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A Conceptual Change Model for Teaching Heat Energy, Heat Transfer and Insulation

C. K. LEE*

ABSTRACT: This study examines the existing knowledge that pre-service elementary teachers (PSETs) have regarding heat energy, heat transfer and insulation. The PSETs' knowledge of heat energy was initially assessed by using an activity: determining which container would be best to keep hot water warm for the longest period of time. Results showed that PSETs could not explain the concept of insulation and heat transfer. Moreover, they held the misconception that a container deemed best to keep water warm would not be the best container to keep ice cream cold. To reconcile the misconceptions of PSETs, the researcher used the ED3U Conceptual Change Model (McComas, 1995) integrated with Posner, Strike, Hewson and Gertzog's (1982) conditions for accommodations for the designed instruction and discussions. Results show PSETs can understand the concepts better when analogy and daily life experiences are used.

KEY WORDS: Science misconception, heat energy, insulation, practical task, conceptual change

INTRODUCTION

Most pre-service elementary teachers (PSETs) learned about heat energy when they were at secondary school. But how many of them fully understand the concept of heat energy, heat transfer and insulation? When PSETs in a science methods class were asked the question - Is there any heat energy in ice? - Many responded negatively. The common failure to understand heat energy by elementary teachers and students seemed to be due to the prevalent assumption that cold substances do not have heat energy. This study examines PSET's existing knowledge on heat energy, heat transfer and insulation by using several hands-on and minds-on activities. The misconceptions of PSETs are reconciled using the ED^{3}U Conceptual Change Model (McComas, 1995) integrated with Posner, Strike, Hewson and Gertzog's (1982) conditions for accommodation.

McComas (1995) proposed the ED^{3}U Concept Change Model. Though the model is listed as a mathematical equation it is not a linear process. It is represented as follows:

* University of Maine at Farmington, 186 High Street, Farmington, ME 04938, USA, email: carole.lee@maine.edu

ED^3U = **E**xplore + **D**iagnose + **D**esign + **D**iscuss +**U**se

The model consists of five iterative phrases and the process can move forward or backward depending on the perceptions and understanding of students. The first phase is teachers diagnosing students' personal understanding and prior knowledge toward a phenomenon by allowing them to explore the phenomenon freely using hands-on activities. Students' concepts toward the phenomenon are revealed through class discussions or written artefacts. It is vital for teachers to understand how students perceive the concepts: Do students fully understand the concepts or do they have misconceptions? This diagnostic stage is for teachers to know the thinking of the students and to see if the preconceptions of students fit with the concepts or not fit with what they are going to learn. From the gathered information indicating how much students know, not know or are confused about the concepts, teachers can target the appropriate teaching pedagogies. Teachers can design and provide students with further hands-on activities to challenge students' current or limited knowledge. At the end of the stage, students are expected to acquire the new knowledge and to apply the knowledge learned to a new situation, and at the same time students' misconceptions are reconciled.

Students who have misconceptions need to undergo a conceptual change process before they can acquire the new knowledge. The existing conception held by the student needs to be challenged and restructured, often away from an alternative or misconception and toward the dominant conception held by experts in the field (Chi & Roscoe, 2002). Posner, Strike, Hewson and Gertzog (1982) state that to reconstruct students' conceptual frameworks they have to be dissatisfied with the existing concepts; and accept the new conceptions that are intelligible, plausible and fruitful.

In the "Explore" stage of the ED^3U Conceptual Change Model, the researcher employed for PSETs one of the 1997 TIMSS (Third International Mathematics and Science Study, Harmon et al., 1997) practical tasks for fourth graders as the lead activity. The TIMSS practical tasks were seen as a good teaching resource as the activities integrate science content knowledge with practical skills. During the analysis of results, PSETs were faced with cognitive and affective conflicts as various containers were identified by their classmates. Using different but related activities, the researcher diagnosed the preconceptions and misconceptions of the PSETs. A variety of instructional designs, such as hands-on activities, discussions, assessment probe, and interviews were used in order for PSETs to be aware of their misconceptions and to construct their own correct science concepts.

Feedback from the PSETs showed their misconceptions were reconciled mainly through discussion with classmates and also through individual interviews with the researcher. Watson and Konicek (1990) stated that the substitution of one theory for another in the conceptual change process was difficult and it was "not as easy as erasing the chalkboard." In this study, the researcher allowed the PSETs to explore their misconceptions on heat energy, how misconceptions could be changed and how science concepts could be taught in an interesting way. Most importantly, PSETs through their own learning experience realized the reconciliation of misconceptions was crucial in helping students construct the relevant science knowledge.

The purpose of this study is to reconcile the misconceptions PSETs have on heat energy using the ED^{3}U Conceptual Change Model integrated with the conditions for accommodation. At the same time, the researcher wants PSETs to learn the instructional strategies for teaching conceptual change. The study is guided by the following research questions:

1. What conceptions do PSETs hold about the concept of heat energy, heat transfer and insulation?
2. What misconceptions do PSETs have?
3. Can the PSETs misconceptions be reconciled? If so, in what way?

(No research question related to the usefulness of the ED^{3}U model)

LITERATURE REVIEW

Research on science misconceptions and pedagogy of conceptual change were popular in 1970s. Since then, various terminologies have been used for misconception, such as naive concepts (Pine, Messer, & St. John, 2001); preconceptions (Benson, Wittrock & Baur, 1993); alternative views (Gabel, Stockton, & Monaghan, 2001; Loughran, 2007); and alternative conceptions (Hewson & Hewson, 2003). For simplicity, this paper used misconception as this was commonly known by teachers. In this study, the researcher adopted Keeley's explanation of misconceptions which is the "pre-existing ideas held by students that are contrary to modern scientific thinking about the natural world" (Keeley, 2012).

After 40 more years, science misconceptions still existed among teachers and students (Gomez-Zwiep, 2008; LoPresto & Murrell, 2011) because misconceptions were "highly robust" (Viennot, 1979) and not easy to dispel. Studies by Viennot (1979) and Driver (1973) showed that erroneous beliefs of personal experiences led to the formation of misconceptions. For example, personal experiences demonstrated that the sun was moving instead of the earth, and a heavy object fell faster than a light object. Yet, based on the Copernicus's theory, it has been believed that the Sun was stationary and the Earth was revolving around the Sun. Similarly, based on Newton's theory on gravity, people believed that a heavy object and a light object land on the ground at the same time, without taking into consideration the effect of air resistance. The possession of misconceptions hindered the progress of science learning (Bransford, Brown, & Cocking, 2000; Donovan & Bransford, 2005; Duit & Treagust, 2003) and the longer a misconception was not challenged, the more likely it was rooted in one's brain (Gooding & Metz, 2011). Misconceptions were not just misunderstandings of a concept, but involved many interrelated concepts that a person could use to explain a phenomenon (Southerland, Abrams, Cummins & Anzelmo, 2001; Gooding & Metz, 2011). If students could grasp the concepts correctly, they were expected to be able to extend the knowledge within and beyond the specific context. Allen and Coole (2012) stated elementary teachers were the "first line of defence" to help children from acquiring the science misconceptions. In reality, many science abstract concepts were challenging to elementary teachers, because they lacked scientific understanding and confidence (Jarvis, Pell, & McKeon, 2003; Lindgren, 2003; Pine, Messer, & St. John, 2001).

Epistemologically, conceptual change in science can be divided into two phases. Lakatos (1970) states that a theory needs to be rejected when it generates problems which cannot be understood, or explained. Gradually, a new theory develops to replace the old, provided the new theory can solve the problem or can be further investigated. Applying Lakatos's theory to a classroom learning situation, it means that students, if they find their existing concepts cannot fit into the explanation of a phenomenon, they modify their existing concepts to deal with the new phenomena. Posner et al. (1982) refers to this kind of conceptual change as assimilation; whereas Duit and Treagust (2003) considers the conceptual change as conceptual capture or weak knowledge restructuring since it needs only a slight adjustment. The further phase of conceptual change requiring a strong and radical restructuring of knowledge is called conceptual exchange, or accommodation (Duit & Treagust, 2003). In this modification, the learner's current concepts are inadequate to understand the new concept and the learners need to reorganize or replace their existing concepts based on their "conceptual ecology" (Toulmin, 1972). The "conceptual ecology" is the concept which governs the conceptual change and it incorporates different kinds of knowledge the learner holds, such as anomalies, analogies and beliefs (Isabelle & de Groot, 2008). According to Posner et al. (1982), four conditions are essential for the conceptual change. First, students must be dissatisfied with their existing conceptions; and the new concepts must be intelligible, plausible and finally, have the potential to be further investigated.

Misconceptions can be dispelled by confronting students with contradictory evidence. Watson and Konicek (1990) describe a study in which students misunderstand that their hats and sweaters can produce heat because students base their thinking on their own winter experience.

To change children's misconceptions, it seems teachers need to confront the deceptive preconceptions of students by allowing them to undertake hands-on activities, and letting them realize the discrepancies that occur. Nevertheless, a barrier seems to come from one's stubbornness and the trusting lifelong convictions which supersede one's logical reasoning. Under such circumstances, teachers cannot expect students to change their old ideas, even if contradictory evidence has been shown. It is human nature to refuse to admit the errors or beliefs that one has held for such a long time. A video documentary, Minds of Our Own (Harvard-Smithsonian Centre for Astrophysics, 1997), shows a middle school student persistently saying that she can still see the apple in total darkness even though she fails to see it in an authentic situation. She has a strong conviction that she can see the apple when her eyes get used to the environment of complete darkness.

Another factor that contributes to misconceptions is the vernacular usage versus the scientific usage of non-scientific terms (Keeley, 2012; Rosebery, Ogonowski, DiSchino & Warren, 2010; Watson & Konicek, 1990). The term "heat" in the science world is considered as a measurable quantity existing in all objects (Hawkins, 1978; Rosebery et al., 2010). On the other hand, heat is preconceived as a sensory function of "hot" or "cold" for most people, especially children. Thus, the perception of heat as temperature felt by the human body conflicts greatly with the scientific concept of heat which is considered an abstract quantity.

METHODOLOGY

Participants

A pilot study was conducted in 2011 with 14 PSETs in an elementary science methods class to assess the suitability of the science knowledge and the process skills of a practical task. The practical task was to investigate which container kept hot water warm for the longest period of time. A follow-up study that included the same practical task with the addition of pre- and post-assessment, use of an assessment probe and interviews was carried out in 2012 with 20 PSETs. Like the 2011 group, the 2012 group also undertook a practical task and answered five questions based on the data collected. In order to have an in-depth understanding of the heat energy concept of the PSETs in the 2012 group, an assessment probe was adopted to diagnose further their concept of heat energy and heat transfer. Individual interviews with all 20 PSETs in the 2012 group were conducted. The interview questions were based on the responses of the PSETs on the practical task, assessment probe and observations made by the researcher during their class discussions.

Assessment Instruments

Several assessment instruments were designed to diagnose the preconception of the PSETs and to assess whether they had fully acquired the concept of heat energy, heat transfer and insulation. The instruments used were:

Pre- and Post-assessment Quiz

A pre- and post-assessment quiz which consisted of three questions was given to the 2012 group at the beginning and end of the semester. The three questions were:

1. Tell me what you know about energy.
2. Can energy be created or destroyed? Please justify your answer by what you know or have learned from your experience.
3. If your answer is ‘yes’ to question 2, tell me the kind or type of energy that can be created or destroyed.

Practical Task

The practical task instrument is an adaptation of the 1997 TIMSS Performance Assessment for fourth grade students. It assesses students’ ability to observe and record measurements of temperature while probing the understanding of the concept of insulation. The researcher believes that if such performance assessment is given to fourth grade elementary students, it is imperative that elementary science teachers need to have a solid base in the assessed knowledge and skills. The practical task is to determine which container is best for keeping hot water warm for the longest time. For this the PSETs are given three cups made of different materials - porcelain, foam and paper. Instructions for the set up and all necessary materials for doing the practical task are provided (Appendix 1). The tasks of the PSETs are to record the temperature of the hot water in each container over a ten-minute interval and to answer the questions.

Assessment Probe

An assessment probe, Ice-Cold Lemonade (taken from Uncovering Student Ideas in Science, Vol.2 by Keeley, Eberle, & Tugel, 2007) was administered two weeks after the discussion of the practical task. The Ice-Cold Lemonade assessment probe described the phenomenon of heat transfer in a cup of ice-cold lemonade. Below is given a description of the assessment probe. PSETs needed to choose the best option for the explanation.

> It was a hot summer day. Mattie poured herself a glass of lemonade. The lemonade was warm, so Mattie put

some ice in the glass. After 10 minutes, Mattie noticed that the ice was melting and the lemonade was cold. Mattie wondered what made the lemonade get cold. She had three different ideas. Which idea do you think best explains why the lemonade got cold?

A. The coldness from the ice moved into the lemonade.
B. The heat from the lemonade moved into the ice.
C. The coldness and the heat moved back and forth until the lemonade cooled.

After the explanation, PSETs were given two more questions. They were:

1. Explain your thinking for the explanation option you have chosen. Describe the "rule" or reasoning you used for your answer.
2. Is there any heat energy in the ice cubes?

Interview

The researcher decided to hold a one-on-one interview with all 20 PSETs in the 2012 group as they showed inconsistency in the data treatment. The purpose of the individual interviews was to give the researcher the opportunity to understand the cause of the PSETs' misconceptions. The interview was semi-structured and the questions, listed below, were related with the practical task and the assessment probe.

1. What determined your prediction related to which container was the best to keep hot water warm for the longest period of time?
2. How did you treat your recorded data?
3. What guided your thinking about which container could keep hot water warm the longest time?
4. What does the word 'insulation' mean to you?
5. How did you feel when you found your response was different from your classmates?
6. Tell me your feelings during the class discussions when you realized your conceptions of energy were different from your classmates.

FINDINGS

Pre- and Post-assessment Quiz

The pre-assessment quiz reviews the existing knowledge and misconceptions that PSETs possessed. One PSET wrote "Energy is a force. A force is the ability to do work. Energy can be captured and made to power many different things." In fact, several PSETs confused "energy" with "force." Some PSETs believed that energy could be created and they gave examples like "creating wind energy, solar energy and light energy." It showed that PSETs were confused with the word "create" and "transform." They took the literal meaning of "creating" as "making or producing." The PSETs do not have the science concepts that wind energy, solar energy and light energy are not created, but are transformed from other kinds of energy. After the pre-assessment quiz, the researcher discussed with the PSETs what energy was and the meaning of "creating energy" and "transforming energy", emphasizing the words such as "create" and "transform" were used differently in science as compared to daily English language. A post-assessment quiz was administered three months later at the end of the semester. It reviews that all PSETs understood the concept of energy by stating that energy cannot be destroyed or created but can be transformed from one form to the other.

Practical Task

When the PSETs were undertaking practical task, the researcher walked around and observed the PSETs performing their investigation and manipulating the thermometers. All PSETs were able to perform the activity and to record the readings. One problem that the researcher noticed was that some PSETs lifted the thermometer above the water level while taking the readings. Both qualitative and quantitative data were collected for the practical task. The qualitative data was gathered through interviews with the PSETs, and the quantitative data collected from the practical task worksheet (Appendix 1) completed by the PSETs. Below is an analysis of the data.

Past and Personal Experience

Before the start of the practical task, the PSETs were asked to predict which cup was the best and which less likely to keep hot water warm for the longest period of time. In the interviews, many PSETs said that they made the decision based on their experience of drinking coffee, or other hot drinks that they bought from the fast food stores. One PSET said,

> *"My prediction is that porcelain cup is the best because this is what we use to drink coffee or tea at home. Then I think foam is the second best because this is what Dunkin Donuts used. Paper cup is the worst because the heat escapes from the side as we feel hot when we are holding the paper cup that is filled with hot liquid."*

Several PSETs shared the same response during the interview that their answers for Q2 (Which container can best keep the temperature for the longest time?) and Q4 (Which container is most suitable for keeping ice cream cold?) were based solely on their daily experiences of drinking coffee and eating ice cream. Most responses of the PSETs were not based on empirical evidence or systematic analysis of their recorded data. This Watson and Konicek (1990) described as "experience is an effective, if fallible, teacher." As for Q. 3 (Explain why the container you chose can best keep the temperature), 15 PSETs provided an answer that was related to insulation. However, when the researcher asked PSETs how much they know about insulation, three of them related thermal insulation of the container with their experiences of the insulation of their houses. To them, if the container was thick, then it would be a good insulator without considering the material used for making it. Hence, they justified that porcelain cup was the best because it was the thickest among the three containers. Only one PSET could relate his/her answer to the properties of the material that made the containers.

Treatment of data

Though all PSETs were able to collect and record the data, they manipulated the data differently. Over 50% of PSETs focused only on the final temperature without considering the starting temperature. If the final temperature was high for a certain container, some PSETs considered that container was the best to keep hot water warm without looking at whether the starting temperature was high or low. Most PSETs did not consider the change in temperature, that is, the subtraction of the final temperature from the starting temperature. It was a surprise to the researcher to notice this discrepancy. When the PSETs were asked about why they did not consider the starting temperature, some simply said that they did not know that they had to treat the data in that way. Others stated that they were unfamiliar with treating numerous data. A few admitted that they had overlooked the starting temperature.

Comparison of PSETs with fourth grade elementary students in the TIMSS study

According to the TIMSS report (1997), this practical task is difficult for fourth graders. However, Table 1 shows that a high percentage of students (98% in the U.S. and 91% in the International Average) are able to use a thermometer (Task 1). The results for Task 2 (Quality of data gathering) for the fourth graders are low (64% for the U.S. and 56% for the International Average) because the data recorded are incomplete or inaccurate. Moreover, as reported by TIMSS, misconception occurs when students are asked to apply their findings to a different situation (Task 5). Students have the misconception that the containers for cold and hot drink need to be different. Even though 15% of students internationally (Task 5) recognize that the best container for keeping a hot drink warm is also the best for keeping ice cream cold, but only 3% can explain the reason (Task 6).

When looking at the two groups of PSETs - 2011 and 2012, their results (Task 3) are quite similar and not much better than the fourth graders. The concept of heat transfer and insulation are clearly lacking in both PSET groups. Less than half of the PSETs can identify the best insulator (Task 3) and are notably below the International Average of fourth grade elementary students. This may be due to the stubbornness of some PSETs who hold strongly to their past experiences and the erroneous way they manipulate the data. Most PSETs use the word "insulation" when explaining the reasons for their identified best container (Task 4), but they do not fully understand the meaning of insulation. Often, PSETs have the misconception that insulation is related with the thickness of the container. One PSET wrote, "The foam cup is a good insulator because it is made up of so many layers." Both groups of PSETs with scores 50% or less can state that the best container for hot drinks is also the best container for ice cream or cold drinks (Task 5). Obviously, PSETs cannot apply the concept of insulation to another similar situation because the results for Task 6 (Explain Application) are 14% and 16% for PSETs (2011) and PSETs (2012) respectively. The low percentages show that many PSETs do not know the explanations despite the fact that their written responses are correct. They do not understand why a container which can keep hot water warm is also a good container to keep ice cream cold. This reveals that the concept of heat energy and insulation are poorly understood not only by fourth graders but by PSETs as well.

Table 1. Responses of PSETs (2011 and 2012), 4th graders in the U.S. and International Average (TIMSS, 1977) on the practical task

Tasks	4^{th} graders in the U.S. (1997) (%)	International Average (1997) (%)	PSETs (2011) (%) *N*=14	PSETs (2012) (%) *N*=20
1 Ability to use a thermometer	98	91	100	100
2 Quality of data gathering	64	56	100	100
3 Identify best insulator	32	48	43	40
4 Explain best insulator	8	6	50	45
5 Apply to ice cream	31	15	36	50
6 Explain application	4	3	14	16

Assessment Probe

The Assessment Probe *Ice-Cold Lemonade* was administered two weeks after the PSETs had completed the practical task. It was designed to reinforce the concept of heat energy and heat transfer. After the PSETs had finished working on the assessment probe, their responses were polled. Table 2showed that 15 PSETs chose "C" (The coldness and the heat moved back and forth until the lemonade cooled off), five chose "B" (The heat from the lemonade moved into the ice) while none chose "A" (The coldness from the ice moved into the lemonade). Apparently, it showed that the PSETs had a strong misconception that the transfer of heat energy was bidirectional, i.e., the coldness from the ice moved to warm lemonade and the heat from warm lemonade moved to the ice. When the researcher were asked PSETs why they did not choose "A", some PSETs responded that heat was needed to move from the lemonade to melt the ice. Though the PSETs did not actually do the activity, they could envisage that the melting of ice involved the transfer of heat and heat was required to melt the ice. When the researcher asked the five PSETs who gave the correct answer "B", they responded that the lemonade was warmer than the ice cubes. The heat from the lemonade tried to make the solution the same temperature so heat moved to the ice and caused the ice to melt. In order to explain the phenomenon of heat transfer between matters, the researcher used the analogy of a rich man and a poor man. The researcher said,

> *"Once there was a rich man who helped the poor man by giving him money. Having little money, the poor man could not afford to give any money back to the rich man. The poor man saved all the money that the rich man had given to him. He slowly and gradually had more money. Finally, the money of the rich man and the poor man were almost the same; and the rich man stopped giving the poor man money."*

During interviews, some PSETs admitted that the use of "The rich man and poor man" analogy helped them understand more about the principles of heat transfer. As to the other question - Is there any heat energy in the ice cubes? - Six responses showed no heat energy in ice cubes while 14 shows that there was a minimum amount of heat energy (Table 2). This reviews that PSETs held the misconception that only hot object had heat energy and they confused heat energy with the word "hot". They thought that there was no heat energy in ice cubes as they were cold. The perception of "hot" or "cold" substances by PSETs conflicted with the science conception that heat was a measurable quantity that existed in all objects.

Table 2: Responses of PSETs in the Assessment Probe (N=20)

	Explanations	Responses of PSET
Question1. Explanation of the ice-cold lemonade phenomenon		
A.	The coldness from the ice moved into the lemonade.	0
B.	The heat from the lemonade moved into the ice.	5 (correct)
C.	The coldness and the heat moved back and forth until the lemonade cooled.	15
Question 2. Is there any heat energy in ice?		
	Yes, little amount	14 (correct)
	No	6

Interview

All interviews were audio-taped and each interview lasted for about 30 minutes. The interview was to understand the type of misconception PSETs held and how it could have developed. The researcher also took this opportunity to refute the misconceptions that PSETs held and to strengthen their correct science principles. The feedback from PSETs indicated they enjoyed and learned much from the individual interview as the researcher could reconcile their misconceptions accordingly, based on their ways of thinking. During the interview, the researcher still found some PSETs were uncertain about some science concepts, such as the transfer of heat energy from a hot liquid to a cold liquid. Hence, the researcher explained the concepts again, making sure that PSETs fully understood the science principles behind all the designed activities. Some PSETs expressed they were confused and in conflict when they realized the concepts they had for years were wrong. It took them some time to think about and reconcile the misconceptions. When they finally understood and were able to comprehend the concepts of heat transfer, they enjoyed the “aha” moment. Below quotes illustrated the feelings of some PSETs.

> *“When I first started the ‘Ice-Cold Lemonade’ Lab, I thought it was the ice cooling down the lemonade since ice is used to cool down drinks. I always thought the coldness of the ice cooled down the lemonade not the other way around. So for the last 20 years, I have had this misconception.”*

> *“When I first learned that I was wrong all these years, I was quite shocked, but now I have learned the truth, I feel like I have learned more because it’s hard to forget*

something that you realized you have been wrong about for so long."
"It was a happy or can't believe it moment when I learned the truth of the misconception I have had all these years."

DISCUSSION

Various assessment instruments are used in this study to diagnose how much PSETs know or not know about energy and what misconceptions are held. The pre-assessment quiz shows PSETs confuse energy with force as it is a very common misconception among students (New York Science Teacher, 2010). Moreover, PSETs possess the vernacular misconception (Keeley, 2012) related to the question "Can energy be created?" PSETs are confused with the meaning of "create" in the science context as they write "creation of solar energy, wind energy or light energy." Many of them do not know that energy is transformed from one form to the other, and energy is conserved. They are not aware that the word "create" used in everyday language has a different meaning when used in science.

The practical task of "containers" is to allow the PSETs to explore the concept of heat loss, insulation and heat transfer. At first, the researcher wanted to discuss the practical task in class by taking a poll of which container was best to keep the hot water warm and ice cream cold. No agreement existed among the PSETs as to which container was the best. The PSETs strongly held the opinions that their collected data and explanations were correct. During the class discussion, the researcher noticed that the collected data were treated inconsistently by PSETs. For example, numerous PSETs took the final temperature in the practical task instead of the difference in temperature to determine which container was a good insulator. Therefore, the researcher thought it would be futile to consider a detailed explanation of the results in class as some PSETs might not have interest in knowing how their classmates came to the conclusion. Gooding and Metz (2011) stated, "Misconceptions could be corrected, but since they were individualized paradigms, they must be corrected by their owners." Thus the researcher decided to interview all PSETs one-on-one in order to understand their ways of thinking and how they interpreted the data. In the interviews, some PSETs described their surprise at realizing that there was not a "single" or "right" answer for the best container. The researcher was then able to discuss with the PSETs about variables and the possible factors affecting the practical investigation.

In order to strengthen the science concepts of heat energy, heat transfer and insulation, several hands-on and minds-on activities were given to PSETs to explore, discuss, explain and evaluate. Through discussions, the researcher was able to diagnose the misconceptions that PSETs held. Some PSETs were confused with the concept of heat transform and heat transfer during the discussions of the pre-assessment quiz and practical task. The researcher then used another related activity *Ice-Cold Lemonade* to reinforce the concept of heat transfer. Figure 1 showed how the process of exploring, diagnosing, designing and discussing were intertwined to strengthen the science concepts of PSETs and to model how conceptual change was to be taught in the classroom. At the same time, it showed the cognitive and affective interaction between the researcher and PSETs during the process.

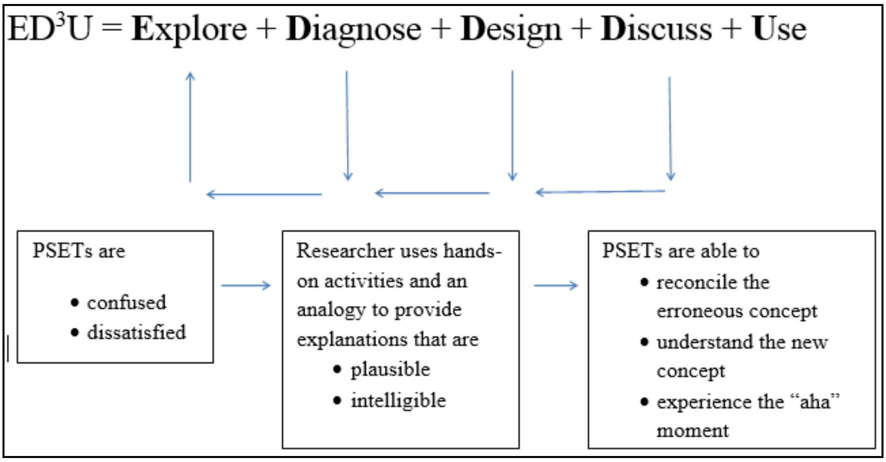

Figure 1. Integration of ED3U Conceptual Change Model (McComas, 1995) and Conditions for Accommodation (Posner et al., 1982)

During class discussions, some PSETs expressed dissatisfaction when they realized that their data were different from their peers. Furthermore, they were confused by a variety of responses provided by their classmates, which conflicted when challenged by the different explanations that followed. Most PSETs claimed their misconceptions were reconciled and the science principles were consolidated during the one-on-one interview as the conversation with the researcher could target on their ways of thinking. The analogy of "The rich man and poor man" in explaining the concept of heat transfer was readily accepted by the PSETs as they found using daily encounter examples could help them to understand the science concepts easily. At the end of the semester, the feedback from PSETs indicated they enjoyed doing the activities and they might use the activities in their future classrooms as well.

When PSETs were asked about their feelings toward the confrontation of misconceptions during the interviews, their comments are:

> *"My first instinct is that I want to argue with you [the instructor] about the bi-directional concept of heat transfer I have possessed for years. However, your analogy of 'rich man and poor man' makes sense to me and easy to accept. Once with a good reason . . . I find it is very logical . . . I cannot argue with."*

> *"The real life situation of using money in the analogy made everything clear for me and will be very beneficial to my future students to be able to understand the concept of energy."*

To reconcile the old ideas with a new concept, PSETs found anomalies when they were faced with the new ideas. The analogies provided by the researcher were crucial to help them in the process of accommodating the new concepts. Since conceptual change was an active learning process, the researcher needed to provide PSETs with opportunities to make predictions based on their pre-existing knowledge or experience. They needed to reflect and think what fitted into the new knowledge or what contradicted. Through this thoughtful process, the new knowledge should embed deeper in the mind of PSETs provided the new concept was relevant, authentic and applicable to their life.

LIMITATIONS AND FUTURE WORK

The limitations of this study are that the data cannot be generalized because of the small sample of participants; and no way can the researcher claim that the group of PSETs have fully reconciled their misconceptions on heat energy. The PSETs may resort back to their misconceptions if the conception is not rooted deeply. Gooding and Metz (2011) mentions that learners construct their own explanations and do not always take in new information if it does not fit their established pattern of thinking. Effort and determination are needed for PSETs to give up their wrong preconceptions before they can readily accept new ideas. Further research is needed to evaluate how PSETs sustain their new learned conceptions and determine whether they resort back to the misconceptions after a period of time (Trundle, Atwood, & Christopher, 2007). Further research of conceptual change and energy concepts could be undertaken when the PSETs were on their field experience for student teaching. At that time, PSETs could report back how they used the pedagogy of conceptual change when confronted with students' misconceptions. Hopefully, they would recall their own experience and be able to model the approach by their science methods instructor.

IMPLICATIONS FOR TEACHING

This research study offers science educators and PSETs novel ideas in teaching science misconceptions and the concept of energy. As stated in the literature review, misconceptions are "highly robust" (Viennot, 1979) and the possession of misconceptions hinders students' learning (Bransford, Brown, & Cooking, 2000; Donovan & Bransford, 2005; Duit & Treagust, 2003). Therefore, it is important for science educators to understand what misconceptions are and to use appropriate teaching strategies for their rectification. Even though this study is focused on PSETs, a cautious assumption can be made that in-service elementary teachers may also have some of the misconceptions when teaching the concepts of energy. In this study, PSETs expressed the greatest impact on them were at the moment when their concepts were being challenged which led them to show confusion and dissatisfaction, and their erroneous concepts were gradually demystified when the science methods instructor used analogies in explaining some abstract science concepts. Thus, the ED3U model (McComas, 1995) and conditions for accommodation (Posner et al., 1982) offer a great insight for science educators and teachers when confronting with students' misconceptions.

As a teacher, it is good to know in advance what misconceptions students hold in relation to the topic taught. Several misconceptions about energy have been revealed in this study. Students are likely to equate energy as force; and do not fully understand the meaning of heat and insulation. The conception that a container which can keep hot water warm can also keep ice cream cold is challenging not only for fourth graders, as reviewed in the TIMSS study, but also for PSETs, as indicated in this study. Moreover, studies show that students who learned science concepts through conceptual change oriented instruction have a better acquisition of knowledge that those students who learned the knowledge in a direct instructional mode (Celikten, Ipekcioglu, Ertepinar & Geban, 2012; Feyzioglu, Ergin & Kocakulah, 2012).

PSETs, being novice practitioners in teaching, feel comfortable if they are aware of some science teaching resources and have the experience of using them. In this study, PSETs have the opportunity to use the TIMSS (1997) hands-on performance assessments and the formative assessment probes written by Keeley, Eberle and Tugel (2007). The intention of the science methods instructor is that PSETs make use of those resources in their future teaching.

CONCLUSIONS

1. What conceptions do PSETs hold about the concept of heat energy, heat transfer and insulation?

2. What misconceptions do PSETs have?
3. Can the PSETs misconceptions be reconciled? If so, in what way?

The lead activity in this study is the practical task, which is taken from the TIMSS Performance Assessment (TIMSS, 1997) of investigating which container is best to keep hot water warm for the longest period of time. This investigation can provide PSETs with an authentic environment of learning science content knowledge as well as science process skills. The findings in this study provide valuable implications to science educators regarding the teaching of heat energy to PSETs. Considerable research has explored students' misconceptions, but less research has been devoted to identifying teachers' misconceptions (Burgoon, Heddle, & Duran, 2010) and the cognitive and affective factors in the learning process (Duit & Treagust, 2003). The process of reconciliation of the misconceptions provides a good opportunity for PSETs to learn the instructional strategies that can elicit changes in students' conceptions. The researcher makes use of the conflicting ideas drawn from the responses of PSETs to guide the discussions, validate the ideas and refute the misconceptions. Once PSETs are aware of their misconceptions, it will deepen their understanding of the science principles and help them to identify the misconceptions that their students may have. During the discussion of the practical task, some PSETs proposed using ice cubes or cold water instead of hot water in the containers. They thought it would be safer for elementary students to handle cold liquid rather than hot liquid. Also, many PSETs concluded that there were many variables affecting the results, such as the amount of hot water, size of the cups, stirring of the water, reading the thermometers, with or without fanning etc. Through discussions, PSETs gradually develop the confidence to modify or redesign inquiry activities that they think are suitable for them to use in elementary classrooms. The purpose of doing various activities not only allows the researcher to diagnose the misconceptions of PSETs, but also help PSETs to reconstruct their own understandings cognitively and internalize the learned concepts. Furthermore, the pedagogies of teaching conceptual change as demonstrated by the researcher can be an instructional model for PSETs to explore when they are teaching in the classroom.

In conclusion, the process of teaching conceptual change is a timely effort that involves various instructional strategies. Yet the learning experience gained by PSETs as reviewed in this study is fruitful and worthwhile. From the feedback of PSETs, it shows that teaching science through the conceptual change model is a good way of helping students to learn science. New knowledge acquired by students through this way will be more robust and the instructional strategies that the science methods instructor demonstrated will also enrich PSETs' teaching practices in their future careers.

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APPENDICES

Appendix 1: Practical Task

Containers

Materials:
Three containers labeled A, B, C respectively
Three thermometers
Stop watch or clock
One cup of hot water (Be careful! Don't let it spill)
Several card papers for fanning
Paper towels
One measuring cylinder

Read the following instructions carefully:

Task: Find out which container can best keep the temperature for the longest time.

Procedure:

- Place the thermometers into three separate containers (A, B, C) and pour hot water into the containers separately.

- Read the temperature in each of the thermometers and record them on the data table.

- Now, you need to measure the temperature change in the three containers over a total of 10 minutes.

→ Determine the number of readings you are going to take

→ Record the temperature readings on the data table

Record sheet

1. Results:

Time (minutes)	Temperature of Container A (A is a ________ cup.)	Temperature of Container B (B is a _______ cup.)	Temperature of Container C (C is a _________ cup.)

2. From the above results, find out which container can best keep the temperature for the longest time.

3. Explain clearly why the container you choose in Q.2 can best keep the temperature.

4. According to your opinion, which container is most suitable for keeping ice cream cold?

5. Why is the container you choose in Q.4 can keep the temperature of the ice cream?

When completed, pour away all the water and tidy up the table. Put all the things (including the cups) on the side bench.