CHAPTER II

LITERATURE REVIEW

Introduction

It is now agreed that students come to class with their own knowledge and ideas (Bell and Freyberg, 1985; Bell, 1993). A student is not an "empty vessel" (West and Pine, 1985) rather each individual has their own conceptions of the world, which are usually different from scientific conceptions. These student conceptions are generally referred to as alternative conceptions. They are a potential barrier to a student's learning of science and teaching which tries to promote in students' development of scientific conceptions. From this perspective, learning science is regarded as a process of conceptual change (Bell, 1993; Duit and Treagust, 1998) in which students modify their existing conceptions and move to understand and accept scientific conceptions (Hewson and Hewson, 1992; Bell, 1993, Schnotz et al., 2000). Learning as conceptual change in this sense does not mean students ignore their existing conceptions and change to hold only the new, more scientific, ones. Rather, teaching for conceptual change is a process of encouraging students to develop their conceptions and to apply their knowledge in appropriate contexts. As such, conceptual change is not a rapid change process which occurs only in classroom. It involves slow change which relates to many factors such as student motivations, student interests, student beliefs and the classroom climate (Pintrith et al., 1993). Because of each student has different ways of conceptualizing the world, based on their experiences (Kalekin-Fishman, 1999), so conceptual change is not seen as occurring solely in students' head but is considered to be shaped by the contexts where a student shares their views about the world and constructs their knowledge. In this sense, conceptual change will occur when a student understand that scientific conceptions can be used to explain phenomena in a particular context and their existing conceptions cannot. Ideas about conceptual change are important in this study where the goal is to develop a teaching unit which uses a conceptual change approach to promote Thai students' understanding of scientific ideas to do with the concept of matter and its properties.

To this end, this chapter sets out views of learning to argue for the efficacy of viewing it as a process of conceptual change. Student alternative conceptions to do with matter and its properties are then reviewed along with a range of teaching approaches previous research has shown to be useful in promoting conceptual change. The chapter concludes with a discussion of the role of the teacher and an outline of the research questions.

Theories of Learning

1. Introduction

Theories of learning are important in this study as a support for the way that the intervention was designed and implemented. Three theories of learning are presented in this section: behaviourism, personal constructivism and social constructivism.

2. Behaviourism

Behaviourism was the major learning theory in education from the late 1950s and to the early 1960s (Schunk, 2000). Behaviourism contends that the way to know student thinking is to observe their behaviour (Ormrod, 2000). Learning is a process which develops out of the relationship between events in the environment (stimuli - an event that activates behaviour) and responses (observable interaction to stimuli) (Ormrod, 2000; Woolfolk, 1998). The role of teacher is in setting up environmental events that help the students change their behaviour. The right response will occur when they meet with certain stimuli. Learning occurs when student response to the stimuli leads to change in behaviour. Students' prior knowledge is not important in this view because it is underpinned by the belief that a person is born with a blank head. Fascinatingly, there is no explanation for what might occur inside students' head. Indeed, most behaviourists regard this as a "black box" (Ormrod, 2000) which nobody can see or open. In this way, behaviourism disregards the internal processes

of a person. Although students might correctly react to the stimuli that a teacher provides, no one knows if or how they understand it. The teaching strategy most supported by behaviourism is the use of reinforcement, which is the event that a teacher provides after appropriate student behaviour, to encourage student learning. The idea is that when a teacher gives reinforcement after the student has given a correct response, it will promote the desired behaviour to occur again. On the other hand, punishment will discourage the student from repetition or consideration of an undesired behaviour (Ormrod, 2000; Woolfolk, 1998).

Although stimuli and reinforcement may explain aspects of students learning, behaviourism fails to take into consideration inner process such as thoughts, beliefs and feelings. This limitation has been challenged by theorists who try to explain what happens inside a person and argue that students come to the class with their own ideas.

3. Personal Constructivism

In contrast to behaviourism, constructivism is a theory of learning which explains learning as a process in which students actively construct their own knowledge and generate meaning from their experiences (Bell, 1993; Driver et al., 1994; Howe, 1996). Personal constructivism comes in part from Piaget who was interested in students' prior knowledge and the adaptation of student conceptions. Piaget proposed that students experienced disequilibrium when a new experience was not compatible with their current cognitive structure and used the term equilibration to describe the process of establishing equilibrium between this and a new experience. Piaget identified two processes of equilibration: assimilation and accommodation. Students assimilate new experience into their cognitive structure when it fits with their own cognitive structure. On the other hand, students accommodate a new experience into their cognitive structure when they modify or reorganize their ideas to make sense of the new experience. In this way, disequilibrium and equilibration contribute to students developing their own ideas.

The constructivist perspective emphasises the comparison between student's prior knowledge and the knowledge of scientists (Barker, 2001). In science education, learning from the point of view of constructivism is the process of students' changing their conceptions towards those of scientists given students' prior ideas usually differ from scientific ideas (Osborne and Freyberg, 1985; Bell, 1993). Obviously, individuals have different existing knowledge and different experiences which explains why students come to class with a range of differing views. Knowledge is constructed and changed inside each individual mind as each individual adapts their cognitive structure to an experience, so this view also explains why each individual might change their ideas in a unique way.

Personal constructivism emphasises individual existing knowledge and the role of physical experience plays in the development of cognitive structures. It does not acknowledge the importance of social interaction and differences in context as facilitators in the construction of knowledge.

4. Social constructivism

Another view of constructivism is social constructivism. This view is based on Vygotsky's work. He explains that learning is embedded in a social and cultural context (Bell, 1993) and knowledge is constructed when students use language as a tool to interact with others such as parents, teachers, peers or other experienced members in a community (Driver et al., 1994; Howe, 1996). Language is an important tool to support knowledge construction because it used to describe experiences and to communicate with others. In this view, discussion helps students to think and to organize their thinking processes. An adult or more experienced member of a community and teachers plays an important role in help students to develop their understanding. These individuals support students with information and assist and mediate learning with most of this guidance provided through language (Tobin, 1990; Driver et al., 1994; Woolfolk, 1998). This help is often called scaffolding. Students use this help to support them while they construct their own understanding to solve problems.

Vygotsky suggests that the students would reach their highest capability if they got appropriate assistance. He identifies the 'zone of proximal development' (ZPD) as the distance between students' actual development where they can solve problems alone and students' potential development where they can solve complicated problems with appropriate help. Put another way, in Vygotsky's view there are two processes for students' development. First, interactions between students and other people help the students solve a problem. Second, students develop their own understandings i subsequently solve similar kinds of problems by themselves so that they do not depend on the scaffolding from the others forever (Hodson and Hodson, 1998; Woolfolk, 1998). Seen this way, the role of a teacher is to work with students in their ZPD, encouraging them to reach their potential and solve problems by themselves (Hodson and Hodson; 1998).

5. A View of Learning for This Study

In this study, learning science is considered to involve both physical experience individually constructed and socially constructed knowledge (Bell, 1993; Driver et al., 1994). This study regards learning as a social process whereby an individual interacts with others in the community. However, this study does not ignore what is going on in students' minds and the impact this will have on student learning. Knowledge is seen as personally constructed as a result of experience and through interaction with others in a social context. The importance of examining student ideas links personal and social constructivism. Both direct attention to students' existing ideas. Both views support the idea that learning occurs when students understand the difference between their existing conceptions and scientific conceptions. Explanation of the process of learning is presented next as that of conceptual change.

Conceptual change has been developed from constructivism which argues that students actively construct knowledge and make decisions about changing their own concepts (Bell, 1993; Tyson et al., 1997; Duit and Treagust, 2003). Student learning is regarded as conceptual development or change, not as an accretion or accumulation

of information (Hewson et al., 1998; Scott, Asoko and Driver; 1992). Personal constructivism focuses on individual experience in the process of conceptual change but social constructivism emphasizes the role of the social environment as a mediator in the process of change (Driver et al, 1994; Hewson et al., 1998). Although personal constructivism depicts the importance of the knowledge which is constructed in the mind of the individual, the individual has to interact with others in the community, such as friends or teachers. The individual not only expresses their conceptions to others but also attempts to interpret both scientific phenomena and the others' conceptions by comparing them with their own leading to the development of their own conceptions (Cobb 1994; Hewson et al., 1998).

Conceptual Change

1. Introduction

Traditional views of conceptual change stress the promotion of student dissatisfaction with existing concepts and the introduction of a new concept which can make sense, be accepted and found to be valuable. This traditional view neglects affective and social factors that can affect conceptual change. Another view of conceptual change, referred to in this study as the new direction of conceptual change, explains conceptual change in relation to affective and social issues. In this view, change is not only thought to occur in students' head but also in their relationship with the world (Duit, 1997). The next two sections present the different of the view of conceptual change.

2. Traditional Views of Conceptual Change

A number of views of conceptual change since 1980s are evident in the literature but all of them identify two distinct forms of change. Harrison and Treagust (2000) and Tyson et al. (1997) identify these two changes as weak knowledge restructuring or weak revision and strong knowledge restructuring or strong revision. In weak revision, the students assimilate the new concept with their own conceptual

structure. In strong revision, the students reorganize their own conceptual structure to fit with the new concept. Posner et al. (1982) and Strike and Posner (1992) draw on Piaget refer to “assimilation” in a manner consistent with weak revision and “accommodation” which is consistent with strong revision. Posner et al. (1982) were interested in accommodation and identified the conditions which are necessary for a conceptual change of this type. They argue that firstly students must become dissatisfied with their existing conceptions through experiences which show that their existing conceptions cannot solve problems. Secondly, they must have access to a new conception that is intelligible or makes sense to them. Thirdly, the new conception must appear plausible or appear to have the ability to solve the problems. Finally, the new conception must be fruitful; it must be able to solve future problems for the students. The focus of the four conditions of conceptual change is related to the notion of conceptual ecology. Posner et al. (1982), Strike and Posner (1985) and Strike and Posner (1992) proposed that conceptual change is influenced by the individual’s current concepts, or conceptual ecology, which include anomalies, analogies and metaphors, exemplars and images, past experiences, epistemological commitments, metaphysical beliefs and knowledge in other fields. However, they do not explain the interaction between students existing conception and the new conceptions (Duit, 1999).

Hewson and Hewson (1992) explain the meaning of conceptual ecology as consisting of the different kinds of knowledge that each student holds: a student s’ conceptual ecology can support some concepts and discourage others. They also present another factor that is involved conceptual change: the status of conceptions. Conceptual change cannot occur without a change in the status of existing conceptions. The status of a conception shows the degree of student acceptance of the conception. The status of a conception will arise when it meets the conditions of intelligle, plausible and fruitfulness. Hewson (1998) argues that dissatisfaction is the key to a change in status. When the students are dissatisfied with their conceptual structure, they will attempt to exchange or accommodate it to fit with a new concept. This means a new concept’s status becomes higher than that of the old concept in the students’ conceptual structure.

Hewson et al. (1998) suggested that the status of concepts is related to conceptual ecology because when the status of one concept changes, it can increase or decrease the status of the related concepts in the context of conceptual ecology.

An important characteristic of people's conceptions for teachers is that they tend to be resistant to change (Duit, 1999). Many studies have shown that it is almost impossible to completely replace student prior conceptions, which often contrast with those of scientists, by scientific conceptions. Prior student ideas are still alive in students' mind after teaching and students may use them again on a later occasion. Some researchers discuss this issue as one to do with context in association with the change in status (Hewson and Hewson, 1992). Duit and Treagust (1998) assert that the purpose of conceptual change is to help students to become aware that in an appropriate context, science conceptions are more fruitful than their own conceptions.

In recent times a number of authors (Strike and Posner, 1992; Duit and Treagust, 2003; Frensham, 2001) have argued that traditional conceptual change focuses too much on cognitive change. They assert that it does not recognize other aspects that influence these concepts such as affective and social factors (Pintrich et al, 1993).

3. A New Direction for Conceptual Change

In contrast to the traditional view of conceptual change as presented by Posner et al. (1982), a more recent view of conceptual change is the development of new conceptions that are more fruitful than student existing conceptions in term of a particular purpose and a specific context (Jung, 1986 in Duit, 1999). Because knowledge is situated in human practice, conceptual change is the change of the situatedness of the concept. In this view, students should be encouraged to understand the difference between contexts and to use concepts in the appropriate context. Hallden (1999) for example, explains that a concept is not isolated, existing only in the individual mind, but is embedded in cognitive, situational and linguistic contexts such as the communication between people in social activities. Seen this

way, the problems of alternative conceptions relate to the student difficulties in distinguishing different contexts for each concept. In everyday life, students use language for communication which is usually different from scientific language. Sometimes, student reasoning is different from the scientific explanation and they cannot apply a scientific conception to everyday life. This does not however mean that they do not understand the scientific concept, but rather that they do not see any fruitfulness in a scientific concept in this situation (Hallden, 1999; Saljo, 1999). Hallen (1999) argues that although students are situated in everyday contexts and have their own explanation about an event, they should also have the ability to contextualize a problem using scientific contexts. They need to be encouraged to understand and explain concepts in a variety of contexts.

Another change has come from an idea that conceptual change is not only a rational process but also related to motivational constructs such as goal orientations, interests, motivational beliefs about self-efficacy and individually controlled beliefs and the classroom climate (hot conceptual change) (Pintrich et al., 1993). They argue for a connection between student cognition, student motivational factors and social factors in the promotion of conceptual change. Moreover, the promotion of intrinsic motivation such as interest in science activities, or confidence to solve problems or change conceptions leads to successful conceptual change rather than the promotion of extrinsic motivation. The students do not need the rewards because they realize the importance of learning, know what learning is worth for them and are aware of the reason why conceptual change occurs (Gustafson, 1991).

Another, but complementary explanation is that explanation, conceptual change occurs only when students intend to change their concepts. Sinatra (2003) and Vosniadou (2003), for example, show the importance of student metaconceptual awareness and the successfulness of intentional learning in promoting conceptual change. Seen this way, student should be thinking about their beliefs and presuppositions and comparing them with new ideas. Vosniadou (2003) gives an example of a student who has a presupposition that the sun and the moon are the same size. After formal instruction, student can use scientific ideas to explain that the size

of the sun and the moon is different but student does not explain this in terms of the sun and moon's size/distance relation. Their explanation is that the sun and moon cannot be seen as different sizes very readily because clouds block the sun. These students are not metaconceptually aware of their conceptual change. Vosniadou (2003) claims that these students are not provided with an explanation of why, in reality, the sun and the moon are a similar size and why, in the classroom, the sun is bigger than the moon. The student only tries to reconcile new information with an existing conceptual structure without metaconceptual awareness. They do not have any ideas about the difference between appearance and reality. It is important to help students to be aware of the differences and similarities between scientific explanations and the appearance of things. She claims that if students decide to adopt a scientific explanation intentionally, they will be aware of these differences and similarities.

4. Conceptual Change in this Study

This study accepts that students' motivation and social environment are important for conceptual change because student form their concepts by interacting and sharing ideas with others in the social environment in which they are situated. This study stresses that one way to facilitate conceptual change is to be aware of student motivations. For example, their interest in science, their beliefs about what learning is and their awareness of the limitations of their existing ideas and so on. Because concepts cannot occur only in student minds, this study also emphasizes social processes as influences concept formation and change. For example, Thai beliefs about science, everyday language and the difference between the school system and students' social system outside school could affect conceptual change.

In this study, conceptual change is seen as involving students changing their ideas towards more scientific ideas. Conceptual change is thought to happen when students find out that their existing idea can not explain some phenomena. But how can we help the student if nobody knows what is the conflict between student ideas and scientific ideas. The review of research on students' ideas was considered as the means for the researcher to access the origin of the problem. The literature reminds

us that there are many conflicts possible between scientific ideas of matter and students' ideas of matter in their daily life.

Student Conceptions of Matter

1. Introduction

In one school, Teacher A introduces new information to students. She hopes that her students can understand it and accept it. Unfortunately, she forgets that her students have some ideas about the topic that she teaches before they come to class. Teacher A's question is "Why do I have to know what is inside the students' minds?" The Students' question is "Why do we have to accept Teacher A's concept?"

In another case, Teacher B realizes that the student's existing ideas are very important. She uses many strategies to investigate her students' ideas. She knows that her students have adequate prior knowledge; she begins to introduce new information. After the unit she finds that her students have some misunderstanding about the concept that she has presented. Teacher B's question is "Where are these misunderstandings coming from?"

These cases show that the problem is that Teacher A does not realize the importance of the students' existing ideas. Actually, she may think it is not necessary to know what students think because she presents the truth to them, and they should accept it. Teacher B's problem is that alternative conceptions occur during her class and she does not know where they are coming from.

This section provides some answers to these issues. The first part details the characteristics of scientific conceptions and student alternative conceptions and their effects of this on student learning. There are many sources for the alternative conceptions, not only do students bring them into the class, but they can also occur during instruction. The last part in this section is a review of student ideas of matter, which shows the crisis of student difficulties in learning about matter.

2. Concepts

A concept is a meaningful class or group of facts. It has a logical structure, making the facts within the concept meaningful and therefore useful in thinking. Each concept has characteristics that distinguish it and make it unique, differentiating it from other concepts (Hurd, 1970). There are two types of concepts: concrete and abstract. Concrete concepts are used to explain the things that can seen, felt, heard, smelled, or tasted on some direct experiential level. They can be observed or evidenced by the senses. Abstract concepts are more sophisticated. They are used to explain non-observable ideas which cannot be linked to observable objects or object quantities (Gibson, 1981; Good and Brophy, 1980, Lasley and Matczynski, 1997). While psychologists explain a concept as a mental grouping or categorizing of individual cognition about a set of ideas, objects, people, events or experiences which members in the group share in common (Eggen and Kauchak, 1997, Jacobsen et al., 1999; Ormrod, 2000,; Woolfolk, 1998) many sociologists claim that a concept not only helps people to categorize ideas, and objects but also seen as a tool for knowledge construction (Kalekin-Fishman, 1999). As such, concepts are embedded in a social context and occur when people are sharing ideas in social activities (Hallden, 1999: xviii; Saljo, 1999: xix). Concepts can be formed and communicated among people by using language. In this study, concepts are seen as group of ideas using for explaining things or phenomena. Concepts can be learnt using language as a tool for interaction among people in community.

3. Scientific Conceptions and Alternative Conceptions

3.1 Scientific Conceptions In the scientific community, scientifically literate people use specialized forms of language and action that enable them to describe, explain, predict, and control phenomena or systems in the world and participate in communal activities (Lee et al., 1993). This form of language and action is called a scientific conception. Scientific conceptions (American Association for the Advancement of Science, 1990) emerge from the process of interpreting phenomena which is based on observations and theories which support explanation. Scientific

conceptions change over time with new observations and explanations which give more information and more reasonable explanations for the same phenomena. Although scientific conceptions can be changed, the present scientific conceptions are always accepted by the scientific community if there is no new information to discard the old ideas.

3.2 Alternative Conceptions Students have ideas about many science topics, even at a young age and before any formal education (Bell, 1993). They develop their own ideas to make sense of the phenomena they experience in the world around them, but in many cases these ideas are quite different from the accepted scientific viewpoint. Although existing conceptions are often different in significant ways from scientists' views, they are reasonable and useful to the children who hold them. Student alternative conceptions can be a barrier to student understandings of the scientific conceptions presented by science teachers and tend to be resistant to change by traditional instruction methods in the classroom where the science teacher is unaware of students' existing conceptions (West and Pine, 1985; Osborne and Wittrock, 1983).

4. Sources of Alternative Conceptions

If alternative conceptions are the obstacle of learning scientific conceptions, the interesting point is where are they come from? Although most researchers argue that students bring their existing ideas (usually referred to as alternative conceptions) to class, it does not mean that alternative conceptions cannot occur during formal learning. This section details possible sources of alternative conceptions from outside and inside school.

4.1 The Teacher The expectations from society to do with science teachers are that they should be professional in teaching and learning science: they should be knowledgeable in teaching and learning, and in particular, should have correct scientific conceptions (Goodwin, 2003). Despite this, many studies show a range of teacher misunderstanding in science concepts. This shows the possibility that student

alternative conceptions occur as they interact with teachers who have alternative conceptions (Wandersee et al., 1994; Haidar, 1997; Valanides, 2000). Teacher alternative conceptions appear in many areas. For example, Valanides (2000) studied primary student teachers' understanding of the particulate nature of matter and its transformations during dissolving. Most student teachers show some alternative conceptions about dissolving. For example, they believed that the solute disappeared because it was invisible in water or it sank to the bottom of the water and stayed there. Similarly, Haidar (1997) studied prospective chemistry teacher conceptions of the conservation of matter and related concepts. He found that most of the teachers in the study had alternative conceptions about the concepts of atomic mass, the mole, conservation, balancing chemical equations and mass concepts. A similar result was found by Goodwin (2003) in a study related to trainee science teachers' understanding of evaporation and boiling. He argued trainee science teacher had alternative conception in these two concepts, including the evaporation from an open container, 'forced' evaporation, boiling water, reducing pressure over water at room temperature, water in a syringe and opening cans of cola. Some of them could not explain basic scientific concepts. For example, What was happening when they open a can of cola? And Was the fizzing cola boiling?. Wandersee et al. (1994) asserts that one reason for alternative conceptions of teachers may be associated with the low quality of teacher education programs in college. They argued that to solve this problem, all colleges and universities should pay more attention in preparing science teachers in all aspects of both teaching strategies and science content knowledge. In this study consideration was given to helping teachers develop both their science understanding and pedagogy.

4.2 <u>Language Issues</u> One problem in teaching and learning science is the learning of scientific language. Language in science is different from everyday language. Some words are the same as everyday language but are used with different meanings and in different contexts. Some are new words that students have never used in their life (Wellington and Osborne, 2001). At this point, many students consider learning science as learning a new language which is unlike their everyday language. There are two sources of problems about language (Clerk and Rutherford,

2000). First, there are some differences between scientific language and everyday life which makes students confused. Second, some students have problems in their linguistic development, such as they are poor at reading or writing; they have difficulties in finding the correct word to explain their ideas. Likewise, some students do not have an ability to understand the relationships between related concepts, often because they do not have essential skills of ordering and sequencing to understand which things or processes come first and later, and do not recognise cause and effect relationships (Wellington and Wellington, 2002).

Lemke (1990) argues that communication in teaching and learning science not only involves scientific words but also a combination of words, pictures, diagrams, images, animations, graphs, equations, tables and charts. Science textbooks uses models, pictures, graphs and words to explain ideas in way that have been found to contribute to student alternative conceptions.

One example of a confusing picture comes from studies of the particle model of matter. The alternative conception of different molecules in water and ice is supported by textbooks which use different colors in illustrations of water particles and ice particles (Jones, 2000). When a textbook presents continuous matter, such as alcohol, the continuum is colored blue so that the students assume that it is water, so the students presume that water is the main component of every liquid. Some textbooks make students confused about the distance between particles in solid, liquid and gas. Additionally, some textbooks contain different statements and illustrations that could be misinterpreted by some students. For example, in electrochemistry when the anode is always on the left-hand half-cell and using only additive method to calculate cell potentials ($E^0_{cell} = E^0_{ox} + E^0_{red}$) (Sanger and Greenbowe, 1999).

All textbooks are written by experts who understand all the scientific ideas and understand the meaning of figures that they have used. On the other hand, the students have different backgrounds from these experts, sometimes they do not understand the meanings that the experts are intending. The scientific words, the complicated and confusing figures that they use without detailed explanation can make the students suffer, rather than help them to understand scientific conceptions

(Eilks 2003). The other problem is that some authors are not interested in the results from research studies of student conceptions. Many cases are found where textbooks are changed into a tool to support student alternative conception. For example, student alternative conceptions that molecules of water and ice are different are supported by the different colors of water and ice molecules in a textbook (Jones, 2001; Eilks 2003). Some textbooks not only mislead students but actively prevent them from engaging with the science learning process or conceptual change. The studies of Shiland (1997) analyzed eight secondary chemistry textbooks on the concept of atomic theory (quantum mechanics). The four elements of conceptual change model: dissatisfaction, intelligibility, plausibility, and fruitfulness are used as criteria to determine the promotion of scientific conceptions relating to atomic theory (quantum mechanics). These textbooks do not have sufficient evidence to encourage the students to accept the new model of the atom (the quantum mechanical model) rather than their existing model of atom (the Bohr model of atom). The dissatisfaction with the Bohr model's capacity to explain the spectra of any elements other than hydrogen is not explained clearly in these textbooks. The low intelligibility of the quantum mechanical model is found because there is no application or example of phenomena which can be explained by this model. Also, the plausibility of quantum mechanics about the ability to predict spectra of atoms with more than one electron is not presented in the chapter discussing the quantum mechanical model. Finally, there are no applications and explanations of the quantum mechanical model which can not be explained by the Bohr model.

Although 80 to 90 percent of classroom and homework assignments are textbook-driven, many weak points and unclear explanations and illustrations in the textbook should remind all science teachers they cannot rely on their textbooks. They should find other resources and choose appropriate ways to present each concept (Jones, 2000).

4.3 <u>Student Everyday Experiences</u> From the view of constructivism, students come to school with existing ideas about the world (Bell, 1993; Driver et al., 1994). Many studies on student conceptions show that these existing ideas are nearly

dissimilar to scientific ideas. These alternative conceptions are supported by and deeply rooted in student everyday experience. Most of them come from student sense experiences, direct observation and perception. Interaction with parents, peers or the effects from culture and language are also sources and supporters of student alternative conceptions (Vosniadou and Brewer, 1992; Wandersee et al., 1994; Duit, 1999: 266-269). Many research studies show that students use these ideas to make decisions and support their explanations. For example, the students who believe that the ground is flat because they think that they see the ground looks flat, so it should in fact be flat (Vosniadou and Brewer, 1992: 576). Another example comes from the studies of student conceptions of abstract ideas such as particle models. Most students cannot discriminate between the visible macroscopic level and invisible microscopic level. Some students use explanations from everyday experience that they observe to explain the phenomena that they cannot observe. For example, most students cannot believe that there is complete emptiness between the particles. They explain that there is water or air between the particles because, in everyday life, they can see water and air continuously moving between microscopic substances (Novick and Nussbaum, 1978; Lee et al., 1993; Johnson, 1998; Eilks, 2003). Some students give a mixed explanation between macroscopic world and microscopic world. For example, the substance itself changes into smell or the liquid particles change into gas (Schollum et al., 1981; Lee et al., 1993).

In summary, a majority of research studies of student alternative conceptions found that teacher language and student experiences are the significant sources of student alternative conceptions. The concept of structures and properties of matter are one of alternative conceptions that these research studies focus on. This section presents some possible sources of some of alternative conceptions of matter. The next section relates to student alternative conceptions with regard to structures and properties of matter.

5. Student Conceptions of Matter and It Properties

5.1 Introduction The concept of matter is important if students are to understand chemistry as well as physics, biology, and earth science. Besides its importance in the classroom, an understanding of matter and its composition is also relevant in everyday life because it can be used to explain everyday situations such as: What is the material on a cold mirror? Does the combustible material disappear after burning?

The Science in New Zealand Curriculum (Ministry of Education, 1993), the National Science Education Standards (National Research Council, 1996) from the US and the National Science Content Standards (IPST, 2002) each include a similar sequence of objectives to do with matter. Ideas to do with the properties of matter in different states (solid, liquid and gas) are presented to young students and ideas of how matter changes with heating or cooling are presented to slightly older children. More complicated ideas, such as those to do with solubility, separating mixtures and chemical change, are introduced to students at ages 10-13. Older students still learn about atoms and molecules and are expected to able to use these concepts to explain many chemical processes and reactions in industry, human activity and the environment.

From the mid 1970s the science education community has been interested in student understanding of matter. A majority of these research studies focus on the properties of matter in different states and on changes in the state of matter. Some research studies investigate student conceptions of chemical change, particularly with respect to combustion. Dissolving is another concept which many researchers have been interested in, especially from 1990s to 2003.

The research studies reviewed for this study focus on the ideas of children aged from three to eighteen, but the most common age is eleven to fifteen years. It appears that younger students (5-11 years) cannot explain the abstract ideas. For example, the explanation about the disappearance of matter is mostly found when

the students explain the change in state of matter. Older students (after 11 years) have an ability to consider the abstract ideas. For example, the students who receive some instruction on particulate nature of matter can explain the change in state of matter at the microscopic level. Combined, these research studies show that students have some difficulties in understanding the topics taught on the aspects of matter. They have alternative conceptions which are incongruent with scientific conceptions.

Only three studies were identified to do with Thai students' conceptions of matter. Savanakunanon (1993) investigated the development of six to thirteen year old children's ideas about matter and nonmatter. Chantanapitan (1997) studied high school student conceptions about structure, composition, size, shape, mass, intermolecular force and energy of molecules and these properties in different phases of matter. Sanguansin (2004) studies student's conception about state and change in state of substances in higher primary level. They found that Thai students had some alternative conceptions about matter, especially in abstract concepts. For example, most students could not separate gases from liquids because they could not explain the different physical properties of gases and liquids. Most students could not explain the changing process which related to gas for example evaporation and condensation. Most students considered that the size of the molecules in each phase of matter is different.

This section will discuss student conceptions of matter under the topics of change in state of matter, solution processes, separating mixtures, chemical change and chemical substances in everyday life. These topics were drawn from the Thai science content standards (IPST, 2002: 19-22). The literature review revealed several issues related to student concepts of matter, which are not specifically included in Thai science curriculum. These include the influence of student appreciation or lack of appreciation of the particle nature of matter and the fact that matter is conserved when it changes state or dissolves, and the impact of scientific language and everyday language on student understanding. All of these issues are used in detail to explain the student understanding of matter and the development of their understanding. These are included in the review.

5.2 Matter and Non-Matter and the Properties of Solids, Liquids and Gases

Krnel et al. (1998) explain that students develop the concept of matter by learning to distinguish between objects and matter through action on the world. For examples, solid can be distinguished from solid because we can hold, break, load solid, and pour, transfer, run liquid. Another suggestion is that the students have prototypes for matter. For example, water is prototype for liquid. Krnel et al. (2003) purposed three groups of criteria that students use to classify matter; intensive criteria, e.g. colour, substance, state of matter; extensive criteria, e.g. object, shape, size and, other criteria, e.g. action, function. They found that the state of matter was rarely found in students aged 3-13 and it was not used as a criterion below students aged 9. Stavy (1991) classify matter and nonmatter. Renstrom et al. (1990) sorts six groups of students' conceptions which describe different pictures of what substance looks like "from the inside". These conceptions were matter as a homogeneous substance, substance units, substance units with "small atoms", aggregate of particles, or particle units and systems of particles. In the first three groups, homogenous substance, substance unit and substance units with "small atoms", the students do not have any idea about the particle model. The students believe that matter can be understood as a homogeneous continuum substance. Most students hesitate about the complete emptiness between the particles. They believe there is water or air between the particles (Novick, 1978; Lee et al., 1993; Johnson, 1998a, b). Although the students from the third group use the word "small atoms", they do not understand what atoms are. They regard atoms as the smallest constituents of matter, and they just put them in the substance like a cake with raisins in it (Renstrom et al., 1990)

5.3 Student Ideas about The Change in State of Matter

5.3.1 Introduction Research into the concept of change in state of matter is usually conducted by investigating student ideas of the changes in the state of water (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983; Stavy, 1990(b); Levins, 1992; Bar and Galili, 1994; Johnson, 1998a, b). A majority of these studies were published from the 1980s to 2003. The research is varied, and studies students aged from five to eighteen. Most studies relate to the students aged eleven. Unlike

older students, 5-11 year students cannot explain abstract concepts in science. Based on their perception, the students explain natural phenomena at macroscopic level. For example, they observe water evaporating, they think that it disappears. In contrast, the older students with more learning experience could explain this change at microscopic level. The interview technique is usually used to elicit student conceptions of changes in states of matter.

The conservation of matter is the main area where most students have misunderstandings. Most students do not accept that when a substance changes state, its mass and chemical properties do not change. The change of state involving invisible gas, such as water evaporating to water vapour also makes them confused about the existence of water. Many students make unclear explanations; water disappears, it changes location or it changes into other substance. Neither can they give a complete explanation about the change in state at the molecular level because they lack ideas about a particle model.

Many student explanations of changes in the state of matter are related to heat and temperature. Most research studies show student misunderstandings of the products of the process of change, such as bubbles and steam from boiling process. Student ideas of the processes in the change; boiling, evaporation, freezing, melting and sublimation are discussed in this section. The different ideas in different age groups, the concept of particulate nature of matter and conservation of matter are also discussed in this section.

In this section, there are seven areas about student conceptions relating to change in state of matter. First, most students are aware that heat and temperature are involved with the change in the state of matter. Second, students explain the existing of water after evaporation and boiling in various ways. They say that water changes its location or is transformed into other forms. Third, the students have some confusion about the extra products from the process of change. For example, some students believe that bubbles formed in the boiling process are made from heat. Fourth, some students consider that only water can be frozen. The last

three topics in this section are related to the different student ideas in different age groups, student ideas about particulate nature of matter and students ideas about conservation of matter.

5.3.2 Heat and Temperature in The Change in State of Matter

Students' conceptions of the role of heat and temperature in the change in state of matter have been identified. For example, some students (8 – 17 years) explain that heat makes ice melt or that when ice is raised above its melting temperature it changes into water (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983). In other studies, the students explained that when water was heated, it reached a certain temperature and boils, and then evaporation occurs (Tytler, 1989; Levins, 1992). Here, the students are confused between evaporation and boiling because they explain boiling point and evaporation as occurring at the same temperature. The scientific view is that the water evaporates into gas at various temperatures and not only at boiling point.

5.3.3 Does It Change Form or Change Location? In the process of change from liquid into gas, evaporation and boiling, the students say that water changes its location or is transformed into other forms. According to this view, water changes its location to somewhere else: water becomes clouds or air or sky or space (Cosgrove and Osborne, 1981; Tytler, 1989; Johnson, 1998(a); Bar and Galili, 1994), someone or something such as humans or animals drink it, or the sun acts as a magnet and sucks water into itself or a cloud (Tytler, 1989). Another students' view is water changes its location and then transforms into other forms, both the visible and invisible (Tytler, 1989; Osborne and Cosgrove, 1983; Levins, 1992; Johnson, 1998(a); Bar and Galili, 1994). The visible forms are the mist, steam, spray or fog. The invisible forms are vapour, gas or air. Some students suggest that water being absorbed into the floor or ground when the wet clothes on a clothes line dry or water goes into clothes, or goes into containers (Cosgrove Osborne, 1981; Osborne and Cosgrove, 1983; Tytler, 1989).

5.3.4 The Extra Products From the Process of Change In the process of change from liquid into gas, there are extra products like bubbles or steam. There are many ideas which the students use to explain these. The main explanations are that the bubbles in boiling water are made of heat, or air, or water, or steam, or oxygen and/or hydrogen (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983; Johnson, 1998(a)). Steam is explained as liquid, or gas, or hot air which is made of water, or heat, or smoke, or mist, or air. For older students explain steam as molecules or particles in water (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983; Levins, 1992). Some students believe that steam can change back into water, but is different from the original water (Osborne and Cosgrove, 1983).

For condensation, the students believe that when water is condensing on the outside surface of container, it is sweat. Some students say that steam changes back into water (Osborne and Cosgrove, 1983). Other students explain that it is liquid, or vapour, or gas from air or water (Johnson, 1998a).

5.3.5 Freezing: the Forgotten Process Only one piece of research was found that relates to the process of freezing. Stavy (1990b) found that most students (9 -15 years) believe that freezing, which is the reverse process of melting, can only happen with water. They consider only water can be frozen and melt back to water and cannot apply this concept to other substances, such as wax. In the view of particles model, the 8-17 years students explain particles being more closely packed together in the freezing process (Osborne and Cosgrove, 1983).

5.3.6 Different Ideas in Different Age Groups Most research findings show a difference between students' ideas in different age groups. Most young students (5-11 years) believe a substance disappears or is dried up when it evaporates or sublimates (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983; Tytler, 1989; Stavy, 1990a; Bar and Galili, 1994). Older students use microscopic views to explain their ideas. For example, they believe that particles in water are moving more when boiled or evaporated. They also think water turns into oxygen or hydrogen or water disperses as particles. The hydrogen and oxygen atoms in steam

can be recombined to form water (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983; Johnson, 1998a). In the melting process, they explain that heat makes particles of ice move further apart (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983).

5.3.7 The Particulate Nature of Matter The studies of students' conceptions of particulate nature of matter show that the students believe that when substances change their states, the particles do the same (Griffiths and Preston, 1992; Lee et al, 1993). Most students transfer the changes in the macroscopic level into the changes in the microscopic level (Harrison and Treaugust, 2002). For example, the liquid particles themselves become gas (Lee et al., 1993), particles expand into empty space(Novick and Nussbaum, 1978), molecules in ice are heavier than those in the liquid, with molecules of water vapour being lighter (Krnel et al., 1998). Andersson (1990) explains that the students, especially young students, regard matter as continuous and static, but the older students can explain the dynamic particulate conceptions in the process of change. The students cannot use the idea of particle models when they explain what occurs in the process of change because they do not have this concept.

5.3.8 Conservation of Matter Students in a wide rage of ages (5 – 18 years) do not accept the conservation of matter. They believe that when matter evaporates or sublimates, it disappears, but the smell, or colour remains. Moreover, the students explain the weight of matter changes because water, ice, and gas are different weighs. Some of them say that liquid evaporates and changes to gas, which weighs less or has no weight (Cosgrove and Osborne, 1981; Osborne and Cosgrove, 1983; Andersson, 1990; Sere, 1986; Stavy, 1990a,b).

5.4 Student Ideas about Chemical Change

5.4.1 Introduction When chemical reaction occurs, new substances are formed and it is difficult to reverse the reaction. This concept is misunderstood by many students. These misunderstandings show in the research studies of student

ideas of what happens when substances react. Combustion is the most popular example of chemical reaction found in the research (e.g. Meheut, 1985; Rahayu and Tytler, 1999; Pireto et al., 1992).

There are three main misunderstandings about chemical change. First, the students believe that there no new substance is formed in a chemical reaction. Second, most students confuse the role of original substances and the occurrence of products from a reaction. There are many explanations which the students use such as the original substance changes state during a chemical change. Students also confuse the role of components in a reaction. The concept of the particulate nature of matter and the conservation of matter in relation to chemical change are integrated in this topic.

5.4.2 <u>No New Substances is Formed</u> A number of studies report the student idea that no new substance is formed in chemical reactions (Schollum, 1981; Meheut, 1985; Rahayu and Tytler, 1999; Pireto et al., 1992). For instance Schollum (1981) examined views held by 11-16 years students and two primary teachers. They were presented with five everyday events which involved chemical change (A redoxon Vitamin C tablet was placed in water, gas from a butane burner was lit, sugar crystals were placed on a spoon and heated above the gas flame, shiny, and rusty nails were observed and Holts Bond-o-Fill plastic filler and hardener were mixed). Student ideas were elicited using an interview-about-events approach. In response to being asked to place a Redoxon Vitamin C tablet into a glass of water and to explain the origin of the bubbles in the water most students explained that water release the bubbles. Some students explained that somebody had added air locks or little air bubbles to the tablet when it was made. Other students said that the bubbles were gas or oxygen or hydrogen and oxygen. In another example, many students explained the rusting of nails by saying that the rust is actually present under the shiny surface of the nail and becomes apparent once the nail is in water. Other students believed that water eats away at the nail to release the rust. Other examples of these view point come from the work of Meheut (1985) categorized the ideas of combustion of 11-12 year old students. One group of student ideas related to the properties of the

substance. The students' view was that the properties of the substances, such as colour or smell were conserved. This group of students believes that the product of combustion is contained in the combustible material. For example, vapour from burning alcohol is not water because there is no water in alcohol, it is alcohol vapour. Similarly, water vapour is not a product of the combustion of wood because it is hard to imagine water vapour in wood.

Another example of research about students' ideas to do with combustion is the study by Rahayu and Tytler (1999). They investigated the ideas about burning held by primary school children of ages 6, 8 and 11. The students' responses to a written task were coded into seven categories: simple description, associations, displacement, modification, transmutation, transformation of substance and chemical reaction. In the category of displacement, the students explained that substances are not changed, but the same material moves from one place to another. For example, they considered the steam that was trapped in the steel wool is released by combustion. The meaning of burning in this sense is the same as Pireto et al. (1992). They investigated the ideas of three hundred 14 and 15 year old students in England and Spain. The students' responses were sorted into three categories namely chemical reaction, transmutation and modification. The meaning of burning from the transmutation category is that of a destructive process which releases or liberates substances from the combustible material.

5.4.3 The Roles of Original Substances and the Occurrence of Products

1) Substances Change Their Form during Reaction

An understanding of chemical change not only involves appreciating that a new substance is formed but also the difference between a chemical reaction and physical mixing or dissolving or change of state (Schollum, 1982). Students sometimes believe that a chemical change involves a change in the form of the original substance. Johnson (2000a, b) found this when he examined the development of children's (ages 11-14) concepts of substances focusing on the idea of chemical

change. The students believed that the product of a chemical change was derived from the original substance when the original substance changes its form into the product (Schollum, 1981; Meheut, 1985; Pireto et al., 1992; Nieswandt, 2001). Meheut (1985) also reported this idea as to do with student responses that some substances (metals, wax, water, and alcohol) change their states (melt or evaporate) rather than burn. Children with this view believed that some of the properties of a substance are conserved because the original substance and the product are the same. For example, these students explained that when the gold melts, it is still gold because it stays the same color.

2) The Product is the Mixture of the Original Substances

Some students believe that the product of a chemical reaction is a mixture of the original substances rather than a new substance in its own right. In this case it seems that students use the idea of mixing and separating substances to explain the phenomena of chemical reaction (Nieswandt, 2001). They think the product has some of the properties of the original substance (Meheut, 1985; Johnson, 2000 (a)). For example, 11-12 years old students suggested a mixture between carbon and oxygen should be 'black and colourless' and 'solid and gas' (Meheut, 1985).

3) The Original Substance is Changed into a New Substance Some students believe the original substance changes into the product (Meheut, 1985; Hessess and Anderson, 1992; Pireto et al., 1992; Rahayu and Tytler, 1999; Johnson, 2000 a, b). The disappearance of the original substance is emphasized in this case. For example, wood disappears after burning and the cinder occurs. This means wood disappears because it changes into cinder (Meheut, 1985).

5.4.4 Failure to Identify Some of the Components in Chemical Reaction

A number of research studies identify that the students do necessarily identify all the different components or reactants in a chemical reaction, especially in the combustion process (Scholum, 1981; Pireto et al., 1992; Rahayu and Tytler, 1999; Johnson, 2000 a, b). Most students for instance are not clear about the role of the oxygen in the combustion process (Rahayu and Tytler, 1999; Johnson, 2000 (a)).

Some students say oxygen may be needed but that it does not interact with combustible material (Pireto et al., 1992). Others think that oxygen or air may be involved in making the flame (Scholum, 1981; Pireto et al., 1992). Alongside this, some students believe oxygen is involved in the combustion reaction but they consider that it is transmuted separately into the product (Pireto et al., 1992) or the combustible substance reacts with oxygen like 'a bull attacking a red rag' (Johnson, 2000 (a): 732). Similarly, most students are not clear about the role of flame. They believe that flame is the source of heat, but they do not understand the affect of the flame on the combustible substance (Pireto et al., 1992; Rahayu and Tytler, 1999).

Rusting is another example where students are confused about the roles of the different reactants. Some students believe that rust just happens when a nail is in water. Another idea is that rust is the result of water plus some impurity in the nail (Hessess and Anderson, 1992; Schollum, 1981)). Some of students consider low temperature make the nail rust (Hessess and Anderson, 1992).

5.4.5 <u>The Particulate Nature of Matter</u> Ultimately, understanding of the particulate nature of matter is important in understanding chemical change. However, Johnson (2000 a, b) found that most 11-14 years students do not recognize the terms "element" and "compound" when they are presented with the formula of water. Most of them are unable to explain what it represents. Others think it has something to do with water, and a few can refer to hydrogen gas and oxygen gas in the chemical reaction but they do not have any ideas about decomposition. The substance is changed into smell, or the color is locked inside colour substances (Schollum et al., 1981). This showed that the students could not explain chemical change in microscopic level.

Meheut (1985) introduced a very simplified form of particle model to elicit students' ideas about combustion. The result was that some students explained that the molecules of combustible material are only one source of the molecules of the products.

5.4.6 Conservation of Matter Most students do not accept that the total amount of substances does not change after chemical reaction in closed-system. Barker (1999) reported the students' conception of conservation of mass in closed - system chemical reaction. Most students explain the change of the mass of a sealed flask of phosphorus and water after the reaction of phosphorus and oxygen is that phosphorus solid has changed into gas or liquid which weighs less or more than solid. Some students believe that it weighs less because phosphorus dissolves or energy is lost or absorbed. Other students believe that the weight cannot have increased because the original substance is used up. Another group of students argue that the weight should have increased because new substances are present (Pireto, 1992; Barker, 1999).

A common misunderstanding with combustion is that the original substance disappears. During combustion, some students explain that the substance is changed from the substance into nothing. As evidence for their view students pointed out that a wood splint weights less after it is burned because it has changed to nothing (Hessess and Andersson, 1992; Pireto et al., 1992).

Meheut (1985) and Nieswandt (2001) show the students' confusion of the properties of substances. Most students believe that there is no conservation of any properties of substance. However, some students believe that the properties of substance are conserved but they give a wrong explanation such as the properties of substance are conserved because the reactant and product are the same (Meheut, 1985; Rahayu and Tytler; 1999)

Majority of students believe that substance can disappear during chemical reaction (Hessess and Anderson, 1992; Pireto et al., 1992). They do not accept that the substance can only react to form something.

5.5 Student Ideas of the Solution Process

5.5.1 Introduction Numerous studies on the solution process

focused on dissolving (most studies have involved dissolving of salt or sugar in water). Most studies in this field were conducted with the students aged five to eighteen. Drawing techniques and written techniques were usually used to probe student understanding.

Most students are familiar with dissolving in daily life, but most students cannot explain it. Firstly, most students can not explain detail of the process of dissolving either at macroscopic level or microscopic level. Secondly, the students are confused by the role of solute and solvent and the solubility of solute dissolving process. Thirdly, most students have unclear explanations about the external influences which affect dissolving.

The student conceptions of the process of dissolving, the role of solvent and solute, solubility and the external influences on dissolving, such as heating and stirring, are discussed in this section. As in previous topics, the concept of conservation of matter and the particulate nature of matter are included in this section.

5.5.2 <u>The Process of Dissolving</u> There are many research studies in dissolving which show that students do not understand the phenomena of dissolving either at the macroscopic level or microscopic level. Students consider the process of dissolving as the interaction between solute and solvent but the interaction is regarded as physical change. For example, the solute and solvent are mixed or they join together. However, some student can not distinguish solute and solvent in the solution because they understand the solution as homogeneous. Another idea is that chemical change, for example solute combined with solvent, give one substance which has properties of both solvent and solute, such as the product of sugar dissolved in water is sugar - water. Other students believe that a new substance is formed during dissolving (Prieto et al., 1989; Ebenezer and Erickson, 1996; Blanco and Prieto, 1997). However, Cosgrove and Osborne (1981) and Liu and Ebenezer (2002) show the students' confusion of the term solute and solvent is revealed by the idea

that they believe water is a solution; the solute was oxygen and solvent was hydrogen because hydrogen is presented in large amounts in water.

5.5.3 The Role of Solute and Solvent Solute and solvent are required in the process of dissolving. Prieto et al. (1989) identified students' conceptions (11-14 years) relating to the role of these two important things. The older students are interested in the interaction between the solute and the solvent while the younger students are interested in the changes undertaken by solute and solvent. They are interested in the simple actions of dissolving a solute in solvent more than the complicate interactions between them.

The majority of the students are interested in the role of the solute more than solvent. The students across a wide range of ages believe that when a solute dissolves, it melts (changing state from solid to liquid), or evaporates (liquid to gas), or decompose (Prieto et al., 1989; Longden et al., 1991; Slone and Bokhurst, 1992; Lee, 1993; Ebenezer and Erickson, 1996; Valanides, 2000; Liu and Ebenezer, 2002). Other students believe that solute disappears because it invisible in water (Cosgrove and Osborne, 1981; Prieto et al., 1989; Longden et al., 1991; Lee, 1993; Selley, 2000; Valanides, 2000). Some older students who receive some instruction on particles believe the solute breaks up or subdivides into small particles or its molecules are separated (Cosgrove and Osborne, 1981; Prieto et al., 1989). The students answer the question how the solute can exist in invisible form in the liquid? (Selley, 2000) that it occupies an air space, or spot, or patch, or cloud in solution (Longden et al., 1991; Ebenezer and Erickson, 1996). Another group of students explain that it sinks to the bottom of the water and stays there (Prieto et al., 1989; Lee et.al., 1993; Valanides, 2000)

The role of solvent is less considered by the students. They explain that the solvent is absorbed, or eliminated, it acquires some properties (colour, smell, taste) (Prieto et al., 1989). Liu and Ebenezer (2002) found the students conceptualized that every solution required water as the solvent because water is a good solvent (Prieto et al., 1989).

5.5.4 Solubility Ebenezer and Erickson (1996) investigated the students' reasoning about dissolving. The students explain that solvent and solute are soluble because of the power of attraction between them for example alcohol has power of attraction with water. The students also explain that solvent and solute are insoluble because the solute does not have sufficient space in the solvent. For example the students explain that paint thinner is insoluble in water because they are not sufficient space in the dissolving medium. Some students explain that paint thinner does not have the element that mixes with water. Some students held alternative conceptions of recystallization. They explain that recrystallized salt can not break down because it is pure element like gold.

5.5.5 External Influences on Dissolving Many research studies have investigated students' conceptions of the external influences on which affect dissolving. The students consider that shaking, or stirring, or heating are the important factors in the process of dissolving (Cosgrove and Osborne, 1981; Prieto et al., 1989; Blanco and Prieto, 1997; Selley, 2000; Liu and Ebenezer, 2002). Selly (2000) working with 12-14 years olds students, found most student explain that hot water is the affect of the greater speed and/or frequency of collision of water molecules with the solid (solute). Some students explain that there is the greater bombardment of the solute particles by the water at high temperature or the faster solute molecules hit the tablet harder. Another group of students explain it through a macroscopic view. For example solute goes faster when it hot, or hot water caused the solute to disintegrate, or the hot water, which contains less oxygen than the cold, will allow faster dissolving, or the solute is "going crazy" in the hot water, but "feeling comfortable" in the cool". Some students believe that temperature changes many characteristics of solutions such as the colour of solutions. Other students explain that if the solute is broken into tiny pieces, it will be dissolved in the solvent in the same way as the paint thinner layer is broken up by heating or stirring (Ebenezer and Erickson, 1996; Prieto et al., 1989). Some of them explain that on cooling, melted solute will reform because molecules slow down (Ebenezer and Erickson, 1996).

5.5.6 Conservation of Matter Many research studies have focused on students' conceptions of conservation of matter in dissolving (Cosgrove and Osborne, 1981; Prieto et al., 1989; Stavy, 1990(b), Longden et al.1991; Rosen and Rozin, 1993; Selly, 2000). Selly (2000) showed that older students accept that solute (sugar) might still be there in some form, but the younger students believe that solute disappears during dissolving (Cosgrove and Osborne, 1981; Prieto et al., 1989); Stavy, 1990(b); Longden et al., 1991).

Most students are confused about conservation of weight in a solution. They say that mass and volume of solution changes; that the solution is heavier than solvent and solute; or the solute disappears; or the dissolved solute has no weight (Prieto et al., 1989; Stavy, 1990(b)). However, Rosen and Rozin (1993) prove that the students appreciate the conservation of property of sweetness in water in which sugar is dissolved and accept that sugar remain in the solution.

5.5.7 The Particulate Nature of Matter Although Rosen and Rozin (1993) identified that preschool students (age 3-5) have begun to realize that matter can be decomposed into tiny pieces which can not seen by the naked eye. Other researchers have found supported that the understanding of the particle explanations for matter improves with age (Longden et al., 1991). Many research studies of students conceptions across a wide range of age show that few students referred to microscopic explanations of dissolving (Prieto et al., 1989; Slone and Bokhurst, 1992; Selley, 2000; Liu and Ebenezer, 2002). The majority of students use the same explanation for dissolving at both microscopic and macroscopic levels and mix microscopic and macroscopic explanations. Selley (2000) concluded that most of student conceptions of a particle model includes many weaknesses and errors. For example, the students believe that when the sugar is put in water, molecules of water and sugar join (Prieto et al., 1989), or the sugar breaks up, or subdivides, or bonds break, or changes into small particles or its molecules (Cosgrove and Osborne, 1981; Selley, 2000; Liu and Ebenezer, 2002), or the sugar would sink to the bottom of the water because sugar is a solid form, or sugar molecules are heavier than water molecules (Lee et al., 1993).

This evidence shows that there are many kinds of difficulties with matter. First, the student's everyday ideas are different from scientific ideas. For example, most students explain that sugar disappears when it dissolves in water because they cannot see it. They do not accept that in reality, the sugar is still in the water. Second, some concepts of matter are abstract and difficult to accept. For example, most students cannot accept that matter consists of particles because they cannot observe these particles. Teaching for conceptual change can solve these difficulties by encouraging the student to aware of the difference between their ideas and scientific ideas and their strengths and weaknesses. They practice to use scientific ideas in appropriate situations.

5.6 Conclusion: The Relationship between the Particle Model, Conservation and Age of Students

There are a number of studies confirm that primary students are capable of understanding the particle model (Skamp, 1999). For example, Rosen and Rozin (1993) demonstrate that preschool students (aged 3-5) have begun to realize that matter comprises tiny pieces which can not seen by the naked eye. Lee et al. (1993) and Selley (2000) identify that students aged 11- 14 can understand many aspects of the particle model are use it to explain the dissolving of sugar in hot water, the nature of solid, liquid and gas and changes in state of matter.

Teaching for Conceptual Change

1. Introduction

The dominant problems in learning and teaching science are not only the result of resistance of student alternative conceptions to change but are also that students are unable to utilize school-learned science in different contexts and they forget what they have learned a short time after instruction (Georghiades, 2000). Teaching for conceptual change is an approach that focuses on solving these problems.

Teaching for conceptual change is based on an understanding that students learn by way of personal and social construction of understanding from experience within the social community (Bell, 1993; Duit and Treagust, 1998; Hewson et al., 1998; Duit and Treagust, 2003). It includes a variety of different pedagogical strategies to help the student experience conceptual change learning. Hewson et al. (1998) argue that conceptual change learning not only occurs in classrooms that teach for conceptual change but also in most classroom situations. Nevertheless, Hewson et al. (1998) and Wandersee et al. (1994) show the evidence that the conceptual change approach is popular and useful to support student learning.

There are some common ideas relating to student and teacher roles within teaching and learning for conceptual change. First, students should have the opportunity to be involved in discussion that helps them to become aware of their own and others' ideas and understandings. Furthermore, students should understand that knowledge can not be provided for them ‘ready made’ (Scott, Asoko and Driver, 1992). They need to take responsibility for making sense of learning activities. Similarly, part of the teacher's role is to become aware of student ideas relating to the topic under consideration and of typical conceptual pathways for that topic. They should have ability to generate learning tasks and to organize and manage the classroom to support student progress. Finally, the teacher should have confidence in their own understanding of the concepts and the topic to be taught (Scott, Asoko and Driver, 1992).

2. Teaching Strategies

Scott, Asoko and Driver (1992) identified two groupings of teaching strategies to promote conceptual change. The first group of strategies is based on cognitive conflict and the resolution of conflicting perspectives. The second group is of strategies that build on learners’ existing ideas.

2.1 Teaching Strategies based on Cognitive Conflict and Its Resolution

The idea of teaching for cognitive conflict originates from Piaget’s view of learning in

which the student plays active role to achieve a mental equilibrium and to free themselves from cognitive conflicts (Schnotz, Vosniadou and Carretero, 1999). This strategy involves providing a challenge situation to create a state of cognitive conflict for the student. There are many ways to create cognitive conflict, such as discrepant events and conflict between ideas. An example of this strategy is shown in Nieswandt's study (2001). She constructed a teaching unit based on the cognitive conflict model of change to promote the understanding of two basic chemistry concepts: properties of substances and the particle model of matter. In the unit, the students were presented with discrepant event to force them to construct new conceptions. The data collection was concerned with how students came to the scientific concepts, what kind of transitions they made from their everyday conceptions to the scientific concepts, and why it was that some did not reach scientific knowledge. The teaching unit started with discussion about students' everyday conceptions and then engaged students in planned cognitive conflicts triggered by a discrepant event which is a phenomenon that cannot be explained with student prior knowledge. The researcher found that most students used scientific explanations and showed some erosion of their everyday conceptions after the end of course. At the same time, some students' notions could be described as a mixture of everyday descriptions and scientific explanation.

Although teaching strategies based on cognitive conflict are popular some researchers claim that cognitive conflict decreases student confidence by the way it undermines students' existing conceptions (Claxton, 1984). Another view is that it is not effective to change student conceptions this way because the important characteristic of alternative conceptions is that they are resistant to empirical evidence (Duit and Treagust, 2003).

2.2 <u>Teaching strategies based on the development of ideas</u> This strategy is different from the strategy based on cognitive conflict because it pays less attention to the role of accommodation by the student. On the contrary, it focuses on developing and extending student ideas toward the scientific ideas. It rejects replacement of student conceptions by the scientific conceptions and seeks to

encourage the student to learn scientific concepts by learning the difference between everyday thinking and scientific thinking. This idea was influenced by Vygotsky who regarded student cognitive development as a process of enculturation. He argued that the student acquires everyday concepts from everyday life and acquire scientific concepts from school. He suggested that the student should be encouraged to compromise their everyday concepts with scientific conception and should apply scientific concepts to their everyday experience (Schnotz, Vosniadou and Carretero, 1999).

From many teaching strategies based on development of ideas developed the numerous research studies about conceptual change learning. Some of these teaching strategies are presented below.

2.2.1 Mental Models/Analogies and Metaphor/ Role Play A mental model is a private and personal cognitive representation and can be formed by an individual either on their own or while they are working in a group (Gilbert, Boulter and Elmer 2001). A mental model is dynamic structure which is generated to explain a particular situation (Vosniadou and Brewer, 1992). Franco and Colinvaux (2001) explain that it is not possible to access the exact mental model of each person but one can be created via materials such as notebooks, diagrams or speech from interviews. It is important to study the processes of development of the mental model because it is impossible to guarantee that the model which is represented is the same as their mental model (Christidou et al., 1997). Franco and Colinvaux (2001) argue that there are two aspects to consider about the mental model. The first is the process of the mental model which focuses on what is going on in the mind of the individual. They represent the case of "coalescence" (Franco and Colinvaux, 2001) the way to trace the process of creating a mental model of Einstein by studying his autobiography. This hint shows that the coalescence occurs during his development of his theory of General Relativity. Einstein creates his mental model about General Relativity by conceptualizing the relationship between two basic concepts of General Relativity which are inertial and gravitational mass. The other aspect is the feature of mental model which is generative, synthetic, involves tacit knowledge, and is constrained by world-views. It means that new knowledge is generated from mental model. Franco

and Colinvaux (2001) claim that models involves tacit knowledge which the student do not concern all of relative aspects of their own mental model when using it to explain their ideas. The mental model also regarded as synthetic. It indicates that student's mental model does not completely explain all aspects of the concept. Finally, they argue that the student develops their own mental model based on their personal belief which is supported by everyday experience and is constrained by a conceptual structure (Vosniadou and Brewer, 1992).

Similarly, Vosniadou and Ioannides (1998) have also studied student mental models. They present the term "initial mental model" (Vosniadou and Ioannides, 1998: 1217) to describe the mental models which students bring with them to formal science classes. This kind of model is affected by students' beliefs and their presuppositions about the world which are supported by everyday experience. They explain that when students receive science instruction they try to reconcile new information (the scientific model) with their own mental model. The model which is created from the process of the student trying to synthesize and interpret the scientific model based on their initial model is called "the synthetic model" (Vosniadou and Ioannides, 1998; Vosniadou, 2003). This synthetic model can be developed into a scientific model. Focusing on the process of developing or changing the synthetic model is different from the idea of conceptual change proposed by Posner et al. (1982). The purpose is not to search for what is mismatched between the student's initial model and the scientific model but to encourage the student to be aware of their beliefs and presuppositions and then to extend the limits of their idea.

Another strategy for building on existing student ideas is the use of analogies. Glynn et al. (1995) explain that an analogy is a way to create a relationship between conceptual networks or information because students cannot learn concepts as lists of facts rather they develop organized networks or related information. In other words, analogy is the process of classifying similarities between two or more concepts. One advantage of analogy is the way they can lead students from their existing conception to understanding a new one. Because students see some similarities between concepts, they can move easily from their existing conception to

the higher concept. The other advantage is helping students to think about the model of the new concept because they already have a familiar mental picture of their existing conception. However, there are some cautions about analogy use. The teacher should make sure that the students understand and are familiar with the similarity in features of the existing ideas concept and the target concept. Treagust et al. (1996) provide an example of the use analogies to promote conceptual change in the concept of the refraction of light. Two classes of students were taught by the same teacher, one by analogy and the other not. The teaching analogy explained the refraction of light by relating it analogically to a pair of wheels travelling from a hard, flat surface to a soft, rough carpet surface. Students in both classes were interviewed by the same interview- about-instances protocol. This interview protocol is used to encourage students to reflect on their own conceptions and to determine student's conceptual status. The findings from this study illustrate the utility of an analogical teaching approach for engendering conceptual change. Most of the evidence from this study indicated that conceptual change matched with the criteria of a conceptual change model-dissatisfaction, intelligibility, plausibility and fruitfulness-was not necessarily an exchange of one conception for another (conceptual exchange). But rather, it increased use of the kind of conceptions that made better sense to the student (conceptual capture).

Christidou et al. (1997) studied the value of metaphor in promoting the representation of abstract and complex ideas and showing the correlation between the use of metaphors and student's mental model of the role and distribution of ozone in the atmosphere and the process of ozone depletion. There are three categorizes of metaphor that the students used: object, substance and person. For example, some students who use substance categories explained that "ozone is like an umbrella made of gases" (Christidou et al., 1997; 544). There are four models of student mental models for the role and distribution of ozone in atmosphere and three models of student mental models for the process of ozone depletion. From the analysis, the students who use the same model to explain their ideas also use the same category of metaphor to express their ideas. Christidou et al. (1997) explain that students use metaphor as the tool of thinking in a consistent and systematic way when they try to

understand, explain and represent the role and distribution of ozone in atmosphere and the process of ozone depletion.

Role play is another strategy used to help students develop their understanding while learning science. This strategy can be used to motivate students to engage with the issue as role plays often involve real situations. The specific goal of a role play is acquiring an understanding with characters in other times or other places. The teacher should be aware of the purpose of activity as the 'science' can easily get lost as students become engaged in the role play. Another point to consider is that student views may affected by the feelings and values involved. Teachers should have a de-briefing of roles at the end of the activity so students can talk through both their feelings of being in role and their own views (Duveen and Solomon, 1994; Lock and Ratcliffe, 1998). In this study, models, analogies and role play will be created as strategies to promote conceptual change.

2.2.2 Metacognition Another strategy that is recommended for promoting conceptual change is to focus on promoting student metacognition. Metacognition is the process of thinking about one's own thinking and actions (Adey and Shayer, 1994). Hewson et al. (1998) argue that alternative conceptions are caused by metacognitive shortage. They assert that teaching for conceptual change should foster metacognitive skills and student awareness of the epistemological status of knowledge. Students are encouraged to recognize, evaluate, and reconstruct their existing ideas by reflecting on their conceptions using their own language (Georghiades, 2000).

Metacognition is not only useful for improving students' ability to think or make decisions (Schunk, 2000) it is important in conceptual change learning as a tool for encouraging the transferability and durability of scientific conceptions (Georghiades, 2000). This means that students should be able to identify and explain scientific conceptions and be able to employ them in different contexts, and bearing in mind that the scientific conceptions are useful for them.

Beeth (1998) studied how teachers and students discussed the definition of the intelligibility and plausibility and how students applied these terms when learning new concepts. His study was with a fifth grade class (12 students, aged 10 to 11) and the topic force and motion. The study was undertaken throughout the academic year. The research showed that as students develop the ability to comment on the status of a conception they change their science content knowledge. Before teaching the unit about force and motion, the students were trained to comment on the status of their ideas. They were asked to construct definitions for the status terms "intelligibility" and "plausibility". The teacher explained to them that applying status constructs would help them to explain their ideas when learning science content. The students were asked to talk and write about what intelligible and plausible meant to them. The teacher spent seven weeks on this aspect to encourage the students to understand the definition, to help them differentiate between the terms "intelligibility" and "plausibility" and to support the students to use these ideas in the discussion of science content. For example, one student asked her friend to explain the phrase "at rest" because they used this phrase in different situations (Beeth, 1998; 349). This situation shows that the students apply the definition of status term to science content. The important point about using these status constructs was that the students should have evidence and consistent reasoning to support their ideas.

In the teaching unit about force and motion, the students are asked to observe moving objects and to explain the motion of each object as it made sense to them. After this the students were asked to put all their description into categories: descriptions of motion (e.g., speeding up, slowing down, and not moving) and causes of motion (e.g., kicks, pushes, and pulls). The teacher told her students that the purpose of this unit is to promote student understanding about the relationship between the causes and effects of force. She expected that the students could explain the cause of motion. For example, the object is pushed or pulled, and what happened during the motion. For example, the objects speed up (Beeth, 1998; 350). From the discussion about concept of force and motion shows that the students have abilities to apply status constructs into this section. For example, the researcher found that this teaching strategy could support change in students from passively receiving

information to actively examining their own conceptions. The role of teacher in this strategy is different from the traditional one because the teacher should provide metacognitive tools such as intelligibility and plausibility as part of her teaching, and foster students learning so they can apply these tools when discussing science concepts.

2.2.3 Practical Work It is accepted by science educators, science teachers and students that practical work plays an important role in teaching and learning science by making a connection between and providing some explanation natural phenomena (Lock and Ratcliffe, 1998; Bennett, 2003). Learning by doing practical activities is one way of producing and representing to students the scientific procedures of inquiry. It can help students acquire some understanding of the way scientific knowledge progresses, but the main advantage of practical work is that it can support student learning by making phenomena real for them. The students learn from real things in the case of teacher demonstrations and field trips and, in some cases, students can conduct experiments themselves (Harlen, 1999; Bennett, 2003). Another advantage is practical work can encourage students to work with others and develop their understanding and problem- solving skills. In the case of practical skills, students can learn to prepare for an experiment, perform the experiment, process the results, justify the experiment and report the results (Alberts et al., 1986; Harlen, 1999). Different types of practical work have different aims and purposes which depend on the scientific ideas in each task (Bennett, 2003). However, most students do not want to do something that they do not understand and are afraid of doing something wrong (Hodson, 1990). Hodson (1993) notes that too much practical work does not motivate students to learn: student interests and satisfaction do not always increase when the amount of practical work is increased. Although many students enjoy practical work, it is unclear that what what specific aspects they enjoy. Bennett (2003) claim that some students like practical work because it helps them to escape from other tasks, for example, listening to teachers and writing. They have a chance to talk with others about subjects which may or may not be related to the practical tasks. In this study, practical work is used as another strategy to promote conceptual

change by designing regard to student interests as well as encourage students to understand scientific ideas and promote science process skills.

2.2.4 Problem Solving Teaching for conceptual change focuses on the ability of students to use scientific conceptions to explain phenomena or solve the problems. Different kinds of problems or questions in science require different level of students' cognitive skills. Students tend to use lower-order cognitive skills (LOCS) for the solution of exercises which involve the simple application of ideas to situations that are familiar to them and to practice procedures that are known to them (Zoller and Tasparlis, 1997). On the other hand, students use higher-order cognitive skills (HOCS) for to solve novel problems which require the application of knowledge to unfamiliar situations. These HOCS capabilities are considered as the most important learning outcomes to which good teaching should aim (Zoller and Tasparlis, 1997).

Problem based learning (PBL) is one teaching strategy which encourages problem solving skills in context, and also encourages student motivation, cooperative learning, higher-order thinking, authenticity and communication skills (Seddigi and Overton, 2003). Watts (1994) proposes that there are many advantages of problem solving. Teachers can explore student ideas and provide tasks that encourage discussion of how things work. Students can be encouraged to work on different aspects of an overall contextual problem. They can work in small groups in which each student has an important role within the team and rotate these roles during the course of the work. The students are encouraged to use a range of communicative techniques to focus upon both specific knowledge and higher level cognitive activities. However, the teachers need to generate different tasks and activities to provide for mixed ability classes. They can also plan activities that move from being teacher-directed to student-directed activities and employ a variety of teaching and learning strategies (Watt, 1994).

Seddigi and Overton (2003) provided evidence for the effectiveness of problem solving in their study. They elicited student impressions of

problem solving activities in a chemistry course for undergraduate engineering students. The problems had been designed to develop critical thinking skills and required logical thought and judgment. The researcher found that most students responded positively. On the basis of their research, they recommended that teachers who use this strategy should leave the students alone to sort out their problems and the teachers should be able to show students why they should learn something, and how the activities relate to students' everyday life. This helps students to see the value of the scientific conceptions that they learn because they are able to use them to solve the problems.

2.2.4 Language and Questioning Techniques Attention to language used when the teaching and learning is another recommended strategy to promote conceptual change. Not only is the language of science often very strange for students but also there are many kinds of language in science as Lemke (2001 a, b) has explained. He suggested the language students needed to learn included words, pictures, diagrams, images, animations, graphs, equations, tables and charts. One suggestion is that some concepts can not be presented by telling or words but they can be made clearer when presented by animation or images. Vygotsky (1962) asserted that language development is related to conceptual development. When the student has the opportunity to use science language, it means they have a chance to develop their concept through the language. Students are also encouraged to express their ideas and develop their understanding such as; talking, writing and drawing. Most students need opportunities and help to express their finding and ideas in their own words (Harlen, 1999). The role of science teacher is to present each concept to the students in the most appropriate way. It showed that the role of science teacher is similar to that of a language teacher because their duty is presenting science language to the students and encouraging them to use it (Lemke, 2001 a, b).

Talking or using spoken language in the science classroom is one way to promote their understanding of science. Talking involves an interaction among students and between teacher and students (Harlen, 1999; Wellington and Osborne, 2001). The students are encouraged to share their ideas with others, both in

small groups and through class discussion and to have opportunities to ask the questions. Students' questions can help the teacher to access student ideas and to understand their thinking. The teacher questions is also very important because the higher level questions which are open and require higher levels thinking such as reasoning skill, prediction and interpretation can find out student ideas and encourage student understanding (Harlen, 1999).

Because learning science is regarded as conceptual change (Bell, 1993), the language problem is a barrier of conceptual change as well. Clerk and Rutherford (2000) queried whether the real problem of students was their misconception or their language problem. Most of science concepts are abstract. These not only mean the students have difficulty understanding them but also talking or writing about them (Wellington and Wellington, 2002). If the real problem is student's language, it is not surprising that many studies have found that alternative conceptions are resistant to change. The point that also needs to be cured is language; it is not only student's alternative conception.

Scott, Asoko and Driver (1992) conclude that the purpose of all strategies is to help student towards a more scientific view of the world. Nevertheless, different strategies have various ways to encourage the student to recognize their ideas and therefore how to construct them. Using the cognitive conflict strategy, the student has been encouraged to exchange existing ideas for entirely new conceptions. Instead, teaching strategies based on the development of ideas suggest that the student should be encouraged to extend or develop existing views and apply them in new situations. Similarly, some researchers in this area argue that the student should be encouraged to develop a scientific understanding which may be held in parallel with existing notions because the way to promote scientific conception is learning the differences between everyday-life thinking and scientific thinking.

3. Successful Teaching for Conceptual Change

There are many studies which show the value of the new direction of conceptual change which not only emphasizes the cognitive aspect but also affective aspects and social factors. Gustafson (1991) , for example, examined how the elementary students' ideas change during the classroom presentation of a teaching unit on sound. He argues that not only for the importance of student's prior ideas for promoting student's change, but also the student's recognition that scientific concepts can be used in appropriate situations. Moreover, he claims that a student's homelife, personality, philosophies, and perception of science also affect their ideas and their change.

Vosniadou (2003) presents the success of a focus on intentional conceptual change, to promote student understanding of the concept of the relative size of the earth, the sun and the moon. She presents the advantages of intentional learning that help the student have on higher metaconceptual awareness of their belief and presuppositions because they relate to the constructs of metacognition, self-regulation, engagement, and critical thinking which facilitate the student's acquisition of knowledge. She also agrees that conceptual change cannot occur in the individual mind but is affected by social/cultural factors and educational settings. Concerning the concept of the relative size of the earth, the sun and the moon, she explains that students come to the class with their own beliefs and presuppositions that are supported by a whole system of observations derived from everyday experience. Some student's ideas are totally different from scientific ideas such as the earth is flat, because they never know the scientific explanation. All of their ideas come from their observation which they interprete in a way that makes sense to them. The process of representing new information to the student is very risky because if it is incompatible with a student's own explanation, it can produce misconceptions. In this case, a restructuring of a student's knowledge base, their beliefs and presuppositions is required before they can be presented with new information. This unit is about the relative size of the earth, the sun and the moon (eight weeks unit). The idea of this unit is the relationship between the apparent size and distance of the sun and moon,

and that the sun is actually much bigger than moon, despite the fact that their size appears to be almost the same. A week after intervention, every student agrees that the sun is much bigger than the moon. However, when the teacher asks the students to explain why the sun appears to be about the same size as the moon when in reality it is much bigger, the students' explanations do not relate to the difference in apparent and real size of the sun and the moon in terms of their size/distance relation as presented in the unit. The students give answer like "I cannot see the differences very well because clouds block the sun" (Vosniadou, 2003: 8). It shows that although students' representations of the sun and the moon have changed, the students are not metaconceptually aware of this change. They do not compare their previous representation or their existing explanation and the new one and do not understand the difference between appearance and reality. Vosniadou (2003) argues that if students decide to adopt the scientific explanation intentionally, they should be aware of the differences and similarities between the scientific explanation and their existing explanation and which one is more advantages. From this problem, she develops a unit that tries to facilitate intentional conceptual change. The students will have an open environment, opportunities to discuss with friends, and an inquiry processes that would allow students to examine their beliefs and question their explanatory ability.

4. <u>Teaching for Conceptual Change in This Study</u>

According to the review of student ideas of matter, it shows that many students have difficulties with this concept. This leads the researcher to the main research question of this study which is how to help the students to get a better understanding of matter? This study explores the answer to this question by using the conceptual change approach. This approach is important to this study because the concept of matter is directly related to a student's everyday life. Every student has experience and their own ideas about matter before they come to class. Their ideas are believable and meaningful to them, although some of them may not be scientifically acceptable. Persuading students to completely change from their existing ideas to scientific ideas is impossible. But the way to encourage the student to apply scientific concepts to appropriate situations is possible. Teaching for

conceptual change is a practical way to present the meaningful aspect of scientific concepts and to show the student that the scientific world and the everyday world are related. This study develops a teaching unit which aims to examine student ideas and encourages the student to accept what is reasonable and advantages about scientific conceptions. All activities in this unit are concerned with motivation in the learning of matter and focus on the link between the classroom and the outside school, in students' everyday life.

The Teacher

The teachers are regarded as key people to encourage student learning, so the development of teachers teaching is take into account in conceptual change teaching and learning. There are many factors influencing teacher teaching which are identified as internal factors and external factors. To understand these factors may help to provide way for developing science primary teachers.

1. Internal Factors

The internal factors namely teacher confidences and view of PCK show how teachers themselves may impact on teaching and learning.

1.1 Teacher Confidences Harlen (1999) refers to research studies which groups teachers according to their confidence and understanding of scientific conceptions. Some teachers do not have a science background but they have confidence in teaching science. Their problem is that their understanding of science is limited. On the other hand, some teachers do not have a science background but they can understand the key scientific ideas. Their problem is they do not have the confidence to teach science and they can not help the students understand science. The last group of teachers do not have a background in science, and lack confidence in teaching science and have even less understanding. This group of teachers forms the majority of science teachers. Most teachers who lack confidence in teaching science try to avoid the point or the topic that they think they do not know and tend to

emphasize the topics they are more confident about. A low confidence in teaching science makes many teachers rely on textbooks and avoid using other ways of teaching such as practical works or experiments because they are concerned that they may do something wrong. Harlen (1999) also explains ways to develop teacher confidence, for example the teacher should have opportunities to discuss with experts or other teachers and develop their understanding of science and teaching science.

1.2 View of PCK The most important idea about teaching science is what the science teacher should know and have pedagogical content knowledge. The blending of content and pedagogy into an understanding of how each topic or content should be taught, how to teach based on student interests and abilities (Shulman, 1987). This means that the teacher should have strong content in their subject matter areas. They should not only explain what the ideas are but also explain why these ideas are important and how they are related with other ideas about in the same area and in both theory and practice (Shulman, 1986). Moreover, the teacher should know how to cope with student existing conceptions which the students bring to school. The teacher should know the strategies which help the student modify their understanding.

2. External Factors

A number of external factors namely the lacking of learning resources, the expectation from National curriculum on teachers' practical skills and using science equipment and the expectations from government about teacher ideal. These factors may also involve in teacher teaching as well as the internal factors.

2.1 Lack of Learning Resources Academic resources and outside help, for example, access to a public or school library or to a laboratory, to university facilities or museums can help students to learn (Wiygul and Vernon, 1987). As well as this, *the National Content Standard of Thailand (IPST, 2000)* focuses on fostering student learning both inside and outside the classroom to reach for life-long learning. The teachers take responsibility to prepare all learning resources for the students. The science learning resources in school include the learning material in the classroom, for

example books, internet, multimedia CAI, VDO, CD-ROM; laboratory and library. Learning resources outside school include science museums, research institutes in the local area, botanic gardens, zoos, factories, and educated people, for example, the students' parents, scientists, researchers, and philosophers in the local area.

A lack of some kinds of learning resources still occurs and this problem relates to a lack of government spending in these areas. Most teachers in rural areas are encouraged by the government to use learning resources in their area as best as they can. Some teachers still do not have any ideas about how to select learning resources for themselves.

2.2 Practical Skills and Using Science Equipment Radford et al. (1992) claims that if teachers expect students to learn the processes of science, then at least three conditions must be present: the teacher must have a command of the process skills; the students must be taught and given opportunities to practice the skills; and student progress in acquiring the skills must be evaluated.

According to *the National Content Standard of Thailand (IPST, 2000),* the emphasis on practical or laboratory activities and the process of science has increased. Teachers are regarded as key people to encourage students to develop their knowledge and skills in science. All science teachers are expected to have enough laboratory skills and techniques, and appropriate strategies of instruction. However, no formal qualifications in science means many teachers lack knowledge and the confidence to do science experiments and do not know how to use science equipment.

2.3 Expectation from Government According to *the National Educational Act (ONEC, 1999),* teachers are expected to think creatively, teach to a high standard, and use research processes to develop their own teaching. They should encourage student-centred in their class and focus on all aspects of student development; cognitive, moral and physical development. The teachers are supposed to be able to design and manage teaching and learning processes based on varying student interests, abilities and other individual differences which encourage the students to

reach their highest potential. The teachers should be able to prepare a suitable learning environment, learning materials and learning resources which encourage a students learning. Moreover, the teachers should have a good relationship with students' parents and members in communities to reach for the purpose of develop student learning. The teachers need to have a professional certification which guarantees that they have enough quality to be a teacher.

Three research questions relate to these aims provide a framework for this study. These questions are:

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) student conceptions about matter and its properties?

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

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

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

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

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 a conceptual change approach-based instructional unit help students to accept scientific conceptions of matter and its properties?

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?

Summary

This study focuses on student conceptions related to matter and its properties and the close relationship between constructivism and conceptual change which focuses on the importance of student existing conceptions. Most of the evidence derived from the study of student conceptions related to matter and its properties suggests that teachers should develop strategies which help students to become more aware of their alternative conceptions and also to accept scientific conceptions. External and internal factors such as expectation from government and teacher confidence which affect student learning also need attention. Here it has been argued that teaching for conceptual change is a way to reach for this purpose. In this approach the teacher is the key person as they bring this approach into classroom.

The ideas from this chapter about the students' alternative conceptions about matter and its properties, the teacher's teaching and ways of teaching for conceptual change are important in this study for the development of a framework for the promotion of teaching and learning about matter using an instructional unit based on conceptual change approach. The appropriate research methodology which was selected for this study is described in next chapter (Chapter 3).