 8 use the inquiry-based approach. Studies show that instructional materials especially those that are activity-based and inquiry-based approach have a positive effect on student achievement (Andersen, 2002; Eya, 2004; Usman & Adewumi, 2006; Arop et al., 2015). Usman and Adewumi (2006) stated that instructional materials stimulate students’ interest and help the teacher and students overcome physical limitation during presentation of subject matter. Eya (2004) further states, that instructional materials enable the teacher to

have an “air of guidance, coordination, supervision and more time for correction, brighten the classroom and bring variety in the class lesson”. In the study by Arop et al. (2006), the use of instructional materials led to higher mean achievement gain score for the treatment group than the control group in learning the concept of diffusion. Moreover, activity-based and inquiry approach learning materials increase learning by helping develop critical thinking of learners (Andersen, 2002). Students from both groups may have benefitted from all these. Thus, it was possible that these positive factors may have influenced positively the performance of students from the Conventional teaching group. However, the percentage increase in the ParNoMA posttest scores of students from the Collaborative Teaching group (over 90%) is higher than that of students from the Conventional Teaching group (about 50%). Thus, perhaps the higher % increase of scores of CT Group students may be accounted for by the type of teaching (or CT), beyond the effect of lecture-based teaching (Mbirimtengerenji et al., 2015), and the Learner’s Material developed by DepEd. Studies show that traditional lecture-based teaching may be a less effective approach in teaching science (Tekkaya, 2003; Caliket al. 2006; Bruck & Phelps, 2010).

Table 4.25 summarizes the improvement in students’ misconception about PNM after Collaborative Teaching.

Table 4.25

*Summary of students' corrected misconceptions after Collaborative Teaching*

Misconceptions before CT	Corrected misconceptions after CT
1. Particles of matter stop moving during freezing.	1. Particles of matter continue to move during freezing.
2. Particles of matter do not move in solids.	2. Particles of matter are moving in solids.
3. The particles of solids are compact with no spaces in between them.	3. The particles of solids are not compact but have spaces in between them.
4. Particles of matter expand during evaporation and/or melting	4. Particles of matter do not expand during evaporation and/or melting
5. Particles of matter shrink during condensation and/or freezing.	5. Particles of matter do not shrink during condensation and/or freezing.
6. Liquid water break down into H <sub>2</sub> and O <sub>2</sub> during evaporation.	6. Liquid water does not break down into H <sub>2</sub> and O <sub>2</sub> during evaporation.
7. Solid water or ice break down into H and O atoms during melting	7. Solid water or ice does not break down into H and O atoms during melting
8. Heating water will break the covalent bonds between H and O.	8. Heating water will not break the covalent bonds between H and O.
9. Phase change is a chemical change.	9. Phase change is only a physical change.
10. Air and smoke are not matter.	10. Air and smoke have mass and volume and therefore are classified as matter.

**Changes in Students' Mastery Level****Descriptive Statistics**

The changes in students' understanding of PNM concepts and phase changes are supported by the quantitative data from ParNoMA test. The students of teachers from the Collaborative Teaching group have an average ParNoMA pretest score of 5.11 out of 20 items or 25.6% (SD=2.48). Individual scores range from 1 to 12. The mean score increased at posttest to 9.94 out of 20 or 49.7% (SD=3.40) with

individual scores ranging from 2 to 19. Thus the score increased by 94.2%. This result is consistent with the increased student achievement in similar studies (Mulford & Robinson, 2002; Punzalan et al., 2013; Stojanovska et al., 2012; Olfos et al., 2014). The mean pretest score indicates that students have initially a rather low (in the 15%-34% category of the DepEd National Achievement Test Mastery Level Descriptive Category) mastery of PNM concepts. In the posttest, the over-all mastery level moved higher to "Average Mastery" (35% to 65%). Figure 4.35 shows the histogram or distribution of the scores of the students for pretest and posttest. The shift of the histogram further towards the right is indicative of the improvement in the mean score of the posttest. Figure 4.36 shows the percentage distribution of students from the Collaborative Teaching group who correctly answered each item. The graph indicates that more students answered correctly the ParNoMa in the posttest than in the pretest. The graph further shows that the average percentage of students who got the correct answer *increased* from about 25% (36 students) to about 47% (68 students).

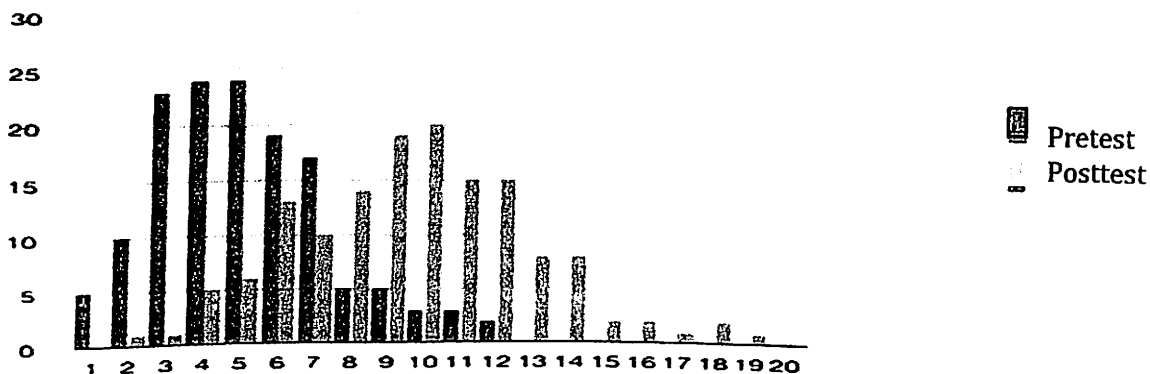


Figure 4.35. Histogram of pretest and posttest ParNoMA scores of Collaborative Teaching Group students.

Furthermore, the graph shows that students developed *greater understanding* of PNM concepts in all 20 items with the exception of Item 9 where there was no increase. In Item 9, students were asked to explain the formation of water droplets on the inside of a lid of a pot with boiling water.

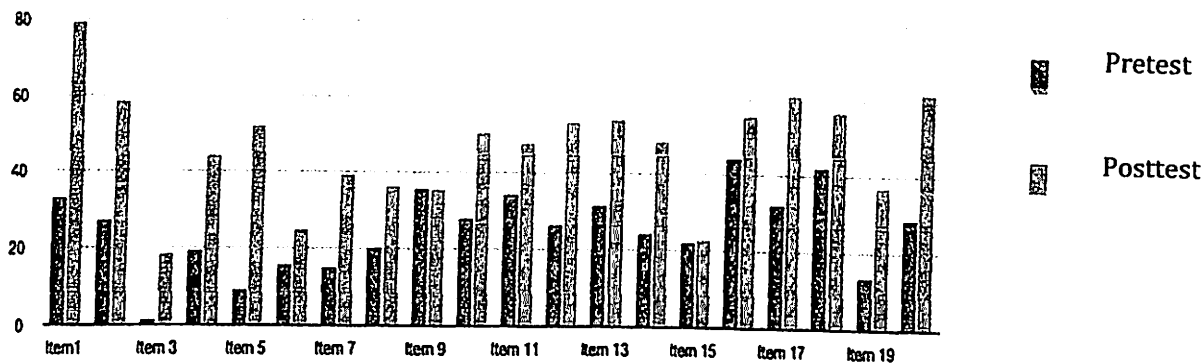


Figure 4.36. Percentage of students of Collaborative Group teachers who answered correctly each item.

Figure 4.36 also shows that in 18 out of 20 questions, more than 65% of students answered incorrectly during the pretest. The number of incorrect answers dropped to 3 out of 20 questions during the posttest. This could mean that Collaborative Teaching have a positive effect in the improvement of the students' understanding of PNM (Lucenario, 2013; Punzalan et al., 2013; Olfos et al., 2014). This increase could also be explained in terms of the curriculum in Science, particularly in the Matter domain. It is only in Grade 8 that the PNM is introduced, and from Grade 3 to Grade 7, concepts were developed at the macroscopic level only. So the increase in the posttest is worth noting, even if the scores are not too high.

Table 4.26 is the Table of Specification (TOS) for the ParNoMA test. The main purpose of this test is to assess the students' understanding of fundamental PNM concepts such as matter consisting of discrete particles with spaces in between. The items are also based on published misconceptions to evaluate students' misconceptions such as size of particles, movement of particles, composition of particles and phases and phase change. Table 4.27 illustrates further the apparent improvement in students' conceptual understanding of PNM in the three major areas of PNM concepts. The students showed the least improvement in their understanding of concepts related to phase changes.

Table 4.26

*Table of Specification for ParNoMA test*

<b>PNM concepts</b>	<b>Items</b>	<b>Points</b>	<b>%</b>
Matter is made up of particles and have spaces in between them	1, 4, 6, 8, 16, 19	6	30
Particles of matter are in constant motion	2, 9,10, 13, 17, 20	6	30
Phase and phase changes	3, 5, 7, 11, 12, 14,15, 18	8	40
<b>Total</b>	<b>20</b>	<b>20</b>	<b>100</b>

Table 4.27

*Improvement of student's scores of Collaborative Teaching group in terms of PNM concepts (N=143)*

<b>PNM concepts</b>	<b>Mean % students with correct answers at Pretest</b>	<b>Mean % students with correct answers at Posttest</b>	<b>Gain</b>
Matter is made up of particles and have spaces in between them (Item 1, 4, 6, 8, 16, 19)	24.8	46.2	+21.4
Particles of matter are in constant motion (Item 2, 9,10, 13, 17, 20)	30.4	53.8	+23.4
Phase changes (Item 3, 5, 7, 11, 12, 14,15, 18)	21.8	42.5	+20.7
<b>Mean</b>	<b>25.7</b>	<b>47.5</b>	<b>+21.8</b>

It has been known that misconceptions are powerful, extremely persistent and hard to change, creating obstacles to further learning (Kirbulut & Beeth, 2013; Canpolat, 2006; Pabuccu & Geban, 2006). Nevertheless, overall the number of students with knowledge and understanding of PNM concepts increased from about 26% to almost 48% (84.8 percentage increase). This is comparable to the result obtained by Stojanovska et al. (2012) which was about 110% increase. The result of the current study is higher than the 44% increase reported by Modic (2011) and 22% increase reported by Nuic and Glazar (2015).

Figure 4.37 shows the histogram of ParNoMA scores of students from the Conventional. Comparison of Figure 4.35 (page 202) and Figure 4.37 shows that the shift for Collaborative Teaching group is greater. The difference in the location of the peaks of the histograms shows that the mean score of students from the

Collaborative group is higher. The lowest posttest score for both groups is the same at 2 points.

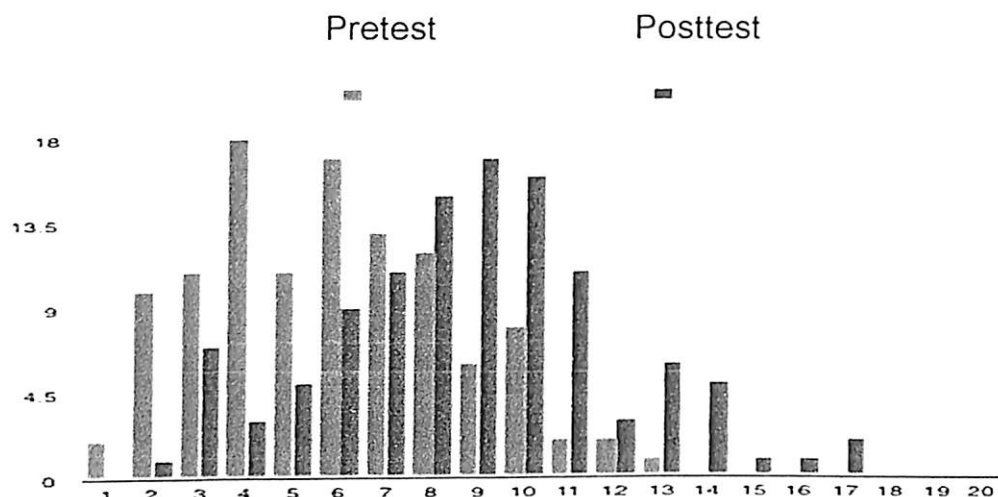


Figure 4.37. Histogram of the ParNoMA scores of students from the Conventional Teaching Group.

The highest score for the Conventional Teaching group is 17 while that of the Collaborative Teaching group is 19. Figure 4.38 shows the percentage of students with correct answer. The posttest percentages for the Collaborative group are higher over-all. This is most evident for Item 5, Item 14 and Item 20, where the Collaborative group percentages are about twice that of the Conventional group.

Table 4.28 compares the pretest and posttest raw mean scores and gain scores of the two groups. Over all, the average gain score of the Collaborative group (+4.8) is about 65% higher than that of the Conventional Teaching group (+2.9).

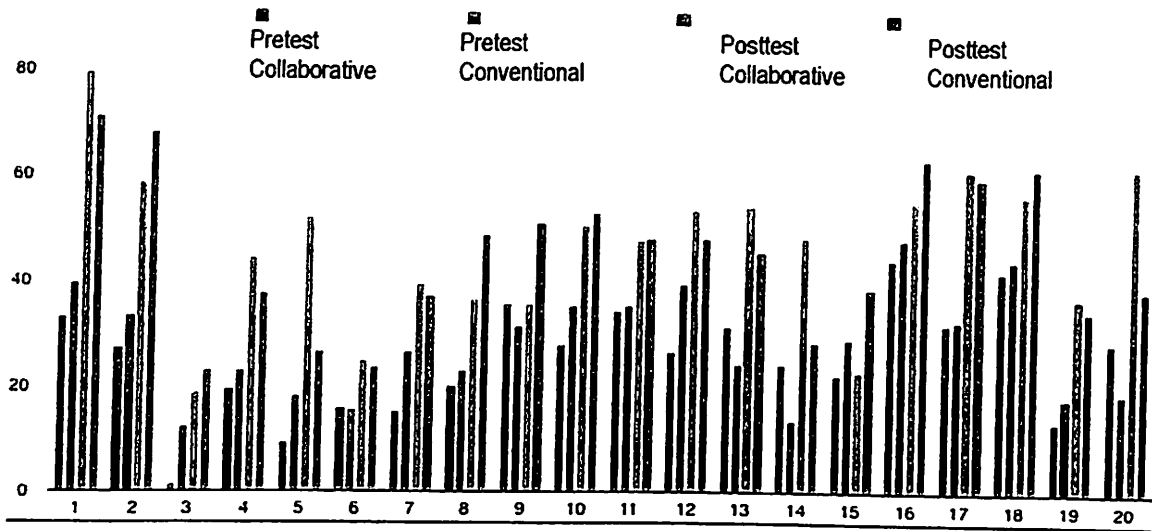


Figure 4.38 Percentage of students who answered correctly each item of the ParNoMA.

Table 4.28

Mean ParNoMA Pretest and Posttest Scores of students from Collaborative and Conventional Teaching Groups

Pretest (Max Score = 20)		Posttest (Max. score=20)		Gain Score			
Collaborative Teaching Group (N=143)		Conventional Teaching Group (N=113)		Collaborative Teaching Group		Conventional Teaching Group	
Sec*		Sec					
1	7.2	6	6.1	12.1	8.9	+4.9	+2.8
20	5.0	9	8.1	8.4	9.5	+ 3.4	+1.4
43	3.6	13	4.5	9.2	9.0	+ 5.6	+4.5
15	4.8	41	4.4	8.3	7.5	+ 3.5	+3.1
18	4.6			10.3		+ 5.7	
21	4.3			10.7		+ 6.4	
Mean	5.1		5.8	9.9	8.7	+ 4.8	+2.9

\* Sec: Refers to Class Section; six sections for Collaborative Teaching group and four sections for Conventional Teaching group

### **National Achievement Test (NAT) Mastery Level**

The standard for a passing grade in the public school system is 75% (zero-based). In the pretest only, none reached the passing score of 15 out of 20. At posttest only 9 students (about 7%) passed. However, as pointed above there is considerable increase or improvement in the posttest score (almost 95% from the pretest). In the Department of Education system, students are assessed yearly. This is called the National Achievement Test or NAT. The student's mastery level is measured in accordance to the Mastery Level Description Equivalent:

96% - 100%	Mastered (M)
86% - 95%	Closely Approximating Mastery (CAM)
66% - 85%	Moving Towards Mastery (MTM)
35% - 65%	Average Mastery (AM)
16% - 34%	Low Mastery (LM)
5% - 15%	Very Low Mastery (VLM)
0% - 4%	Absolutely No Mastery (ANM)

The ideal mastery level is 75%. Currently, the National NAT score for Science is at 47%. In the current study, the mean posttest score of the students from the CT group is at about 50% with Mastery Level at the 35%-65% or Average Mastery level. Thirty-eight (38) students out of 143 or 26.6% got "Very Low Mastery" rating in the pretest. Sixty-nine (69) students or 48.2% got "Low Mastery" rating. Thirty-six (36) students or 25.2% got "Average Mastery" rating.

In contrast, in the posttest, those who got “Very Low Mastery” rating were down to only 2 students out of 143 or 1.4%. Those who got “Low Mastery” rating were down to 24 students or 16.8%. Those who got “Average Mastery” rating increased to 99 students or 69.2%. Fourteen (14) or 9.8% got “Moving Towards Mastery” rating. Four (4) students or 2.8% got “Closely Approximating Mastery” rating.

Table 4.29 shows how many students changed in their mastery rating. This includes the number of students whose rating improved, did not change or became lower. Moving from the leftmost column to the right, the number in each cell shows exactly how many students changed in their mastery ratings. Thus, this indicates the number of students who actually improved in their knowledge and understanding of PNM concepts. The diagonal cells represent the number of students whose rating did not change even after Collaborative Teaching intervention. The cells above the diagonal cells represent the number of students whose rating improved after Collaborative Teaching intervention.

Table 4.29

*The number of students whose mastery rating improved, decreased or remain unchanged in the Collaborative Teaching group*

Pretest/Posttest	VLM	LM	AM	MTM	CAM	M
VLM*	0	8	30	0	0	0
LM	2	14	47	6	0	0
AM	0	2	22	8	4	0
MTM	0	0	0	0	0	0
CAM	0	0	0	0	0	0
M	0	0	0	0	0	0

\*VLM –Very Low Mastery, LM – Low Mastery, AM – Average Mastery, MTM – Moving towards Mastery, CAM – Closely Approximating Mastery, M- Mastered

The cells below the diagonal cells represent the number of students whose rating became lower after Collaborative Teaching intervention. The number of students whose rating improved is as follows:

- a. Changed from "Very Low Mastery" to "Low Mastery" are 8.
- b. Changed from "Very Low Mastery" to "Average Mastery" are 30.
- c. Changed from "Low Mastery" to "Average Mastery" are 47.
- d. Changed from "Low Mastery" to "Moving towards Mastery" are 6.
- e. Changed from "Average Mastery" to "Moving towards Mastery" are 8.
- f. Changed from "Average Mastery" to "Completely Approaching Mastery" are 4.

There were only 4 students out of 143 or 2.8% whose rating became lower. There were 36 students or 25.2% whose rating remained unchanged. There were 103 students or 72.0% whose rating improved. Thus, students' understanding of PNM improved over-all. This is an indication that the CT intervention their teachers went through had a positive effect on the students' scores.

For the Conventional Teaching Group none got the passing score of 15 out of 20 in the pretest. In the posttest, only 4 students (about 4% of total students) passed. Table 4.30 show the number of students in the Conventional Teaching group whose mastery level changed. The mastery level of both groups is "Average Mastery" level, Collaborative Group at 49.7% and Conventional Group at 43.6%. However, comparing Table 4.29 above and Table 4.30 reveals that the Collaborative Teaching group showed greater improvement over-all. From the Collaborative Teaching group there were only 4 students out of 143 or 2.8% whose rating became

lower. There were 36 students or 25.2% whose rating remained unchanged. There were 103 students or 72.0% whose rating improved. In contrast, there were 13 students out of 113 or 11.5% whose rating became lower in the Conventional Teaching group. There were 36 students out of 113 or 31.9% whose rating remained unchanged. There were only 64 students out of 113 or 56.6.0% whose rating improved.

Table 4.30

*The number of students whose mastery rating improved, decreased or remain unchanged in the Conventional Teaching group*

	VLM	LM	AM	MTM	CAM	M
VLM	1	5	14	3	0	0
LM	4	5	36	1	0	0
AM	2	7	30	5	0	0
MTM	0	0	0	0	0	0
CAM	0	0	0	0	0	0
M	0	0	0	0	0	0

\*VLM –Very Low Mastery, LM – Low Mastery, AM – Average Mastery, MTM – Moving towards Mastery, CAM – Closely Approximating Mastery, M- Mastered

### Wilcoxon Test

Analysis through non-parametric statistical tests supports the qualitative results and the other descriptive statistical results discussed above. A non-parametric test was used since the researcher has no exact knowledge if the population distribution is normal (Siegel & Castellan, 1988). The Wilcoxon Sign test is ideal because it enables one to determine which is “greater than” between two

pairs of values, e.g. pretest and posttest scores (Siegel & Castellan, 1988). Wilcoxon Sign Ranks Test analysis of the ParNoMA scores of students from the Collaborative Teaching Group shows that the posttest scores of the students are statistically higher than the pretest ( $p = 0.000$  at  $\alpha = 0.05$  and 1-tailed test) as shown in Table 4.31. Furthermore, Wilcoxon-Mann-Whitney Test analysis shows that the posttest scores of students from the Collaborative Teaching Group is statistically higher than that of the Conventional Teaching group ( $p = 0.0005$  at  $\alpha = 0.05$  and 1-tailed test) as shown in Table 4.32. Lastly, Wilcoxon-Mann-Whitney Test analysis shows that the gain score of the students from the Collaborative Teaching Group is statistically higher than that of the Conventional Teaching Group ( $p = 0.000$  at  $\alpha = 0.05$  and 1-tailed test) as shown in Table 4.33. It is also worth noting that the pre-post analysis of the Conventional group using Wilcoxon Sign Rank Test show that the pretest and posttest scores of the students from the Conventional group show a significant difference ( $p = 0.000$  at  $\alpha = 0.05$  and 1-tailed test). This supports the conclusion made in previous discussions about the effectiveness of the K-12 inquiry based instructional materials used by teachers and students. Be that as it may, the difference in the posttest scores of the two groups and the difference in the gain score of the two groups were still found to be statistically significant based on the Wilcoxon -Mann Whitney test.

Table 4.31

*Wilcoxon Signed Ranks Test of ParNoMA scores of Collaborative Teaching*

*Group*

<b>Null Hypothesis</b>	<b>Test</b>	<b>Significance</b>	<b>Decision</b>
H <sub>0</sub> : The median of difference between Pretest and Posttest equals 0. H <sub>1</sub> : Posttest is higher than Pretest	Related Samples Wilcoxon Signed Rank test	p= 0.000	Reject the null hypothesis

Table 4.32

*Wilcoxon-Mann Whitney Test of posttest ParNoMA scores of Collaborative*

*Teaching Group and Conventional Teaching Group*

<b>Null Hypothesis</b>	<b>Test</b>	<b>Significance</b>	<b>Decision</b>
H <sub>0</sub> : The median of difference between Posttest Col and Posttest Conv equals 0. H <sub>1</sub> : Posttest Col is higher than Posttest Conv	Independent Samples Wilcoxon-Mann Whitney Test	p= 0.0005	Reject the null hypothesis

Table 4.33

*Wilcoxon-Mann Whitney Test of ParNoMA gain scores of Collaborative Teaching*

*Group and Conventional Teaching Group*

<b>Null Hypothesis</b>	<b>Test</b>	<b>Significance</b>	<b>Decision</b>
H <sub>0</sub> : The median of difference between Gain score Col and Gain score Conv equals 0. H <sub>1</sub> : Gain score Col is higher than Gain score Conv	Independent Samples Wilcoxon-Mann Whitney Test	p= 0.000	Reject the null hypothesis

## Summary of Discussion of Results for Research Question #2

The Collaborative Teaching intervention presented in this study provided teachers a professional development framework that is situated and social. Research Question #2 dealt specifically the task of developing students' conceptual understanding of PNM concepts. Though there were unique classroom situation and challenges for each teacher, the Collaborative Teaching intervention fostered a community of practice (Lave & Wenger, 1991; Darling-Hammond & McLaughlin, 1996) where they could deal with their respective teaching and learning situations and worked as a team addressing students' misconceptions and learning difficulties. This goal to improve student learning is one driving force of collaborative professional development such as Collaborative Teaching (Alozie, 2010; Prytulla & Weimann, 2012). In an environment of collegiality, mutual respect and interdependence the teachers sought to improve the lesson so students understand PNM concepts. As one teacher puts it,

*"We can communicate with one another...we can correct each other for [the benefit of] our students. We can deliver a better quality of education, unlike if we do not discuss we approach our lesson in many different ways; at the same time we cannot correct our mistakes. Here [in Collaborative Teaching]. We can discuss what we should emphasize, what [strategies or concepts] are not appropriate to use...so we can improve the quality of education."*

*"There is teamwork, we cooperate. We help one another to come up with the better [teaching] strategy. We help identify overlooked concepts. We discuss*

*concepts; this is really neat. I realized there is much we can do together...isn't that great?"*

The discussions focused what really worked and did not work from their lesson plans. It focused on what caused students to learn PNM concepts. As one teacher puts it:

*"I really like the collaboration. We are continually updated. We are continually corrected, what is needed to be done [in the class], what is the more efficient process to use. There is continuity so learning process is improved continually, the students learn better."*

**Research Question #3: To what extent did changes in teachers' PCK facilitate student conceptual understanding of PNM?**

*The discussion of Research Question #1 established the effect of Collaborative Teaching on the PCK of PNM of six Grade 8 Science teachers. The discussion of Research Question #2 established the effect of Collaborative Teaching on students' conceptual understanding of PNM. The discussion that follows focuses on the extent of improvement in teachers' PCK of PNM that facilitated student conceptual understanding of PNM.*

Results from PCK-PNM Questionnaire (PCK-PNMQ), PCK-PNM Observation Rubric (PCK-PNMOR), teacher and student interviews and researcher field notes show that all six teachers from the Collaborative Teaching group improved their PCK of PNM. For instance, the total PCK rating of the teachers improved from being "Emergent" to "Proficient" as assessed by PCK-PNMOR as shown in Table 4.34. The components of PCK included in this study are Knowledge of Science Content (KSC), Knowledge of Student Understanding (KSU) and Knowledge of Teaching Strategies (KTS), as described by Grossman (1990) and Magnusson et al. (1999). Thus the total PCK rating is the sum of these components. From the transformative view of PCK, the different PCK components were transformed and combined through the experience of teachers into the improved PCK of PNM (Shulman, 1986; Grossman, 1990; Cochran et al. 1993; Gess-Newsome, 1999). Each teacher was observed two times during the Collaborative Teaching intervention.

Table 4.34

*PCK-PNM Observation Rubric Score of Collaborative Teaching group (N=6)*

<b>PCK Components</b>	<b>Mean Observation 1 Score</b>	<b>Mean Observation 2 Score</b>
KSC (Max. score=12)	x = 6.8 SD = 1.7	x = 9.7 SD = 1.6
KSU (Max. score=16)	x = 10.0 SD = 2.2	x = 13.3 SD = 2.3
KTS (Max. score=20)	x = 10.2 SD = 2.1	x = 14.3 SD = 2.9
<b>TOTAL</b> (Max. score=48)	x = 27.0 SD = 5.7	x = 37.3 SD = 6.6

PCK-PNMOR Scoring – Novice: 12-20; Emergent: 21-29; Proficient: 30-38; Advanced: 39-48  
Observation 1 was done at the early stage of Collaborative Teaching. Observation 2 was done towards the latter part or end of Collaborative Teaching.

The improvement in the teachers' PCK can be seen also in the mean posttest scores of the teachers in the PCK-PNMQ. The teachers showed a 40% increase in PCK from 26.8 out of 48 in the pretest to 37.5 in the posttest as shown in Table 4.35.

Table 4.35

*PCK-PNM Questionnaire scores of Collaborative Teaching group (N=6)*

<b>PCK Components</b>	<b>Mean Pretest</b>	<b>Mean Posttest</b>
KSC (Max. score= 20)	x = 12.0 SD = 3.7	x = 18.2 SD = 3.0
KSU (Max. score= 8)	x = 3.8 SD = 0.75	x = 5.3 SD = 1.2
KTS (Max. score= 20)	x = 11.0 SD = 1.7	x = 14.0 SD = 2.3
<b>TOTAL</b> (Max. score=48)	x = 26.8 SD = 4.7	x = 37.5 SD = 4.8

Table 4.35 further shows the improvement in the PCK components, KSC, KSU and KTS. The KSC which measures the teachers' content knowledge of PNM

concepts increased, by 52%. The KTS which measures the teachers' knowledge and practice of teaching strategies increased, by about 28%. The KSU which measures the teachers' awareness and understanding of students' misconceptions increased, by about 40%.

The above observations show that the PCK of the teachers from the Collaborative Teaching group improved after Collaborative Teaching intervention. In the same way, the ParNoMA scores of their students increased. The scores of their students showed a percentage increase of almost 95% from about 5 out of 20 in the pretest to about 10 out of 20 in the posttest as shown in Table 4.36.

Table 4.36

*Mean ParNoMA Pretest and Posttest Scores of students from Collaborative Teaching Group*

	Section	Pretest (Max. score=20)	Posttest (Max. score=20)	Gain Score
Collaborative Teaching Group (N=143)	1	7.1	12.0	+4.9
	20	5.0	8.4	+ 3.4
	43	3.6	9.2	+ 5.6
	15	4.8	8.4	+ 3.6
	18	4.6	10.3	+ 5.7
	21	4.3	10.7	+ 6.4
<b>Mean</b>		5.1	9.9	+ 4.8

Table 4.37 further compares the improvement of the teachers' PCK of PNM scores with the improvement of the ParNoMA scores of their respective students. This matrix shows that improvement in PCK scores parallels improvement in student scores. In addition, the greater improvement of the scores of teachers from the

Collaborative Teaching Group parallels with a greater improvement of the scores of their students when compared with the Conventional Teaching Group.

Table 4.37

*Comparison of Teachers' PCK scores with their students ParNoMA scores*

	Teacher	PCK-PNMQ Pretest	PCK-PNMQ Posttest	Gain Score	ParNoMA Pretest	ParNoMA Posttest	Gain Score
Collaborative Teaching Group	A	34	43	+9	7.1	12.0	+4.9
	D	29	39	+10	5.0	8.4	+3.4
	F	24	37	+13	3.6	9.2	+5.6
	B	29	42	+13	4.8	8.4	+3.6
	C	21	32	+11	4.6	10.3	+5.7
	E	24	32	+8	4.3	10.7	+6.4
		Mean = 26.8 SD = 4.7	Mean = 37.5; SD = 4.8	Mean = 10.7 SD = 2.1	Mean = 5.1 SD = 2.3	Mean = 9.9 SD = 3.0	Mean = +4.8 SD = 1.2
Conventional Teaching Group	G	21	28	+7	6.1	8.9	+2.8
	H	25	29	+4	8.1	9.5	+1.4
	I	19	26	+7	4.5	9.0	+4.5
	J	18	22	+4	4.9	6.5	+3.10
			Mean = 20.8 SD = 3.1	Mean = 26.2 SD = 3.1	Mean = 5.5 SD = 1.7	Mean = 5.8 SD = 2.4	Mean = 8.7 SD = 3.0

Several studies support this observation where improved PCK of teachers result in improved student learning (Meyer, 2005; Waller, 2012; Gess-Newsome et al., 2010; Olfos et al., 2014; Lucenario et al., 2016). For instance, Waller (2012) showed in her study of 65 teachers and their students that teachers' PCK was a good predictor of student achievement in mathematics. Lucenario et al. (2016) reports that among four high school chemistry teachers involved in PCK-guided Lesson Study, improved PCK competencies resulted in enhanced student conceptual

understanding of chemical solutions (Lucenario, 2013).

The following discussion focuses on the specific ways that changes in Collaborative Teaching group teachers' PCK facilitated their student conceptual understanding of PNM. These are presented with respect to the components of PCK, namely the Knowledge of Science Content, Knowledge of Student Understanding and Knowledge of Teaching Strategies.

### **Changes in teachers' content knowledge about PNM improve students' conception about particles of matter and their behavior during phase changes.**

The subcomponent of PCK that pertains to the teachers' content knowledge about PNM is Knowledge of Science Content (KSC). In this study a "Proficient" KSC rating means that the teacher showed generally a good grasp of PNM concepts. The teacher has a good grasp and understanding that matter is made of discrete particles and that there are spaces in between the particles. The teacher understands that particles of matter are in constant motion and their motion influences the forces of attraction between particles. In addition, the teacher with a "Proficient" rating of KSC is able to explain phase changes using macroscopic, sub-microscopic and symbolic levels of representation including the Kinetic Molecular Theory. Table 4.38 shows a portion of the PCK-PNMOR describing the KSC using the different criteria.

Results from the various sources mentioned above show that the teachers from the Collaborative Teaching group developed the correct construct about elements and compounds after CT intervention. Furthermore, the teachers were

able to correct their specific misconceptions about phase changes of matter such as water breaking into  $H_2$  and  $O_2$  during evaporation and/or melting as seen in Table 4.1 (page 103).

Table 4.38

*A portion of PCK-PNM Observation Rubric showing criteria related to KSC*

Advanced	Proficient	Emergent	Novice
<p>☐ Responses and actions showed COMPLETE MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes</p>	<p>☐ Responses and actions showed AVERAGE MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes</p>	<p>☐ Responses and actions showed LOW MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes</p>	<p>☐ Responses and actions showed NO MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes</p>
<p>☐ Used language that is COMPLETELY ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>	<p>☐ Used language that is MOSTLY ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>	<p>☐ Uses language that is SOMEWHAT NOT ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>	<p>☐ Uses language that is MOSTLY NOT ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>
<p>☐ Used AT LEAST THREE appropriate, accurate examples of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>	<p>☐ Used TWO appropriate, accurate examples of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>	<p>☐ Uses ONE POTENTIALLY appropriate, accurate example of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes</p>	<p>☐ Uses NO appropriate, accurate example of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes</p>

Table 4.1

*Teachers' corrected misconceptions about phase changes of water*

<b>PRIOR MISCONCEPTIONS</b>	<b>CORRECTED CONCEPTIONS</b>
1. Water breaks into H <sub>2</sub> & O <sub>2</sub> during evaporation and/or melting	1. Water does not break down into its elements during evaporation. Evaporation is only a physical change.
2. Particles stop moving during freezing.	2. Particles do not stop at freezing; particles of matter are in constant motion.
3. Molecular structure changes during phase change; phase is a chemical change.	3. Molecular structure does not change during phase change; phase change is a physical change.

It is worth noting that some of the students' misconceptions parallel those of the teachers (Kruse & Roehrig, 2005; Lemma, 2013; Yates & Marek, 2014) as shown in Table 4.39. These misconceptions were collected from teachers' answers to PCK-PNMQ and students' answers to ParNoMA.

Table 4.39

*Comparison between teachers' and students' misconceptions about PNM concepts*

<b>TEACHERS' MISCONCEPTIONS</b>	<b>STUDENTS' MISCONCEPTIONS</b>
1. Particles stop moving during freezing.	1. Particles stop moving during freezing.
2. Evaporation of water will separate it to oxygen and hydrogen atoms.	2. Evaporation of water will separate it to oxygen and hydrogen atoms.
3. Melting of ice will separate it to oxygen and hydrogen atoms.	3. Melting of ice will separate it to oxygen and hydrogen atoms.
4. Phase change is a chemical change	4. Phase change is a chemical change

Studies show that one source of students' misconception is teachers' misconception (Kruse & Roehrig, 2005; Lemma, 2013; Yates & Marek, 2014). For instance, the study of Kruse & Roehrig revealed that misconceptions of students ( $N=1418$ ) parallel chemistry teachers' misconceptions ( $N=45$  teachers). Lemma (2013) reported in her study that 90% of students' misconceptions ( $N=192$ ) had a significant correlation with those of chemistry/science teachers' misconceptions ( $N=6$ ), implying that teachers are responsible for most (90%) of their students' misconceptions.

Therefore, the teachers' misconception may have contributed to the early misconceptions of the students that were resistant to change even in the posttest.

*On the other hand, these studies also point out that the students of teachers who possess a relatively better content knowledge have an increased opportunity to learn and retain concepts they learn. Furthermore, their students have an opportunity to minimize the number of new misconceptions acquired during the course of instruction* (Lankford, 2010). Many other researchers and authors emphasize that teachers need to have the content knowledge in order to be an outstanding teacher (Shulman, 1986; Geddis, 1993; Sanders & Horn, 1994; Bucat, 2004; Ozden, 2008). Geddis (1993) says, *"The outstanding teacher is not simply a 'teacher', but rather a 'History teacher', a 'Chemistry teacher', or an 'English teacher'. While in some sense there are generic teaching skills, many of the pedagogical skills of the outstanding teacher are content-specific. Beginning teachers need to learn not just 'how to teach', but rather 'how to teach electricity', 'how to teach world history', or 'how to teach fractions'".* Bucat (2004) adds, *"... 'how to teach stoichiometry', or 'how to teach chemical equilibrium', or 'how to teach stereochemistry.'" Teachers from the*

Collaborative Teaching group echo this same realization especially towards the end of the intervention:

*"Because of CT, I learned how to do the **best presentation of lesson, best illustration and strategies so my students learn better, their PNM misconceptions corrected, for better understanding of lessons.**"*

*"We learned how to **correct our mistakes [PNM misconceptions] and deliver a better quality of education for our students.**"*

Sanders and Horn (1994) revealed a 39.0 percentage point difference in student achievement gains between students with most effective and least effective teachers. Ozden (2008) and Kaya (2009) showed in their studies that content knowledge had a positive influence on pedagogical content knowledge and effective teaching.

The KSC score of the Collaborative Teaching group increased more than 50% from 12 out of 20 in the pretest to more than 18 in the posttest (Table 4.29). Data derived from the iterative pre- and post-lesson discussions on PNM concepts support teachers' improved KSC. The teachers were able to identify and correct their misconceptions. Some teachers shared:

*"Through our discussion we understand better the meaning of space, the difference between atoms and molecules. Even us teachers get confused so what more the students. At least by Activity Lesson 3 students have better understanding about particle and atoms."*

*“What I like about Collaborative Teaching is that our [PNM] misconceptions are corrected; we are better prepared to teach.”*

Collaborative Teaching provides the avenue and environment where teachers are able to examine their own knowledge of science content – what concepts they understand deeply and what concepts they are not clear about. In this study, the latter is both a self-examination and group examination, as they participate in pre and post lesson discussions. One specific improvement of teachers is their level of explanation of phase changes. In the posttest of the PCK-PNM Questionnaire, the teachers showed increased use of *macroscopic, sub-microscopic and symbolic representations* explaining phase changes. The teachers were also able to use *Kinetic Molecular Theory* more correctly and completely in the posttest of PCK-PNM Questionnaire. The following is an example of where a teacher’s improved understanding of KMT helped her guide her students in understanding evaporation in Activity 3 (*Are particles moving? What is between them?*):

Teacher: *“How did water become steam? By adding heat or by removing heat?”*

Students: *“Add heat.”*

Teacher: *“What is the source of heat?”*

Students: *“Alcohol lamp.”*

Teacher: *“What did the alcohol lamp do?”*

Students: *“Heat the water.”*

Teachers: *“What happened when water is heated by lamp?”*

Students: *"Water particles became lighter (gumaan)."*

Teacher: *"What do you mean by "lighter"? How do the particles of water look like?"*

Students: *"They are farther apart (medyo naghihiwalay)."*

Teacher: *"What about their movement?"*

Students: *"The particles are moving faster (bumibilis)."*

Teacher: *"The water particles are lighter ("gumaan") because they were moving faster and moving farther apart."*

The teacher-student discourse above showed the teachers' better understanding of KMT. Her pretest and posttest explanation for Item 1 about evaporation in the PCK-PNMQ shows this improvement:

Pretest: *"The molecule became excited when heated."*

Posttest: *"The molecules of water will gain more kinetic energy that at some point will break the attractive forces between them causing them to move farther from each other."*

She also showed full knowledge and understanding that matter is made up of particles and there are forces of attraction between particles. Her improved KSC enabled her to guide her students to deeper understanding of evaporation both at the macroscopic and sub-microscopic levels. In the discourse above, the students were able to construct a narrative explanation for evaporation. The students were

able to infer correctly that the alcohol lamp heated the water that caused the molecules of liquid water to move faster (*bumibilis*) and to move farther apart (*medyo naghihiwalay*). It could be inferred from the students' reply and the teacher's concluding statement that "gumaan" may mean that liquid water turned to gaseous water. However, the term, "gumaan" is an indication of both the student's and the teacher's misconception that particles in the gaseous state are lighter than particles in the liquid state. It is apparent that at the latter stage of Collaborative Teaching intervention, the students could explain and represent phase changes at the macroscopic and sub-microscopic level. Moreover, they were also able to make symbolic representation of the process as shown by Figure 4.39. This new knowledge of students could be attributed to the teachers' improved ability to explain phase changes at different levels. Teachers need to possess the knowledge content or KSC for students to learn scientific concepts accurately (Shulman, 1986; Geddis, 1993; Sanders & Horn, 1994; Bucat, 2004; Ozden, 2008).

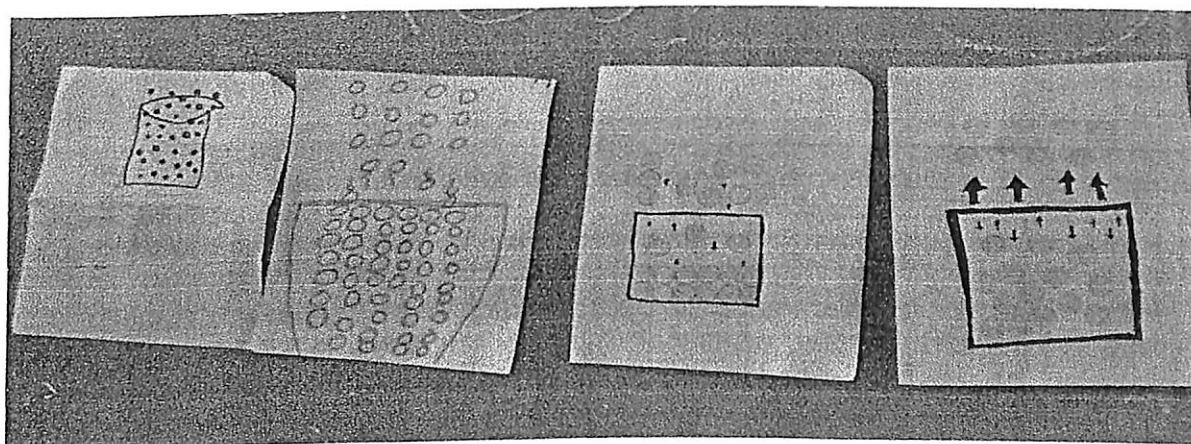


Figure 4.39. Students' sub-microscopic and symbolic representation of water undergoing evaporation.

Table 4.40 illustrates some of the improvements in the knowledge of science content

about PNM of teachers from the Collaborative Teaching group and their students' improved understanding of PNM. These observations are consistent with studies showing that the teachers' content knowledge facilitates teaching and learning of PNM concepts (Summers & Kruger, 1993; Harlen, 1997; Ozden, 2008; Uzak et al., 2011).

Table 4.40

*Some of the improvements in the KSC of PNM of CT Group teachers and their students' improved understanding of PNM concepts*

	<b>Pre-CT KSC about PNM</b>	<b>Post-CT KSC about PNM</b>	<b>Improved student understanding</b>
Teacher A	Inconsistent distinction between elements and compounds	Consistently distinguish between elements and compounds	Able to classify correctly substances as elements or compounds
Teacher B	Could not explain clearly how particles of matter behave during phase change	Able to explain phase changes using macroscopic, sub-microscopic and symbolic levels and KMT.	Students were able to explain and represent correctly the particles during phase change.
Teacher C	Could not explain that the movement of particles is related to their average kinetic energy	Able to integrate KMT in explaining the movement of particles during phase changes	Could explain that heat during evaporation causes particles to move faster making them move apart
Teacher D	Had misconceptions that water breaks into H <sub>2</sub> and O <sub>2</sub> during evaporation.	Developed correct conception that water does not break into its elements during evaporation.	Students know that heat does not break the covalent bond between H and O during evaporation or melting.
Teacher E	Phase change involves molecular change/a chemical change	Phase change is only a physical change; no molecular changes	Students know that heat does not break the covalent bond between H and O during evaporation or melting.
Teacher F	Had misconception that particles of matter stop moving during freezing.	Developed correct conception that particles of matter continue to move during freezing.	Students could represent particles of matter during freezing; that they continue to move.

According to Harlen (1997), teachers' content knowledge is needed so that they can ask questions that lead students to reveal and reflect on their ideas for better

learning of concepts. Because of improved KSC of PNM, teachers were able to correct their own misconceptions. In turn, they are able to identify and address their students' misconception (Austria et al., 2013; Yates & Marek, 2014).

Below is another example of a teacher from the Collaborative Teaching group who was able to help her students understand evaporation and condensation in Activity 4 (*What changes take place when water is left in an open container? In a closed container?*). She had prior misconception about water breaking into its components, which she later corrected with the help of CT discussions. . Studies show that teachers' increased awareness of their own misconceptions and their being able to correct these misconceptions enables them to address students' misconceptions and learning difficulties (Kruse & Roehrig, 2005; Kapylla et al., 2010; Stojanovska et al., 2012). The teacher asked the students to explain what they observed:

Teacher: *"What happened to the water in the open container?"*

Student: *"Natuyo po (Dried up), nag-evaporate pumunta sa taas (went up)..."*

Teacher: *"What do you mean "sa taas"?"*

Student: *"The particles went up into the air."*

Teacher: *"What happened to the water in the closed container?"*

Student: *"Evaporation then condensation."*

Teacher: *"What do you mean?"*

Student: *"Coz the particles of the liquid turn to gas, evaporation, the particles of the gas is turn into liquid, condensation."*

According to Shulman (1986), the expert teachers' PCK enables him or her to teach the content or subject matter in a way that facilitates student learning. Content knowledge is therefore critical for teachers to begin developing their PCK (Smith & Neale, 1989; van Driel et al., 1998; Grossman et al., 2005; Ball et al., 2008).

The observed improvement of the students' conceptual understanding of PNM could ultimately be attributed to the Collaborative Teaching approach used by their teachers. Collaborative Teaching provides an avenue for teachers to reflect on their teaching, what they know and do not know yet, and how students are responding to their teaching (Williams, 2010; Ronda, 2013). Darling-Hammond (2003) states: "Teachers learn best by studying, doing, and reflecting; by collaborating with other teachers." She further states that teachers improve their teaching by looking closely at students and their work and by sharing what they see. Teachers in this study commented about how CT helped them in improving their knowledge about PNM concepts, which in turn benefitted the students:

***"The concepts, ideas and strategies we discuss improve even more the way we teach which has a huge impact on our students' learning."***

*"In Collaborative Teaching, we have teamwork; we cooperate and help each other to have the best strategies, **identify concepts we don't know or overlook**. We have discussions and we realize we can do so much more as teachers, isn't that great?"*

**Changes in teachers' understanding of students' misconceptions and difficulties about PNM concepts help students develop correct conceptions about states of matter and phase changes.**

The subcomponent of PCK that pertains to the teachers' understanding of students' misconceptions and difficulties about PNM is Knowledge of Students' Understanding (KSU). As pointed out earlier, the teachers from the Collaborative Teaching group was found to have a "Proficient" rating at posttest of the PCK-PNMOR. In this study, a teacher with a "Proficient" rating of KSU uses knowledge of students' learning difficulties, prior knowledge, and misconceptions in either planning or teaching PNM concepts. In addition, the teacher addresses some of the learning difficulties and misconceptions of students in order for them to acquire correct and deeper understanding of PNM concepts. Table 4.41 shows a portion of the PCK-PNMOR describing the KSU with the different ratings. The mean KSU score in the PCK-PNM Questionnaire of the Collaborative Teaching group increased by about 40%, from 3.8 out of 8 in the pretest to more than 5 in the posttest (Table 4.35).

The following quotes show teachers' awareness of various misconceptions of students, which guided them to correct these misconceptions:

*"In melting and freezing they [students] do not know how to describe what happens to the particles, how to represent each state of matter; that of the spaces in solid they thought only particles of liquid and particles of gas move. They also thought that if heat is absorbed the chemical bond is broken."*

Table 4.41

*A portion of PCK-PNM Observation Rubric showing criteria related to KSU*

Advanced	Proficient	Emergent	Novice
<input type="checkbox"/> Uses knowledge of students' learning difficulties in planning and teaching PNM concepts	<input type="checkbox"/> Uses knowledge of students' learning difficulties in either planning or teaching PNM concepts.	<input type="checkbox"/> DOES NOT use knowledge of students' learning difficulties in planning and teaching PNM concepts	<input type="checkbox"/> Show NO AWARENESS of students' learning difficulties about PNM concepts
<input type="checkbox"/> Uses knowledge of students' prior knowledge in both planning and teaching PNM concepts.	<input type="checkbox"/> Uses knowledge of students' prior knowledge in either planning or teaching PNM concepts.	<input type="checkbox"/> DOES NOT use knowledge of students' prior knowledge in planning and teaching PNM concepts.	<input type="checkbox"/> Show NO AWARENESS of students' prior knowledge about PNM concepts
<input type="checkbox"/> Uses knowledge of students' misconceptions in both planning and teaching PNM concepts.	<input type="checkbox"/> Uses knowledge of students' misconceptions in either planning or teaching PNM concepts.	<input type="checkbox"/> DOES NOT use knowledge of students' misconceptions in planning and teaching PNM concepts.	<input type="checkbox"/> Show NO AWARENESS of students' misconceptions about PNM concept
<input type="checkbox"/> CONSISTENTLY and EFFECTIVELY addresses all learning difficulties and misconceptions of students that lead to correct and deeper understanding of PNM concepts.	<input type="checkbox"/> SUCCESSFULLY addresses some of the learning difficulties and misconceptions of students that lead to correct and deeper understanding of PNM concepts	<input type="checkbox"/> ATTEMPTS to address the learning difficulties and misconceptions of students for correct and deeper understanding of PNM concepts.	<input type="checkbox"/> DOES NOT ADDRESS the learning difficulties and misconceptions of students.

*"Phase changes, physical change according to the students, students initially thought particles or molecules of water, hydrogen and oxygen separate but later became clearer. They were able to correct that if water undergoes phase change nothing happens to the bond between the atoms. Students said atoms of hydrogen and oxygen do not separate."*

*“They do not know that particles are continually moving; even though they are very close to each other, they are still moving but minimal for solid, for liquids faster. Another is that there are spaces in between particles. They thought that solids are super-compact and no spaces in between particles; then in melting and freezing they do not know how to describe what happens to the particles, how to represent each state of matter; that of the spaces in solid, they thought only particles of liquid and particles of gas move. They also thought that if heat is absorbed the chemical bond is broken.”*

Studies show that teachers' increased awareness of students' misconceptions enables them to address students' misconceptions and learning difficulties (Kruse & Roehrig, 2005; Waller, 2012; Kapylla et al., 2010; Stojanovska et al., 2012). Waller (2012) showed in her study of 65 teachers and their students that knowledge and understanding of students' conception and level of understanding of math concepts have significant positive relationship with student achievement. On the other hand, Kapylla et al. (2009) revealed in their study that teachers who are not cognizant of sixth grade students' lack of conceptual understanding about photosynthesis resulted in lower student achievement.

In this study for instance, through iterative pre- and post-lesson discussions on PNM concepts teachers were able to identify student misconceptions about phase changes. This helped a teacher address a similar misconception that many of his students had. Besides using a particle model (Figure 4.12), he also demonstrated how particles behave during evaporation and condensation using two

students. He called it the “friendship analogy.” To illustrate condensation he told the students to draw closer to each other just like friends who are close to each other. To illustrate evaporation, he had the students move away from each other just as when friends have misunderstanding sometimes. Needless to say, the students

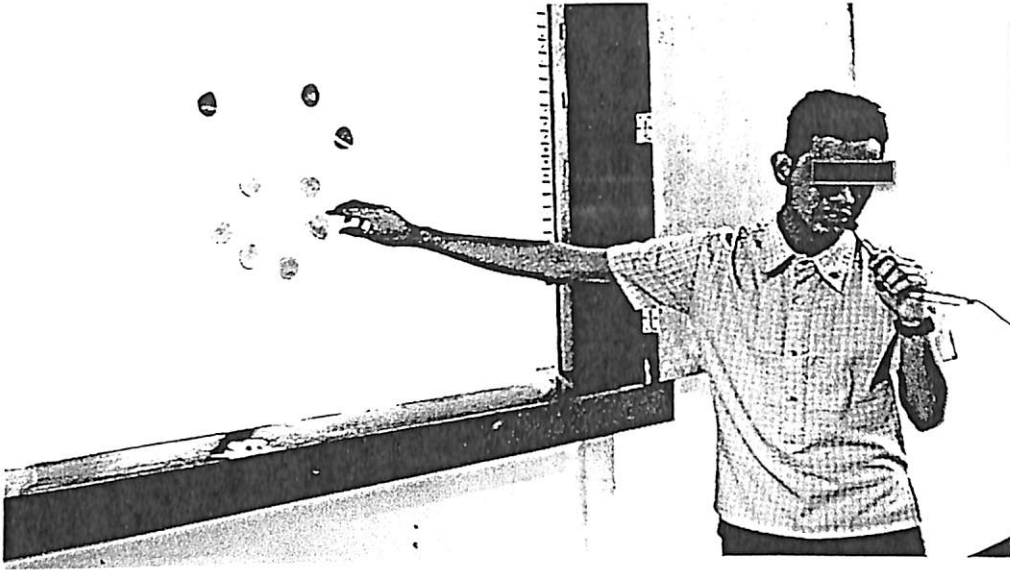


Figure 4.12. A teacher using the Particle Model

enjoyed the illustration. During post lesson interview after Activity 5 Lesson (*What changes take place when water is heated and when it is cooled?*) his students showed that they began to understand what happens to water particles during evaporation and condensation. The following quotes are students' explanation for evaporation and condensation:

Student 1: *“Evaporation at saka boiling, about molecules kapag malamig nagdidikit sila, pagmainit naghihiwalay.” (“Evaporation and boiling, about molecules when it is cold they move closer together, when it is hot, they separate from each other.”)*

Student 2: *“Ganun din po pagmainit naghihiwalay, pagmalamig nagdidikit-dikit sila.”* (“Same thing when it is hot they separate from one another, when it is cold they move closer together.”).

Student 3: *“Ano yung solid to liquid, liquid to solid tapos about molecules kapag mainit naghihiwalay sila, pagmalamig nagdidikit sila.”*

*(“What is solid to liquid, liquid to solid and then about molecules when it is hot, they separate from one another, when it is cold, they move closer together.”)*

Studies show that teachers' lack of understanding about students' misconceptions lead to lower student achievement (Kapylla et al., 2009; Waller, 2012). Waller (2012) showed in her study of 65 teachers and their students that knowledge and understanding of students' conception and level of understanding of mathematics concepts have a significant positive relationship with student achievement. Kapylla et al. (2009) revealed in their study that teachers who are not cognizant of sixth grade students' lack of conceptual understanding about photosynthesis resulted in lower student achievement.

Collaborative Teaching intervention afforded the teachers the impetus to be intentional in addressing the students' misconceptions. Collaboration of teachers in preparing and evaluating the lesson plans and implementation of the plan contribute to improve the teachers' awareness of students' misconceptions and learning disabilities that led to increased student learning. Park and Oliver (2008) concluded

that the teacher's reflections on teaching as a whole and that the teacher's understanding of students' misconceptions is the main factor that influences planning, conducting, and evaluating teaching in terms of PCK.

The teachers from this current study expressed these same aspects of CT. One of the teachers from the Collaborative Teaching group expressed during the FGD that CT indeed helped improve her teaching strategies, which in turn helped her students learn better:

*"The concepts, ideas and strategies we discuss **to improve the way we teach** helps us, then **the impact on the students is great** if there is collaboration.*

Another teacher shared that the regular discussions during CT helped her understand better and correct the concepts to be taught. This gave her confidence that what she passes on to her students is conceptually right:

*"We share, we help each other **how to analyze and understand the given concept if there are misconceptions**. What I like about this group is our collaboration; We share the ideas, what we have, what our weaknesses, what our strong points. You feel you are already good but when we talk about it **you still have something to improve**. Your strengths and weaknesses you can use during the teaching."*

**Changes in teachers' teaching strategies enable students to correct misconceptions and develop deeper understanding of PNM concepts.**

The subcomponent of PCK that pertains to teaching strategies is the Knowledge of Teaching Strategies or KTS. The teachers from the Collaborative Teaching group were found to have a "Proficient" rating in the posttest of the PCK-PNMOR. In this study, a teacher with a "Proficient" rating of KTS uses specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts. The teacher uses illustrations, examples, models, or analogies to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities. Table 4.42 shows the other characteristics of a teacher with a "Proficient" KTS. Knowing what the specific misconceptions of the students are, helped teachers adjust their strategies or their knowledge of teaching strategies or KTS (Mulford and Robinson, 2002). Collaborative Teaching allowed teachers to reflect on their students' learning.

The teachers from the Collaborative Teaching group recognized that knowing and anticipating students' misconceptions about PNM help them to plan better the lesson to ensure student learning:

*"If we know our students, our preparation and teaching will run well which is helpful for our students."*

*"Knowing how to adjust our pedagogy to the kind of students we have and how to transfer and process concepts to the students."*

Table 4.42

*A portion of PCK-PNM Observation Rubric showing criteria related to KTS*

Advanced	Proficient	Emergent	Novice
<p><input type="checkbox"/> Selected AT LEAST THREE specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts.</p>	<p><input type="checkbox"/> Selected TWO specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts.</p>	<p><input type="checkbox"/> Selected ONE specific instructional strategy or activity based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts.</p>	<p><input type="checkbox"/> DID NOT select specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts</p>
<p><input type="checkbox"/> Used AT LEAST THREE illustrations, examples, models, or analogies to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities.</p>	<p><input type="checkbox"/> Used TWO illustrations, examples, models, or analogies to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities.</p>	<p><input type="checkbox"/> Used only ONE illustration or example or model, or analogy to represent Particulate Nature of Matter concepts to facilitate student learning and may not understand the strengths and weaknesses of such representations and/or activities.</p>	<p><input type="checkbox"/> DID NOT use illustrations, examples, models, or analogies. to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities.</p>
<p><input type="checkbox"/> Varied and adjusted MORE THAN ONCE teaching according to classroom situation.</p>	<p><input type="checkbox"/> SUCCESSFULLY varied and adjusted the teaching ONCE according to classroom situation.</p>	<p><input type="checkbox"/> ATTEMPTED to vary and adjust the teaching according to classroom situation but was not</p>	<p><input type="checkbox"/> DID NOT vary and adjust teaching according to classroom situation.</p>
<p><input type="checkbox"/> Questions CONSISTENTLY CHALLENGED students to explain, reason, and/or justify.</p>	<p><input type="checkbox"/> Questions SOMETIMES CHALLENGED students to explain, reason, and/or justify.</p>	<p><input type="checkbox"/> Questions focused on MORE THAN ONE correct answer; some open response opportunities.</p>	<p><input type="checkbox"/> Questions focused on ONE correct answer; typically short answer responses.</p>
<p><input type="checkbox"/> CONSISTENTLY and effectively engaged students in open-ended questions, discussions, investigations, and/or reflections.</p>	<p><input type="checkbox"/> SUCCESSFULLY engaged students in open-ended questions, discussions, investigations, and/or reflections.</p>	<p><input type="checkbox"/> ATTEMPTED to engage students in open-ended questions, discussions, investigations, and/or reflections but was not successful.</p>	<p><input type="checkbox"/> DID NOT engage students in open-ended questions, discussions, investigations, and/or reflections.</p>

One specific teaching strategy the teachers used to facilitate student learning of PNM concepts is the use of models. The shift to the use of this strategy took place as the Collaborative Group did a post lesson review and reflection on Activity Lesson 2 (*“What is Matter Made of?”*). This discussion led to the idea of using the Particle Model. In the discussion, the teachers pointed out that majority of students could not explain and represent the dissolution of sugar in water or the mixing of food coloring in water. The teachers admitted that before CT, they were generally content with students’ usual explanation such as “water turn to color red” or “sugar mixed with water and disappeared”. Teacher D and Teacher F added that in the past they did not emphasize in their discussions that dye particles or sugar particles moved into the spaces in between the water particles. Teacher A at some point suggested that perhaps using models to show the spaces in between particles and movement of particles might help students understand and represent PNM phenomena. Therefore, the group agreed to use the Particle Model which became common as the teachers taught the rest of the Learning Activity lessons. The teachers commented towards the end of the CT intervention that using models was a huge help for students to understand PNM concepts:

*“Before we did not have the Particle Model, more on videos only. Now we can give students a deeper conception or understanding of PNM concepts.”*

*“Students find it difficult to visualize and represent movement of particles. We can clarify the meaning of space between particles using models.”*

*"I learned how to use models, not just chalk and board only."*

*"We learned about how our students learn, constructivist approach; they are visual learners so models, experiments and activities, we have a good formula for student learning."*

The use of visuals, particularly models, had a great impact on students' understanding of PNM concepts. The Particle Model of Matter (example, Figure 4.37) taught students how to represent the particles of matter and the spaces in between particles. It also enabled students to represent how the particles behave during phase changes. Thus, the teachers' improvement in PCK in terms of their KTS led to improvement in students' understanding of PNM concepts. Table 4.43 shows some of the improvement in the teachers' KTS and the improvement in students' understanding of PNM. The teachers from the Collaborative Teaching group used models to help students represent particles of matter and to visualize the spaces in between particles as evidenced by the students' answers to the researcher's interview after Activity 2 (page 238).

Many students had difficulty visualizing the spaces between particles. In fact, teachers encountered this learning difficulty among students early on. Many students thought that the particles in solids are packed and there are no spaces in between particles. The use of models helped students visualize and subsequently describe more accurately what happens to particles of matter as they dissolve, e.g., sugar dissolving in water.

Table 4.43

*Some of the improvement in the KTS of CT Group teachers and their students' improved understanding of PNM concepts*

	Pre-CT KTS	Improved or Post CT KTS	Improved student understanding
Teacher A	Lecture-based teaching; used technology	Used particle model of matter to represent phase changes.	Students could explain phase changes using sub-microscopic and symbolic representations.
Teacher B	Lecture-based teaching	Used interactive activities such as "Human Particle."	Students able to visualize and represent the distance between particles during phase changes.
Teacher C	Lecture-based teaching	Used particle model of matter to explain behavior of particles during phase changes.	Corrected misconception, such as water breaking into its elements during melting and evaporation.
Teacher D	Lecture-based teaching; used technology	Used particle model of matter to explain behavior of particles during phase changes.	Students able to explain and illustrate correctly phenomena, such as the process of sugar dissolving in water.
Teacher E	Lecture-based teaching	Used HOTS questioning.	Develops critical thinking such that his students could explain why pushing plunger with water is more difficult than when it is empty.
Teacher F	Lecture-based teaching; with visuals	Used HOTS questioning	Develops critical thinking such that her students could classify and explain why a substance is matter or not.

The researcher interviewed some students after class in relation to Activity 2 (*What is matter made of?*). He asked them what they learned from the lesson. Their answers, although not thorough, is a fairly accurate description of what happens as sugar dissolves in water as illustrated in the quotes below. The researcher noted that the teacher was consistently using models as she began the unit.

Student 1: *"When sugar dissolves in water, the sugar molecules get in*

*between the spaces in between water molecules.”*

Student 2: *“The sugar occupied the space while in the water. The small sugar particles occupied the space.”*

Studies show that using models helps students understand the macroscopic and sub-microscopic representation of particles of matter thereby improving performance (Hinton & Nakleh, 1999; Ardac & Akaygun, 2005; de Jong et al., 2005; Onwu & Randall, 2006). Onwu & Randall (2006) concludes in their study that students are able to display consistent reasoning about the particulate nature of matter if they have appropriate representational model on which to base their thinking.

Improvement of teachers' PCK also manifested in their ability to use Higher Order Thinking Skills or HOTS questions. One teacher shared how her involvement with Collaborative Teaching helped her to develop the skill of asking HOTS questions.

*“You probably saw me during the first day, at my first demo (Cycle 1, Activity 1 Research Lesson) I was so nervous. I did not know how to use HOTS questions. I did not know how to draw out answers from my students. Later I began to learn how to use HOTS questions with my student. The outcome on the students is good.”*

Another teacher recognized also that Collaborative Teaching enabled her to develop critical thinking among her students through HOTS questioning:

*“How students learn, constructivist approach, the HOTS questions. We have a very good formula. We were able to develop their higher order thinking skills, all of this will become engaging, learning at its best.”*

The value of asking HOTS is consistent with studies that demonstrate how quality questioning develops students' thinking and performance (Strother, 1989; King, 1994; Jiang & Ellen, 2011). It also fosters higher student engagement (Warfa et al., 2014). Warfa et al. (2014) points out in their study that teachers' efforts to ask students meaningful questioning (he refers to as dialogic discourse) increases engagement and student understanding of concepts.

The teachers' ability to ask HOTS questions resulted to students developing deeper understanding of matter as exemplified by the following interaction:

Teacher: *“Is sugar matter or not matter?”*

Student: *“Matter”.*

Teacher: *“Why do you say it is matter?”*

Student: *“Because it has mass and volume.”*

Teacher: *“So, you say because it has mass and volume. What if only one is present? Volume or mass only.”*

Student: *“It is not matter.”*

The teacher's first question is close-ended to which the student gave an appropriate response. The next two questions, “Why do you say it is matter” and “What if only one is present” were the probing and HOTS questions. The second question

required the student to explain or give a reason why he thinks sugar is matter. The third question tests whether the student understands deeply the criteria for classifying a given sample is matter or not matter. Through asking HOTS questions the teacher helped the student deepened his understanding that a sample is classified as matter if it has volume and mass. The two conditions must be met.

Table 4.44 summarizes what students' misconceptions were addressed by a specific teaching strategy:

Table 4.44

*Teaching Strategies used by teachers to address specific student misconception*

Students' Misconception/ Learning difficulty	Teaching Strategy used to address misconception
1. Matter is continuous rather than discrete.	Use of the <b>Particle Model</b> consisting of colored circles to represent particles. Visually, students are then able to represent particles and the spaces in between them. Figures 4.12 and 4.13 are examples of this.
2. Students' difficulty visualizing that there are spaces in between particles in everyday substances such as stone.	Use of the <b>Particle Model</b> consisting of colored dots; alternatively, use of an <b>interactive activity</b> called <b>Human Particle</b> where students simulate the particles of matter in different states or at different phases.  Use of <b>Higher Order Thinking Skills</b> or HOTS questioning to help students deepen understanding that matter is made up of discrete particles with spaces in between them. A sample HOTS questioning is found on pages 231 and 235 above.
3. Particles in ice stop moving during freezing.	3. Use of the <b>Particle Model</b> consisting of colored dots or the <b>Human Particle Activity</b> to show particles move at all states.
4. Water breaks into hydrogen and oxygen during evaporation or melting	4. Use of the <b>Particle Model</b> made of colored circles with <b>H-O-H</b> illustrating a water particle to explain what evaporation liquid water or melting of ice. Figure 4.32 is an example.
5. Particles increase in size during evaporation or shrinks during freezing.	5. Use of the <b>Particle Model</b> to illustrate evaporation and freezing coupled with <b>HOTS questioning</b> so students can conclude that the size of particles does not change during phase changes.
6. Students' difficulty classifying smoke and air as matter or not matter.	6. Use of <b>HOTS questioning</b> such as the sample conversation on page 248.  Use of " <b>Pollution</b> " as a <b>concrete example</b> under Learning Activity 1 to illustrate that air consists of particles.

#### IV. The case of Teacher F

The researcher attempted to create a holistic picture of the PCK of the Collaborative Teaching group by establishing patterns using constant comparative analysis. These became the themes through which the researcher pieced together a picture of the Collaborative Teaching group's PCK (Crowe et al., 2011). Dye et al. (2000) used a "kaleidoscope" metaphor to the process of using data bits to come up with a final template to make sense of the various data points from different sources. These data points were taken from each of the selected teachers, and in particular, the teachers from the Collaborative Teaching group. The researcher presents one of the teachers from this group, Teacher F, to represent the changes in the group's PCK of PNM. Any of the six teachers could have been equally chosen. Teacher F's comments about the impact of Collaborative Teaching on her is a significant piece of the holistic picture of the Collaborative Teaching group's PCK picture and its impact on students' understanding of PNM concepts.

Teacher F has been teaching science for seven (7) years. Teacher F handles Section 43, the lowest among the classes involved in this study. Teacher F considered it challenging at first to be doing the Collaborative Teaching because she teaches the lowest section. She was paired with Teacher A, who handles Section 1 in applying the CT process to Activity 1 and Activity 4. She expressed it was a challenge to modify the lesson considering the big difference between the two sections:

*"Ma'am A handles Section 1, mine is Section 43; so the challenge for me is what strategy to use; of course Section 1 students can process fast, my*

*Section cannot. How can I help them get the concept, understand how can I get them to understand the very concept I want to teach them; to think of a strategy that fits my section.”)*

The students of Teacher F had a mean ParNoMA pretest score of 3.62 out of 20 (18.1%) and mean posttest score of 9.19 (45.95%). This is equivalent to a 153.9% increase. As expected, her students scored the lowest among all the sections in the pretest. The mean pretest score indicates that Teacher F's students have initially a very low understanding of PNM concepts (almost at the 5%-15%, Very Low Mastery level). In the posttest, the over-all mastery level moved higher to "Average Mastery" (35% to 65%). Her students improved two levels up. In 19 out of 20 questions, more than 70% of her students answered incorrectly during the pretest. The number dropped to 7 incorrectly answered questions out of 20 in the posttest. Overall, Teacher F's students developed greater understanding of concepts covered. However, there was a drop in the percentage of students with correct answers in the posttest for the following questions: Question 9 (from 23.53% of the students with correct answer to 0%), Question 13 (from 23.53% of the students with correct answer to 11.76%), Question 14 (from 29.41% of the students with correct answer to 23.53%) and Question 15 (from 17.65% of the students with correct answer to 5.88%). This drop in the percentage of students with correct answer in the posttest scores could indicate that some of her students may have retained their misconception that particles change in size during phase change (Questions 14) and that oxygen and hydrogen separate during evaporation (Question 15). Some of her

students may still have partial understanding of what happens to particles of matter during phase change (Question 9) and the effect of heat on the movement of particles (Question 13). However, in these same concepts, Teacher F's students showed significant increase for those who answered correctly: Question 5 (from 0% to 76.47%), Question 11 (from 23.53% to 64.71%), Question 12 (from 0% to 47.06%) and Question 18 (from 17.65% to 52.94%). Studies show that early misconceptions about particle size and water separating into oxygen and hydrogen during evaporation are those retained among secondary students (Osborne & Cosgrove; Stojanovska et al., 2012; Mayer, 2011; Regan et al., 2011). These same misconceptions can persist even among college students (Mulford & Robinson, 2002).

At the early stage of the study her students showed very limited knowledge and understanding of PNM concepts. When asked about what they learned in their lesson on Activity 1 ("Which is matter, which is not?"), the students expressed incomplete and unclear answers:

*"Paano mag timbang, paano makuha ang gram." (how to weigh);*

*"Paano mag measure ng mass and volume" (how to measure mass and volume);*

*"Mag determine ng matter" (to determine which is matter).*

However, samples of students' output during the lesson indicate that students are beginning to understand what matter is as shown by Figure 4.40. Students were able to correctly conclude that heat and light are not matter since they do not occupy

space and do not have mass. When they were doing Activity 4 ("What changes take place when water is left in an open container? in a closed container?"), Teacher F's students began to have a greater grasp of PNM concepts.

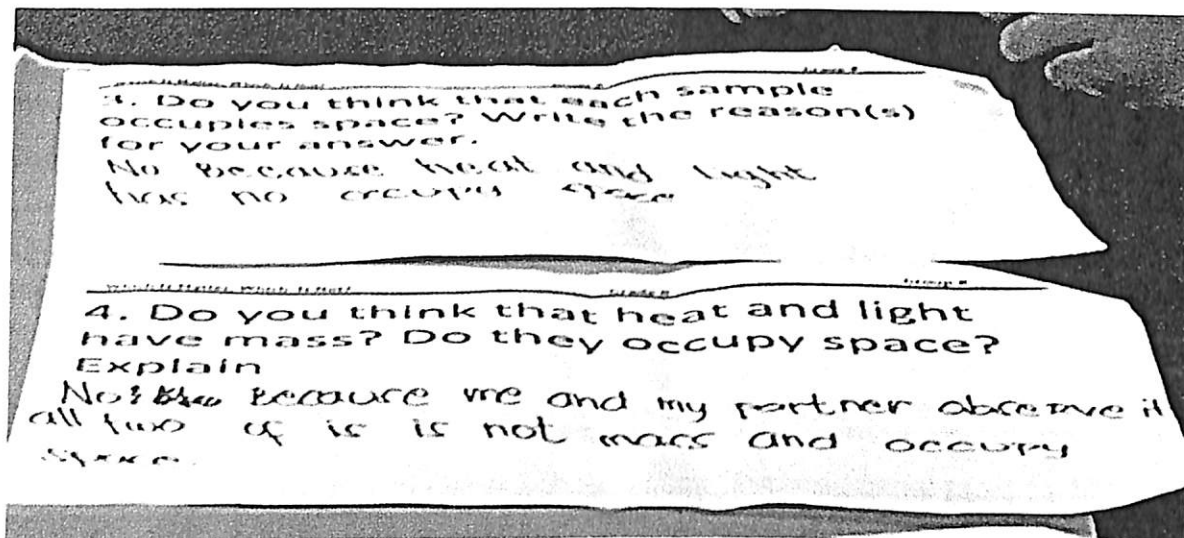


Figure 4.40. Responses of students of Teacher F to Activity 1 questions.

Figure 4.41 shows their representation of what happens when water evaporates.

They have begun to make submicroscopic representations.

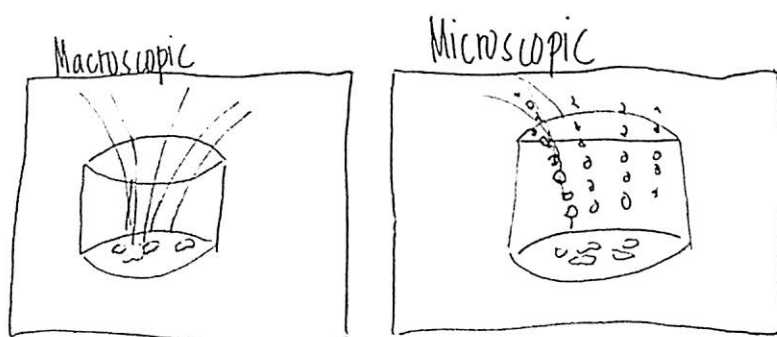


Figure 4.41. Teacher F's students representation of what happens when water evaporates.

Teacher F showed much improvement in her PCK of PNM, resulting in improvement of her students' understanding of PNM. Her PCK-PNM Observation Rubric rating during Observation 1 is 21, "Emergent". She got a rating of 34, "Proficient" at Observation 2. Her PCK-PNM Questionnaire pretest score is 24, one of the lowest. Her posttest score is 37, which is among the upper 25% quartile. Though she handles the lowest section and being one of the least experienced, she showed significant improvement of PCK. As a result, she was able to help her students learn better. She shared at the beginning of CT that she learned a lot from the discussions. She shared how Collaborative Teaching helped her correct her misconceptions, improved her teaching strategies, and grow professionally:

*"It is because our misconceptions are corrected. I am not really a Chemistry major; my misconception is corrected like that of element, molecule even if three; O<sub>3</sub> but still an element. We thought it is classified as compound."*

*"We are being observed so we get to know our strengths and weaknesses. So our weaknesses are corrected; we grow. We are able to correct for the next demo; we get to share strategies. The outcome is ok for the students."*

Her words at the last focus group discussion sums up her experience with Collaborative Teaching and how it improved her PCK of PNM:

*"Although I used to borrow activities before when we did not have [Collaborative Teaching] study yet, I still use my own strategy, rely on myself, and I do not ask for suggestions from other teachers. So, I do not get the*

*benefit of getting feedback and corrections. But when Lesson Study came, I really grew as a teacher. You probably saw me during the first day during my first demo (Implementation 1, Activity 1 Lesson). I was so nervous. I did not know how to use HOTS questions, I did not know how to draw out answers from my students. As the Collaborative Teaching continued I began to learn how to use HOTS questions on my students. As we were being observed when we teach, our strengths and weaknesses were pointed out and so our weaknesses are corrected. We grow as teachers. We get corrected and improve for the next demo. We share strategies. The outcome on the students is good."*

The case of Teacher F shows that Collaborative Teaching facilitate development of teachers' PCK regardless of teaching background, experience and context (teaching the lowest section). Discussion with fellow teachers encouraged her to share her lack of confidence, knowledge and understanding with the topics she taught. In an environment where she is free to share, she also learned from the inputs of her fellow teachers. She was able also to give inputs to herself as she shared what worked well in class. By doing this, others learned from her experience. She also helped fellow teachers by giving feedback as they taught.

Her case shows that Collaborative Teaching can facilitate deeper understanding even among students from low performing classes and in Teacher F's case, the lowest section in Grade 8. Her students' raw posttest scores are even higher than seven other teachers as shown by Table 4.45. Her students' raw gain

score is the third highest among the ten (10) sections but the highest in terms of percentage increase (154%) of score from pretest (3.62) to posttest score (9.19).

Table 4.45

*Mean PCK-PNMQ Pretest and Posttest Scores of students from Collaborative and Conventional Teaching group*

	Section	Pretest (Max. score=20)	Posttest (Max. score=20)	Gain Score
Collaborative Teaching Group (N=143)	1	7.2	12.1	+4.9
	20	5.0	8.4	+ 3.4
	43	3.6	9.2	+ 5.6
	15	4.8	8.4	+ 3.6
	18	4.6	10.3	+ 5.7
	21	4.3	10.7	+ 6.4
Over-all Mean		5.1	9.9	+ 4.8
Conventional Teaching Group (N=113)	6	6.1	8.9	+ 2.8
	9	8.1	9.5	+ 1.4
	13	4.5	9.0	+ 4.5
	41	4.4	7.5	+ 3.1
Over-all Mean		5.8	8.7	+ 2.9

### **Integrative Picture of PCK Development**

The changes in each PCK component influences the changes observed in the other components (Shulman, 1986; Grossman, 1990; Cochran et al. 1993; Gess-Newsome, 1999). There is mutual effect of the changes among the components. Figure 5.1 is a representation of these mutual effects. Improvement of teachers' knowledge of science content improves their knowledge of student understanding. In turn, improvement in teachers' knowledge of student understanding is an impetus for

teachers to improve their knowledge of science content. Improvement of teachers' knowledge of student understanding informs their knowledge of teaching strategies. In turn, their knowledge of

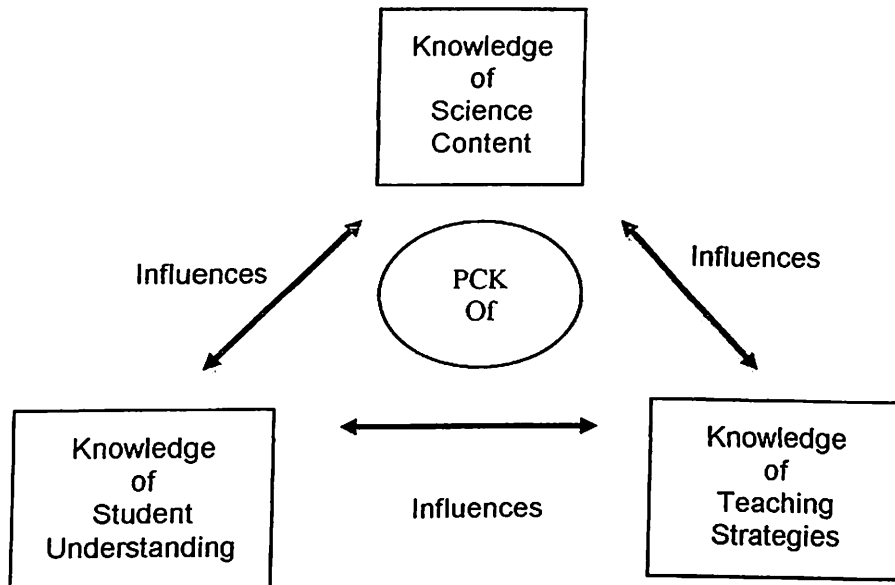


Figure 4.42. Representation of the mutual effects of PCK elements.

teaching strategies helps them gain more insight about student understanding. Improvement in teachers' knowledge of teaching strategies deepens their knowledge of science content. In turn, improvement in their knowledge of science content informs their knowledge of teaching strategies.

### Revisiting the Collaborative Teaching Framework

The theoretical framework proposed for this study consisted of three important elements of Collaborative Teaching: social, teacher-directed and situated (Figure 2.9). The teachers of the Collaborative Teaching group experienced these

elements as they went through the six weeks of intervention:

### 1. Collaborative Teaching is Social.

*There was teamwork.* Teachers worked as a team planning the research lessons, implementing, evaluating and reflecting on the implementation of each lesson, revising and improving the lesson to improve student learning. The teachers taught as a team, not individually. Although only one teacher taught one specific section or class, the collective ideas, knowledge, and experiences of all the teachers went into the planning and preparation of each lesson. The teachers gave inputs to the one teaching on how he or she could improve for better student learning. The group became a learning community where they gave and received feedback, corrections, and ideas in a safe environment of mutual respect. The teachers expressed their desire for the group to continue practicing Collaborative Teaching. They also intend to invite others to join them so that Collaborative Teaching becomes part of the school's culture and practice.

*There was collegiality.* The camaraderie and relationship among teachers was strengthened as they met at least three to four times a week for six weeks over lunch. Sharing and cooperation became more evident as the Collaborative Teaching progressed. The teachers shared ideas, teaching tools, visuals and their time. Initially, the teachers felt awkward and conscious as they were being observed. As the Collaborative Teaching intervention continued, the teachers felt more at ease being observed, given comments and suggestions after teaching a lesson. The teachers felt safe and comfortable to receive and give feedback as well as suggestions. The atmosphere was supportive, affirming, positive, and encouraging

for the teachers. There was sharing of ideas and resources. The unanimous desire to continue Collaborative Teaching after the study is an indication of the positive impact of Collaborative Teaching.

## 2. Collaborative Teaching is Teacher-directed.

*The teachers themselves facilitated their professional development.* The teachers shared ideas, suggestions, strategies and tools drawing from each other's unique background and experience. By doing this, they helped each other improve their PCK. The researcher merely guided the group during evaluation and discussions. They were teaching each other, acting as "donor-and-acceptor" of knowledge, borrowing from acid-base analogy in chemistry. The teachers themselves are the "trainers" and "experts." Although the teachers expressed their need for the researcher to support and encourage them, they also expressed that they can actually continue CT as a professional learning community in their school, even after this intervention.

*The teachers felt empowered to grow and improve.* They realized that they have found one way they can improve their teaching through Collaborative Teaching. The practice of using Collaborative Teaching during the intervention enabled them to examine their own teaching and how their students learn. Going through six weeks of Collaborative Teaching made them realize that they can do it even after the study. Some of them expressed that perhaps the group can use CT for other chemistry concepts, notably solutions and stoichiometry. They realized that despite individual limitations and limited resources of the school, it is possible to improve the quality of teaching.

### 3. Collaborative Teaching is Situated.

*The context of the CT intervention was unique for the participants.* This included the unique situation of the students, teachers, and classrooms in that particular school. In particular, the study took place in a public school where class size is bigger than those in private schools. Moreover, the typical classroom size in public schools is smaller than those in private schools. The teachers in the study had to factor in these limitations in preparing their lesson plans. Here is one of the strengths of Collaborative Teaching. The feedback and suggestions during pre- and post-lesson discussions were based on the realities the teachers encountered in their classrooms. The discussion of teachers revolved around what exactly happened as the lessons were taught. They were also based on how the students responded to the teacher and lesson. The situatedness also pertains to the actual prior knowledge, learning difficulties, and misconceptions of the students who participated in the study.

The three elements of Collaborative Teaching facilitate the development of the teachers' PCK of PNM. The Social element of Collaborative Teaching was exemplified as teachers work as a team to plan the lesson, implement and revise to improve it. Teachers learned from one another to improve their teaching. In an environment of mutual respect where they feel safe, teachers could give feedback, corrections, suggestions, and contribute to improve the lesson and help each other. The Situated element was exemplified as teachers work together to analyze, reflect on and address common classroom and school contexts. The feedback, suggestions, and improvements are products of what just took place in the

classroom as they taught each research lesson. The Teacher-directed element was exemplified as teachers facilitated the professional development of each other, receiving and giving input at the same time. Each teacher brought their expertise and experience into their lesson discussions. Thus, teachers were learners and facilitators at the same time. These three elements provided a rich environment and experience for the teachers' professional development.

Collaborative Teaching in the context of this study was used as a mode of professional development for science teachers teaching Particulate Nature of Matter concepts to Grade 8 students. The three elements of CT impacted the knowledge base and practice, the PCK of PNM of the teachers; hence the arrow towards the right. The knowledge bases include particularly the teachers' Knowledge of Student Understanding (KSU) of PNM, the Knowledge of Science Content (KSC) about PNM and the Knowledge of Teaching Strategies (KTS) about PNM. The practice included all that the teachers did in response to the context of their students' learning such as students' misconceptions, learning difficulties, and thinking processes (Ulep, 2008; Cerbin & Kopp, 2006). The practice also included their individual and collective experiences as they taught PNM using CT process (Oliver & Park, 2008). As Oliver and Park emphasized, PCK is both the understanding and enactment of how to "help a group of students understand specific subject matter using multiple instructional strategies, representations, and assessments while working within the contextual, cultural, and social limitations in the learning environment." Collaborative Teaching facilitated the development of teachers' PCK (understanding or knowledge base, and practice) of PNM.

The CT process is also impacted – enriched or made meaningful by the teachers' PCK development, as the teachers collaboratively contributed to the development of knowledge and practice of each member of the team. Individually and as a group, each teacher' PCK of PNM influenced the CT process as they brought into the process their unique and collective knowledge and practice contribution to the development of PCK of each member. This was facilitated as they worked together, struggled, reflected, planned and implemented ways to make students learn better. Thus, the arrow moving towards the left makes sense, Figure 5.2, where the interaction between CT and teachers' PCK of PNM is depicted.

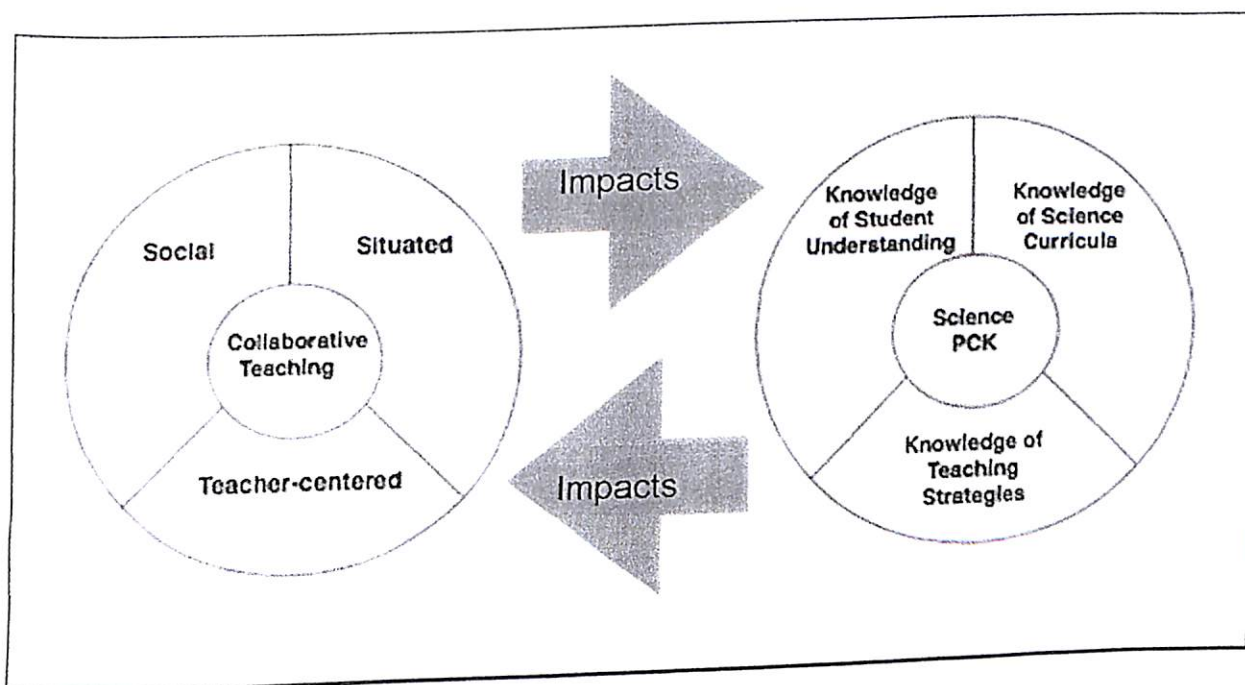


Figure 4.43. Interaction between CT Process and PCK of PNM.

### Reconceptualized Framework

Figure 4.44 shows a reconceptualized framework of this research as drawn from the results and discussions. The elements of CT (teacher-directed, situated, social) influence and drives the iterative pre-lesson collaboration, implementation of lesson

and post-lesson reflection, discussion and revision the teachers did. The iterative process leads to increasing improvement of teachers' content knowledge of PNM, knowledge and awareness of students' misconceptions and learning difficulties (KSU) and knowledge of teaching strategies that addressed students' misconceptions and learning difficulties (KTS).

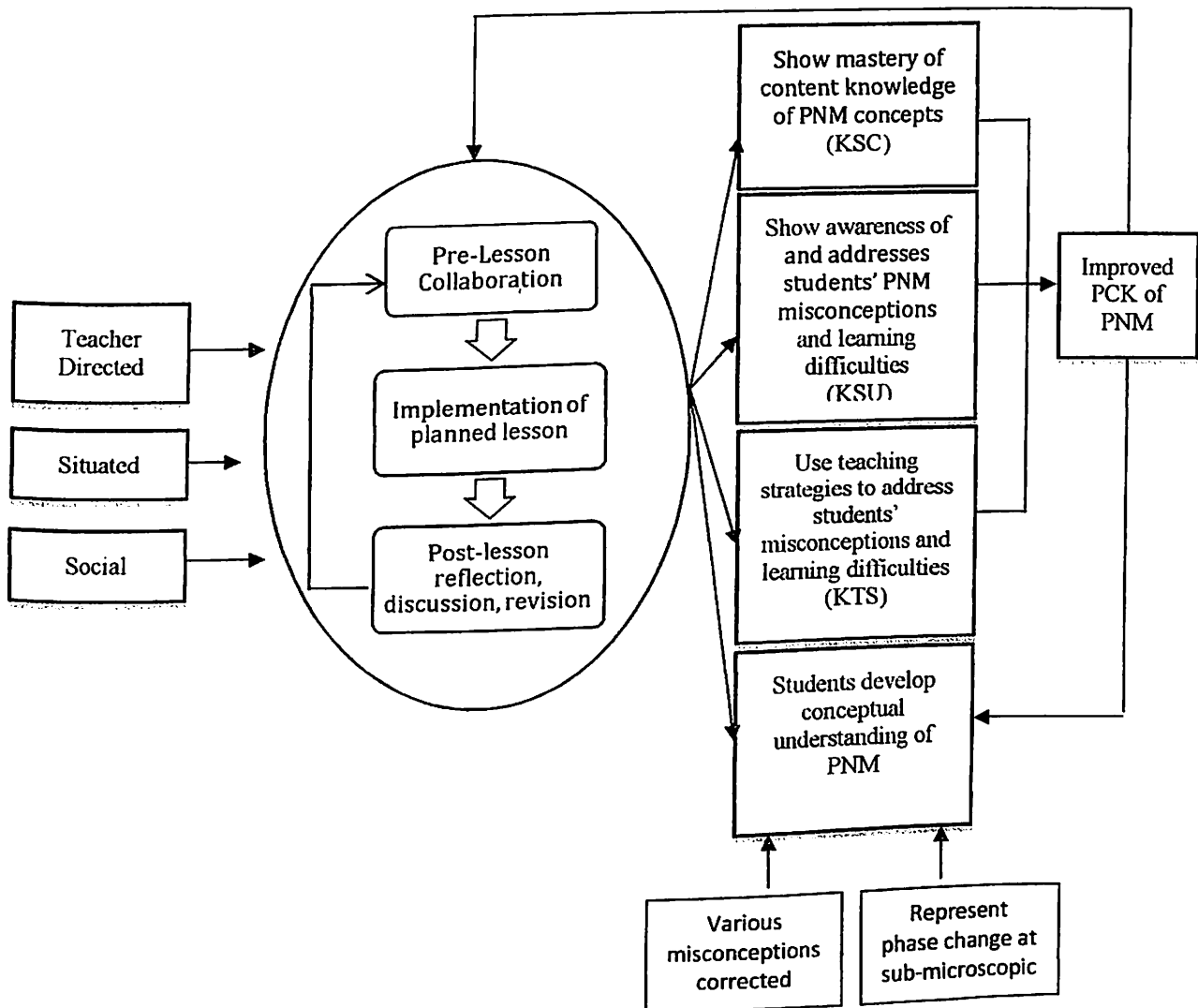


Figure 4.44. Reconceptualized framework for Collaborative Teaching.

From the transformative view of PCK, the different PCK components were transformed and combined through the collaborative teaching experience of

teachers into the improved PCK of PNM (Shulman, 1986; Grossman, 1990; Cochran et al. 1993; Gess-Newsome, 1999). The improvement in the teachers' PCK, also influences in return the CT process as teachers then use their improving PCK to give inputs into the pre-lesson preparation, implementation, and post-lesson revisions. Furthermore, the iterative CT process also leads to improvement of student learning as students develop conceptual understanding of PNM. Consequently, the students corrected their various PNM misconceptions and have developed their ability to represent phase change at the sub-microscopic level.

## Implications of the Study

### 1. Teacher development

The results of the study show that collaboration among teachers facilitates change in the learning and practice of teachers. The teachers moved from teacher-centered strategies (e.g. lecture) into more student-centered and constructivist strategies (e.g. games, using models and HOTS questions). The teachers corrected their misconceptions and developed a deeper and complete understanding of PNM concepts. The teachers also learned how to anticipate students' prior knowledge, misconceptions and possible learning activities to enhance their lesson planning and choice of appropriate teaching strategies and tools. Thus, perhaps in-service trainings or teacher development in general should focus on training teachers in a collaborative context and environment. Just as teaching need not be individualistic, teacher development need not be individualistic but instead be collaborative and collegial. From the study, change is facilitated when there is collegiality,

camaraderie, teamwork or collective reflection, commitment and effort.

## 2. Lesson planning

Although lesson planning is only as good as what is actually implemented during the actual teaching, it is still a powerful tool for teacher development. When used by supervisors and teachers effectively, it can contribute to increased student learning. This was shown in the study as teachers were asked to incorporate into their lesson planning students' anticipated difficulties, misconceptions, and prior learning very specifically. It is possible for a group of teachers in a school to prepare Collaborative Teaching lesson plans for specific topics. For instance, the final version of Particulate Nature of Matter CT lesson plans developed by teachers can be used in the following school year by other teachers who will teach the same lesson.

## 3. Support systems

Like most changes, the changes that Collaborative Teaching has brought into the teachers' learning and practice could not have taken place without the support of the science level coordinator, department head, and the principal. The researcher was able to meet with the teachers for discussions and interviews because of the strong support of the principal and the science department head.

*The implementation of Collaborative Teaching as a mode of teacher development requires that teachers be given time to meet regularly. The administration should designate a specific time for teachers to do this. Creating*

Collaborative Teaching communities within a school is seen as viable and sustainable for as long as there is a strong and consistent support from the administration. When this is a reality, Collaborative Teaching can be sustained and can become part of the culture of the school.

#### 4. Teacher practice

The study shows that Collaborative Teaching facilitates changes in what the teacher does at pre-lesson (planning), during the lesson (classroom teaching), and post lesson (reflection and revision). Slight changes at each portion of the teaching process lead to great improvement in teacher learning and practice. Thus, the additional step and more intentional habit of specifying in the lesson plan the students' misconceptions, learning difficulties and prior learning help teachers in choosing the most appropriate teaching strategies and tools. Using HOTS questioning, models and interactive strategies can enhance teacher-student interaction and student engagement. The habit of reflecting and revising lessons immediately after teaching in a collaborative manner can increase teacher learning and practice. This iterative process of improving teacher practice can be implemented by group of teachers, or by whole departments, or by an entire school.

#### 4. Classroom teaching

The teachers in the study became more intentional in addressing students' misconceptions as this was emphasized repeatedly during pre- and post-lesson

discussions. This had a positive effect on students' conceptual understanding of PNM. Teachers should be intentional in addressing misconceptions as they teach. Teachers should be actively on the lookout for students' misconceptions while teaching and make efforts to effectively address these. As studies have shown, misconceptions are powerful and can be stumbling blocks for students' learning. While the lecture has its place as a teaching strategy, teachers should incorporate collaborative and interactive learning strategies that increase students' interest and motivation to learn. Teachers should also be more intentional in the use of strategies that promote student-teacher interaction and higher order thinking skills, and active involvement in the learning process. As has been found to be effective in this study, teachers must intentionally include the use of models in teaching science concepts to facilitate and deepen student understanding. If the set of concepts covered by the Particulate Nature of Matter are understood well by students, then they will be enabled to understand more complex chemistry concepts. In this study, as students understood the sub-microscopic representation of matter, it became easier for them to understand the particle behavior of matter during phase changes.

##### 5. Student Achievement

Science teachers can use their PCK to address students' misconceptions and learning difficulties to increase student learning. An assessment tool like the *ParNoMA* may be helpful to anticipate students' misconception and learning difficulties.

## Chapter 5

### SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

#### Summary and Conclusions

This research sought to provide data with the end in view of helping improve the professional development of science teachers through Collaborative Teaching.

The study sought to answer the following questions:

1. What changes occurred in the PCK of PNM of science teachers after Collaborative Teaching?
2. What changes occurred in the conceptual understanding of PNM among students whose teachers underwent Collaborative Teaching?
3. To what extent did *changes in teachers' PCK facilitate student conceptual understanding of PNM?*

#### **Research Question #1: What changes occurred in the Science teachers' PCK of PNM as a result of Collaborative Teaching?**

The PCK rating of the six teachers from the Collaborative Teaching group improved from being "Emergent" to "Proficient" as assessed by PCK-PNMOR (see Table 4.28). The mean score of the teachers in the PCK-PNMQ increased 40% from 26.8 out of 48 in the pretest to 37.5 in the posttest.

Analysis using constant comparative method reveals patterns that show Collaborative Teaching facilitated change in the PCK of Particulate Nature of Matter of the six teachers from the Collaborative Teaching group. The PCK changes are

demonstrated in terms of improvement in the teachers' knowledge of science content about PNM (KSC), knowledge of students' understanding of PNM (KSU), and knowledge of teaching strategies about PNM (KTS).

### **The teachers' knowledge of science content about PNM (KSC) improved after Collaborative Teaching.**

The mean KSC score of the Collaborative Teaching group increased by 50%, from 12 out of 20 in the pretest to more than 18 in the posttest (see Table 4.29). In this study a "Proficient" KSC rating meant that the teachers have a good grasp and understanding that matter is made of discrete particles and that there are spaces in between the particles. The teachers also understand that particles of matter are in constant motion and their motion influences the forces of attraction between particles. In addition, the teachers were able to explain phase changes using macroscopic, sub-microscopic and symbolic levels of representation as well as invoking the *Kinetic Molecular Theory*.

Prior to Collaborative Teaching the teachers showed several misconceptions about PNM concepts. After going through CT, the teachers showed improved understanding of PNM concepts in the following:

a. *Construct of elements and compounds.* The dominant teachers' construct of elements and compounds prior to CT is based on the number of atoms. The teachers perceived elements as monoatomic (only one atom) while compounds as polyatomic (two or more similar or different atoms). They made the association that

atoms are to elements while molecules are compounds. The pre and post lesson discussions of Learning Activity 1 (“Which is matter, which is not?”) surfaced teachers’ misconceptions. Enlightening to teachers was the realization that polyatomic molecules made up of one kind of element such as  $H_2$ ,  $N_2$  and  $O_3$  are classified as elements. In an open and collegial environment, teachers from the Collaborative Teaching group corrected their construct of elements and compounds to the one based on the kind of atom instead of the number of atoms.

b. *Construct on behavior of particles during phase changes.* Before CT, the following specific misconceptions were observed:

- 1) The teachers held a wrong construct that particles stop moving during freezing. They thought that water molecules stop moving during freezing as described in other studies.
- 2) Teachers thought that water breaks into hydrogen and oxygen molecule during evaporation and melting. They wrongly thought that liquid water breaks down to hydrogen gas and oxygen gas during evaporation and/or melting. They thought that heat causes the covalent bond between oxygen and hydrogen to break during evaporation and melting.

After CT, the teachers from the Collaborative Teaching group developed the correct understanding that water molecules do not separate into hydrogen and oxygen molecules. The correct understanding became consistent with the teachers’ prior understanding that phase change is only a physical change, not a chemical change. They also developed the correct understanding that molecules continue to

move even during freezing.

c. *Teachers' level of explanation of phase changes of matter.* The level of explanation of the teachers about evaporation, freezing and condensation were analyzed according to levels of representation in chemistry – macroscopic, sub-microscopic and symbolic. Their explanations were also analyzed for consistency with the Kinetic Molecular Theory (KMT). Evidence of connections between these levels in their explanations was also noted.

Before CT, the teachers used largely the macroscopic level of representation in their explanation. Explanations of those that used both macroscopic and sub-microscopic levels did not show conceptual connections between the levels. The teachers who used the KMT in their explanation showed limited knowledge of KMT:

- 1) There was no mention about forces of attraction between particles and how they are affected by the temperature change.

- 2) The teachers' explanations were also not very clear that increased or decreased heat causes the average kinetic energy of the molecules to increase or decrease, which eventually determines the distance between particles.

- 3) The conceptual relationship between temperature, heat, kinetic energy of particles, forces of attraction and distance between particles were not clearly described.

The teachers also held the wrong construct attributing bulk properties such as size, shape, mass, volume, color and hardness, of substances to particles of the substance.

After CT, the teachers improved in their level of explanation about evaporation, freezing and condensation of water in terms of the levels of representations and the use of KMT. They could describe more completely and correctly the particle nature of matter and phase changes at the macroscopic, sub-microscopic, and even symbolic levels of representation. Explanations moved from the macroscopic level towards more to the sub-microscopic level when using the KMT. The teachers also improved in their symbolic representation of phase changes as indicated in the increased use of models as CT progressed. The conceptual relationship between the levels of representation was also more apparent. Lastly, the explanations using KMT showed the relationship among temperature, heat, speed of movement of particles, forces of attraction, and distance between particles are more logically connected. In addition, the teachers' explanations that included KMT aspects showed a correct and complete understanding of KMT in relation to phase changes as follows:

- a) Increased heat causes evaporation and melting to take place.
- b) The increase in the movement of particles was associated with increased heat and kinetic energy (KE).
- c) Increased KE and increased heat cause molecules in liquids to become disorganized.
- d) *Increased kinetic energy causes the particles to move farther apart.*
- e) The distance between particles of gases is larger (or farther) compared to that in liquids.
- f) Decrease in temperature causes molecules to move slower.

- g) Decrease in temperature and release or removal of heat are related.
- h) Lower kinetic energy causes particles to move slower.
- i) Particles moved closer together after water vapor is cooled because of decrease in temperature.
- j) When gaseous particles (water vapor) are cooled, they lose heat energy.

The open, collegial and safe environment during the Collaborative Teaching intervention facilitated the change in the teachers' knowledge of content about PNM. Teachers were willing to admit their lack of understanding and confusion about the concepts of Particulate Nature of Matter required to be taught in specific Grade 8 lessons. As a community of learning, teachers were able to give feedback, correct each other and give inputs for their professional improvement as well. In this manner, the misconceptions among them and their students were identified and addressed more successfully. The teachers *working as a team* facilitated the improvement of the knowledge of science content about PNM of every member of the group. This is an illustration of the *social aspect* of Collaborative Teaching. Collaborative Teaching empowers the teachers to improve their knowledge and practice thus facilitating the professional development of the participant teachers while improving student learning in the process. Such is the *teacher-centeredness* of CT. The teachers giving feedback, correcting and giving inputs to one another *illustrates the teacher-centeredness* of Collaborative Teaching. The collaboration among teachers to learn and improve was focused on teaching of PNM concepts and how best to effect learning among the Grade 8 Science students. The feedback, correction and suggestions for improvement were based on what the teachers

experienced in their respective classes. This is an illustration of the *situated nature* of Collaborative Teaching.

## **2. The teachers' knowledge of student understanding about PNM (KSU) improved after Collaborative Teaching.**

The mean KSU score in the PCK-PNMQ of the Collaborative Teaching group increased by 40%, from 3.8 out of 8 in the pretest to more than 5 in the posttest. In this study, the teachers with a "Proficient" rating of KSU used their knowledge of students' learning difficulties, prior knowledge and misconceptions in both planning and teaching PNM concepts. In addition, the teachers addressed the learning difficulties and misconceptions of students that lead to correct and deeper understanding of PNM concepts. Prior to Collaborative Teaching, the teachers did not specify in their lesson plans the prior learning and misconceptions of students.

As the CT progressed, the teachers improved their lesson plans to reflect their knowledge of students' misconceptions and learning difficulties about PNM. Pre- and post-lesson discussions became intentional in surfacing students' misconception and learning difficulties so lessons could be adjusted and improved. Through CT, teachers learned to think about and anticipate students' misconceptions and learning difficulties. The pre and post-discussions became an avenue for them to share how students were learning or not learning the concepts. In a collegial environment, the teachers shared their ideas and suggestions about how to address their students' specific learning difficulties and misconceptions. They also found it helpful that they got to observe each other, gave and received feedback

about how they were able to address successfully students' learning difficulties and misconceptions during the class. Feedback and suggestions were relevant and effective because they were based on what the teachers observed and/or experienced in a class that happened just a few hours earlier. This is another evidence that CT is situated.

### **3. The teachers' knowledge of teaching strategies of PNM (KTS) shifted from lecture-based to more student-centered strategies.**

At the beginning of the CT intervention the teachers used **lecture** and **reporting by students** as primary teaching strategies. A few teachers used **concept mapping** to review what students know about classification of matter. The teachers were not intentional in choosing strategies that address specific misconceptions and learning difficulties of their students. Towards the end of CT, the teachers from the Collaborative Teaching group began shifting toward use of **models**. The teachers developed a Particle Model, which consisted of circles made from colored cartolina. Teachers used this to illustrate that matter is made up of particles and there are spaces in between them. They also used this model to explain the process of sugar dissolving in water in Activity Lesson 2. They also used this model when they explain phase changes in Activity Lessons 3 to 5. The teachers' use of models helped students visualize the particles and the distance between them. This facilitated understanding of PNM concepts and behavior of particles during phase changes. The teachers also used higher order thinking skills or **HOTS questioning**. HOTS questioning helped teachers clarify to students the

behavior of particles during phase changes. The KTS score of the Collaborative Teaching group in the PCK-PNMQ increased by about 28% from 11.0 in the pretest to 14 in the posttest (Table 4.29).

The iterative nature of CT afforded the teachers repeated opportunities to discuss and reflect on their teaching and classroom experiences. Their reflections included what strategies worked and did not work well. It also included how to adjust their teaching to address students' misconceptions and learning difficulties. Collaborative Teaching fostered collaboration in the preparation and the use of visual and teaching aids. Their reflections, discussions and planning together led them to come up with creative and effective teaching strategies and tools. The **creative strategies and tools** used by the teachers included **games** (e.g., "4 pics, "one word," and puzzles) and **interactive group activities** (e.g., "Human Particle Activity"). The teachers used **artwork, models, Predict-Observe-Investigate, videos, and slide presentations**. Some teachers used **colorful liquids, sweets** for the freezing activity, **concept mapping, think-pair-share, mind-splatter, and music**.

### **Research Question #2: What changes occurred in the conceptual understanding of PNM among students whose teachers underwent Collaborative Teaching?**

Analysis of data indicates that Collaborative Teaching facilitates change of students' conceptual understanding of PNM by addressing students' misconceptions, learning difficulties and limited understanding of PNM concepts.

The classroom outputs of the students are the qualitative evidence of the effect of Collaborative Teaching on the students' understanding of PNM. These include answers to activity sheets, responses to interviews, diagrams and drawings about the particle nature of matter and answers to ParNoMA. The following changes were observed in students' conceptual understanding after Collaborative Teaching:

### **1. Students' view of matter changed from continuous to particle nature.**

Initially, students held a Type 1 or continuous and naive view of matter. At least 70% of students who participated in the study showed difficulty classifying smoke, air, heat and light as matter or not. For the students, matter is something that they can see, touch, hold or feel. They lack knowledge and understanding of the sub-microscopic level of representation to illustrate that matter is made up of particles and there are spaces in between them. Initially, they could not use the sub-microscopic representation to explain why food coloring and sugar spread when each is placed in a container of water. They could not also illustrate sub-microscopic representations to explain phase changes. Majority of the students lacked knowledge that matter is made up of particles and there are spaces between these particles. After CT, students with a Type 1 view or continuous view of matter underwent conceptual change shifting their view of matter from continuous to particle nature. This shift enabled students to visualize and represent the sub-microscopic level of phase changes of matter.

## 2. Students' conceptual understanding of phase changes of matter and the behavior of particles improved.

Students held misconceptions about the behavior of particles during phase changes such as the following:

- a. particles stop moving during freezing.
- b. molecules expand during evaporation and contract during freezing.
- c. melting of ice would separate it to oxygen and hydrogen atoms.
- d. evaporation would separate liquid ammonia into nitrogen and hydrogen atoms.
- e. vaporization of water would break the bonds between atoms.
- f. when water evaporates, it would no longer exist as anything.
- g. particles in solids are not moving. They also thought solids are compact and have no spaces in between.

By the end of CT, students from the Collaborative Teaching group were able to improve their conception of the particle nature of matter and the behavior of particles during phase changes. More specifically, the students improved their understanding that particles of matter continue to move during freezing; that particles in solids are moving; that the size of particles do not change during phase changes; that substances, e.g., water and ammonia, do not break into its component atoms during evaporation and melting. In the early stages of CT, students were limited to a more narrative explanation and of what they observe. Their explanations of their observations, e.g., sugar dissolving in water and boiling of water, were limited to the macroscopic level. At the latter stage of Collaborative Teaching,

students could already use sub-microscopic representation of phase changes to describe the particles. Students could explain the macroscopic phenomena such as melting, evaporation, and condensation using sub-microscopic representations of the particles of water. The mean ParNoMA scores of students from the Collaborative Teaching group increased from 5.1 out of 20 in the pretest to almost 10 out of 20 in the posttest, or a percentage increase of more than 94%. In contrast, the mean ParNoMA scores of students from the Conventional Teaching group increased only by about 51%, from 5.8 in the pretest to 8.7 in the posttest. Based on the Department of Education NAT Mastery Level Equivalent, 103 students out of 143 students (or 72%) from the Collaborative Teaching group improved their mastery level. Ninety-seven (97) students attained "Average Mastery" level or better. In the pretest, only 36 students have "Average Mastery" level or better.

### **Research Question #3: To what extent did changes in teachers' PCK facilitate student conceptual understanding of PNM?**

The PCK rating of the teachers, as assessed by PCK-PNMOR, improved from being "Emergent" to "Proficient." The teachers' mean PCK of PNM score, as assessed by PCK-PNMQ, increased 40% in the posttest. Similarly, their students' mean ParNoMA score increased almost 95% in the posttest.

1. *Improvement of teachers' knowledge of science content enabled teachers to address students' misconceptions and learning difficulties about PNM.*

The teachers' misconceptions paralleled some of students' misconception.

These included:

- (1) Water breaks down into  $H_2$  and  $O_2$  during evaporation.
- (2) Particles of matter stop moving during freezing.
- (3) Melting of ice will separate it to oxygen and hydrogen atoms.
- (4) Phase change is a chemical change.

Improvement of teachers' PCK in terms of their knowledge of science content of PNM (KSC) enabled them to address their own misconceptions of PNM concepts. As a result, the teachers were able to address effectively students' misconceptions of students about particles of matter and their behavior during phase changes. Improvement of teachers' PCK in terms of their knowledge of science content of PNM (KSC) enabled them to explain phase changes and behavior of particles using the macroscopic, sub-microscopic and symbolic levels of representation. This improvement enabled them to deepen the students' conceptual understanding of PNM concepts in the context of phase changes. As a result of these improvements, students' misconceptions about matter, phase change and behavior of particles were corrected. Students showed improved conceptions regarding the following:

- a. Air and smoke have mass and therefore are classified as matter.
- b. The particles of solids are not compact but have spaces in between them.
- c. Liquid water does not break down into  $H_2$  and  $O_2$  during evaporation.
- d. Solid water or ice does not break down into H and O atoms during melting.
- e. Particles of matter do not stop moving during freezing.
- f. Phase change is not a chemical change but a physical change.
- g. Heating water will not break the covalent bonds between hydrogen and oxygen.

- h. Particles of matter do not expand during evaporation and/or during melting.
- i. Particles of matter do not shrink during condensation and/or during freezing.
- j. Particles of matter do not stop moving in solids. They are in constant motion in all states.

*2. Improvement of teachers' PCK in terms of their knowledge of students' misconception enabled them to adjust their pedagogy to increase student learning.*

The empirical data also reveal that improvement in the teachers' knowledge of student understanding (KSU) of PNM enabled them to incorporate students' prior learning, misconceptions and possible learning difficulties into their lesson preparation. This improvement led them to anticipate and plan appropriately; thus, ensuring that students gain deeper understanding of concepts. Specifically, the teachers' improved knowledge of students' prior learning, misconceptions and possible learning difficulties enabled them to choose the appropriate teaching strategies and tools. Thus, knowing for instance that students struggle to understand and visualize the particle nature of matter led teachers to use models such as the Particle Model. The Particle Model helped students represent particles of matter at the sub-microscopic level. Students were able to demonstrate the sub-microscopic representations of the following:

- a. Sugar dissolving in water.
- b. Food coloring dissolving in water.
- c. Liquid water turning to gaseous water (evaporation).
- d. Gaseous water turning to liquid water (condensation).

- e. Solid water or ice turning to liquid water (melting).
- f. Liquid water turning to solid water or ice (freezing).
- g. Pushing an empty plunger.
- h. Pushing a plunger with water.

As a result, students were able to explain more correctly the behavior of particles of matter during phase changes using macroscopic, sub-microscopic and symbolic representations.

*3. Improvement of teachers' PCK in terms of their knowledge of teaching strategies improved students' understanding of particle behavior of matter during phase changes.*

The empirical data also indicates that improvement in the teachers' knowledge of teaching strategies about PNM (KTS) enabled them to choose and employ effective strategies and tools that could address the misconceptions and learning difficulties of their students. Teachers adjusted the strategies they used in accordance to the students' level of understanding of a particular lesson. The use of creative and interactive strategies increased student engagement and deeper understanding of PNM concepts. The following were the significant changes in teachers' knowledge of teaching strategies which led to greater conceptual understanding of PNM of students:

- a. Shift towards use of models to illustrate, explain and generate understanding of PNM concepts. Models used by teachers include:
  - 1). Particle Model which consists of circles, cut outs of colored cartolina to

illustrate various phenomena, e.g., sugar or food coloring dissolving in water. Some of the teachers used cut outs of H-O-H to illustrate the actual water molecule in explaining about behavior of water particles during phase changes.

2). Human Particle to illustrate the spaces in between particles of different states of matter.

3). "Friendship" analogy to explain and differentiate the spaces in between particles during evaporation and condensation.

b. Using Higher Order Thinking Skills questioning to improve critical thinking among students.

c. Use of interactive strategies such as games and music to increase student engagement.

## **Recommendations**

### **1. School-based Professional Development**

The results of the study indicate that school-based professional development programs, such as Collaborative Teaching, are viable complements to conventional ways of teacher development. Therefore, the Department of Education and the Commission on Higher Education should highly encourage and support it. This professional development approach is cheaper because teachers do it in their respective schools or departments. It is sustainable because once Collaborative Teaching becomes part of the school culture, the teachers themselves do it (teacher-directed), based on their own schedule and relevant situation and needs

(situated). It is also sustainable because it is collegial, which leads to the formation of communities of practice or professional learning communities within the school (social). For Collaborative Teaching to be truly viable and sustainable, the principal and the rest of the school administration must support it. They should carve out times for teachers to meet for collaboration such as those done in lesson study.

## 2. Collaborative Framework of Professional Development

Professional development planners can propose a framework that includes the three elements of Collaborative Teaching (specify here these elements in parenthesis). They should emphasize collaboration in teaching and discourage isolation. In this study, teachers realized that having a safe and open environment to share experiences with one another was very helpful. Trainings and seminars should foster teachers working together from beginning to end and not just at punctuated times. Planners and designers can be intentional also in considering the realities or context of recipients rather than adopting a “one size fits all” modality. Finally, professional development planners must strive to empower teachers to direct their own development and professional growth. This encourages ownership rather than passive dependence on the higher authorities.

## 3. PCK-driven Professional Development

Although there are many areas that can be targeted in seminars and trainings for teachers, a focus on the KCS, KTS and KSC is worth emphasizing. In the study, the teachers’ knowledge about PNM and their knowledge of students’

misconceptions and learning difficulties enabled them to come up with the appropriate strategies to help students learn. Teacher in-service programs that emphasize the three components can have the potential to impact teacher knowledge and practice.

#### 4. Chemistry Topic-specific PCK-driven Collaborative Teaching

Many researches on teacher collaboration in literature such as those in Lesson Study and PLC are on mathematics. There is a need to increase chemistry-related lesson studies since this could increase the level of expertise of those teaching the subject. With the introduction of the spiral curriculum in the new K to 12 system, many non-chemistry teachers teach the chemistry portion of the curriculum. A chemistry-focused Collaborative Teaching will equip these teachers to handle the subject more adequately. There are many areas in chemistry that are considered very challenging for teachers to teach and for students to learn (Johnstone, 2010). Aside from the Particulate Nature of Matter, other topics to include are stoichiometry, mole, chemical reactions/equations, solutions, bonding, equilibrium, electrochemistry, and periodicity. Collaborative Teaching focused on strengthening the PCK of teachers around these given difficult topics can increase the confidence and capability of the non-chemistry teachers as they handle the chemistry portion of the curriculum.

#### 5. Increase sample size

The samples size used in the study was small ( $N=12$ ). Increasing the

number of teacher participants can increase validity and generalizability. More than increasing statistical power, having more teachers in PCK studies mean more students will ultimately benefit from it. Development of PCK instruments can benefit from broader studies to improve the factor analysis, both exploratory and confirmatory. However, Collaborative Teaching will be more challenging for a large number of participants. For instance finding a common time to meet may become more difficult. Managing a large group for the coordinator may also be taxing. Thus, it is recommended that the Collaborative Teaching group be kept between six to ten teachers.

#### 6. Longer time frame

The time frame of the study was limited to six weeks due to the scheduling of topics in the new spiral K-12 Science curriculum. The development of the teachers' PCK may have not achieved optimum level over a short period of time. Also, the factors that cause the change in PCK can be studied more in depth with a longer time frame. A longitudinal study involving PCK of in-service teachers can help track how their PCK develops. This should be done to help scaffold professional development efforts of beginning teachers. Perhaps a study can be designed around the limitations encountered by this study to include a longer time frame. A longitudinal study utilizing whole classes could be studied for at least two school years.

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## Appendix A. PCK of Particulate Nature of Matter Questionnaire (PCK-PNMQ)

Instruction: Answer the following briefly but completely. You have 60 minutes to complete this questionnaire.

For items 1-5, choose the best answer and give a short explanation.

1. When water at 25°C is heated and changes to a gas at 110°C, the water molecules

- A. become more organized.
- B. move farther apart.
- C. stop moving.
- D. move closer together.
- E. move more slowly.

2. When water at 24°C is cooled to 0°C and freezes, the water molecules

- A. become less organized.
- B. move much faster.
- C. stop moving.
- D. break apart.
- E. move much more slowly.

3. Consider three samples of water in three phases. The first is solid water (ice) at 0°C, the second is liquid water at 24°C, and the third is gaseous water at 100°C. The water molecules in the liquid phase \_\_\_\_\_ the water molecules in the gaseous phase.

- A. move faster than
- B. move slower than
- C. move at the same speed as
- D. move more randomly than
- E. travel in the same direction as

4. When water is vaporized, it is changed to

- A. hydrogen and oxygen
- B. hydrogen only
- C. gaseous water
- D. air, hydrogen, and oxygen
- E. oxygen only

5. A pot of water on a hot stove begins to boil rapidly. A glass lid is placed on the pot and water droplets begin forming on the inside of the lid. What happened?

- A. The lid became sweaty.
- B. Steam cools and water molecules moved closer together.
- C. Water from outside leaked into the pot.
- D. Hydrogen and oxygen combined to form water.
- E. Steam combined with the air to wet the inside of the lid.

For items 6-10, comment on the students' responses to the following questions.

6. Describe and give examples of atoms and molecules.

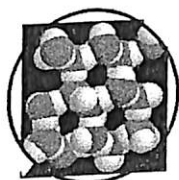
*"Atoms are the smallest part of a matter; example proton, neutron, electron. Molecule is the smallest part of an atom; example solid molecules, liquid molecules, gas molecules."*

*"Atom is the smallest part of an element; example liquid, solid, gas. Molecule is the larger part of an element; example neutron, electron, proton."*

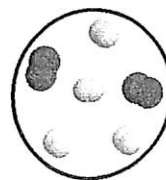
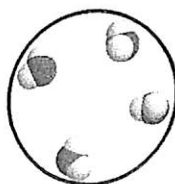
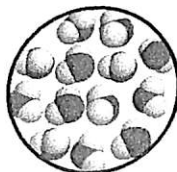
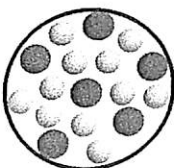
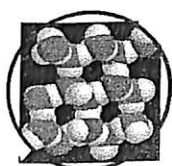
7. Describe how air, water and sugar would appear through a very powerful magnifying glass.

*"Air will not be seen because it cannot be seen. Water look like very small drops. Sugar will look like small circles."*

8. A diagram representing water molecules in the solid phase (ice) is shown below.



Which of these diagrams best shows what water would look like after it melts (changes to a liquid)?



A.

B.

C.

D.

E.

*Student 1: B; Student 2: A Student 3: E*

9. Give a short explanation for the following three familiar events:

A. A toy balloon becomes smaller and softer after two days.

*Student 1: Air is evaporating*

*Student 2: "Espiritu" is lost.*

*Student 3: Air is compressed.*

B. Without stirring, ink drop spreads evenly in water.

*Student 1: Something is pushing the ink.*

*Student 2: Ink atoms are lighter than water.*

*Student 3: There are spaces between molecules.*

C. Bagoong smells.

*Student 1: Odor is caused by the fish.*

*Student 2: There is air in the bagoong.*

*Student 3: There is evaporation and mixing in the air.*

10. Classify whether the drawing shown in cards below represent only elements, only compounds, or both (elements and compounds) and give a short explanation.

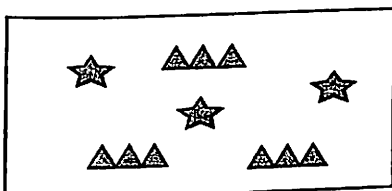


Figure A.

*"Elements and compounds because some are single, others are triple."*

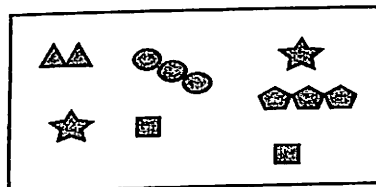


Figure B.

*"Elements and compounds because some are single, others are connected."*

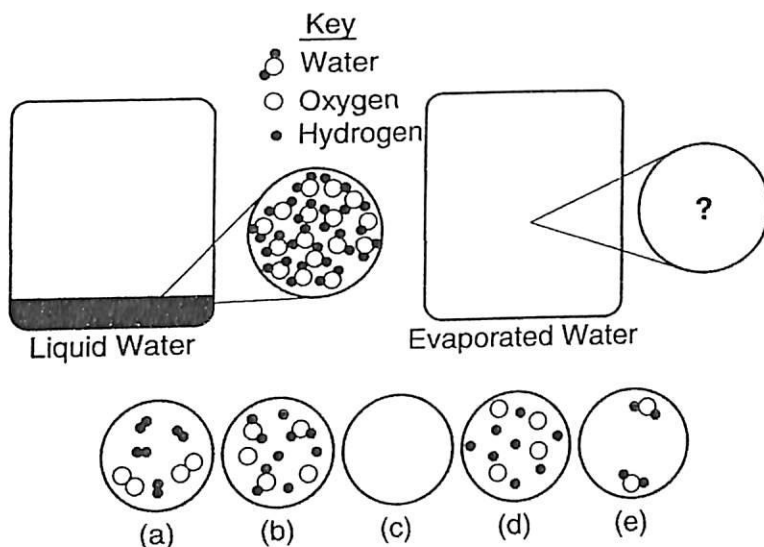
11. A teacher has a Grade 8 Science class. The class consists of mixed-ability students; but, overall, they can be considered as medium-ability students. She just finished covering Unit 2 about Earth and Space. In their next class, she will introduce the particulate nature of matter to students. This will be the first class where the teacher will introduce the particulate nature of matter. The students have not learned anything formally about the particulate nature of matter in the previous lessons. Furthermore, the teacher is not certain about a way to introduce this topic to this particular group of students.

*If you were the teacher, how would you introduce this topic? Which teaching strategies would you use to introduce this topic?*

12. A teacher asked the following question to her Grade 8 Science class. To her dismay all except five students gave the correct answer. Many answered (d) and a few others (c).

Comment on the students understanding of phase changes. How will you help the students develop the right conceptual understanding?

Assume a beaker of pure water has been boiling for 30 minutes.  
What is in the bubbles in the boiling water?



13. The following scenario takes place in a Grade 8 Science classroom:

Teacher: Who can share to us their idea of what a molecule is?

Student 1: Molecules are the particles in a particular atom. Far apart and not in order.

Student 2: If it is an element then atom and if it is a compound then molecule.

Teacher: How about molecule for element?

Student 3: No, atoms is for elements.

Teacher: Do you agree, class?

Class: Yes!

*What would you do in this particular situation in order to help students develop a conceptual understanding of atoms and molecules.*

14. A teacher asks her Grade 8 class the following question: "What will happen to a spoonful of sugar if you put it in a glass of water?" Students responded in the following manner:

“Sugar will melt in the water and its element will combine with water easily and color of water will change.”

“Sugar eventually becomes water.”

“The sugar disappears because it will mix into water and combine in the water.”

“The sugar will melt and spread evenly into the water.”

“Sugar changes into liquid sugar.”

“The sugar disappears because it will mix into water and combine in the water.”

*If you were the teacher, how will you go about teaching the topic on melting and dissolving?*

15. Students were asked to draw how air in a covered flask, water in a basin, and sugar would appear through a very powerful magnifying glass. A few students drew dots to represent sugar. Almost all used wavy lines to represent air in the flask and water in a basin.

*If you were the teacher, how will you handle the class in such a way that students visualize the fact that matter is made up of discrete particles.*

## Appendix B. Teacher Interview Questions

*Instruction to the interviewer: Ask the following questions plainly, avoiding comments and asking leading questions. Record the answers verbatim. Remind the participants to speak clearly and loudly for audio recording purposes.*

Name of Teacher: \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_  
Time Started \_\_\_\_\_ Time ended \_\_\_\_\_

- 1) How long have you been teaching?
- 2) What grade levels and number of years at each level have you taught?
- 3) Have you been involved in any specialized teaching (i.e. as a special science teacher, etc.)?
- 4) Have you participated in professional development for improving your science teaching? Describe the extent of your professional development.
- 5) What university level science courses have you taken?
- 6) What science content areas do you feel most (least) prepared to teach? Why?
- 7) What do you think is the best way to teach science in high school classrooms? Why? Do you feel as though this is the way that you teach science in your classroom? Why or why not?

## Appendix C. PCK of Particulate Nature of Matter Observation Rubric (PCK-PNMOR)

*INSTRUCTION: Use the following statements to assess the over-all PCK of the teacher by checking the statement(s) that best applies.*

PCK Dimension	Advanced	Proficient	Emergent	Novice
Knowledge of Science Curricula	<input type="checkbox"/> Responses and actions showed COMPLETE MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes	<input type="checkbox"/> Responses and actions showed AVERAGE MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes	<input type="checkbox"/> Responses and actions showed LOW MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes	<input type="checkbox"/> Responses and actions showed NO MASTERY of knowledge and understanding of Particulate Nature of Matter concept(s) being taught: what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes
	<input type="checkbox"/> Used language that is COMPLETELY ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Used language that is MOSTLY ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Uses language that is SOMEWHAT NOT ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Uses language that is MOSTLY NOT ACCURATE, descriptive, purposeful, useful and appropriate for Grade 8 students to understand what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes
	<input type="checkbox"/> Used AT LEAST THREE appropriate, accurate examples of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Used TWO appropriate, accurate examples of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes	<input type="checkbox"/> Uses ONE POTENTIALLY appropriate, accurate example of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, phase changes	<input type="checkbox"/> Uses NO appropriate, accurate example of the PNM concepts to explain what matter is, what matter is made of, that particles of matter move and has spaces between them, and phase changes

PCK Dimension	Advanced	Proficient	Emergent	Novice
Knowledge of Teaching Strategies	<input type="checkbox"/> Selected AT LEAST THREE specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts.	<input type="checkbox"/> Selected TWO specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts.	<input type="checkbox"/> Selected ONE specific instructional strategy or activity based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts.	<input type="checkbox"/> DID NOT select specific instructional strategies and activities based on how students learn and what will facilitate student understanding of Particulate Nature of Matter concepts
	<input type="checkbox"/> Used AT LEAST THREE illustrations, examples, models, or analogies to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities.	<input type="checkbox"/> Used TWO illustrations, examples, models, or analogies to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities.	<input type="checkbox"/> Used only ONE illustration or example or model, or analogy to represent Particulate Nature of Matter concepts to facilitate student learning and may not understand the strengths and weaknesses of such representations and/or activities.	<input type="checkbox"/> DID NOT use illustrations, examples, models, or analogies to represent Particulate Nature of Matter concepts to facilitate student learning and understands the strengths and weaknesses of such representations and/or activities.
	<input type="checkbox"/> Varied and adjusted MORE THAN ONCE teaching according to classroom situation.	<input type="checkbox"/> SUCCESSFULLY varied and adjusted the teaching ONCE according to classroom situation.	<input type="checkbox"/> ATTEMPTED to vary and adjust the teaching according to classroom situation but was not successful	<input type="checkbox"/> DID NOT vary and adjust teaching according to classroom situation.
	<input type="checkbox"/> Questions CONSISTENTLY CHALLENGED students to explain, reason, and/or justify.	<input type="checkbox"/> Questions SOMETIMES CHALLENGED students to explain, reason, and/or justify.	<input type="checkbox"/> Questions focused on MORE THAN ONE correct answer; some open response opportunities.	<input type="checkbox"/> Questions focused on ONE correct answer, typically short answer responses.
	<input type="checkbox"/> CONSISTENTLY and effectively engaged students in open-ended questions, discussions, investigations, and/or reflections.	<input type="checkbox"/> SUCCESSFULLY engaged students in open-ended questions, discussions, investigations, and/or reflections.	<input type="checkbox"/> ATTEMPTED to engage students in open-ended questions, discussions, investigations, and/or reflections but was not successful.	<input type="checkbox"/> DID NOT engage students in open-ended questions, discussions, investigations, and/or reflections.
	<input type="checkbox"/> Uses knowledge of students' learning difficulties in planning and teaching <i>PNM concepts.</i>	<input type="checkbox"/> Uses knowledge of students' learning difficulties in planning or teaching PNM concepts but not <i>both.</i>	<input type="checkbox"/> Does NOT use knowledge of students' learning difficulties in planning and teaching <i>PNM concepts</i>	<input type="checkbox"/> Show NO AWARENESS of students' difficulties about PNM.

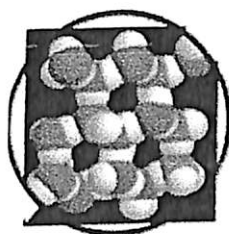
<b>PCK Dimension</b>	<b>Advanced</b>	<b>Proficient</b>	<b>Emergent</b>	<b>Novice</b>
Knowledge of Students' Understanding	<input type="checkbox"/> Uses prior knowledge in both planning and teaching PNM concepts.	<input type="checkbox"/> Uses knowledge of students' prior knowledge in planning or teaching PNM concepts but not both.	<input type="checkbox"/> Does NOT use knowledge of students' prior knowledge in planning and teaching PNM concepts.	<input type="checkbox"/> Show NO AWARENESS of prior knowledge of students about PNM concepts.
	<input type="checkbox"/> Uses knowledge of students' misconceptions in both planning and teaching PNM concepts.	<input type="checkbox"/> Uses knowledge of students' misconceptions in planning or teaching PNM concepts but not both.	<input type="checkbox"/> Does NOT use knowledge of students' misconceptions in planning and teaching PNM concepts.	<input type="checkbox"/> Show NO AWARENESS of students' misconceptions in about PNM concepts.
	<input type="checkbox"/> CONSISTENTLY and effectively addresses all learning difficulties and misconceptions of students that lead to correct and deeper understanding of PNM concepts.	<input type="checkbox"/> SUCCESSFULLY addresses some of the learning difficulties and misconceptions of students that lead to correct and deeper understanding of PNM concepts.	<input type="checkbox"/> ATTEMPTED to address the learning difficulties and misconceptions of students for correct and deeper understanding of PNM concepts.	<input type="checkbox"/> DID NOT ADDRESS the learning difficulties and misconceptions of students.

### Appendix D. Particulate Nature of Matter Assessment (ParNoMA)

(Used with permission from Yeziarski, E. J., & Birk, J. P. (2006). Misconceptions about the particulate nature of matter. Using animations to close the gender gap. *Journal of Chemical Education*, 83, 954-960. doi:10.1021/ed083p954)

**Instructions:** Carefully read each question and choose the best answer.

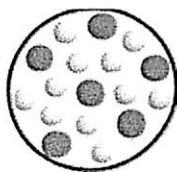
1. A diagram representing water molecules in the solid phase (ice) is shown below.



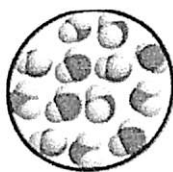
Which of these diagrams best shows what water would look like after it melts (changes to a liquid)?



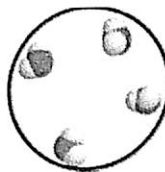
A.



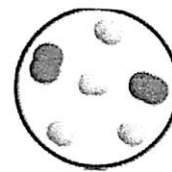
B.



C.



D.



E.

2. Consider three samples of water in three phases. The first is solid water (ice) at  $0^{\circ}\text{C}$ , the second is liquid water at  $24^{\circ}\text{C}$ , and the third is gaseous water at  $100^{\circ}\text{C}$ . The water molecules in the liquid phase \_\_\_\_\_ the water molecules in the gaseous phase.

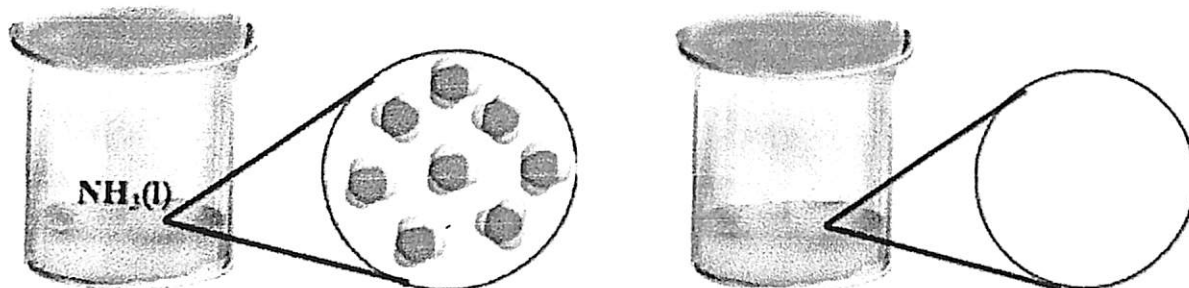
- A. move faster than
- B. move slower than
- C. move at the same speed as
- D. move more randomly than
- E. travel in the same direction as

3. Which of the following processes will make water molecules larger?

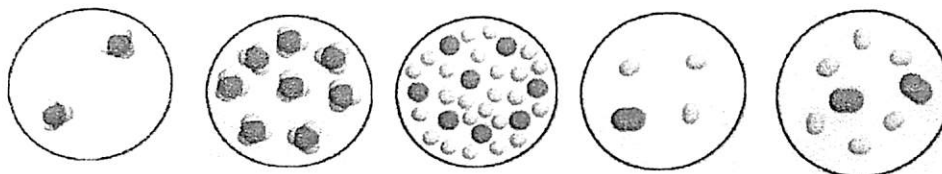
- A. freezing
- B. melting
- C. evaporation

- D. condensation  
E. none of the above

4. A sample of liquid ammonia ( $\text{NH}_3$ ) is completely evaporated (changed to a gas) in a closed container as shown:



Which of the following diagrams best represents what you would “see” in the same area of the magnified view of the vapor?



A.

B.

C.

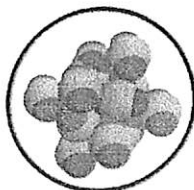
D.

E.

5. When water changes from a liquid to a gas through evaporation or vaporization, energy is required to
- A. break the bonds between the hydrogen atoms.  
B. form new bonds between the atoms.  
C. break the bonds between the oxygen and hydrogen atoms in the molecules.  
D. break the water molecules away from other water molecules.  
E. form new bonds between the molecules.
6. A water molecule in the gas phase is \_\_\_\_\_ a water molecule in the solid phase.
- A. smaller than  
B. lighter than  
C. heavier than  
D. larger than  
E. the same weight as
7. When water is vaporized, it is changed to
- A. hydrogen and oxygen

- B. hydrogen only  
C. gaseous water  
D. air, hydrogen, and oxygen  
E. oxygen only
8. A pot of water is placed on a hot stove. Small bubbles begin to appear at the bottom of the pot. The bubbles rise to the surface of the water and seem to pop or disappear. What are the bubbles made of?
- A. heat  
B. air  
C. gaseous oxygen and hydrogen  
D. gaseous water  
E. none of the above
9. A pot of water on a hot stove begins to boil rapidly. A glass lid is placed on the pot and water droplets begin forming on the inside of the lid. What happened?
- A. The lid became sweaty.  
B. Steam cools and water molecules moved closer together.  
C. Water from outside leaked into the pot.  
D. Hydrogen and oxygen combined to form water.  
E. Steam combined with the air to wet the inside of the lid.
10. Consider three samples of water in three phases. The first is solid water (ice) at  $0^{\circ}\text{C}$ , the second is liquid water at  $24^{\circ}\text{C}$ , and the third is gaseous water at  $100^{\circ}\text{C}$ . The water molecules in the liquid phase \_\_\_\_\_ the water molecules in the solid phase.
- A. move faster than  
B. move slower than  
C. move at the same speed as  
D. move less randomly than  
E. travel in the same direction as
11. A wet dinner plate is left on the counter after it has been washed. After awhile it is dry. What happened to the water that didn't drip onto the counter?
- A. It changes to carbon dioxide.  
B. It just dries up and no longer exists as anything.  
C. It goes into the air as molecules of water.  
D. It goes into the plate.  
E. It changes to oxygen and hydrogen in the air.

12. Which of the following processes does **NOT** require heat energy?
- A. evaporating water
  - B. melting ice
  - C. boiling water
  - D. vaporizing water
  - E. condensing water
13. When water molecules in the gas phase are heated, the molecules themselves
- A. expand.
  - B. move faster.
  - C. become less massive.
  - D. change to a liquid.
  - E. release air.
14. Which of the following processes will make molecules smaller?
- A. freezing
  - B. melting
  - C. evaporation
  - D. condensation
  - E. none of the above
15. Oxygen and hydrogen gases may be formed from liquid water through the process of
- A. vaporization.
  - B. evaporation.
  - C. decomposition.
  - D. freezing.
  - E. boiling.
16. A diagram representing carbon dioxide molecules in the solid phase, also known as dry ice, is shown below.



Which of these molecular diagrams best shows what dry ice would look like after it melts (changes to a liquid)?



## Appendix E. Pre-Lesson Reflection Guide

NAME: \_\_\_\_\_ LESSON TO TEACH: \_\_\_\_\_  
TIME STARTED: \_\_\_\_\_ TIME ENDED: \_\_\_\_\_ DATE: \_\_\_\_\_  
\_\_\_\_\_

1. What will be the main ideas or concepts of this class session or lesson?
2. What specifically do you intend your students to learn about these main ideas or concepts?
3. Describe how you will teach these main ideas or concepts, and explain why you chose to use these strategies.
4. Why is it important for students to know the aforementioned main ideas or concepts taught during this class session?
5. What do you anticipate will be some difficulties and/or limitations connected with teaching these ideas or concepts?
6. What knowledge about students' thinking and/or learning influences how you teach the main ideas or concepts?
7. *How will you assess* students' understanding of, or confusion about the ideas or concepts you *will cover*?

## **Appendix F. Focus Group Discussion Question for Teachers**

*Instruction to the facilitator: Ask the following questions plainly, avoiding comments and asking leading questions. Record the answers verbatim. Remind the participants to speak clearly and loudly for audio/video recording purposes.*

1. What aspects of collaboration were you most happy about and why?
2. What aspects were challenging and why?
3. Which part of the lesson (Activity 1-6), were you most satisfied?
4. Which parts would you do differently next time?
5. What misconceptions about PNM did you identify?
6. What were the students' difficulties with the lesson on Particulate Nature of Matter?
7. What aspects of Collaborative Teaching/Lesson Study will be of value to you?
8. How do you think Collaborative Teaching/Lesson Study help improve your PCK?

## Appendix G. Teacher Post Lesson Interview

*Instruction to the interviewer: Ask the following questions plainly, avoiding comments and asking leading questions. Record the answers verbatim. Remind the participants to speak clearly and loudly for audio recording purposes.*

Name of Teacher: \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_

Time Started \_\_\_\_\_ Time ended \_\_\_\_\_

1. Which part of the lesson were you most satisfied?
2. Which parts would you do differently next time?
3. What misconceptions about PNM did you identify?
4. What were the students' difficulties with the lesson on Particulate Nature of Matter?
5. How would you assess and describe your ability to ask good questions during the class? Were you satisfied with the way you responded to the questions?
6. Were you satisfied with the questions of your students?
7. I have selected some parts of the lesson I found particularly interesting. I want us to watch them together and ask you some questions about them.
8. Let's watch this part (interviewer asks questions starting in one of the following categories based on the reason for selecting the specific interesting instance).
  - a. What were you thinking when this was occurring? Tell me more about what was happening when you \_\_\_\_\_.
  - b. Was there a time during the instruction when you changed your plan? Tell me about that.
  - c. What do you think was the student thinking? Why do you think the student was having difficulty at that point? What knowledge about students did you use to make instructional decisions? In what ways, did students influence your teaching decisions today?
  - d. Tell me about that (example/analogy/activity/)? Why did you decide to use that? How did this teaching strategy help you achieve your overall goals? Where did you learn to teach it that way?
  - e. Did the activities achieve the purpose you intended? Why do you think that is so? How did your curriculum materials support or hinder you in implementing your plan?
  - f. What do you think students got out of the lesson? How do you know? Tell me about how you found out about student learning. Why did you decide to do that? Where did that idea come from? How do you think it worked?

**Appendix H. Student Post Lesson Interview**

*Instruction to the interviewer: Ask the following questions plainly, avoiding comments and asking leading questions. Record the answers verbatim. Remind the participants to speak clearly and loudly for audio recording purposes.*

Name (s) of Student: \_\_\_\_\_ Section \_\_\_\_\_ Date \_\_\_\_\_  
Time Started \_\_\_\_\_ Time ended \_\_\_\_\_

1. What did you like about the class today?
2. What did you learn about \_\_\_\_\_ (topic/concept covered during the day of interview)?
3. How would you describe the interaction between students and the teacher?
4. Were you motivated to ask questions?
5. Which part of the lesson was not so clear to you at first or you had difficulty understanding?
6. Did these things become clearer by the end of the class?

**Appendix I. Post Lesson Discussion Guide**

LESSON: \_\_\_\_\_ DATE TAUGHT: \_\_\_\_\_  
TAUGHT BY: \_\_\_\_\_ DATE REVISED: \_\_\_\_\_  
REVISED BY: \_\_\_\_\_

1. What were the strengths of the way the lesson was taught particularly instructional strategies, teacher questioning, addressing student misconceptions and over-all teacher-student interaction?
2. What revisions will you recommend?
3. What additions will you suggest?
4. What adjustments should be made for the next implementation with emphases on improving instructional strategies, teacher questioning, addressing student misconceptions and over-all teacher-student interaction?

## Appendix J. Collaborative Teaching Schedule

Schedule	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
October	Plan the unit goals with the teachers and decide the six research lessons topics (See Appendix 8) (October 7 )					
October	Teacher A prepares Lesson Plan 1 (Oct 10-11)	Teacher C prepares Lesson Plan 2 (Oct 10-11)	Teacher E prepares Lesson Plan 3 (Oct 10-11)	Teacher B prepares Lesson Plan 4 (Oct 10-11)	Teacher D prepares Lesson Plan 5 (Oct 10-11)	Teacher F prepares Lesson Plan 6 (Oct 10-11)
October	Teacher A presents Lesson plan 1 to the group for critiquing, questions, feedback and suggestions (Oct 12)	Teacher C presents Lesson plan 2 to the group for critiquing, questions, feedback and suggestions (Oct 12)	Teacher E presents Lesson plan 3 to the group for critiquing, questions, feedback and suggestions (Oct 12)	Teacher B presents Lesson plan 4 to the group for critiquing, questions, feedback and suggestions (Oct 13)	Teacher D presents Lesson plan 5 to the group for critiquing, questions, feedback and suggestions (Oct 13)	Teacher F presents Lesson plan 6 to the group for critiquing, questions, feedback and suggestions (Oct 13)
October	Revision 1: Teacher A revises Lesson plan 1 according to the suggestions from the group discussion (Oct 12)	Revision 1: Teacher C revises Lesson plan 2 according to the suggestions from the group discussion (Oct 12)	Revision 1: Teacher E revises Lesson plan 3 according to the suggestions from the group discussion (Oct 12)	Revision 1: Teacher B revises Lesson plan 4 according to the suggestions from the group discussion (Oct 13)	Revision 1: Teacher D revises Lesson plan 5 according to the suggestions from the group discussion (Oct 13)	Revision 1: Teacher F revises Lesson plan 6 according to the suggestions from the group discussion (Oct 13)
October to Nov	Implementation 1: Teacher A implements the revised Lesson plan 1 while Teachers B, C, D, E, F observe. (Oct 21 AM)	Implementation 1: Teacher C implements the revised Lesson plan 2 while Teachers A, B, D, E, F observe. (Oct 23 AM)	Implementation 1: Teacher E implements the revised Lesson plan 3 while Teachers A, B, C, D, F observe. (Nov 3 AM)	Implementation 1: Teacher B implements the revised Lesson plan 4 while Teachers A, C, D, E, F observe. (Nov 9 AM)	Implementation 1: Teacher D implements the revised Lesson plan 5 while Teachers A, B, C, E, F observe. (Nov 11 AM)	Implementation 1: Teacher F implements the revised Lesson plan 6 while Teachers A, B, C, D, E observe. (Nov 16 AM)
<i>Post-lesson teacher and student interview</i>						

Schedule	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
October to Nov	Post-implementation Reflection 1 & discussion: Teachers B, C, D, E, F give feedback about the Lesson 1 implementation; group further reflect and discuss how the lesson can be improved. (Oct 21 PM)	Post-implementation Reflection 1 & discussion: Teachers A, B, D, E, F give feedback about the Lesson 2 implementation; group further reflect and discuss how the lesson can be improved. (Oct 23 PM)	Post-implementation Reflection 1 & discussion: Teachers A, B, C, D, F give feedback about the Lesson 3 implementation; group further reflect and discuss how the lesson can be improved. (Nov 3 PM)	Post-implementation Reflection 1 & discussion: Teachers A, C, D, E, F give feedback about the Lesson 4 implementation; group further reflect and discuss how the lesson can be improved. (Nov 9 PM)	Post-implementation Reflection 1 & discussion: Teachers A, B, C, E, F give feedback about the Lesson 5 implementation; group further reflect and discuss how the lesson can be improved. (Nov 11 PM)	Post-implementation Reflection 1 & discussion: Teachers A, B, C, D, E give feedback about the Lesson 6 implementation; group further reflect and discuss how the lesson can be improved. (Nov 16 PM)
October to Nov	Revision 2: Teacher B will revise the Lesson plan 1 according to the input from the group.	Revision 2: Teacher D will revise the Lesson plan 2 according to the input from the group.	Revision 2: Teacher F will revise the Lesson plan 3 according to the input from the group.	Revision 2: Teacher A will revise the Lesson plan 4 according to the input from the group.	Revision 2: Teacher C will revise the Lesson plan 5 according to the input from the group.	Revision 2: Teacher E will revise the Lesson plan 6 according to the input from the group.
October to Nov	Implementation 2: Teacher B implements the improved Lesson plan 1 to her section while Teachers A, C, D, E, F observe. (Oct 22 AM)	Implementation 2: Teacher D implements the improved Lesson plan 2 to her section while Teachers A, B, C, E, F observe. (Nov 2 AM)	Implementation 2: Teacher F implements the improved Lesson plan 3 to her section while Teachers A, B, C, D, E observe. (Nov 4 AM)	Implementation 2: Teacher A implements the improved Lesson plan 4 to her section while Teachers A, B, C, D, E observe. (Nov 10 AM)	Implementation 2: Teacher C implements the improved Lesson plan 5 to her section while Teachers A, B, C, D, E observe. (Nov 12 AM)	Implementation 2: Teacher E implements the improved Lesson plan 6 to her section while Teachers A, B, C, D, E observe. (Nov 17 AM)
	Post-lesson teacher interview and student interview					

Schedule	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
October to Nov	Post-implementation on reflection 2 : the group reflects and discusses how Lesson 1 can be improved further. Group finalizes the lesson. (Oct 22 PM)	Post-implementation on reflection 2: the group reflects and discusses how Lesson 2 can be improved further. Group finalizes the lesson (Nov 2 PM)	Post-implementation on reflection 2: the group reflects and discusses how Lesson 3 can be improved further. Group finalizes the lesson (Nov 4 PM)	Post-implementation on reflection 2: the group reflects and discusses how Lesson 4 can be improved further. Group finalizes the lesson (Nov 10 PM)	Post-implementation on reflection 2: the group reflects and discusses how Lesson 5 can be improved further. Group finalizes the lesson (Nov 12 AM)	Post-implementation on reflection 2: the group reflects and discusses how Lesson 6 can be improved further. Group finalizes the lesson (Nov 17 AM)
	Focus Group Discussion 1 (Nov 5 AM)			Focus Group Discussion 2 (Nov 18 AM)		

## Appendix K. UNIT 3 MODULE 1 (CHEMISTRY)

### Activity 1: Which is matter, which is not?

#### Objectives:

After performing this activity, you should be able to:

1. Describe common properties of matter;
2. Distinguish properties of matter from those of non-matter; and
3. Demonstrate the skill of measuring mass.

#### Materials Needed:

- 1 teaspoon sugar in a plastic cup or small beaker
- ½ cup tapwater
- 1 piece, stone or small rock
- 1 piece, ball (basketball, volleyball, or small beach ball)
- 3 pieces of leaves (from any plant or tree)
- 5 small wide-mouthed bottles or cups or 150-mL or 200-mL beakers
- 1 platform balance or weighing scale
- 1 small air pump

#### Procedure:

Among the materials displayed in front of you, which do you think is classified as matter? Put a check (ü) under the appropriate column in Table 1. You may make a table similar to the one below. With your group mates, discuss the reason to explain your answer for each sample. Write your answer in the last column.

Table 1. Identifying which is matter

Sample	Is the sample matter?			Reason for your answer
	Yes	No	Not sure	
sugar granules				
water				
stone				
air inside ball				
leaves				
smoke				
heat				
light				

If your group cannot agree on a common answer, you may put a check mark under “not sure” and write all the reasons given by the members of your group.

Q1. What similarities do you observe among the first five given samples? Write these common characteristics.

Q2. Does each sample have a measurable mass? Prove your answer by demonstrating how you measure the mass of each sample. Record the mass you got for each sample.

Q3. Do you think that each sample occupies space? Write the reason(s) for your answer.

Q4. How about smoke? Does it have mass? Does it occupy space? Explain your answer.

Q5. Do you think that heat and light have mass? Do they occupy space? Explain your answer.

## Activity 2: What is matter made of?

### Objectives:

After performing this activity, you should be able to:

1. Infer from given situations or observable events what matter is made of; and
2. Explain how these observed situations or events give evidence that matter is made up of tiny particles.

### Materials Needed:

- ½ cup refined sugar
- 1 cup distilled or clean tap water
- 1 piece, 100-mL graduated cylinder
- 1 measuring cup (1 cup capacity)
- 1 piece transparent bottle (can hold one cup of water) or 250-mL beaker
- food coloring (blue, green, or red)
- 1 dropper
- 1 stirrer (plastic coffee stirrer or stirring rod)

### Procedure:

Using a clean and dry graduated cylinder, pour sugar until the 20 mL mark of the graduated cylinder.

Transfer the *measured sugar* into a 250-mL beaker or transparent bottle.

Measure 50 mL of distilled or clean tap water using graduated cylinder.

Add the 50 mL water to the sugar and mix thoroughly until all the sugar dissolves. Taste the resulting solution. (CAUTION: Do not taste anything in the laboratory unless specifically told to do so by your teacher)

Q1. What is the taste of the resulting mixture?

Q2. Think about sugar and water as made up of tiny particles. With your groupmates, discuss and give your reason(s) for the observations you made in Q1. You may draw illustrations to further explain your reason(s).

Transfer the sugar mixture into a graduated cylinder.

Q3. What is the volume of the sugar and water mixture?

Q4. Is the volume of the resulting sugar mixture equal, more than or less than <sup>[1]</sup>the sum (20 mL sugar + 50 mL water) of the volumes of the unmixed sugar <sup>[1]</sup>and water?

Q5. Think about sugar and water as made up of tiny particles. With your groupmates, discuss and give your reason(s) for the observations you made in Q3. You may draw illustrations to further explain your reason(s).

Pour one cup of tap water into a transparent glass bottle.

Add one small drop of food coloring slowly along the side of the transparent bottle.

Q6. Describe what you observe after adding the food coloring.

Set aside the bottle with food coloring in a locker or corner of your room without disturbing the setup. Describe the appearance of the contents of the bottle after one day. Compare it with the appearance when you left the bottle the previous day.

Q7. What happens to the food coloring dropped in the bottle containing <sup>[1]</sup>water? Write all your observations in your notebook.

Q8. Think about food coloring and water as made up of particles. With your groupmates, discuss and give your reason(s) for the observations you made in Q6. You may draw illustrations to further explain your reason(s).

### **Activity 3: Are the particles of matter moving? What is between them?**

#### **Objectives:**

After performing this activity, you should be able to:

1. Infer from observations that particles of matter move; and
2. Represent through a drawing/illustration what is between particles of matter.

### Materials Needed:

2 cups tap water  
 1 piece, 30 mL plastic syringe (without the needle)  
 1 piece, wide-mouthed transparent bottle (200 or 250 mL capacity)  
 1 piece, narrow-mouthed transparent bottle (100 mL capacity)  
 1 plastic or glass dinner plate  
 ½ cup rock salt (not iodized salt) or ½ cup sand  
 food coloring (blue, green, or red)

### Procedure:

Pull the plunger of the syringe until it reaches the 30 mL mark of the syringe.

Press your thumb on the tip of the plunger and use your other thumb to push the plunger once.

Q1. Can you push the plunger all the way through the syringe while your thumb presses on the tip of the plunger? Why or why not?

Q2. What do you feel as you push the plunger?

This time, push the plunger of the syringe all the way to the end of the syringe. Suck water from the cup or container up to the 30-mL level of the syringe. Cover tightly the tip of the syringe with your thumb.

Q3. What do you feel as you push the plunger?

Q4. Compare what you felt when you pushed the plunger with the air and with the water?

Q5. Explain what you observe. You may represent your comparison by drawing an illustration of the syringe and the particles of air and another illustration of the syringe and the particles of water.

Pour ½ cup of tap water into one transparent glass bottles.

Pour the ½ cup of tap water in step #4 into another bottle or beaker. Observe carefully the flow of water.

Q6. Did water take the shape of the container?

This time, pour the water just on the flat surface of a dinner plate.

Q7. What do you observe? Write all your observations.

Examine a single piece of bottle cap. Put it inside the bottle. Observe carefully what happens as you transfer it by tilting the bottle into the dinner plate.

Q8. What do you observe? Write all your observations.

Pour  $\frac{1}{2}$  cup of rock salt or sand into the narrow-mouthed bottle. Observe carefully what happens to rock salt as you pour it into the bottle and when all of it has been transferred.

Q9. Did rock salt or sand take the shape of the bottle? Did the particles of rock salt change in shape?

**Activity 4: What changes take place when water is left in an open container? In a closed container?**

**Objectives: After performing this activity, you should be able to:**

1. Describe what happens to water when it is left in an open container for some time;
2. Represent through drawings/illustrations what happens to the particles of water when it is left in an open container;
3. Describe what happens to water when it is left in a closed container for some time; and
4. Explain the processes taking place at the sub-microscopic level.

**Materials Needed:**

1 cup tap water  
 3 pieces, watch glass or 2 pieces, shallow transparent plastic container with covers (used for condiments)  
 1 piece, 1 teaspoon or  $\frac{1}{2}$  measuring tablespoon

**Procedure:**

Pour 1 teaspoon or  $\frac{1}{2}$  tablespoon of tap water into the watch glass. This is container No. 1. You can write "No. 1" on a piece of paper and place it under the watch glass. Cover container No. 1 and set it aside.

Pour 1 teaspoon or  $\frac{1}{2}$  tablespoon of tap water into the second watch glass. This is container No. 2. Do not cover container No. 2.

Put container No. 2 beside container No. 1 in an area of your laboratory or room where these can be kept overnight.

During your next science class, discuss with your groupmates the following questions

and write your answers in your notebook.

Q1. Describe what happened to the water in container No. 1.

Q2. Describe what happened to the water in container No. 2. Compare the volume of water left in container Nos. 1 and 2.

Q3. Where do you think did the water go? Describe this process by writing your description or drawing an illustration. Label the parts of your drawing. You can use “call outs” in your drawing.

Q4. Would anything happen differently if you heated container No. 2? Explain your answer.

### Activity 5: What changes take place when water is heated or cooled?

#### Objectives:

After performing this activity, you should be able to:

1. Describe what happens to water when it is heated;
2. Describe what happens to water when it is cooled;
3. Represent through drawings/illustrations what happens to the particles of water when it is heated and then cooled; and
4. Explain the processes taking place at the sub-microscopic level.

#### Materials Needed:

- 100 mL tap water (or ½ cup tap water)
- 1 piece, beaker or Erlenmeyer flask, 200 or 250 mL
- 1 piece, small watch glass
- 1 piece, tripod
- 1 piece, wire gauze (without the asbestos)
- 1 piece, alcohol lamp
- safety matches
- 1 marker pen (any color)

#### Procedure:

##### Part A. Boiling Water

Pour ½ cup or 100 mL of water into the beaker and mark the level of water outside the

beaker.

Put the beaker with water on top of the tripod as shown in Figure 5.

Let the water boil using the alcohol lamp. Observe carefully what is happening to the water when it is already boiling.

Q1. Describe what you observe in the water inside the beaker and above the level of water. You may do any of the following: write a description or draw a cartoon or illustration to demonstrate how the particles of water behave as they are heated.

Add to your skit or cartoon or illustration your answers to Q2 to Q5.

Q2. What do you think is inside the bubbles that form when the water boils? Where did they come from?

Q3. If you keep the water boiling for more than 10 minutes, what do you think will happen to the amount of water in the beaker? Why?

Q4. Where did the water go?

Q5. Can you explain by illustration how the water changes from liquid to gas? What is happening to the particles of water?

### **Activity 6: What changes take place when ice turns into liquid water?**

#### **Objectives:**

After performing this activity, you should be able to:

1. Represent through drawings or cartoons what happens to the particles of ice when it turns to liquid; and
2. Explain the processes taking place using the particle model of matter.


#### **Materials Needed:**

- 2 pieces, ice cubes
- 1 piece, watch glass or saucer

#### **Procedure:**

Put one piece of ice cube on a watch glass or small saucer.

Observe what happens to the ice cube after 2 minutes.

You may do any of the following: write a description or draw a cartoon or  illustration to show how the particles of water behave as ice changes to a liquid.

Q1. Explain what is happening to the particles of water in ice as it turns to liquid using the particle model of matter.

Q2. Explain what will happen to the liquid on the watch glass or saucer if it is transferred into a small container and left inside the freezer after a few hours or overnight?



## Appendix M. Improvement of Lesson Plan for Learning Activity 1

Before pre-lesson discussion: Absence of anticipating students' misconceptions

### DAILY LESSON LOG

Lesson Log #

Subject: Matter

Grade Level: Grade 8

Grading Period: 3<sup>rd</sup> Grading

8-Babbler November 9, 2015

8-Sunbird November 10, 2015

8-Nightingale November 9, 2015

8-Albatross November 9, 2015

#### I. LEARNING OBJECTIVES

Given the necessary materials, 75 % of the students should be able to:

1. distinguish properties of matter from those of non-matter
2. demonstrate the skill of measuring mass
3. actively participate in the group activity

II. TOPIC: Matter and Non-matter

#### III. REFERENCES:

1. Teacher's Guide Grade 8
2. Other References: Internet website
3. Science and Technology 8 by Gerona Z.M. et al.
4. Practice Science Concepts and Skills Grade 8 by Evangelista, LT et al. 6-6 GCSE Chemistry multimedia

#### LEARNERS' MATERIAL USED

Textbook / Learner's Materials page 172

#### IV. MATERIALS

Various materials

1 teaspoon sugar in a plastic cup or small beaker

½ cup tap water

1 piece, stone or small rock

1 flashlight

1 candle

1 piece, ball (basketball, volleyball, or small beach ball)

3 pieces of leaves (from any plant or tree)

5 small wide-mouthed bottles or cups or 150-ml. or 200-ml. beakers

1 platform balance or weighing scale

#### IV. STRATEGIES

##### A. Classroom Routine/ Preparation

1. Prayer
2. Checking of classroom environment
3. Checking of the attendance by the Group leader

##### B. Recall

Students will play game about matching sample pictures and the classification of matter.

Afterwards students will complete the concept map about the classification of matter.

##### C. Activity Proper

Students will perform the activity by group. Afterwards, the students will analyze the questions and collaborate in answering the questions.

#### PROCEDURE

1. Identify whether the following samples have mass by putting check (✓) or (X). If the sample has mass record the data using the digital scale or balance.
2. Identify the following samples have volume by putting check (✓) or (X).
3. Identify each sample is matter or not by writing yes, no or not sure and write the reason for answering.
4. Analyze the questions and collaborate the answer within your group. Be ready for the group presentation.

## DATA COLLECTION

Sample	Properties of matter		Is the sample matter (Yes, No, or Not Sure)	Explanation  Reason for your answer
	Has Mass (/ or X)  if / indicate the mass	Has Volume (/ or X)  if /		
1 sugar granules				
2 water				
3 rock				
4 air inside ball				
5 leaves				
6 heat				
7 light				
8 smoke				

## ANALYSIS

1. What similarities do you observe among the first given samples? Write these common characteristics.
2. Does each sample have a measurable mass? Prove your answer by writing how you measure the mass of each sample.
3. Do you think that each sample occupies space? Write the reason(s) for your answer.
4. How about smoke? Does it have mass? Does it occupy space? Explain your answer.
5. Do you think that heat and light have mass? Do they occupy space? Explain.
6. Based from the experiment, what are the two important properties that identify if a sample is a matter?

## GENERALIZATION

7. State the properties of matter.

D. Integration (values, language, economy, history)  
 English- comprehending the procedure and following instructions  
 Values- showing cooperation and support in the group activity

After pre-lesson discussion: Added application on Pollution to address Students' difficulty classifying smoke and air as matter.

### DAILY LESSON LOG

Lesson Log # 73

Subject: Matter

Grade Level: Grade 8

Grading Period: 3<sup>rd</sup> Grading

8-Babbler November 9, 2015

8-Sunbird November 10, 2015

8-Nighthawk November 9, 2015

8-Albatross November 9, 2015

#### I. LEARNING OBJECTIVES

Given the necessary materials, 75 % of the students should be able to:

1. differentiate properties of matter from those of non-matter
2. prove the properties of matter from those of non-matter
3. actively participate in the group presentation.

II. TOPIC: Matter and Non-matter

#### III. REFERENCES:

1. Teacher's Guide Grade 8
2. Other References: Internet website
3. Science and Technology 8 by Gerson Z.M. et al.
4. Practice Science Concepts and Skills Grade 8 by Evangelista, L.T. et al.
6. GCSE Chemistry multimedia

#### LEARNERS' MATERIAL USED

Textbook / Learner's Materials page 172

#### IV. MATERIALS

Audio Visual presentation

Printed materials

1 teaspoon sugar in a plastic cup or small beaker

½ cup tapwater

1 piece, stone or small rock

Flashlight

candle

1 piece, ball (basketball, volleyball, or small beach ball)

3 pieces of leaves (from any plant or tree)

5 small wide-mouthed bottles or cups or 150-ml or 200-ml beakers

1 platform balance or weighing scale

#### IV. STRATEGIES

##### A. Classroom Routine/ Preparation

1. Prayer
2. Checking of classroom environment
3. Checking of the attendance by the Group leader

##### B. Recall

Students will be asked what the class have performed and the activity was all about.

##### C. Group Presentation

The speakers in each group will present their performance output while checking their responses.

#### DATA COLLECTION

	the mass	If /		
1. sugar granules				
2. water				
3. stone				
4. air inside ball				
5. leaves				
6. heat				
7. light				

### ANALYSIS

1. What similarities do you observe among the first five given samples? Write those common characteristics.
2. Does each sample have a measurable mass? Prove your answer by writing how you measure the mass of each sample.
3. Do you think that each sample occupies space? Write the reason(s) for your answer.
4. Do you think that heat and light have mass? Do they occupy space? Explain
5. Based from the experiment, what are the two important properties that identify if a sample is a matter?

### GENERALIZATION

6. State the properties of matter.

### APPLICATION:

Air Pollution - Killing Us  
Softly And Quietly  
By Rafael Castillo, MD  
Philippine Daily Inquirer News Service  
3-12-5

'...6,000 TONS of particulates, chemicals and other pollutants are emitted DAILY by metropolitan Manila's two to three million vehicles, hundreds of factories, and households.'

How is smoke classified? Matter or not a matter? Students must lead to the idea that smoke is one of the components of air pollution. Students must be able to realize the significant impact of pollution in the country.

#### D. Integration (values, language, numeracy, history)

English- oral communication

Values- evaluating the impact of air pollution to the country.

#### VI. ASSESSMENT TOOLS

Feedback and answering the activity paper

## Before pre-lesson discussion; Implementation 2: Added plan to unlock possible difficulties of students; use of an activity for classification of matter

- LESSON LOG No. 74**
- Subject: SCIENCE Grade Level: Grade 8  
Date: November 13, 2013 (Wed)
- I. Objectives (s)  
Given the necessary materials, 75% of the students should be able to:
- differentiate properties of matter from those of non-matter
  - prove the properties of matter from those non-matter
  - actively participate in the group presentations
- II. TOPIC: Unit 3-Matter  
Subtopic: Matter and Non-matter
- III. Reference/s  
Learner's Guide- Science Learner's Material pp 172-173  
Learner's Guide- Teacher's Guide pp .  
Other Reference: internet Website
- IV. Materials:  
Visual Aid & laptop  
Sugar water stone flashlight  
Ball leaves beaker weighing scale
- V. Strategy:  
Monitoring of Room cleanliness  
Check of Attendance
- A. Review (Previous Lesson)  
Picture Analysis and Concept Mapping
- B. Activity
- Pre-activity
    - unlocking of difficulties
    - terminologies
    - procedures to follow
  - Activity Proper
    - Students will do Activity No. 1 (see attach sheet)
    - Students will answer the given questions
  - Post Activity
    - Recording and reporting the group results
    - Analyzing and comparing results (see pg. 173)
    - Lecture and discussion about the difference between Matter and Non-matter
- C. ABSTRACTION
- Matter can have different properties. You measured the mass of each sample of matter using a balance or a weighing scale. The mass of an object is a measure of the amount of matter the object has.
  - Matter occupies space. The measure of the **SPACE occupied by** an object is called **VOLUME**.
  - All matter have mass and volume. There are other properties of matter such as hardness, texture, color, flexibility, malleability, and electrical conductivity which vary from one sample to another.
- D. ANALYSIS
- Recording and reporting the group results

Characteristics.

- Does each sample have a measurable mass? Prove your answer by demonstrating how you measure the mass of each sample. Record the mass you got for each sample.
- Do you think that each sample occupies space? Write the reason(s) for your answer.
- How about smoke? Does it have mass? Does it occupy space? Explain your answer.
- Do you think that heat and light have mass? Do they occupy space? Explain your answer.

### E. Generalization

State the properties of matter

### F. Application:

Air Pollution – Killing Us  
Soft and Quietly  
By Rafael Castillo, MD  
3-12-5

... 4,000 tons of particulates, chemicals and other pollutants are emitted (only) by metropolitan Manila's two to three million vehicles, hundreds of factories, and households.  
How is smoke classified? Matter or not a matter? Students must lead to the idea that smoke is one of the components of air pollution. Students must be able realize the significant impact of pollution in the country.

### F. Integration: (Valuing)

Values: accuracy and diligence in working  
English: comprehension

### VI. Assessment Tools:

- Feed Back

### VII. REMARKS:

Section  
Spiderherder: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
Said: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
Sleptic: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
Watercock: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
Teaching and Learning Difficulties:

Students could be uncomfortable in their learning environment

### Possible Causes:

Weather condition, use of the classroom and ventilation

### VIII. Intervention(s) made

Provide them with an electric fan

### REFLECTION:

Teaching is a commitment that required a product which learning should be achieve.

Prepared by:

Tula Marie O. Padulo

Date:

Checked by:

Marie C. Anil, HT VI  
Science Department Head

Noted:

SHERIDAN G. EVANGELISTA  
Principal IV

After pre-lesson discussion; Implementation 2: planned to use HOTS questions or clarifying questions during discussion; clarify the terms, volume and mass

Subject: SCIENCE Grade Level: Grade 6  
 Date: November 11, 2018 08:32

I. Objectives (to)

Given the necessary materials, 75% of the students should be able to:

- differentiate properties of matter from those of non-matter
- prove the properties of matter from those non-matter
- actively participate in the group presentation

II. TOPIC: Unit 3-Matter

Subtopic: Matter and Non-matter

III. References

- Teacher's Guide: Science Learner's Material pp 177-179
- Learner's Guide: Teacher's Guide pp
- Other References: internet, library

IV. Materials:

- Small Air & water
- Super soaker, straw, flashlight
- Ball, tubero, bucket, emptying can

V. Strategy

- Motivation of Learners: questions
- Check attendance
- Prepare students for each group
- A. Review (Previous Lessons)
  - Prove analysis and Concept mapping
  - Use pictures of matter, and students to explain their answer, clarify elements and compounds

B. Activity

- Pre-activity
  - Learning situation: Review how to use balance to determine mass or calculate during weighing of objects
  - Technology: Explain volume and measurement: relation to matter to both evenly heat, light and sound and air
  - Precautions to follow

b. Activity proper

- Students will do Activity 1 (see sheet sheet)
- Students will answer the given questions
- To avoid crowding an activity in their factor, only designated student should weigh the objects and record results

c. Post Activity

- Recording and reporting the group results
- Analyzing and comparing results (see page 177)
- Lesson and discussion about the difference between Matter and Non-matter
- Use clarifying questions (HOTS) questions to help students deepen understanding

C. ABSTRACTION

- Matter can have different properties. You measured the mass of each sample of matter using a balance or a weighing scale. The mass of an object is a measure of the amount of matter the object has.
- Matter occupies space. The amount of the space occupied by an object is called volume.
- All matter has mass and volume. There are other properties of matter such as hardness, texture, color, flexibility, malleability, and electrical conductivity which vary from one sample to another.

Recording and reporting the group results

- What conclusion do you observe among the first four samples? Write these answers characteristics.
- Does each sample have a measurable mass? Prove your answer by demonstrating how you measure the mass of each sample. Record the mass you get for each sample.
- Do you think that each sample occupies space? Write the amount for your answer.
- How about volume? Does it have mass? Does it occupy space? Explain your answer?
- Do you think heat and light have mass? Do they occupy space? Explain your answer.

D. Generalization

State the properties of matter

F. Application

Air Pollution - Killing the Earth and Quality of Human Health. 100-112

USE THIS of pollution, chemicals and other pollutants are called ONLY in categories that are in their own words, instead of various characteristics. How is matter classified? Matter is not a matter? Students must lead to the idea that matter is one of the components of an object. Students must be able to realize the significant conceptual pollution in the activity.

G. Integration Planning

Volume - accuracy and tolerance in reading digital measurements

VI. Assessment Tools

- Form sheet

VII. REFLECTION

Teacher: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
 Student: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
 Student: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level  
 Student: \_\_\_\_\_ out of \_\_\_\_\_ reached the mastery level

Teaching and Learning Difficulties

Students could be overwhelmed in their learning environment. Possible Causes: Mismatch condition, size of the classroom and materials. Students difficulty using the balance. Possible Causes: Bad time for lesson, lack of experience.

VIII. Intervention(s) used

Provide them with clearly the instructions to use balance

DEFINITION

Learning is a commitment that requires a product which learning should be achieved

Prepared by

Fate Made O. Padala

Date

Checked by

Anna C. Jolid, ET W  
 Science Department Head

Notes

WISCONSIN STATE UNIVERSITY  
 MARSHFIELD

**Appendix N. Particulate Nature of Matter Assessment (ParNOMA) scores of Students**

Collaborative Teaching Group			Conventional Teaching Group		
Student	Pretest	Posttest	Student	Pretest	Posttest
1	11	11	1	4	8
2	4	15	2	4	5
3	6	11	3	4	8
4	12	12	4	5	7
5	10	13	5	5	7
6	7	10	6	1	11
7	6	10	7	6	9
8	8	10	8	3	10
9	7	11	9	7	6
10	7	9	10	5	8
11	10	12	11	4	8
12	6	13	12	9	9
13	5	10	13	6	8
14	9	14	14	7	10
15	6	11	15	2	4
16	7	18	16	4	12
17	9	17	17	2	13
18	3	10	18	4	8
19	8	16	19	4	6
20	12	18	20	3	7
21	4	13	21	4	9
22	7	10	22	5	8
23	7	8	23	3	8
24	6	13	24	9	5
25	9	12	25	4	3
26	11	16	26	4	5
27	4	12	27	2	9
28	7	13	28	9	5
29	6	9	29	3	3
30	5	10	30	2	9
31	3	13	31	3	5
32	3	7	32	2	6
33	10	14	33	6	7
34	8	9	34	5	9
35	5	12	35	9	9
36	2	11	36	8	13
37	6	6	37	5	8
38	3	11	38	2	10

39	3	10	39	8	10
40	3	5	40	6	11
41	2	7	41	4	5
42	6	12	42	10	14
43	4	8	43	5	7
44	5	10	44	3	9
45	2	9	45	6	10
46	3	12	46	4	6
47	4	6	47	5	7
48	2	9	48	8	11
49	3	9	49	9	9
50	5	10	50	6	13
51	3	8	51	8	2
52	4	9	52	7	12
53	6	10	53	3	4
54	2	9	54	2	13
55	3	10	55	4	8
56	5	7	56	10	15
57	6	8	57	6	10
58	7	9	58	5	8
59	8	14	59	8	10
60	3	6	60	7	3
61	1	6	61	8	11
62	4	5	62	6	7
63	8	6	63	2	11
64	5	9	64	8	9
65	6	12	65	5	3
66	6	12	66	7	10
67	4	14	67	6	3
68	5	7	68	6	8
69	7	9	69	7	11
70	6	4	70	7	14
71	3	5	71	7	6
72	2	10	72	6	10
73	5	6	73	6	8
74	6	6	74	5	3
75	7	19	75	6	10
76	4	8	76	4	9
77	3	7	77	1	15
78	4	8	78	5	11
79	5	5	79	3	7
80	5	8	80	3	17
81	7	8	81	8	8

82	1	10	82	4	4
83	5	7	83	7	10
84	4	11	84	6	7
85	4	10	85	5	10
86	2	10	86	5	11
87	4	6	87	7	8
88	2	8	88	3	10
89	4	7	89	6	7
90	5	5	90	1	10
91	4	11	91	3	8
92	5	7	92	2	9
93	4	11	93	3	7
94	4	13	94	3	9
95	5	4	95	2	6
96	6	7	96	7	11
97	6	10	97	9	10
98	6	9	98	6	5
99	5	7	99	10	10
100	5	8	100	8	9
101	7	11	101	6	11
102	6	5	102	10	12
103	3	8	103	8	9
104	6	10	104	4	8
105	5	8	105	11	8
106	9	6	106	5	15
107	5	8	107	4	8
108	1	12	108	4	3
109	5	10	109	9	7
110	1	12	110	9	13
111	11	15	111	13	11
112	7	8	112	7	12
113	5	14	113	7	10
114	4	3			
115	4	14			
116	3	11			
117	6	7			
118	7	14			
119	2	9			
120	4	8			
121	4	10			
122	4	10			
123	5	10			
124	3	11			
125	7	10			

126	4	15			
127	7	12			
128	7	10			
129	4	11			
130	5	11			
131	4	9			
132	2	13			
133	5	9			
134	9	12			
135	5	12			
136	3	12			
137	3	10			
138	4	10			
139	1	8			
140	5	11			
141	3	9			
142	3	12			
143	2	9			