Science Education International
Vol. 26, Issue 3, 2015, 376-391

A Study of the Effect of Affective and Social Factors on Teaching for Conceptual Change in Primary Science

P. PIMTHONG*

ABSTRACT: The purpose of this research was to study primary science students' conceptual development as it related to their understanding of materials and their properties: in particular, to determine how and why some students changed their concepts while others did not. The participants were thirty-two Grade 5 (10-11 year old) students. An instructional unit based on the conceptual change perspective was developed and presented. Data were collected through pre- and post-instructional surveys, classroom observations, student work, and student interviews. The results showed the influence of instructional activities that challenged students' preconceptions and encouraged students' conceptual change, indicating the effects of affective, social, and language factors on students' conceptual development.

KEY WORDS: Materials and Their Properties, Conceptual Change, Primary Science, Motivational Belief

INTRODUCTION

Chemistry studies basically involve three types of chemical representations: macro, sub-micro and symbolic (Johnstone, 1993). Research consistently shows that the students encountered difficulties in understanding and interpreting these representations (especially sub-micro) and interpreting between the three types of representation so as to build their own representation (Johnstone, 1993; Treagust, et. al. 2003; Chittleborough & Treagust, 2007; Gkitzia, et. al. 2011). To construct a more in-depth conceptual knowledge of chemistry, lessons need to include all three types of representation.

A number of research studies in science education have focused on students' conceptions of physical materials. For example, a recent study has investigated different connections between education and concept formation with respect to both the physical and chemical properties of materials as well as the classification of materials within the disciplinary frameworks of science, technology, and techniques in a French primary

---

* Instructor at Kasetsart University, Bangkok Metropolitan Area, Thailand, pattjai@hotmail.com

school setting (Chatoney, 2006). Another study has investigated the feelings, experiences, and design ideas of children aged 5-11 as related to a variety of materials within the framework of technology and design education (Fleer, 1999). There is also a study of Grade 3 students' logical reasoning abilities as applied to rolling and of their reasoning as to why different objects are made up of different materials (Liu, 2000), as well as an investigation of four-year-old students' reasoning about the affordance of various materials and tools (Carr, 2000). Other research about materials includes a study of methods of preparing students to make value judgments about genetic engineering in the context of technology education (Conway, 2000). These and similar studies show that many researchers are interested in material and its properties in terms of technology (via its shape or structure) to design and apply to everyday life rather than solely in terms of science. However, there are a few studies that relate more directly to the teaching of science concepts such as the properties of materials, for example, fusion, liquefaction, and solidification (Chatoney, 2006). Overall, studies about learning processes related to materials may involve any of three distinct areas: namely, science (Physics and Chemistry), technology, and vocational subjects (Blicblau, 1997).

The *National science content standards* of Thailand (IPST, 2002) identify eight specific content standards, the third of which is concerned with matter and its properties. Some conceptual skills covered in this standard include understanding the definitions of specific materials, understanding their properties (hardness, strength, elasticity, heat transferability, electric transferability, and density), and learning to identify and choose appropriate materials for use in everyday life. An understanding of concepts related to specific materials is a prerequisite for understanding more general concepts of matter, which in turn are considered necessary for studies in physics, chemistry, technology and some types of vocational education (Blicblau, 1997). Thus, it is very important for Thai students to clarify their ideas about physical material and its properties in order to proceed further in understanding basic science.

Students may well approach their formal learning activities with a variety of alternative conceptions about material and its properties. As we know, alternative conceptions are a potential barrier to students' learning, and they tend to be resistant to change (Duit, 1999, pp. 266-269). The usual approach to teaching science is to encourage students to modify their existing conceptions and progress to understanding and accepting established scientific conceptions (Hewson & Hewson, 1992; Bell, 1993; Schnotz, Vosniadou, & Carretero, 1999). In short, learning science is regarded as a process of conceptual change (Bell, 1993; Duit & Treagust, 1998).

Conceptual change is a perspective used in the science education community to explain the process of how students' initial understanding of a topic might change into more scientific conceptions (Wandersee, Mintzes, & Novak, 1994; Duit & Treagust, 2003). Since the 1980s, there have been many research studies on conceptual change (for example, Posner, Strike, Hewson & Gertzog, 1982). However, many of those studies primarily emphasize the cognitive domain, or adopt an overly rational approach (Pintrich, Marx, & Boyle, 1993). The question that cannot be answered by those studies is why some students learn, but others in the same classroom do not. Nor do those studies necessarily indicate the most salient factors that contribute to conceptual change. In recent years, many educators have paid attention to these questions and have investigated other potential causes of conceptual change, such as affective motivation and social factors (Pintrich et al., 1993; Tyson, Venville, Harrison, & Treagust, 1997).

This paper reports on a study focused on developing a group of Thai Grade 5 (11-12 years old) students' understanding of material and its properties while identifying and investigating the factors that might have an impact on those students' conceptual change.

LITERATURE REVIEW

For many researchers, conceptual change research originates with surveys of students' preconceptions (Cosgrove & Osborne, 1981; Happs, 1980; Pfundt & Duit, 1994; Schollum, 1981; Schollum, 1982; Tytler, Prain, & Peterson, 2007; Yuenyong & Yuenyong, 2007). The results of these studies show that while students' preconceptions are important factors in their science learning, most of these preconceptions are not consistent with established scientific conceptions (Duit & Treagust, 2003; Treagust & Duit, 2009).

In studies of conceptual change, an important foundational concept is the distinction between weak and strong restructures (Duit & Treagust, 2003; Treagust & Duit, 2009; Tyson et al., 1997). Traditional views of conceptual change stress the promotion of students' dissatisfaction with their preconceptions and the introduction of new concepts that make sense, are accepted, and are found to be valuable (Posner et al., 1982). Moreover, Hewson, Beeth, and Thorley (1998) argue that dissatisfaction is the key to a change in status in this context. When students are dissatisfied with their conceptual structure, they will attempt either to exchange it for a new concept or else to accommodate it to fit with that new concept. This means that the new concept's status becomes higher than that of the old concept in the students' conceptual structure. There are numerous research studies based on this view of conceptual change (Baddock & Bucat, 2008; Çelikten, İpekçioğlu, Ertepınar, & Geban, 2012; Coştu, Ayas, Niaz, Ű̋nal, & Çalik, 2007; Lee, 2014; Nieswandt, 2001).

A number of recent studies of conceptual change are influenced by a constructivist learning theory. Several researchers (Duit & Treagust, 2003;

Pintrich et al., 1993; Sinatra & Pintrich, 2003) argue that the more traditional conceptual change research perspective focuses too narrowly on cognitive change. They suggest that perspectives on conceptual change need to incorporate additional theoretical frameworks: in particular, epistemology, ontology, and affective framework (Duit & Treagust, 1998; 2003; Treagust & Duit, 2008; 2009).

However, research studies on conceptual change that employ such alternative theoretical frameworks are limited in number. Treagust and Duit (2009) reference the study of Treagust et al. (1996) on the relationship between students' interests and conceptual change. Lynch and Trujillo (2011) identify the relationship between students' motivational beliefs and their academic performance. Duit and Treagust (2003) and Treagust and Duit (2009) suggest that research on conceptual change should close the gap between theory and practice by bringing conceptual change to ordinary classrooms. Teachers should be encouraged to include the idea of conceptual change in their instructional plans, place more attention on affective factors, and emphasize the strength of a variety of types of evidence of students' conceptual change. Duit and Treagust (1998) assert that the purpose of conceptual change is to help students to become aware that, in an appropriate context, scientific conceptions are more fruitful than their own preconceptions. This means that students' conceptual change is dependent on their determination to change.

To answer the question why some students learn but others in the same classroom do not, researchers need to study other aspects that influence conceptual change, such as affective and social factors (Pintrich et al., 1993; Vosniadou, 1999; Tyson et al., 1997). Sinatra and Pintrich (2003) argue that conceptual change is more than conceptual; affective and social factors are essential for students' conceptual change (Pintrich et al., 1993; Treagust & Duit, 2008), as also is the intention of the student (Sinatra & Pintrich, 2003). This view of conceptual change emphasizes the importance of learners' active intent to learn. This means that the role of affective and social factors is to support conceptual change on the level of science-content knowledge (Pintrich et al., 1993; Treagust & Duit, 2008). However, most traditional research on conceptual change has not included the assessment of affective factors and has largely ignored the ways in which the learning environment may support knowledge acquisition (Duit & Treagust, 2003; Pintrich et al, 1993).

Seen in this way, the process of conceptual change occurs only when students intend to change their concepts and realize the importance of their learning (Sinatra & Pintrich, 2003). Many factors affect the process of conceptual change; for example, students' motivational beliefs (self-efficacy, epistemological belief, interest and value, or control belief), student ontologies, and social and context factors (Hallden, 1999) all need to be taken into account.

The study described in this paper attempted to respond to these challenges by bringing conceptual change to the ordinary classroom while being aware of both affective and cognitive factors. The study aimed to investigate the effectiveness of the conceptual change approach as related to material and its properties and to identify the connections between multiple factors and students' conceptual change. As a teacher and researcher, I began by identifying difficulties and factors that affect teaching and learning about material and its properties in a Thai school setting. Then, I designed and implemented an instructional unit based on a conceptual change approach in order to help students develop scientific concepts about material and its properties.

METHODOLOGY

The conceptual change unit covering material and its properties was developed, based on Thailand's *National science content standards* (IPST, 2002). The instructional unit was designed for 14 periods of 50 minutes each. It included seven lesson plans (2 periods/lesson), as follows: an introductory lesson on the definition of material; five lessons on the properties of materials (hardness, strength, elasticity, heat transferability, and electric transferability); and a final lesson on how to identify and choose appropriate materials for use in everyday life.

Teaching strategies that had been found to promote conceptual change were included in the unit as appropriate to each concept. The development of activities also took into account three factors: motivational belief, social factors, and language difficulties. One aim of this study was to develop the students' motivational beliefs and conceptions (Treagust & Duit, 2009). Interesting activities were chosen in order to stimulate the students' epistemological beliefs to construct the meaning of the natural world for themselves. All activities were designed to encourage students to show their abilities in different ways so as to promote their self-efficacy and reinforce their control belief as to the value of science learning. All activities encouraged the students to set their own learning goals. In addition, the study investigated the way in which a learning environment might support science learning (Pintrich et al., 1993) and attended to students' language difficulties that might hinder their science learning (Pimthong et al, 2012). The researcher in this study was a teacher who tried to facilitate and set up a warm, friendly classroom atmosphere.

An interpretive methodology was used in this study, because the study focused on understanding and describing students' learning in a classroom in which an instructional unit was being implemented. The interpretive paradigm involved studying things in their natural settings and interpreting phenomena from the point of view of the participants in a particular social world (Bryman, 2001). From this perspective, the interactions in a social world were considered to show the participants' intentions and meanings (Walsh, Tobin & Graue, 1993). People were considered to interact with each other to construct meanings and actions which were influenced by situations and contexts (Denzin & Lincoln, 1994).

The study was conducted from a conceptual change perspective. Multiple data generation methods (school and classroom observations, student concept surveys, student and teacher interviews, and student work) from multiple sources of data were used. The study consisted of three phases, as follows:

1. A preliminary survey of a variety of factors that could affect science learning (e.g., motivational belief and social factors). This phase was a semester in length, and involved the researcher's observations of the school context, class activities, and science classrooms, as well as interviews with students and science teachers.
2. A survey of Grade 5 students' preconceptions on the topic of material, after which the students' concepts were used to develop a conceptual change unit about material and its properties.
3. Implementation of the unit in the Grade 5 science class.

RESEARCH FINDINGS

The first phase of this study consisted of surveying the school context, which was that of a small rural school in northeast Thailand. Most students had relatively low achievement; the majority of them came from poor and sometimes dysfunctional families, and most stated that they had no educational goals for their future. The school had no teacher with a degree in science teaching, nor did it have a laboratory. The students typically had few opportunities to do hands-on activities in their science classes. Most teachers in the school appeared to believe that poor reading skills were an important problem for their students. They thought that if students could improve their reading skills, then they would be able to learn any subject.

The participants of this study comprised thirty-two Grade 5 students (10 males, 22 females) from diverse backgrounds. Most were not skilled in science and some had poor writing and reading skills. Many students stated they did not like science and thought science was not a necessary subject. The predominant culture of this school was such that all students trusted and respected their teachers. Most students followed what their teachers advised. However, strict teachers were found to hinder student learning. For example, most students never presented their ideas if their teacher did not encourage them to do so.

In the second phase, data on student's preconceptions concerning material and its properties were collected using a concept survey. The same survey was given to students at the end of the unit. Students' responses from the pre- and post-instructional surveys were as categorized in Table 1.

This categorization of concepts was adapted from Andersson (1990), Tytler and Peterson (2000), and Chatoney (2006). All students' responses were read and categorized into groups, based on similarities. Each category was compared with scientific concepts. In Table 1, the first through fifth categories are consistent with scientific conceptions, while the sixth through the tenth are not.

Throughout the instructional unit, field notes were taken by the researcher, and the activities of the whole class were videotaped. Interviews were used to assess the students' understanding of material and its properties, using questions such as the following:

- What should (object) be made of and what should it should not be made of, and why?
- Consider this picture of a house. Why would you choose brick for making the walls?
- What are the differences in clothing for each season?

All the data from interviews were audio-taped and transcribed verbatim in Thai. All data were triangulated.

In the third phase, a conceptual change unit on material and its properties was implemented within the school to enhance students' scientific conceptions and to determine the factors that appeared to affect students' conceptual change. The findings showed that the use of an instructional unit about material and its properties could help students to understand and accept scientific conceptions and to apply those concepts in appropriate contexts. Moreover, the findings appeared to show an increase in students' motivational beliefs. Four teaching strategies based on the conceptual change perspective were used: namely, practical work (the use of experiments), the historical approach, role-playing, and problem-solving. Different teaching strategies were used for different topics, depending on the scientific concepts involved and the students' receptiveness. The Thai curriculum mandated the study of six distinct scientific concepts at this level, as presented in Table 2.

Students' conceptual changes between the pre- and post-instructional surveys were apparent across all of the concepts related to material and its properties. Regarding the strength of material, when asked to choose a suitable material for specific objects, the number of students who referred to strength to explain appropriate situations increased between the two surveys. For example, most students explained that they chose nylon for their fishing line because of its strength (22 out of 32 students). However, some students chose nylon for the fishing line, but referred to hardness,

Table 1 Students' Responses Categories

No	Category	Descriptions	Examples
1	Strength - ST	Responses included the explanation of material’s resistance to breaking or tearing.	A ball should be made of leather because of its strength.
2	Elasticity - F	Responses included the identification of materials that continue to be the same shape after force or action.	A ball should be made of leather because it continues to be the same shape after being kicked.
3	Hardness - H	Responses included the explanation of a material’s resistance to scratching and pressure.	A ball should be made of leather because it is soft.
4	Heat transferability - HE	Responses included the explanation of the heat transferability of materials.	An adapter should be made of plastic because plastic does not transfer heat.
5	Electric transferability - E	Responses included the explanation of electric transferability of material.	An adapter should be made of plastic because plastic does not transfer electricity.
6	Visibility - V	Responses included the explanation of a material's opaque quality.	A ball should be made of leather because leather's surface is opaque.
7	Usability - U	Responses included the explanation of how to use objects (e.g., using them for play, or to contain something).	A ball should be made of leather because it can be kicked.
8	Weight - W	Responses included the explanation of the weight of material.	A ball should be made of leather because leather is light.
9	Touch - T	Responses included the explanation of the texture of the material.	A ball should be made of leather because of its smoothness.
10	Size – S	Responses included the explanation of size of the material.	A ball should be made of leather because of its thickness.

Table 2 Learning activities

No	Concept	Teaching strategies	Reason for selection	LD	SF	EB	GO	SE	CB	IV
1	Strength	Conduct an experiment	Encourage students to experience real material (plastic bag) to facilitate understanding and awareness of its properties and benefits.	√	√					√
2	Hardness	Conduct an experiment + historical approach	Use the historical case of the Mohs Scale to enable students to study how scientific knowledge is constructed. Students not only learn what hardness is, but also investigate and understand scientific procedures by themselves.	√	√	√	√	√	√	√
3	Elasticity	Conduct an experiment + role-playing	Students perform role- playing (a young designer) that involves solving unfamiliar problems related to elasticity.	√	√		√	√	√	√
4	HE	Conduct an experiment	Use experiments and games to motivate students to explain heat transferability in everyday situations.	√	√	√	√	√	√	√
5	E	Conduct an experiment	Students conduct an experiment to explore which materials can transfer electricity.	√	√	√	√	√	√	√
6	Material selection	Problem solving	Students share their ideas about the properties of materials to solve problems related to everyday life situations.	√	√	√	√	√	√	√

LD: Language Difficulty; SF: Social Factor; EB: Epistemological Belief; GO: Goal Orientation; SE: Self-Efficacy; CB: Control Belief; IV: Interest & Value instead of strength. For example, one student stated, “Nylon is hard because it resists force or attack. It can be stretched and it is harder than rope.” This quote shows that the student had attained the concept of strength, but chose different words to reflect his understanding.

With respect to hardness of material, the researcher found that an activity based on the Mohs Scale helped the students to articulate their understanding of the property. Presented with several choices, students identified the material that was most resistant to scratching and breaking. In the post-instructional survey, most students referred to the Mohs Scale activity to support their explanations of hardness. For example, B2 stated, “I chose it [brick] to build a wall because it is hard.” This explanation is different from B2’s pre-instructional survey response, which was, “We can build a high wall using bricks.”

Elasticity is a property with which most students were initially unfamiliar. Moreover, the researcher found some language barriers with this concept, inasmuch as the north-eastern Thai dialect is different in certain respects from that of central Thailand. There was some confusion with respect to scientific terms when they were rendered in the north-eastern dialect. After the lesson on the elasticity of material, most students were able to use this concept to explain their choices of appropriate materials for certain uses. Some students explained that they had thought that the main property of nylon was elasticity, but they had not known how to explain this property. Some mentioned that they had not realized that elasticity was an important criterion for the selection of any materials. After the “Young Designer" activity, students came to realize that different materials have different elasticity properties, and accepted that studying properties such as elasticity could help them to make decisions when they had to choose a material for a particular situation.

With regard to heat transferability, a number of conceptual changes on the students’ part could be noted between the pre- and post-instructional surveys. In the latter survey, many students referred to their experiences during the heat transferability experiment in which they selected appropriate materials according to their heat transferability properties. Similarly, while most students had adequate prior knowledge concerning the materials that could transfer electricity, the students generally could not clearly express their understanding of the concept of electricity. In the class activity, students investigated the electric transferability properties of different materials using a simple electric circuit. Each student had the opportunity to study how a simple electric circuit worked and what roles each component played in the circuit. Finally, the students had opportunities to test their hypotheses by conducting experiments to explore which materials transferred electricity. After the class activity, the survey demonstrated that most students had changed their conceptions regarding appropriate materials for producing electrical plugs. Some students explained that the reason we should not use metal, stainless steel, and copper to produce electrical plugs was because these materials could cause a “short circuit," or because "metal could transfer electricity to people."

It appears that multiple factors, most importantly including motivational beliefs, learning environment, and language difficulties, may affect students' conceptual change. The success of the instructional activities is promoted by social factors such as a warm, friendly learning environment and an awareness of the differences between scientific language and the language of everyday life. Most students participate in all of the activities and share their leaning goals and their ideas. Students show particular interest in the activities related to everyday life, such as the strength activity and the elasticity activity. Knowledge of the way in which scientific inquiry works and of how scientific knowledge is constructed is presented to students through activities like the hardness activity. Students are encouraged to construct their understanding for themselves rather than waiting for knowledge to be imparted by their teachers. This helps students to change their epistemological beliefs. Lessons such as the heat and electricity transferability activities aim to encourage students to work collaboratively in hands-on inquiry projects. Most students take responsibility for and made decisions about their work, thus increasing their self-efficacy and their control belief.

DISCUSSION AND IMPLICATIONS

Before the study, students had a relatively limited understanding of the properties of materials. Some students knew some materials’ properties, but could not provide scientific explanations of their understanding. They could not identify why some materials were suitable for making certain objects. According to the pre-instructional survey, most students had developed alternative conceptions concerning the properties of materials that were unfamiliar to them. There were also issues regarding the differences between the meanings of scientific terms as presented in the central Thai language textbooks and the same words’ meanings in the local dialect. For example, some words such as “strength” and “elasticity” were unfamiliar to students as they were rarely used in everyday situations. This presented a considerable challenge for the students’ ability to undergo conceptual change. This finding was consistent with the study of Wellington and Osborne (2001). Furthermore, students initially confused some of the words used in everyday life with certain scientific terms. For example, most students used “hardness” to explain the properties of plastic bags. In scientific terminology, however, the term “strength” was used to refer to a property of materials, which were resistant to breaking and tearing. This terminological confusion likely promoted the development of students’ alternative conceptions (Vosniadou & Brewer, 1992; Wandersee et al., 1994; Duit, 1999). Consequently, the researcher made an effort to encourage students to use the unfamiliar scientific terms in learning activities such as investigating the strength properties of plastic bags. The conceptual change that occurred in students' conceptions could be described as a change, which started from and built upon students' initial conceptions (Duit & Treagust, 2003). During this process, students' initial conception regarding plastic bags was reconciled with a new conception related to strength properties. They learned that good plastic bags should have good strength properties. Hewson and Hewson (1992) and Posner et al. (1982) have called this process conceptual capture or assimilation.

Another problem identified in the preliminary survey was that most students did not pay attention to certain materials' properties. For example, most students understood "hardness," but they did not realize that this property was important when choosing material for a task. For example, students considered wood to be the most appropriate material for a door, because it could be cut. Similarly, most students knew which materials transferred electricity, but could not elaborate on how a given material could do so. They were also unable to make appropriate selections of material for producing certain objects. This problem was consistent with Hallen's finding (1999). Hallen explained that alternative conceptions result from students' difficulties in identifying adequate contexts for specific concepts. There were often no hints available to them in order to contextualize appropriately, even in those contexts that were most familiar to them. Teaching new concepts should focus, therefore, explicitly on identifying adequate contextualizations, which were meaningful to the students. In this case, the researcher prepared adequate contexts for the students to apply their knowledge of materials' properties to explain their use in a variety of situations. For example, the Mohs Scale was presented so as to enable the students to identify the concept of hardness in everyday situations.

The current study also found that the social and classroom contexts affected students' learning. Affording students opportunities to experience a variety of activities and experiments and to explain their ideas enhanced their understanding and motivation to learn. The researcher's supportive demeanour encouraged and motivated students with questions, praise, and attention to the students' thoughts.

Another important finding from this research was the effect of motivational beliefs on conceptual change. The researcher found that most students were aware that they did not need to wait for knowledge to be given by their teachers, and that there was no absolute truth. Students' learning behaviours exemplified the epistemological belief that they were capable of constructing the meaning of various phenomena by themselves. This belief promoted the students' interest in investigation, testing, and conducting inquiries. Consequently, students were able to explain various phenomena through supported participation in a variety of activities. Because students understood their roles, they were able to establish their goal orientation and were empowered to identify what they wanted to do or to learn. Moreover, when the students had the chance to make their own decisions, they were able to reach high levels of self-efficacy, possess clear control beliefs, and accept scientific conceptions. This finding was consistent with the observations of Pintrich et al. (1993).

The implications of this study indicate that it is important for science teachers to be concerned with affective and social factors when developing learning strategies to facilitate conceptual change. Attending to these factors is extremely important for supporting students' motivational beliefs and creating beneficial learning environments that support student inquiry.

ACKNOWLEDGEMENT

This work was supported by the Thailand Research Fund (TRF) [grant number MRG5080262].

REFERENCES

Barsalou, L.W. (1992). *Cognitive Psychology: An Overview for Cognitive Scientist.* Hillsdale., New Jersey: LEA (Lawrence Erlbaum Associates), 410 page.

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

Baddock, M., & Bucat, R. (2008). Effectiveness of a classroom chemistry demonstration using the cognitive conflict strategy. *International Journal of Science Education*, *30*(8), 1115-1128.

Bell, B. (1993). *Children's sciences, constructivism, and learning in science.* Victoria, Australia: Deakin University.

Blicblau, A. (1997). The trend towards materials in science and technology education. *Journal of Science Education and Technology*, *6*(3), 231-240.

Bryman, A. (2001). *Social research methods.* Oxford, UK: Oxford University Press.

Carr, M. (2000). Technological affordance, social practice, and learning narratives in an early childhood setting. *International Journal of Technology and Design Education*, *10*, 61-79.

Çelikten, O., İpekçioğlu, S., Ertepınar, H., & Geban, Ö. (2012). The effect of the conceptual change oriented instruction through cooperative learning on 4th Grade students' understanding of earth and sky concepts. *Science Education International*, *23*(1), 84-96.

Chatoney, M. (2006). The evolution of knowledge objects at the primary school: A study of the material concept as it is taught in France. *International Journal of Technology and Design Education*, *16*, 143-161.

Conway, R. (2000). Ethical judgements in genetic engineering: The implications for technology education. *International Journal of Technology and Design Education*, *10*, 239-254.

Coştu, B., Ayas, A., Niaz, M., Űnal, S., & Çalik, M. (2007). Facilitating conceptual change in students' understanding of boiling concept. *Journal of Science Education and Technology, 16*, 524-536.

Cosgrove, M., & Osborne, R. (1981). *Physical change*. LISP Working Paper 26. Hamilton, NZ: University of Waikato.

Denzin, N. K., & Lincoln, Y. S. (1994). *Handbook of qualitative research*. Thousand Oaks, CA: Sage.

Duit, R. (1999). Conceptual change approaches in science education. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 263-282). Amsterdam, the Netherlands: Pergamon.

Duit, R., & Treagust, D. F. (1998). Learning in science—From behaviorism towards social constructivism and beyond. In B. Fraser & K Tobin)Eds.), *International handbook of science education*, *Part 1* (pp. 3-25). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education, 25*(6), 671-688.

Fleer, M. (1999). The science of technology: Young children working technologically. *International Journal of Technology and Design Education*, *9*, 269-291.

Hallden, O. (1999). Conceptual change and contextualization. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 53-65). Amsterdam, the Netherlands: Pergamon.

Happs, J. (1980). *Particles*. LISP Working Paper 18. Hamilton, NZ: University of Waikato.

Hewson, P. W., & Hewson, M. (1992). The status of students' conceptions. In R. Duit, F. Goldberg, & H. Niedderer (Eds.), *Research in physics learning*: *Theoretical issues and empirical studies* (pp. 59-73). Proceedings of an International Workshop held in Bremen. Kiel, Germany: Institute for Science Education at the University of Kiel.

Hewson, P. W., Beeth, M. E., & Thorley, N. R. (1998). Teaching for conceptual change. In G. Tobin & B. Fraser (Eds.), *International handbook of science education (*pp. 199-218). Dordrecht, the Netherlands: Kluwer Academic Publishers.

Institute for the Promotion of Teaching Science and Technology (IPST). (2002). National science content standards, in IPST, *Science standard learning management manual*. Bangkok: Curu Sapa Printing and Publishing Co. Ltd.

Lee, C. K. (2014). A conceptual change model for teaching heat energy, heat transfer, and insulation. *Science Education International*, *25*(4), 417-437.

Liu, X. (2000). Elementary school students' logical reasoning on rolling. *International Journal of Technology and Design Education*, *10*, 3-20.

Lynch, D. J., & Trujillo, H. (2011). Motivational beliefs and learning strategies in organic chemistry. *International Journal of Science and Mathematics Education, 9*, 1351-1365.

Nieswandt, M. (2001). Problems and possibilities for learning in an introductory chemistry course from a conceptual change perspective. *Science Education*, *85*, 158–179.

Pfundt, H., & Duit, R. (1994). *Bibliography: Students' alternative frameworks and science education* (4th ed.). Kiel, Germany: Institute for Science Education at the University of Kiel.

Pimthong, P., Yutakom, N., Roadrangka, V., Sanguanruang, S., Cowie, B., & Cooper, B. (2012). Teaching and learning about matter in Grade 6 classrooms: A conceptual change approach. *International Journal of Science and Mathematics Education*, *10*(1), 121-137

Pintrich, P. R., Marx, R. W., & Boyle, R. A. (1993). Beyond cold conceptual change: The role of motivational beliefs and classroom contextual factors in the process of conceptual change. *Review of Educational Research*, *63,* 167-199.

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*, 211-227.

Schnotz, W., Vosniadou, S., & Carretero, M. (1999). Preface. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. xiii-xxiv). Amsterdam, the Netherlands: Pergamon.

Schollum, B. (1981). *Chemical change*. LISP Working Paper 27. Hamilton, NZ: University of Waikato.

Schollum, B. (1982). *Reaction*. LISP Working Paper 37. Hamilton, NZ: University of Waikato.

Sinatra, G. M., & Pintrich, P. R. (2003). *Intentional conceptual change*. New York, NY: Lawrence Erlbaum Associates.

Treagust, D .F., Harrison, A. G., Venville, G.J., & Dagher, Z. (1996). Using an analogical teaching approach to engender conceptual change. *International Journal of Science Education*, *18*, 213-229.

Treagust, D. F., & Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological, and practical challenges for science education. *Cultural Studies of Science Education*, *3*(2), 297-328.

Treagust, D. F., & Duit, R. (2009). Multiple perspectives of conceptual change in science and the challenges ahead. *Journal of Science and Mathematics Education in Southeast Asia*, *32*(2), 89-104.

Tyson, L. M., Venville, G. J., Harrison A. G., & Treagust, D. F. (1997). A multidimensional framework for interpreting conceptual change events in the classroom. *Science Education*, *81*, 387-404.

Tytler, R., & Peterson, S. (2000). Deconstructing learning in science—Young children's responses to a classroom sequence on evaporation. *Research in Science Education*, *30*(4), 339-355.

Tytler, R., Prain, V., & Peterson, S. (2007). Representational issues in students' learning about evaporation. *Research in Science Education*, *37*(3), 313-331.

Vosniadou, S. (1999). Conceptual change research: State of the art and future directions. In W. Schnotz, S. Vosniadou, & M. Carretero (Eds.), *New perspectives on conceptual change* (pp. 3-13). Amsterdam, the Netherlands: Pergamon.

Vosniadou, S., & Brewer, F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology*, *24*, 535-585.

Walsh, D., Tobin, J., & Graue, M. (1993). The interpretive voice: Qualitative research in early childhood education. In B. Spodek (Ed.), *Handbook of research on the education of young children* (pp. 464-476). New York, NY: Lawrence Erlbaum Associates.

Wandersee, H., Mintzes, J., & Novak, D. (1994). Research on alternative conceptions in science. In Gabel, D. (Ed.), *Handbook of research on science teaching and learning* (pp.177-203). Washington, DC: National Science Teachers Association.

Wellington, J., & Osborne, J. (2001). *Language and literacy in science education*. Buckingham, UK: Open University Press.

Yuenyong, C., & Yuenyong, J. (2007). Grade 1 to 6 Thai students' existing ideas about energy. *Science Education International*, *15*(4), 289-298.