

CHAPTER VII DISCUSSION, CONCLUSION AND IMPLICATIONS

Introduction

One believes in one's own opinion. The truth for someone depends on how he or she perceives. (Buddhatas (Buddhadasa foundation), 1985:3-4)

This study has explored the development of student conceptions of matter and its properties at Grade 6 level. Building on an analysis of the difficulties in teaching and learning matter and its properties in Thailand and a review of the literature an instructional unit was designed based on the notion of conceptual change as a way to help students develop their existing conceptions towards more scientific conceptions of matter and its properties. This chapter sets out the findings of the study and discusses their implications.

Overview of the Study

1. Research Questions

1.1. *Research question 1:* What is the existing situation of teaching and learning about matter and its properties in Thailand?

1.1.1. *Research question 1.1:* What are the Grade 6 (age 11-12) student conceptions about matter and its properties?

1.1.2. *Research question 1.2:* What are teacher perceptions about their understanding of science concepts, teaching, and students' learning?

(1) *Research question 1.2.1:* What do teachers consider as the problems in teaching about matter and its properties in a science classroom?

(2) Research question 1.2.2: What serve as useful teaching strategies and what are the challenges to students' learning about matter and its properties?

1.2 *Research question 2:* How can a conceptual change approach-based instructional unit be developed and teachers be prepared to teach it?

1.3 *Research question 3:* What is the impact of the implementation of the conceptual change approach-based instructional unit on teaching and learning about matter and its properties?

1.3.1 *Research question 3.1:* How can a conceptual change approach-based instructional unit help students to accept scientific conceptions of matter and its properties?

1.3.2 *Research question 3.2:* How does a conceptual change approach-based instructional unit help primary teachers to change or develop their perceptions of their understanding of science concepts, of teaching and of student learning?

2. Purposes of the study

2.1 To explore Grade 6 (aged 11-12) student conceptions about matter and its properties and teacher perceptions of their own understanding of matter and its properties and associated teaching strategies along with what challenges there are students learning about matter and its properties.

2.2 To design and implement a conceptual change approach-based instructional unit on matter and its properties concepts and examine the effectiveness of the unit.

2.3 To study how can develop a conceptual change approach-based instructional unit and prepare teachers to teach it.

3. Subjects

The phase I participants were six teachers and fifty Grade 6 students (11-12 years old) from six primary schools in Saraburi province, Thailand.

The phase II participants were eighty-one Grade 6 students (11-12 years old) from three primary schools in Saraburi province. The schools were School TK (n=22 students), School JF (n=28 students), and School AB (n=29 students). One teacher from each of the three schools taught a Grade 6 class using the conceptual change-based instructional unit designed within the research.

4. The Conceptual Change -Based Instructional Unit

The conceptual change-based instructional unit about matter and its properties was planned and developed based on *The National Science Content Standards of Thailand* (IPST, 2002), a literature review of teaching and learning about matter and its properties, and surveys of teaching and learning about matter in Thailand. The instructional unit comprised activities on basic concepts about matter and its properties, including the change in state of matter, solution processes, the separation of matter, and chemical reaction. The development of teaching strategies in the unit was informed by a conceptual change approach.

The literature pointed out key considerations which included the importance of existing student conceptions, ways to encourage students to become aware of their existing conceptions, and ways to help them develop scientific conceptions intentionally. The view of a conceptual change used in this study acknowledges that change or development not only occurs in a student's head but also changes students' relationships within their social world. Affective and social factors were considered influences on change and were taken into account in the development of the unit.

In this study, analogies and models, role plays, experiments, and problem solving were employed to encourage student conceptual awareness and the development of more scientific conceptions. The successes of these teaching strategies were explained in Chapter 6. Issues around language such as the students' limited abilities in reading and writing, and confusions between scientific terms and everyday language were also addressed. The instructional unit lasted for 12 periods and included five lessons.

5. Data collection

A variety of data collection methods were used to assess students' understanding of matter and its properties. In Phase I a concept survey was used to survey student conceptions about change in state of matter, a solution process, the separation of mixtures and chemical reaction. The survey was conducted after formal instruction in these topics. The survey included multiple-choice questions, drawing and open-ended items. Interviews were used to explore teacher perceptions about teaching and learning.

In Phase II, data collection included a pre-and-post unit concept survey, classroom observations, interviews, and the collection of students' work. The initial concept survey was distributed to explore students' existing ideas and interpretations of change in state of matter, a solution process, the separation of mixtures and chemical reaction across a range of different situations that were familiar to the students. The whole class teaching and learning activities of the three classes in Phase II the study were observed by the researcher and data collected using a video tape. Interviews were used to assess students' understanding of the concept of matter and teachers' perceptions about the teaching and learning that took place in their classes during the unit. Teacher and student interviews were audio tape recorded and transcribed verbatim by the researcher.

6. Data analysis

In Phase I, the students' responses from a survey were categorized into groups. The building of the categories of students' responses was developed based on studies by Andersson (1990) and Tytler (2003). The students' responses were differentiated into seven categories of responses namely: Perceptual (P), Association (A), Displacement (D), Modification 1(M 1), Modification 2 (M 2), Transmutation (T), Chemical reaction (C) (see detail in Chapter 6). The teacher interviews about their perceptions related to teaching and learning about matter and its properties were transcribed and analysed and reported.

In Phase II of the study, the analysis of the teaching and learning that occurred through the implementation of a conceptual change based instructional unit was based on the triangulation of interview data, classroom observation data, student concept surveys and student work samples. The triangulated data about student conceptions from these resources were categorized into groups. As well as, the triangulated data about teacher changes from these resources were summarized.

Summary of the Findings

RQ.1- What is the existing situation of teaching and learning about matter and its properties in Thailand?

1.1 What are the Grade 6 (age 11-12) students' conceptions about matter and its properties?

The findings of Phase I of this research (described in detail in chapter 4) indicate that Thai student alternative conceptions are similar to those found in other research studies in non-Thai contexts. For example, Thai students had difficulties explaining the change from liquid to gas. They said sunlight sucked the water from clothes when they dried and that the water went to the sky or air. These findings resemble those in studies by Cosgrove and Osborne (1981), Osborne and Cosgrove

(1983), Tytler (1989), Johnson (1998a), and Bar and Galili (1994) who also found that many students think water changes its location or someone or something sucks water into itself. Like the students in studies by Cosgrove and Osborne (1981), Osborne and Cosgrove (1983) and Johnson (1998a), Thai students had difficulties explaining the formation of bubbles in boiling water. They said bubbles were made of heat, or air, or water, or steam, or oxygen and/or hydrogen. Another finding from Phase I was that most students could not explain situations such as the dissolving of sugar where no change was observable. They considered that sugar had disappeared or changed into water. This finding concurs with other studies by Prieto et al. (1989), Longden et al. (1991), Lee (1993) and Valanides (2000). Another idea about the solution process from this research, as in other research studies, is that most students explained that the solute disappears during dissolving. Students did not realize that the solute is conserved in the solution (Cosgrove and Osborne, 1981; Prieto et al., 1989; Stavy, 1990b; Longden et al., 1991). For the concept of chemical reaction, the findings in this study support the ideas from other studies in that a majority of students thought there is no new substance formed during a chemical reaction and the chemical reactions occur because the original substance changes its form into the product, or changes place (see Schollum, 1981; Meheut, 1985; Prieto et al., 1992). Some students thought all chemical reactions are dangerous.

The findings of phase I also revealed that most students can use scientific terms or phases but they do not necessarily know their meanings. For example, the students' definition for matter was exactly the same as the textbook. Evidence that the definition was not meaningful to them came in the way they changed their responses when the situation changed. As Eilks (2003) suggests, scientific words and explanations from textbooks may confuse students rather than help them to understand scientific conceptions.

Interestingly, two student ideas specific to the Thai context were found in this study. First, the students had confusion in the use of the scientific terms for melting and dissolving, and for evaporation term and sublimation. This is likely because melting and dissolving have the same word in everyday conversation in Thai

and the words for evaporation and sublimation have similar pronunciations. The scientific terms melting or sublimation are strange to students and rarely used in everyday life which, as Wellington and Osborne (2001) pointed out, can pose a challenge for students. Another idea related to the Thai context came from the way some words are used differently in scientific language than in everyday conversation (Clerk and Rutherford, 2000). For example, the students perceived that gases are toxic because in everyday life they know about the dangers of cooking gas. Others have argued that these effects of confusions between scientific language and language in everyday life support student alternative conceptions (Vosniadou and Brewer, 1992; Wandersee et al., 1994; Duit, 1999)

Another finding from this study is that Thai students had no ideas about particulate nature of matter and conservation of matter. This is not surprising however because there is no content about these concepts in the Thai curriculum.

1.2 What are the teachers' perceptions about their understanding of science concepts, teaching, and students' learning?

1.2.1 What do teachers consider the problems in teaching about matter and its properties in a science classroom?

1.2.2 What serves as useful teaching strategies and what are the challenges to students' learning about matter and its properties?

The findings of Phase I suggest that Thai Grade 6 teachers perceive some barriers to the development of Grade 6 student understanding, and students applying science ideas to every day life. The teachers considered a majority of students lacked knowledge of science process skills and science content, and that some students had personal problems which reduced their motivation to learn and their science achievement. They identified a lack of science equipment as a problem they faced. The teachers also perceived that their own lack of formal qualifications in science to be an important issue to their developing student learning in science. All of the teachers in the study relied on the textbook. Moreover, the teachers explained that

they have no time to prepare learning activities for science because they are required to perform a lot of extra activities.

The findings indicate that Thai Grade 6 teachers perceive that learning from real things, experiments, and field trips are effective strategies to facilitate student learning in science. In this, their perceptions concur with teaching strategies based on constructivism which focus on promoting student interaction and construction of knowledge (see Chapter 2 section Theory of Learning). These teacher ideas are also in line with the ideas of Hodson and Hodson (1998) who suggest that the role of constructivist teachers is to prepare opportunities and work with students to encourage them to reach their potential and solve problems. Just as importantly, these strategies are consistent with the objectives of the National Science Content Standards (2002) and the National Education Act (1999) which emphasizes those Thai teachers should develop student understanding, skills and scientific attitudes, and awareness of the relation of science to everyday life.

RQ.2- How can a conceptual change approach-based instructional unit be developed and teachers prepared to teach it?

The educational reconstruction model (Duit et al., 1997) informed development of the instructional unit in this study. First, an analysis of the content structure in the Thai curriculum was undertaken. Second, an empirical investigation examined Thai student and teacher conceptions about matter, teaching and learning about matter. Research studies on conceptual change approaches to teaching and learning were reviewed. The survey of Thai student conceptions, along with Thai teacher perceptions about science teaching and learning, as reported in Research Question 1, allowed for the research material to be contextualised for the Thai context. Third, an initial instructional unit was constructed. This unit was then refined to increase the chance that it would meet the needs of Grade 6 Thai students. The researcher piloted the instructional unit herself to check that it promoted student understanding, that the language used was appropriate and that students found the activities motivating. The teachers who taught the unit had three opportunities to

provide feedback on the unit; once before they taught the unit, once during the teaching and again after teaching. The findings of the study indicate that this process, particularly the opportunity for teachers to have input and discuss the unit prior to and during teaching, played a significant role in the success of the implementation. Specifically, the process supported a process of conceptual change for teachers in how they thought about teaching and learning and their own understanding of the science ideas.

The findings of Phase II of this study suggest that when the process of development of an instructional unit takes a conceptual change approach this can help teachers to understand constructivism and the conceptual change approach as it may apply to the students they teach. Teachers who agree to try a new approach or unit benefit from opportunities to contribute to the unit activities. In this study, the teacher conferences provided the teachers time to discuss the instructional unit and how they might adapt it to their classes. Teacher understandings about conceptual change perspective were promoted by encouraging the teachers to think they were similar to students in that they were participating in a conceptual change approach through the process of the teacher conferences (Hewson, 1998). The process of teacher conferences running parallel to the teachers implementing the unit was important in helping teachers become aware of and see the development in their own thinking (see Chapter 5). The findings suggest that when a researcher works with teachers in this way teachers' confidence in their own content knowledge and their abilities in teaching science increase. Teacher conferences provide opportunities for the teachers to develop themselves both in content knowledge and in teaching strategies. Thus, this finding lends support to a suggestion by Harlen (1999) that the teacher should have opportunities to discuss with experts and or other teachers to develop their understanding of science and teaching science.

RQ.3-What is the impact of the implementation of the conceptual change approach-based instructional unit on teaching and learning about matter and its properties?

3.1 How can the conceptual change approach-based instructional unit help students to accept scientific conceptions of matter and its properties?

Student change

The findings from the pre-survey of student conceptions in Phase II were consistent with the findings in Phase I (see Research Question 1 above) and confirmed that the Thai students in the study held alternative conceptions that were similar to those found in other countries.

The data from the case studies presents evidence of the student conceptual development that occurred over the time of implementation of the unit. The data presented in Chapter 6 suggested that after the teaching a majority of students in the three classes could use a particle model to explain the change in state of matter. Most students understood the processes of change from liquid to gas. Moreover, a decrease in language confusion was found. TK 23's response in Chapter 6 Case study I is a good example of this change in understanding. She completed the change in state of matter lesson with the ability to use the particle model and understanding more about the formation of bubbles in boiling water. Seen this way, the findings of this study confirm the findings from the studies of Lee et al. (1993) and Selley (2000) who also found that primary students could use a particle model to explain the change of matter. Another finding about the advantages of a particle model and experiments is that the students had more understanding of the conservation of matter. For instance, Student TK21, Chapter 6 Case study I changed her explanation about conservation of matter in the solution process after she was confronted with experiments and learned to use the particle model.

For chemical reactions, the findings showed that most students changed from the idea of substances changing form or displacement to an idea of the formation of a new substance. For example, a response of JF 12, Chapter 6 Case Study II changed her idea about rust. Her response after instruction was different from her pre-instruction response in which she thought rust was present in water. She developed her understanding that the rust happened because of a chemical reaction. Finally, most students could select an appropriate method for separating a mixture even though they could not explain why they chose the method.

How did student change occur?

The student comments suggested they thought their learning was helped by doing experiments and doing activities which related to everyday life. For example, a student in case study of TK 1 said he had fun when he thought and did science experiments. AB 26 from case study III was another example of a student who said he considered science important and related to his life after the teaching (See details in Chapter 6). Both of these aspects were deliberately incorporated into the unit as key aspects of a conceptual change approach. Posner et al. (1982) and Hewson and Hewson (1992) assert that the scientific conception are not added to or replaced but linked to students' prior knowledge. Hence, activities which relate to student everyday life have the potential to help students to make these links and to understand a concept across the context of science and everyday life (Hallden, 1999). In another example of this link, melting and dissolving are different processes but students use the same Thai word to explain dissolving and melting in everyday life. After the teaching, students still used the Thai words but they understood the two different processes (see example in Case Study III).

Finally, the findings indicate that the unit activities encouraged students' motivational belief. Most students said they were happy to learn science and their belief in their own ability had increased in parallel with their understanding in science. For example, JF 28 said he had more inspiration to learn after participating

in this study. This lends support to research by Pintrich et al. (1993) and Tyson (1997) who note the importance of affective and social factors in conceptual change.

3.2 How does the conceptual change approach-based instructional unit help the primary teachers to change or develop their perceptions about their understanding of science concept, teaching, student learning?

Teacher changes

The three teachers in Phase II of this study developed their teaching in many ways that encouraged student understanding about scientific conceptions. First, the teachers had more confidence in their own understanding of science and teaching science. Ms Pailin's case study (Case study III) is an example of this. She said her confidence in teaching and learning science increased after she participated in the study. She said she knew more about science and doing science and so she could help her students more than she had been able to in the past. This confirms the view that teacher confidence and teachers' own conceptual development is important and not only because teachers who hold alternative conceptions may hinder students' development of scientific conceptions (Wandersee et al., 1994; Haidar, 1997; Valanides, 2000).

All three teachers realized the importance of the key component of conceptual change which is that students have different prior knowledge because they actively construct their own knowledge and generate meaning from their own experiences (Bell, 1993; Driver et al., 1994; Howe, 1996). All three teachers became aware of the importance of surveying students' conceptions and abilities. Initially, Ms Chujai from Case I was unsure why she needed to survey students' conceptions before teaching. During the implementation, she said she became aware of the advantages of surveying students' conceptions and abilities as a way to know and understand student differences and to be able to prepare a more appropriate way to facilitate the students to learn. All the teachers also realized the benefits of formative assessment for

promoting student conceptual change and as a way of monitoring students' emerging ideas and providing feedback to the students, and asking students to reflect on their ideas (Cowie, 2002). Mr. Mana from Case Study II said he found that giving more feedback and interacting more with his students helped him to understand more about the students' development of understanding and alternative ways to help each student to learn.

The findings suggest that teacher beliefs about student abilities to understand concepts and to do science are a key influences their encouraging student conceptual change. Mr. Mana is an example of this. As he showed more belief and respect to his students and their abilities he found that his students had more confidence and motivation to learn and tried harder to understand science.

Teaching for conceptual change

This study has provided evidence of the success of teaching strategies developed to promote conceptual change (See Chapter 6). As in other research studies which have used analogy and models (Vosniadou and Ioannides, 1998; Treagust et al., 1996), this study found that these strategies can help students to understand abstract ideas such as the particulate nature of matter. Students from Case Study I showed that they could present their understanding about the solution process through the particle model. The use of this model helped the students to understand and present ideas about how a solute behaves in solution. Experiment and discussion are also strategies which can support students to recognize, evaluate and reflect on their ideas (Georghiades, 2000) thereby helping students to become aware of their ideas and to promote conceptual change. As well, problem solving as a strategy can help students see the value of scientific conceptions and provide an opportunity to use them (Seddigi and Overton, 2003). For example, in the lesson on the boiling process in Case Study I the teacher did not tell the students that their understanding that "bubbles in boiling water are made up of water" was wrong. The students were given opportunities to compare their prior ideas to their new ideas during and after doing an

experiment. The students realized by themselves which idea was reasonable. Moreover, the experiments which related to everyday life motivated the students to learn by seeing the concrete situation. They encouraged the students to practice their science process skills (Alberts et al., 1986; Harlen, 1999; Bennett, 2003), all factors that have been shown by others to contribute to conceptual change. Finally, the findings about teaching for conceptual change show that student research can provide opportunities for students to make choices and exercise autonomy in applying knowledge. For example, each group of students from Case Study III showed their creative abilities in applying knowledge by presenting their understanding in a variety of ways such as role play, drama, experiments and a science project. Thus, this activity supported conceptual change by encouraging the students to talk about, compare and apply their ideas

Implications of the study for the current educational reform in Thailand

This study on the use of a conceptual change based instructional unit has reinforced the importance of the teacher as a key person in the design and implementation of new curricula. The findings show that the use of an instructional unit based on a conceptual change approach can help teachers to develop their own ability, interest and attitudes toward teaching and learning science and their skills in teaching and using research to develop the science teaching and learning process. These teacher changes support the requirements of The National Education Act (ONEC, 1999) and The National Science Content Standards (IPST, 2002).

For student learning, the increase in student-teacher and student-student interaction to support a student learning process based on constructivism and conceptual change relates to the objective of student-centered approaches which are emphasized in The National Education Act (ONEC, 1999) and The National Science Content Standards (IPST, 2002). Students have more opportunities to develop understanding, skills and scientific attitudes and become aware of and understand science and its relation to everyday life when these aspects are deliberately included in a unit that seeks to promote conceptual change.

Recommendations

1. Professional developers and science educators

The findings from this study indicate that science content knowledge, science process skills and the ability to design classroom curriculum are all important for pre-service and in-service primary teachers. Professional developers and science educators need to take this into account and pay attention to teacher alternative conceptions and to explore ways to promote teacher scientific conceptions. Moreover, both pre-service and in-service teachers need to have opportunities to learn about conceptual change approaches as one way to encourage students to learn science. One way of doing this would be for professional development providers to allow teachers to participate in a teacher-as-learner process that is underpinned by a conceptual change approach.

2. Science teachers

The findings from this study suggest that science teachers need to consider students' existing conceptions when planning for teaching. The use of teaching strategies such as discussion and experiments, problem solving, and exploration of the particle model are recommended in teaching about matter and its properties. Teachers also need to consider the factors such as students' belief in their own ability and their interests as these factors impact on student conceptual change.

3. Policy makers

Policy makers would be advised to support the use of a conceptual change based instructional approach as a tool to promote more student-centered teaching and learning in Thai classrooms.

Suggestions for further research

This research could be extended through the following studies:

1. The conduct of studies about the impact of a conceptual change approach on the student learning about matter in different grade levels.
2. A longitudinal study about students' conceptual change and the persistence of students' alternative and scientific conceptions about matter and its properties.