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# 研究“雙重情境學習模式”對不同本質理化概念的改變與重建之影響(3/3)

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# Fostering Radical Conceptual Change through Dual-Situated Learning Model

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Abstract: This article examines how the Dual-Situated Learning Model (DSLM) facilitates a radical change of concepts that involve the understanding of matter, process, and hierarchical attributes. The DSLM requires knowledge of students' prior beliefs of science concepts and the nature of these concepts. In addition, DSLM also serves two functions: it creates dissonance with students' prior knowledge by challenging their epistemological and ontological beliefs about science concepts, and it provides essential mental sets for students to reconstruct a more scientific view of the concepts. In this study, the concept "heat transfer: heat conduction and convection," which requires an understanding of matter, process, and hierarchical attributes, was chosen to examine how DSLM can facilitate radical conceptual change among students. Results show that DSLM has great potential to foster a radical conceptual change process in learning heat transfer. Radical conceptual change can definitely be achieved and does not necessarily involve a slow or gradual process. © 2004 Wiley Periodicals, Inc. J Res Sci Teach 41: 142–164, 2004

Previous studies have suggested that two types of knowledge restructuring—namely, weak restructuring and radical restructuring—are involved during conceptual change (Carey, 1985, 1986; Vosniadou & Brewer, 1987). In the past 2 decades, many researchers in cognitive psychology have focused on studying and proposing theories to explain what would make certain types of conceptual change harder to occur than others (Chi, Slotta, & deLeeuw, 1994; Carey, 1985, 1986; Thagard, 1992; Vosniadou & Brewer, 1987). On the other hand, researchers in science education have concentrated on investigating theories and strategies that would facilitate the understanding of scientific concepts and bring about conceptual change (Brown, 1993; Clement, 1991, 1993; Posner, Strike, Hewson, & Gertzog, 1982; Steinberg & Clement, 1997; Stofflett, 1994).

Review of the progress of conceptual change studies from both cognitive psychology and science education fields has indicated the limitations of both sides. This study examines how the Dual-Situated Learning Model (DSLM) (She, 2001, 2002, 2003) can facilitate the restructuring of concepts that involve understanding matter, process, and hierarchical attributes.

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## Theoretical Frameworks

Many researchers in the field of cognitive psychology have proposed theories that explain the difficulties faced by students when learning certain scientific concepts (Carey, 1986; Chi et al., 1994; Thagard, 1992; Vosniadou & Brewer, 1987). Of these, Chi et al. developed a theory to explain why certain concepts are more difficult to change than others. Their theory assumed that students perceive things in basic ontological categories called ontological trees. Scientific concepts are classified by three ontological attributes: namely, matter, processes, and mental states. Each ontological tree contains only one attribute. Conceptual change occurring within the same ontological tree, which often happens when students learn science concepts, does not pose much difficulty. Most difficulties that have been empirically observed arise when ontological shifts are required. In other words, a concept changing from one ontological tree to another, such as shifting from matter to process, involves radical conceptual change. For instance, after acquiring an understanding of the kinetic theory of gases, students would shift from viewing heat as a substance belonging to the matter ontological tree to regarding it as belonging to the process ontological tree (Rohr & Reimann, 1998).

Thagard (1992) proposed a model containing nine various types of conceptual change ranked according to degree of increasing severity. In his analysis of scientific conceptual systems, scientific concepts are divided into treelike structures. These structures include kind-relations (birds, mammals, and reptiles are kinds of animals) and part-relations (birds have feathers and beaks), as well as relations between concepts and rules that link concepts (whales eat sardines), which are in turn parts of the concept itself. He used these notions to create a hierarchy of change types. In his model, the first seven kinds of change, including adding a new instance, a new weak rule, a new strong rule, a new part-relation, a new kind-relation, and a new concept, as well as deleting part of a kind-hierarchy, are all common in science learning. However, other concepts that involve reorganizing hierarchies by branch jumping and tree switching are the most dramatic kinds of conceptual change and are common in scientific conceptual revolution.

The models of both Chi et al. (1994) and Thagard (1992) describe why some conceptual changes are more difficult than others. Though different, their theories share a similar view that looks at the nature of concepts from their ontological categories, which in turn determines whether conceptual change would occur.

The author argues that attributing a radical conceptual change to an ontological shift (Chi et al., 1994) or tree switching and branch jumping (Thagard, 1992) might be too simple and there might be other reasons for the difficulty in conceptual change. Often, radical conceptual change involves more complex mental and instructional activity than just shifting an ontological view from matter to process attributes. For instance, the concept of buoyancy is difficult for students. She's (2002) empirical study on fostering conceptual change on buoyancy claims that in addition to the reasons proposed above, the hierarchical level of the concept is a crucial factor influencing the relative ease or difficulty students experience in understanding physical concepts. Concepts of higher hierarchical level subsume more essential underlying concepts, making it difficult for conceptual changes to occur. That study also described how an understanding of six mental sets is needed to achieve buoyancy restructuring. Clearly, helping students reconstruct the concept of buoyancy is not just an ontological shift or tree switching or branch jumping; the hierarchical level of the concept itself is also involved. However, the author agrees with both Chi et al. and Thagard that understanding the nature of science concepts from its ontological category has an important role in fostering the process of radical conceptual change.

Vosniadou and Brewer's (1994) model suggests that both epistemological and ontological presuppositions can either facilitate or constrain conceptual change. Epistemological presuppositions include the criteria that individuals use to judge what constitutes a phenomenon and the assumptions that phenomena require an explanation and that causal explanations can be used to account for physical phenomena. Ontological presuppositions are the basic beliefs about the nature of objects, such as that physical objects are solid and will fall down if not supported (Vosniadou & Brewer, 1994). That study also suggested that conceptual change entails a slow and gradual process rather than a sudden shift of theory. Changes in understanding usually involve smaller changes that can be described in terms of changes in underlying beliefs, adjustments of mental models on the basis of new information, instruction, addition, deletion, reorganization, or strengthening of relations between concepts, and so on. The author agrees with Vosniadou and Brewer that students' epistemological and ontological beliefs have an important role in the conceptual change process, but questions whether the process involved must be slow. Further understanding of this issue may indicate whether there is a way to speed up the conceptual change process.

Another factor influencing conceptual change is motivational beliefs about learning itself. Although these beliefs are a resource to support conceptual change, they can be hinder conceptual change (Duit, 1999; Pintrich, Marx, & Boyle, 1993). Vosniadou and Brewer (1994) suggested that various motivational beliefs about the learner and learning itself could also act as presuppositions that can either facilitate or constrain conceptual change. Engaging in deeper processing of information can foster conceptual change (Chinn & Brewer, 1993) and the various cognitive operations that result in deeper processing often depend on various motivational beliefs of the learner himself (Pintrich & Schrauben, 1992). Pintrich (1999) suggested that motivational beliefs might not directly influence conceptual change; however, as presuppositions or theories about the learner and the learning, they may support and constrain conceptual change. Smith, di Sessa, and Roschelle (1993) called for a constructivist model of misconception that regards motivational beliefs as the cognitive resources that can support the bootstrapping of more advanced cognitive structures. All of these studies indicate that the issue of motivation should be taken into account when developing an effective conceptual change model.

Posner, Strike, Hewson, and Gertzog's (1982) and Strike and Posner's (1985) work on the conceptual change view of learning and understanding is one of the most popular theories used to explain how conceptual change happens in science education. In their theory, *accommodation* is used to refer to large-scale conceptual changes, and *assimilation* refers to learning in which a major conceptual revision is not required. They further showed that conceptual change is oriented more to accommodation than to assimilation. They also proposed that students' conceptual ecology might influence their selection of new conceptions. Posner et al. suggested four conditions for accommodation (conceptual change) to occur: (a) students must be dissatisfied with their existing concepts, (b) students must have at least a minimal understanding of the new concept, (c) the new concept must appear plausible, and (d) the new concept should appear fruitful. Strike and Posner proposed that accommodation be viewed as a competition between alternative conceptions. Once students are aware of an understandable and initially plausible alternative to an existing conception, the relative status of these conceptions becomes the issue. Dissatisfaction with the existing conception decreases its status, whereas exploring the fruitfulness of an alternative conception increases the alternative's status (Hewson, 1983). Whenever the alternative's status exceeds the existing conception's status, accommodation will move forward.

The studies of Posner et al. (1982) have provided science educators frameworks for developing different views, theories, and strategies to facilitate the understanding of scientific concepts and bring about conceptual change. Hewson and Hewson (1983) employed a conceptual change model to help students' conceptual change involving mass, volume, and density. Their model considers students' prior knowledge for designing conceptual change instructional materials, based on the conceptual change theory of Posner et al. (1982). Driver and Oldham

(1986) also addressed the need for conceptual change to consider students' prior ideas. All of those studies provide principles for letting students actively engage in the process of construction and reconstruction of their knowledge; however, the models lack concern for the nature of ontological categories of science concepts and do not address the possibility of radical conceptual change. The author argues that radical conceptual change involves complex mental processing unless the experiment design specifically focuses on the mental sets students lack for constructing a specific concept. These previous studies also did not address how their models would solve the problem of concepts of higher hierarchical level subsuming more essential underlying concepts. However, the author agrees with Hewson and Hewson (1983) and Driver and Oldham (1986) that considering students' previous knowledge and actively engaging students in the process of conceptual change are important factors for conceptual change.

Other trends in the study of science education have focused on proposing ways to bring about specific conceptual change. Some studies have suggested the use of analogies and models as a resource for stimulating conceptual change (Brown & Clement, 1989; Brown, 1993; Clement, 1991, 1993); others proposed the use of discrepant events (Liem, 1987; Steinberg & Clement, 1997). Clement and Rea-Ramiez (1998) noted that the limitation of previous studies using analogy or discrepant event is that they either help students create a new model or create dissonance. They suggested that certain carefully chosen discrepant events may actually be sources for the construction of new schema and simultaneously create internal dissonance to bring about conceptual change. The author agrees with their ideas that the use of learning resources needs to be carefully designed to help students create dissonance and encourage students to move beyond the old model toward a revision or construction of a new model. In addition, Berlyn (1965) believed that an optimal degree of cognitive dissonance leads to curiosity and learning. There are many sources of dissonance, both internal and external, that may work together to cause conceptual change. These include discrepant events, analogies, familiar exemplars, and criticisms, as well as internal reflection. The use of dissonance should not so strong as to cause conflict, but just strong enough to cause students' disequilibrium and willingness to engage in internal struggle and to seek changes. The author agrees that carefully designed learning activity should be another critical point to motivate students' conceptual change.

Moreover, some studies have identified the social processes that need to be taken into account in the learning process (Edwards & Mercer, 1987). Other recent works recommended the application of a constructivist approach to conceptual change (Driver & Oldham, 1986; Hewson & Hewson, 1988; Stofflett, 1994). These studies emphasized the importance of the social factor and the subjectivity of the learner.

However, research to date has not shown any models or mechanisms that can bring about radical conceptual change effectively and efficiently, so this clearly is an important challenge for cognitive scientists and science educators. Studies from both of these fields have provided the author with valuable bases on which to develop the DSLM (She, 2001, 2002, 2003). This model has demonstrated its potential to facilitate students' conceptual change involving concepts of air pressure and buoyancy through interview-based instruction (She, 2002) and thermal expansion through classroom instruction (She, 2003). This current study aims to extend the potential of this model to make conceptual change less difficult and speed up the process, particularly of radical conceptual change.

## DSLM

The DSLM is composed of six major stages: Stage 1—examining the attributes of the science concept. This stage provides information about which essential mental sets are needed to construct a scientific view of the concept. Stage 2—probing students' misconceptions of the science concept, which requires probing students' beliefs concerning the science concept. Stage 3—analyzing which mental sets students lack. This would reveal which mental sets students lack specifically for the construction of a more scientific view of the concepts. Stage 4—designing dual-situated learning events. The design of dual-situated learning event is according to the Stage 3 results, indicating which mental sets students lack. If two mental sets are needed to help students construct a more scientific view of the concepts, it might be necessary to design at least two dual-situated learning events. Stage 5—instructing with dual-situated learning events. This emphasizes giving students an opportunity to make predictions, provide explanations, confront dissonance, and construct a more scientific view of the concepts. Stage 6—instructing with challenging a situated learning event. This provides an opportunity for students to apply the mental sets they have acquired to a new situation to ensure that successful conceptual change has occurred (Table 1 and Figure 1).

This DSLM has been shown to have the potential to promote students' conceptual change. *Situated learning* means that the process of conceptual change should be situated on the nature of science concepts and students' beliefs of the science concepts to determine what essential mental sets are needed for constructing a more scientific view of the concepts. Identifying the nature of a science concept would decide which and how many mental sets are needed for constructing a more scientific view of the concept. Probing students' beliefs of the science concept would provide a deeper understanding of students' misconceptions and what causes them. Information obtained from this probing would help pinpoint which and how many particular mental sets students lack for restructuring the science concept. It would further help science educators design specific situated learning events to supplement such deficiency and foster conceptual change.

*Dual* means that this model possesses two functions in many of its facets. First, conceptual change should be built on both the nature of science concepts and students' beliefs of science concepts. Second, the conceptual change process should create dissonance with students' preexisting knowledge and provide new mental sets for them to achieve a more scientific view of the concept, which can be either a revision of the old model or the construction of a new one. Third, the process of creating dissonance needs to arouse students' motivation and challenge their beliefs of the concepts. Fourth, the process of conceptual change needs to challenge students' ontological and epistemological beliefs of science concepts (Table 1 and Figure 2).

## Features of DSLM

As described previously, a major feature of the DSLM is to create dissonance with students' preexisting knowledge that would arouse students' curiosity and interest, as well as challenge their epistemological and ontological beliefs of the science concepts. Once they are motivated to engage in event prediction and visualize what actually happens, the possibility increases of restructuring their epistemological and ontological beliefs of the concepts.

Second, providing the new mental set should be the platform on which knowledge reconstruction can occur. As suggested by Posner et al. (1982), students must see the new mental set as intelligible, plausible, and fruitful for conceptual change to happen. It can be any type of instructional activity such as analogy, modeling, discrepant events, and inquiry activities, as long as it fulfills the suggestions of Posner et al. and provides students with opportunities to visualize what actually happens, to reconstruct new mental sets.

Third, all situated learning events should be designed according to the nature of the science concepts and students' beliefs of them. In other words, information about which and how many

Table 1
*Descriptions and characteristics of Dual-Situated Learning Model*

| Dual-Situated Learning Model | Descriptions | Characteristics |
|---|---|---|
| **Stage 1: Examining attributes of the science concept** | This stage provides information about which essential mental sets are needed to construct a scientific view of the concepts. | The nature of science concept is the crucial part of determining whether conceptual change can be achieved. For instance, some concepts may be classified as process, higher hierarchical level, abstract, invisible, etc. These attributes of science concepts should be analyzed before planning dual-situated learning events. |
| **Stage 2: Probing students' misconceptions of the science concept** | This involves probing the students' beliefs concerning the science concept. | Students' belief of science concept is another crucial part of determining whether conceptual change can be brought about. These would pinpoint what misconception students have. |
| **Stage 3: Analyzing which mental sets students lack** | It would pinpoint which and how many particular mental sets students lack specifically for restructuring the science concepts. | These would help design specific situated learning events to supplement a deficiency of particular mental sets and foster conceptual change. |
| **Stage 4: Designing dual-situated learning events** | The design of dual-situated learning events is according to Stage 3 results determining which mental sets students lack. | The design of each event needs to create dissonance with students' original beliefs of science concept, and provide a new mental set for them to achieve a more scientific view of the concept. Its design of creating dissonance can arouse students' motivation as well as challenge students' beliefs of the concepts. |
| **Stage 5: Instructing with dual-situated learning events** | This emphasizes giving students an opportunity to make predictions, provide explanations, confront dissonance, and construct a more scientific view of concepts. | During the instruction, each event would allow students to confront their beliefs of science concepts, and arouse their curiosity and interest them to challenge their epistemological and ontological beliefs of science concepts. Moreover, each event would provide students a new mental set with which knowledge reconstruction can occur. |
| **Stage 6: Instructing with challenging situated learning event** | It provides an opportunity for students to apply the mental sets they have acquired to a new situation to ensure that successful conceptual change occur. | The design of challenging situated learning events needs to combine all of the particular mental sets students lacked before and by now have reconstructed through a series of dual situated learning events. |

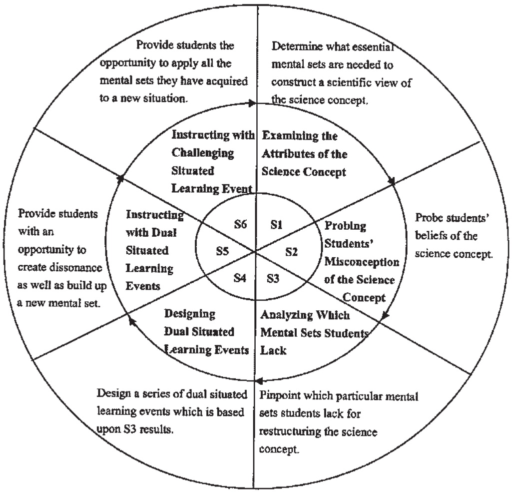

*Figure 1.* Dual-Situated Learning Model.

particular mental sets students lack for restructuring the science concept would therefore determine which and how many specific situated learning events need to be designed to supplement such a deficiency and foster conceptual change. She's previous study (2002) proposed that the concepts of higher hierarchical level subsume more essential underlying concepts, making it difficult for conceptual changes to occur. The number of dual situated learning events required would depend on the number of mental sets students lack for constructing a more scientific view of the concepts. More important, each dual-situated learning event should connect with the others, and it needs to build on a prior dual-situated learning event.

The last feature provides an opportunity to challenge students to see whether they can really apply to another situation the mental sets they have revised or constructed, thus achieving a successful conceptual change. The design of a challenging situated learning event needs to combine all of the particular mental sets students previously lacked and which have been reconstructed through a series of dual-situated learning events.

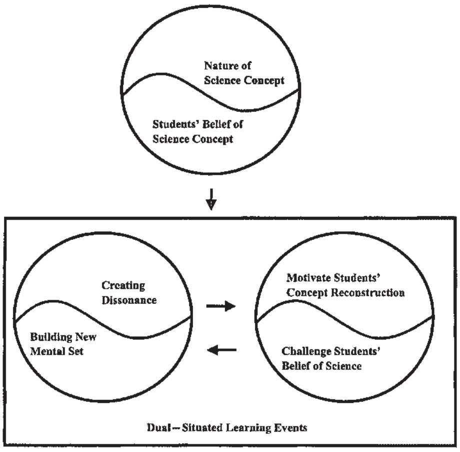

*Figure 2.* Mechanism of Dual-Situated Learning Model.

## Purpose

The DSLM has demonstrated its potential to facilitate students' conceptual change involving the attributes of various level of hierarchical concepts such as air pressure and buoyancy (She, 2002) and thermal expansion (She, 2003). This study aimed to extend the potential of this model to facilitate conceptual change and speed up the process, especially of radical conceptual change. The concept of "heat transfer: heat conduction and convection," which requires an understanding of matter, process, and hierarchical attributes, was chosen to investigate the nature and process of students' conceptual change and further demonstrate how DSLM contributes successfully to bringing about a radical conceptual change within a short time.

More specifically, the research questions that guided this study were: Can DSLM facilitate students' conceptual change of heat transfer? How can DSLM facilitate a conceptual change in students' understanding of heat transfer?

## Methodology

### *Participants and Procedures*

Twenty-seven ninth-grade students randomly selected from an average achievement class of a middle school participated in this study. All the participants were taught the concept of heat transfer in their eighth-grade physical science course. A panel of eight experts including science educators, scientists, and school physical science teachers was involved in DSLM Stages 1–4. After the panel decided what concepts and events need to be used to probe students' prior knowledge, the author trained the interviewers to ensure they knew how to interview the students. Similarly, after the panel decided on a series of dual-situated learning events, the author trained the interviewers on how to do the interview-based instruction. These interviewers were involved in Stages 2 and 5. All interviews were held from dual-situated learning Events 1–6 and then challenging situated learning events sequentially. The interviewers were requested to follow the sequences and instructions, which can be found in Appendix A. They were allowed to remind students to observe the events carefully. During the interview, each student was asked to think aloud about his beliefs concerning the concepts and events that interviewers asked and presented. All students were involved in a series of processes fostering conceptual change (DSLM Stages 2, 5, and 6). Stage 2 lasted 30–45 minutes, during which the students' beliefs concerning the concepts were probed; Stage 5 lasted 2–2.5 hours, during which the dual-situated learning events were presented; and Stage 6 lasted 30–45 minutes, when the challenging situated learning event was instructed. Therefore, the individual interview given to each student was a total of 4–4.5 hours. The whole interview processes were tape-recorded and then transcribed for further analysis.

### *Research Design*

This study employed DSLM to investigate students' conceptual change involving heat transfer: heat conduction and convection.

*Stage 1 (S1): Examining the Attributes of Heat Transfer: Heat Conduction and Convection.* The first stage was to examine carefully the attributes of the two types of heat transfer, conduction and convection, which indicated which essential mental sets were needed for constructing a more scientific view of these concepts. According to the experts on the panel, conceptual changes related to conduction and convection could be categorized as radical changes because these concepts involve understanding matter and process (Chi et al., 1994), and hierarchical level (She, 2002, 2003).

After the attributes and essential underlying concepts were identified, the experts on the panel reached a consensus that one particular mental set was needed before constructing the notion of heat conduction and convection. Mental Set 1 states that heat is the total kinetic energy of the molecules of a substance, and heat transfer refers to the process by which heat energy gets from one place to another.

Because heat can be transferred via conduction, convection or radiation, in addition to Mental Set 1, two other mental sets are needed for students to understand heat conduction. Mental Set 2 states that conduction is the transfer of kinetic energy via collisions between molecules. Mental Set 3 states that the molecules are fixed and cannot move from one place to another, so solids usually transfer heat via conduction. Furthermore, two other mental sets are needed for students to understand heat convection in addition to Mental Set 1. Mental Set 4 states that convection is the transfer of energy via the movement of groups of molecules. Mental Set 5 indicates that the molecules actually move from one place to another via convection, so liquid materials usually transfer heat via convection. Because the colder portion of a fluid is denser than the hotter portion, it sinks to the bottom of the container, forcing the hotter, lighter fluid to the top. The position of the hotter and colder fluid would decide whether heat is transferred via conduction or convection. To identify when liquid materials would transfer heat via conduction and when they would transfer via convection, two more mental sets are needed for students in addition to those described above. Mental Set 6 states that the density of a hotter fluid is smaller than a colder fluid. Mental Set 7 states that when the hotter portion of the fluid is at the bottom and the colder portion of the fluid is at the top, the colder fluid would force the hotter fluid to the top, so heat is transferred via convection. On the contrary, if the hotter fluid is at the top and the colder fluid is at the bottom, there will be no force to move the molecules, so heat is transferred via conduction.

*Stage 2 (S2): Probing Students' Misconception of Heat Transfer: Heat Conduction and Convection.* The second stage involves investigating students' beliefs concerning the concepts of heat, heat transfer, heat conduction, and heat convection. To elicit students' understanding of these concepts, they were asked to explain what heat is, what is involved in heat transfer, and how heat can be transferred within solid and liquid materials. Then, Events 2 and 3, which were similar, were put forward without demonstration (see Appendix A) to detect students' understanding about heat convection and heat conduction. During the process, each student was asked to think aloud about these concepts and events. This qualitative method enabled us to examine the nature of students' understanding about a semantically rich concept (Goetz & LeCompte, 1984).

All processes were recorded and students' responses were transcribed for further analysis. Analysis of students' beliefs of heat showed that about 89.5% of students perceived heat to be a form of energy existing within the molecules of a substance. Only 5.3% further described heat energy as able to be transferred from one place to another, and 63.1% focused specifically on the measurement of heat (Table 2). About 81% of students only described solid materials transfer heat via conduction and did not provide further explanation about the reason and process involved; the rest thought that heat is transferred via convection and radiation. About 75% of students stated only that liquid material would transfer heat via convection and did not provide further explanation about the reason and process involved; the rest suggested that heat is transferred via conduction (Table 2). Similarly, Events 2 and 3 were given to students without demonstration to elicit their perception about what types of heat transfer would occur in liquid. Among students, 95% suggested that both events involved heat transfer via convection to reach equilibrium.

Table 2
*Students' alternative conceptions of heat transfer*

| Alternative Conception | Students (%) |
|---|---|
| Heat | |
| 1. Heat is a form of energy. | 15.8 |
| a. Heat is a form of energy; it does not have any specific shape; you cannot feel it. | 5.3 |
| 2. Heat is a form of energy and can be transferred from one substance to another. | |
| a. Heat is a form of energy; it can be transferred from one substance to another and change its temperature. | 5.3 |
| 3. Heat is a form of energy and can be measured. | 5.3 |
| a. Heat is a form of energy and can be measured as calories. | 15.7 |
| b. Heat is a form of energy and make 1 g water increase 1°C. | 21.1 |
| c. Heat is a form of energy and heat capacity is a unit of energy which can be measured. | 15.7 |
| d. Heat is a form of energy and represents the temperature of a substance. | 5.3 |
| 4. Heat is the hotter substance. | 10.4 |
| Heat transfer (heat conduction) | |
| 1. Solid material transfers heat via conduction. | 80.9 |
| 2. Solid material transfers heat via convection. | 14.3 |
| 3. Solid material transfers heat via radiation. | 4.8 |
| Heat transfer (heat convection) | |
| 1. Liquid material transfers heat via conduction. | 25.0 |
| 2. Liquid material transfers heat via convection. | 75.0 |

*Stage 3 (S3): Analyzing Which Mental Sets Students Lack.* Results from Stages 1 and 2 indicate which specific mental sets students lack for constructing a more scientific view of the heat transfer: conduction and convection, thus providing specific information to teachers for designing a series of dual-situated learning events for conceptual change.

According to results obtained in Stage 2 (Table 2), only 10.5% of students lacked Mental Set 1, whereas most lacked the other mental sets. In other words, Mental Sets 2–7 are needed for students to construct a more scientific view of heat conduction and convection.

*Stage 4 (S4): Designing Dual-Situated Learning Events.* The fourth stage was to design a series of dual-situated learning events according to the attributes of the concepts as well as students' beliefs about the concepts. In this study, six dual-situated learning events concerning heat transfer were chosen both to help students construct Mental Sets 2–7 (Appendix A) and to create dissonance. The first dual-situated learning event was designed to allow students to observe what would happen to the water temperature after a heated screw was immersed into water. This enabled students to understand the process of heat conduction to facilitate their construction of Mental Sets 2 and 3. The second dual-situated learning event involved putting a cold water bottle on top of a hot water bottle, which helped students create dissonance with their prior knowledge and construct Mental Sets 4 and 5. The third dual-situated learning event was the reverse of the second event: that is, a hot water bottle was placed atop a cold water bottle, which created dissonance with students' Mental Sets 2–5 and further helped them construct Mental Sets 6 and 7. The fourth, fifth, and sixth dual-situated learning events involved adding cold water to hot water, adding saltwater to hot water, and heating the water in the flask with a capillary tube, respectively. These events were purposely designed to facilitate students' construction of Mental Sets 6 and 7.

*Stage 5 (S5): Instructing with Dual-Situated Learning Events.* Stage 5 presents dual-situated learning events which challenge students' epistemological and ontological beliefs of science concepts. Before the dual-situated learning events were presented, students were asked to predict what would happen and provide an explanation for their prediction. After the presentation or demonstration of the events, students were asked to explain why the events were different from their prior epistemological and ontological beliefs and to reconstruct a more scientific view of the concepts according to the events presented. To understand the process of students' conceptual change, they were asked to think aloud during the process of making predictions and providing explanations before and after events. Students' responses were transcribed for further analysis.

*Stage 6 (S6): Instructing with Challenging Situated Learning Event.* The last stage presented challenging situated learning events, which provided an opportunity for students to apply to a new situation the mental sets they had acquired, to ensure that successful conceptual change had occurred.

The previous six discrepant events were chosen and designed to help students visualize and observe changes due to heat convection and conduction, and to gain a better understanding about the matter, process, and hierarchical attributes of heat transfer via convection and conduction. The challenging situated learning event was putting a hot water beaker into a cold water beaker. This event served to check whether students could apply Mental Sets 2–7, which they learned from the previous six events, to the new situation.

## Results

Table 3 presents the nature and percentage of students' alternative conceptions of heat transfer that changed from before to after the intervention of each dual-situated learning event from 1 to 6 and challenging situated learning event.

### *Dual-Situated Learning Event 1*

Before Dual-Situated Learning Event 1, 74.7% of students (see Table 3, Dual-Situated Learning Events 1, 1a, 1b, 1c, and 1f) held the view that after the heated screw was immersed into the water, the water temperature would increase owing to heat transfer via conduction. In addition, 45.1% (1a and 1b) suggested that solid materials transfer heat through conduction, but none of the students explained the process of conduction. In this event, small pieces of wood were added to the water to indicate the movement of water molecules. The following excerpts, representative of the types of responses of 45.1% of students (1a and 1b), are given below.

> Interviewer (I): Could you predict what would happen to the temperature of water after immersing a heated screw?
> Student (S) 1: I think the temperature of water would increase.
> I: Why do you think so?
> S1: Because the heated screw would transfer heat to water. It transfers heat via conduction. Solid materials transfers heat via conduction, and water transfers heat to water via convection.

After the event was presented, about 95.6% of students (1b, 1d, 1e, and 1f) changed to believe that heat is transferred via conduction. Among them, 74% reported that they observed the wood pieces did not move, implying no movement of water molecules, so no convection was involved. The following excerpts represent the types of responses of 74% of students (1d).

Table 3
*Students' alternative conceptions of heat transfer before and after intervention with Dual-Situated Learning Events 1–6 and challenging situated learning event*

| | Students (%) | |
|---|---|---|
| Alternative Conception | Before Event | After Event |
| Dual-Situated Learning Event 1 | | |
| 1. The temperature would increase because of heat conduction | | |
| a. Solid material transfers heat via conduction. | 4.4 | 0 |
| b. The heated screw transfers heat to water which absorbs the heat of the metal. In addition, solid material transfers heat via conduction. | 40.7 | 11.1 |
| c. The temperature of the water and the heated screw will reach equilibrium. | 7.4 | 0 |
| d. Because the small pieces of wood do not move around, the heated screw transfers heat through conduction. | 0 | 74.0 |
| e. Heat will move from the hot region to the cold region. | 0 | 4.4 |
| f. No further explanation. | 22.2 | 4.4 |
| 2. The temperature would increase because of heat convection. | | |
| a. The heated screw transfers heat to water. | 14.8 | 0 |
| 3. The temperature increases because of heat conduction and convection. | 7.4 | 0 |
| 4. The temperature would increase because of heat radiation. | | |
| a. The heated screw transfers heat to water via radiation. | 0 | 4.4 |
| 5. The temperature would stay the same. | 4.4 | 0 |
| Dual-Situated Learning Event 2 | | |
| 1. It would transfer heat via convection. | | |
| a. Hot water would rise, cold water would sink, and then mix together. | 66.6 | 92.6 |
| b. The water stays separated; there is no change. Only a little heat change is involved. | 3.7 | 0 |
| c. There is no relationship between the positions of the hot and cold water. | 7.4 | 0 |
| d. No further explanation. | 14.8 | 0 |
| 2. There is no heat transfer. | | |
| a. The water would not move. | 7.4 | 0 |
| 3. Do not know. | 0 | 7.4 |
| Dual-Situated Learning Event 3 | | |
| 1. It would transfer heat via conduction. | | |
| a. The water would not move; heat is transferred at the surface of the hot and cold water via conduction, and heat would sink downward. | 11.1 | 0 |
| b. Heat is transferred at the surface of the hot and cold water via conduction; the water finally would mix together; however, it would not happen in a short time. | 7.4 | 85.2 |
| 2. It would transfer heat via convection. | | |
| a. The water would not move; the heat would start to transfer at the surface. | 3.7 | 0 |
| b. The density of hot water is smaller than that of cold water, so hot water would not sink. | 3.7 | 0 |
| c. The cold water would rise and hot water would sink, and the water would mix together. | 48.1 | 0 |
| d. The cold water would rise and hot water would sink, which has nothing to do with the position of hot and cold water. | 7.4 | 3.7 |
| 3. There is no heat transfer. | | |
| a. The water would not move; therefore, there is no heat transfer; the water would stay the same | 14.8 | 11.1 |
| 4. It would transfer heat via heat conduction and heat convection. | | |
| a. Heat transfer is via conduction; after removing the plate away, it is via heat convection. | 3.7 | 0 |

(*Continued*)

Table 3
(*Continued*)

| | Students (%) | |
|---|---|---|
| Alternative Conception | Before Event | After Event |
| Dual-Situated Learning Event 4 | | |
| 1. Cold water added would disappear at the hot water surface. | | |
| a. The cold water added would absorb heat from hot water and become part of hot water. | 3.7 | 0 |
| b. The density of cold water is the same as that of hot water. | 18.5 | 0 |
| c. There is no relation with density. | 3.7 | 0 |
| d. No further explanation. | 25.9 | 0 |
| 2. Cold water added would sink quickly. | | |
| a. The cold water added would sink because of heat convection. | 3.7 | 0 |
| b. It is because the density of hot water is smaller than that of cold water. | 40.7 | 64.0 |
| c. It is because the density of cold water is smaller than that of hot water. | 3.7 | 0 |
| d. The density of cold and hot water are the same. | 0 | 14.8 |
| e. No further explanations. | 0 | 21.2 |
| Dual-Situated Learning Event 5 | | |
| 1. Saltwater added would disappear at the water surface. | | |
| a. It would dissolve and has nothing to do with density. | 11.1 | 0 |
| 2. Saltwater added would sink. | | |
| a. The density of saltwater is greater than that of water. | 77.7 | 100 |
| 3. Nothing happens. | 3.7 | 0 |
| 4. Do not know. | 7.4 | 0 |
| Check students' understanding of Dual-Situated Learning Events 4 and 5 | | |
| 1. Hot water density is smaller than cold water density. | | |
| a. The temperature of cold water is lower, so the density is greater than that of hot water. | 3.7 | |
| b. The volume of cold water is less, so the density is greater than that of hot water. | 3.7 | |
| c. The cold water would sink. | 55.5 | |
| d. No further explanation. | 14.8 | |
| 2. Cold water density is less than hot water density. | 7.4 | |
| 3. Do not know | 11.1 | |
| 4. The density of both cold and hot water are the same. | 3.7 | |
| Dual-Situated Learning Event 6 | | |
| 1. Water level would rise because of heat expansion. | | |
| a. The volume of water would expand when heated and shrink when chilled. | 48.1 | 0 |
| b. The volume of water would expand while heated, thus decreasing the density; therefore, the density of hot water is smaller than that of cold water. | 0 | 100 |
| c. The volume of flask is limited; the water would expand and rise when heated and shrink when chilled. | 3.7 | 0 |
| 2. Water level would rise because of temperature changes. | | |
| a. The temperature increases. | 3.7 | 0 |
| b. Because it is heated. | 11.1 | 0 |
| c. The temperature increases; the density becomes smaller. | 3.7 | 0 |
| 3. Water level would rise. | 3.7 | 0 |
| 4. Water level would sink because of heat expansion. | | |
| a. The flask would first expand and the water would then expand. | 18.5 | 0 |
| b. No further explanation. | 7.4 | 0 |
| Challenging situated learning event | | |
| 1. It would transfer heat via convection. | | |
| a. The hot water would rise and cold water would move into the hot water beaker. | 3.7 | |
| b. The hot water would rise and cold water would sink. | 7.4 | |
| c. The density of hot water is smaller than that of cold water; therefore, hot water would rise and cold water would sink, thus forming convection. | 70.3 | |

Table 3
(*Continued*)

| | Students (%) | |
|---|---|---|
| Alternative Conception | Before Event | After Event |
| 2. It would transfer heat via conduction. | | |
| a. The hot water would rise. | 3.7 | |
| b. The hot water would rise because the density of cold water is greater than that of hot water. | 3.7 | |
| 3. It would transfer heat via heat conduction and convection. | | |
| a. The hot water would mix with cold water; high temperature would go into cold water. | 3.7 | |
| b. The heat convection refers to the transfer of heat from the hot to cold region that occurs between the regions of hot and cold water, while that elsewhere is via heat conduction. | 3.7 | |
| c. The heat conduction occurs around the hot water beaker; it would move toward the cold place. Heat convection will cause the hot water to move upward and the cold water to move downward because hot water has a lower density than cold water. | 3.7 | |

I: You have found that the temperature measured by the thermometer increases, and could you explain why would water temperature change after immersing a heated screw?
S1: The temperature indeed increases. It transfers heat via conduction.
I: Why do you think so?
S1: I think it is because the small pieces of wood did not move around.

Students attributed the transfer of heat from the hot screw to conduction, which indicates that students can understand the process of heat conduction. They came to realize that the molecules are fixed and cannot move, so heat can only be transferred via conduction.

### *Dual-Situated Learning Event 2*

Dual-Situated Learning Event 2 investigated what students thought would happen to the water after removing the plastic plate between the two bottles, with the cold water bottle on top of the hot water bottle. Before the event was presented, about 92.6% of students (see Table 3, Dual-Situated Learning Events 2, 1a, 1b, 1c, and 1d) thought heat was transferred via heat convection, and only 66.6% (1a) thought hot water would rise and cold water would sink, mixing together; the rest of the students held different explanations. The following excerpts represent the types of responses of 7.4% out of 92.6% of students (1c).

I: Could you predict what type of heat transfer is involved after removing the plastic plate between two bottles, a cold water bottle on top of a hot water bottle?
S2: I think heat transfers via convection.
I: Why do you think so?
S2: They will mix together, and it does not have to do with the position of hot and cold water.

After the event was presented, 92.6% of students still believed that heat transfer was via convection; however, all of them changed their answer to state that hot water would rise and cold water would sink, so eventually the two would be mixed together. The following excerpts are representative of the types of responses from 92.6% of students (1a).

> I: You have found that the hot water rises, cold water sinks, and then mix together. Could you explain what type of heat transfer is involved?
> S2: I think it is heat convection because hot water rises, cold water sinks, and they finally mix together.

This indicates that most students understood the process of heat convection when molecules can move from one place to the other, thus transferring heat via convection.

### *Dual-Situated Learning Event 3*

Dual-Situated Learning Event 3 examined what students thought would happen to the water after removing the plastic plate between the two bottles, with the hot water bottle on top of the cold water bottle. Before Event 3 was presented, about 18.5% of students (see Table 3, Dual-Situated Learning Event 3, 1a and 1b) thought heat was transferred via conduction, 62.9% believed it to be via heat convection (2a, 2b, 2c, and 2d), and 14.8% stated there was no heat transfer (3a). The following excerpts represent the types of responses of 48.1% out of 62.9% of students (2c).

> I: Could you predict what type of heat transfer is involved after removing the plastic plate between two bottles, with a hot water bottle on top of a cold water bottle?
> S3: I think heat transfers via convection.
> I: Why do you think so?
> S3: I think hot water would sink; cold water would rise and then mix together. This is heat convection.

After the event was presented, 85.2% of students (1b) believed heat transfer was via conduction and stated that conduction would occur at the surface between cold and hot water, which would finally mix together but not within a short time. The following excerpts represent the types of responses of 85.2% of students (1b).

> I: You have found that only the surface of hot and cold water has a little interaction. Would you explain what type of heat transfer is involved?
> S3: I guess it is heat conduction because cold water with dye does not rise and mix with hot water immediately. In addition, only the surface of hot and cold water has a little interaction. It should not be heat convection.

This shows that these students believed liquid can transfer heat via conduction, depending on whether the molecule is fixed or movable.

### *Dual-Situated Learning Events 4 and 5*

As seen in Table 3, before Events 4 and 5, about 48.1% and 77.7%, respectively, of students believed that added cold water and saltwater would sink quickly (see Table 3, Dual-Situated Learning Event 4, 2a, 2b, and 2c; and Dual-Situated Learning Event 5, 2a). Moreover, 40.7% and 77.7%, respectively, of students explained that the density of cold water was greater than that of hot water (2b), and that the density of saltwater is greater than that of water (2a). The remaining 51.9% of students believed that cold water would disappear at the hot water surface (1a, 1b, 1c, and 1d). The following excerpts represent the types of responses of 18.5% out of 51.9% of students (1b).

> I: Could you predict what would happen if cold water is added to hot water?
> S4: I think it would disappear while cold water is added to the hot water.
> I: Why do you think so?
> S4: It is because they all are water, so the density of cold and hot water are the same.

After the events, 64% and 100% of students believed cold water and saltwater would sink quickly, and they all attributed such an observation to the greater density of cold water and saltwater (2b and 2a). The following excerpts represent the types of responses of 64% of students (2b).

> I: You have found that cold water added would sink quickly. Could you explain why?
> S4: I think it's just like the density of saltwater is greater, thus it sinks. So the density of hot water is less than cold water, so cold water added would sink quickly.

Right after Events 4 and 5, students were asked to predict the relative densities of cold and hot water to check their understanding about Dual-Situated Learning Events 4 and 5. As shown in Table 3, 77.7% of students believed the density of hot water was less than that of cold water (1a, 1b, 1c, and 1d). About 7.4% said that the temperature of cold water is lower or the volume of cold water is smaller, so its density is greater (1a and 1b), whereas 55.5% simply said that cold water would sink (1c). This indicates that these students did not yet have a firm grasp of the notion of the relative densities of cold and hot water and did not understand why the density of cold water is greater than that of hot water. Therefore, the following events were provided to reinforce this concept.

### *Dual-Situated Learning Event 6*

Dual-Situated Learning Event 6 tested what the students believed would happen to the water level of the flask when heated. Before the use of this event, about 74.1% of students thought the water level would rise (see Table 3, Dual-Situated Learning Event 6, 1a, 1c, 2a, 2b, 2c, and 3). About 51.8% believed the volume of water would expand when heated and shrink when chilled (1a and 1c); the others thought the temperature would increase (2a, 2b, and 2c). Their explanations show they only had an understanding of expansion due to heat, without considering that the volume of water would increase and the density would decrease as the temperature increased. The following excerpts represent the types of responses from 48.1% of students (1a).

> I: Could you predict what would happen to the water level of the capillary tube when the flask is heated?
> S5: I think the water level would rise because of heat expansion.
> I: Why do you think so?
> S5: I think the volume of water would expand when heated and shrink when chilled.

After the event, almost all students believed the water level would finally rise because the volume of water would expand when heated, thus decreasing the density. This is why the density of hot water is smaller than that of cold water. The following excerpts represent the types of responses of almost all students (1b).

> I: You have found that the water level rises. Could you explain why?
> S5: I think that the water level rises after being heated means that the volume of water increase while heated, thus the density of hot water would decrease.
> I: Which density is less? Hot water or cold water?
> S5: The density of hot water should be less than cold water.

This indicates that all of the students not only believed that the density of cold water was greater than hot water, they also understood the reasons.

### *Challenging Situated Learning Event*

As seen in Table 3, before the challenging situated learning event was presented, 81.4% of students believed that heat was transferred via convection (see Table 3, Challenging Situated Learning Event 6, 1a, 1b, and 1c). About 70.3% explained that the density of hot water is smaller than that of cold water, so hot water would rise and cold water would sink, thus forming convection (1c). About 11.1% simply described that hot water would rise and cold water would sink or become mixed with the hot water (1a and 1b). About 7.4% (2a and 2b) believed that heat transfer was via conduction and explained that hot water would rise because the density of cold water was greater than that of hot water. The remaining 11.4% believed that both heat conduction and convection were involved in this process (3a, 3b, and 3c). The following excerpts represent the types of responses of 70.3% of students (1c).

> I: Could you predict what would happen when a hot water beaker is put into a cold water beaker, and what type of heat transfer is involved?
> S6: I think hot water would rise and cold water would sink, thus forming convection.
> I: Why would you think so?
> S6: It is because the density of hot water is less than cold water. Therefore, it transfers heat via convection.

This clearly indicates that 81.4% of students could apply their mental sets acquired from previous events to this challenging event.

## Conclusions

This study has found evidence that the use of DSLM indeed facilitates the conceptual change of heat transfer among students. Careful examination of the process involved in the conceptual change reveals how students progressed from preknowledge toward a more scientific view of the concepts. Before the intervention, analysis of students' beliefs concerning heat transfer showed most of the students possessed only matter knowledge about heat, heat transfer, conduction, and convection. None could describe the process of heat conduction or heat convection, or explain when and why the substance would transfer heat via conduction or convection. After the intervention, a series of six dual-situated learning events and one challenging situated learning event successfully helped students reconstruct a more scientific view of heat conduction and convection.

After Dual-Situated Learning Events 1 and 2, 92–95% of students could correctly describe the processes of heat conduction and heat convection. After they visualized Dual-Situated Learning Event 3, 85.2% of students started to believe that heat could also be transferred via conduction in liquid, and were able to describe the process of heat conduction in liquid. After Dual-Situated Learning Events 4 and 5, 64% of students were able to attribute the sinking of cold water to its greater density. Immediately after Events 4 and 5, a question was posed to check students' beliefs concerning the relative density of cold and hot water. About 77.7% of students believed the density of hot water is smaller than that of cold water, whereas the rest of the students were not sure. However, the major problem is that all of them do not really understand why the density of cold water is greater than that of hot water. Therefore, Dual-Situated Learning Event 6 was given. After that, all of the students were able to explain that the volume of water would expand when heated, thus decreasing its density; and therefore, that the density of hot water is smaller than that of cold water. After the instruction of the challenging situated learning event, about 81% of students stated correctly that heat was transferred via convection when the hot water beaker was put into the cold water beaker. More important, about 70% of them were able to attribute the observed phenomenon to the smaller density of hot water than that of cold water; therefore, hot water would rise and cold water would sink. These properties would determine when and why heat transfer is by conduction or by convection.

This study demonstrates how instruction using these six dual-situational learning events helped students successfully construct seven mental sets concerning the matter, process, and hierarchical attributes of heat transfer. In particular, explanations offered by the students provided further evidence of how students' ontological and epistemological beliefs concerning heat transfer via conduction and convection changed and progressed from event to event. Moreover, use of the challenging situated learning event demonstrated how students successfully applied the concepts they constructed from the previous events to the new event.

## Discussions and Implications

The most significant question to be asked of the present model would be, is DSLM just another conceptual change model? A response to this question is by no means simple. DSLM is different in its underlying theoretical framework and forms well-established stages in bringing about conceptual change. First, it emphasizes that conceptual change should be built on both the nature of science concepts and students' beliefs of science, rather than only one of them. These provide specific information about which specific mental sets the students lack and which serve as the basis for designing appropriate dual-situated learning events to foster conceptual change. Second, the design of the dual-situated learning event needs to fulfill two requirements: creating dissonance and providing new mental sets rather than just creating dissonance. Students would not simultaneously build a new mental set while they dissatisfy their own conceptions unless we carefully design the event which contains both functions we described above. In addition, this model also emphasizes that the design of events must be able to challenge students' personal epistemology and ontological beliefs concerning the concepts, and motivate students' willingness and interest to engage in the conceptual change process. Third, DSLM emphasizes the idea that conceptual change cannot be achieved by using a single event. Instead, it requires a series of well-designed dual-situated learning events embedding a series of mental sets, particularly when the science concept involves the understanding of higher hierarchical level of concepts or concepts of more than one attribute, such as matter and process.

The DSLM is clearly a well-developed instructional model for facilitating students' conceptual change. Moreover, this model has previously been successfully tested in various concepts, such as air pressure and buoyancy (She, 2002), and thermal expansion (She, 2003). This empirical study further demonstrates that even radical conceptual change such as heat transfer can be successfully changed through the use of DSLM instruction. More important, it shows that conceptual change is not necessarily a slow and gradual process, and conceptual change can be achieved within a short time through the use of DSLM.

One limitation of this study is that DSLM is employed based on interviews. An important question is whether the present model can also bring about conceptual change among students when implemented in classroom teaching. A previous study (She, 2003) provided evidence that conceptual change involving thermal expansion can occur using DSLM in classroom instruction. The teacher involved in that study indicated that students were indeed motivated to learn science out of curiosity aroused by events that created dissonance, in addition to developing new mental sets. This is encouraging because none of the other models and strategies of conceptual change have reported the same success in promoting students' conceptual change as the DSLM.

The next question might be how classroom teachers can adopt this model for conceptual change? According to experience working with science teachers, once teachers realized how to analyze the nature of science concepts, conceptual change occurred. The key to analyzing the nature of science concepts is to grasp the major concepts first, and then to think about what other essential underlying concepts (mental sets) are needed to understand these major concepts. The other point is how to probe students' misconceptions; there are many alternative ways of doing this. For example, the teacher may form questions based on the results of nature of science concept or searching other two-tier tests available. Once teachers are able to identify what essential mental sets students lack, they will be able to design dual-situated learning events. This suggests that several teachers working together in a group will be better able to design a series of successful dual-situated learning events, as well as provide challenging situated learning events. The criteria and format of designing and instructing dual situated learning events have been clearly provided in this study. Moreover, the events chosen would better provide learners with opportunities to visualize the observable changes of substances, thus facilitating their understanding of both the process and matter of science concepts. During instruction, teachers should require all students to fill out worksheets to ensure that each student is actively involved in the overall process of creating dissonance, challenging beliefs of science concepts, increasing motivation, and building new mental sets. It also can bring about more successful conceptual change if teachers try to bring students back to whole classroom discussion once they have finished each dual-situated learning event, and remind students of what they have experienced in the earlier events. The successful results of this empirical study suggest that teachers should be encouraged to integrate the DSLM instructional approach into their classroom teaching to promote conceptual change among students.

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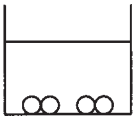
## Appendix A

### *Dual-Situated Learning Events for Instruction on Heat Transfer*

(1) First dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what would happen to the temperature of water after immersing a heated screw. Why?



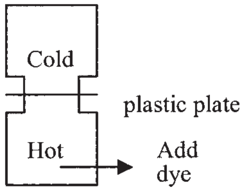
Sep 2 (After visualizing the event)

Ask students to explain why the temperature of water would change after immersing a heated screw.

(2) Second dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what type of heat transfer is involved after removing the plastic plate between two bottles, a cold water bottle on top of a hot water bottle. Why?



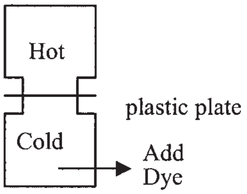
Step 2 (After visualizing the event)

Ask students to explain why that type of heat transfer is involved after removing the plastic plate between two bottles, a cold water bottle on top of a hot water bottle.

(3) Third dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what type of heat transfer is involved after removing the plastic plate between two bottles, a hot water bottle on top of a cold water bottle). Why?



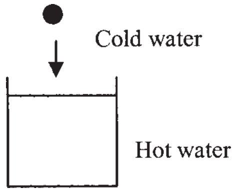
Step 2 (After visualizing the event)

Ask students to explain why that type of heat transfer is involved after removing the plastic plate between two bottles, a hot water bottle on top of a cold water bottle).

(4) Fourth dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what would happen if cold water is added into hot water. Why?



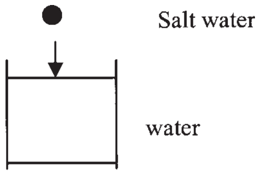
Step 2 (After visualizing the event)

Ask students explain why the cold water added would sink quickly to the bottom of hot water quickly.

(5) Fifth dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what would happen if salt water is added into water. Why?



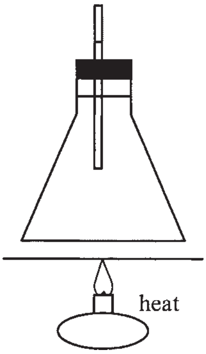
Step 2 (After visualizing the event)

Ask students to explain why the salt water added would sink quickly to the bottom of the water.

(6) Sixth dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what would happen to the water level in the capillary tube when the flask is heated. Why?\



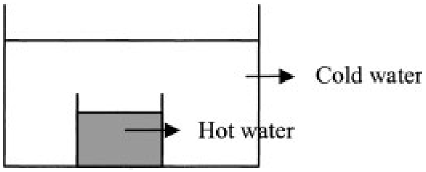
Step 2 (After visualizing the event)

Ask students to explain why the water level in the capillary tube would change when the flask is heated

(7) Challenging dual situated learning event for heat transfer

Step 1 (Before the event)

Ask students to predict what would happen when a hot water beaker is put into a cold water beaker, and what type of heat transfer is involved. Why?



Step 2 (After visualizing the event)

Ask students to explain why that type of heat transfer is involved when a hot water beaker is put into a cold water breaker.

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