THE EFFECTS OF USING THE CONCEPTUAL CHANGE MODEL TO DISPEL MISCONCEPTIONS IN SCIENCE IN ELEMENTARY CHILDREN

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY

Bozeman, Montana

July 2010

STATEMENT OF PERMISSION TO USE

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Elementary children come to school with a mental schema of scientific principles that come from their everyday experiences and observations. Sometimes this mental schema contains misconceptions. This study used the Conceptual Change Model as a methodology to identify these misconceptions and target instruction with experiments that gave students the opportunity to validate or invalidate these preconceptions. A group of 63 fourth grade students and four elementary teachers were involved in this study. The CCM methodology was used in a unit on heat and energy that spanned an eight week time period. Students were interviewed before the unit and diagnosed for misconceptions with pre assessment questions. After treatment students were then assessed with the same questions and the percentage difference between pre and post answers was analyzed. Data from this study indicate that the CCM is an effective tool in dispelling student misconceptions as well as helping students who have no preconceptions in place at all to develop valid mental schemas. Additionally the results suggest that the CCM stimulates student interest and engagement in science. Elementary teachers also indicated that the help of a science specialist was beneficial in implementing the CCM effectively.

INTRODUCTION AND BACKGROUND

Project Background

Teaching Experience and Classroom Environment

I am a high school biology and chemistry teacher working overseas at the American International School of Budapest (AISB) in Hungary. AISB is comprised of 760 students from 60 different nationalities and English is a second language for more than half of them. These students are children of expatriates who are typically working overseas on two to three year contracts. The community is a transient one, but the parents tend to be very involved and supportive. The academic expectations in our school are high and most students in the high school are enrolled in the International Baccalaureate (IB) program. The IB exams taken in the senior year determine university placement for most European universities. The elementary curriculum is based on the Primary Years Program (PYP). At AISB we are undergoing a major curriculum review and revision process that includes working towards more vertical alignment of the curriculum K-12 (www.aisb.hu/).

Due to this process of curriculum review and revision I have been working closely for the past two years with several elementary teachers who are the science representatives for the standards and benchmarks committee. These teachers have expressed concern over the new changes in standards and benchmarks in science. The focus in the elementary seemed to be the FOSS (Full Option Science System) kits that were available for experiments (www.fossweb.com). The teachers wanted to pick only the benchmarks for each grade level that matched a pre-existing FOSS kit. So the high school teachers suggested that we could help the elementary to develop kits that include appropriate experiments and activities for each of the benchmarks and therefore allow more flexibility so that the curriculum is developed with a focus on vertical alignment of skills and concepts rather than FOSS kit availability.

I began to work with the elementary teachers and taught a few science lessons in order to introduce some ideas for experiments that would be appropriate for a given grade level and benchmark. I came to realize how little science is actually being taught at the elementary level. In the fourth grade students are enrolled in five different specialist classes in addition to their homeroom. These electives include physical education, drama, music, art, a foreign language class and computers. The amount of time that students spend in art, music and physical education amounts to 56 hours for each elective. The homeroom class focuses on reading, writing and mathematics. Humanities and science are taught in two or three block units throughout the year and are often integrated so that the emphasis is more on reading and writing about science rather than doing any experimentation. The total amount of time devoted to science this year in the fourth grade was fourteen hours. This time was divided into two units with each unit lasting for approximately eight weeks. Much of the methodology being used is more of a teacher directed approach where students are given information or asked to do research in the form of poster board projects. There are few inquiry-based activities and very little true experimentation where students collect and analyze data in order to determine an outcome. The teachers are trying to use FOSS kits in order to incorporate more experimentation into their lessons but the FOSS kits do not match all of the benchmarks.

While working with these elementary children and through experience with my own child I have come to appreciate how truly curious and interested children are in science.

Children at a very young age begin to question the world around them and to develop their own little "theories" and ideas to explain what they see. What a critical window of opportunity we have as science educators to capture that natural curiosity and enthusiasm and to help children develop their conceptual framework. Sometimes the theories that children have can become misconceptions because they have not been given the proper opportunity to fully explore their ideas. Sometimes students just stop asking so many questions because they are not encouraged to do so. The elementary students I have been working with ask far more questions than my high school students. I began to see my work with the elementary teachers as an opportunity to develop more than just a vertically aligned K-12 curriculum. I saw an opportunity to introduce and encourage the use of a more experimental and inquiry based science program into the elementary school. Furthermore, working with elementary students gave me the unique opportunity to further explore a teaching methodology called the Conceptual Change Model (CCM). Through this methodology student misconceptions can be identified with pre-assessments and explored through experimentation.

Focus Question

The purpose of my research was to use the Conceptual Change Model (CCM) as a teaching methodology in elementary science lessons. My focus question was to determine if preconceptions that students have could be changed when they are given the opportunity to experiment with their ideas using the Conceptual Change Model. Some subtopics that I also explored are as follows:

1. What are the current misconceptions that students have about scientific concepts?
2. Does the use of the Conceptual Change Model encourage students to develop their curiosity and enthusiasm for science?
3. What are the issues that might make it difficult for elementary teachers to engage students in more experimentation in science?
4. Does the use of a science specialist in the elementary classroom help to implement the Conceptual Change Model more effectively?

CONCEPTUAL FRAMEWORK

A young girl is convinced that she should be able to see an apple in a completely dark room, once her eyes have a chance to adjust to the darkness. After twenty minutes of sitting in the dark and clearly unable to see the apple in front of her she still continues to hold on to her misconception that an object can be seen by the human eye in the absence of light (Schneps & Sadler,1985).

This example of a student misconception comes from a video created by Schneps and Sadler of the Science Education Department at the Harvard-Smithsonian Center for Astrophysics (1997). This video led to a project called the Private Universe, which was funded by the National Science Foundation, the Annenburg Media Math and Science Project, and the Smithsonian Institution Universe. The Private Universe Project has produced a series of videos and interactive teleconferences for teachers that examine the current research on how children learn science. Through the research, which included a series of interviews with students ranging in age from elementary school to university graduates, they found that student misconceptions can pose critical barriers to learning science (Private Universe Project, 1997). The National Science Foundation (2007) did a recent survey to assess science literacy in the average American and found that two-thirds of Americans surveyed do not clearly understand the scientific process.

- 55% cannot define DNA
- more than half mistakenly believe that humans lived at the same time as the dinosaurs
- nearly half believe antibiotics can kill viruses. (p. 3-7)

The natural questions that arise from studies such as these include inquiries into how science is being taught in our public schools. Depending on the school and their curriculum, some topics that are covered in elementary school may never again be covered in following years. One common example is the seasons and phases of the moon. Typically taught in elementary programs, but not in middle school or high school, this is a topic that many adults, including elementary school teachers have misconceptions about (Atwood & Atwood, 1997; Parker & Heywood, 1998, and Trundle, K.C., Atwood, R.K., & Christopher, J.E., 2002). If they are not given opportunities to test their misconceptions through investigations and observations, students will continue to carry their misconceptions into adulthood.

Misconceptions are defined as conceptions that produce errors systematically and are resistant to change. They can result from faulty instruction or may exist before instruction due to the life experiences of the child. There is however some disagreement regarding misconceptions. Vosniadou (2002) argues that these misconceptions are in fact naive conceptions that result from a complex process by which children organize the perceptual experiences and information they receive regarding the physical world. These conceptions therefore may not need to be replaced since they are usually fragmented pieces of knowledge rather than well structured developed concepts. Vosniadou maintains that the learning process is a slow and gradual one where “children attempt to organize their perceptual experiences and information they receive from culture into explanatory frameworks.” (p. 62)

Elementary education captures students in their most formative years of cognitive development. Children begin asking questions about the world around them long before they begin to read and write. In addition to asking questions they are actively putting together ideas and theories in order to make sense of the things they observe. Children use their everyday experiences to construct explanations for the things they observe and these explanations often differ from scientific explanations (Suping, 2003). Children begin school with minds full of mental models that are often at odds with the conceptual models that are being taught in school (Duit & Glynn, 1995). Therefore it is in the early preschool and elementary years of school that teachers can best focus on preventing the formation of these misconceptions so that the mental models that children develop and carry with them throughout life are not in opposition to the conceptual models that are supported by the scientific community.

Since the 1970’s science researchers have found that students begin lessons on most science contents with preconceptions that differ from scientific conceptions (Gyoungho, 1999). These preconceptions are frequently very resistant to change. Arendt (1978) made a distinction between comprehension and apprehension. Just because students comprehend and understand a scientific concept doesn't mean that they believe or apprehend it (Cobern, 1993). "It is not that students fail to comprehend what is being taught- it is that they simply do not believe it" (Corbern, p. 1). Therefore according to Gyoungho (1999), "it is not enough that we simply inform students of their misconceptions. Students must also be convinced that the scientific conceptions are more intelligible, plausible and fruitful than their own mental models" (p. 2).

Studies of experts and novices in the physical and life sciences have shown that an expert's knowledge is a network of conceptual relationships that is quickly and easily stored, retrieved and applied to novel situations (Duit & Glynn, 1995). Conversely, a student or a novice's knowledge is often easily forgotten and not easily transferred to new situations because it has been learned by rote memorization. Therefore the challenge that educators face is to find teaching strategies that effectively replace student misconceptions with scientific conceptions that they comprehend, but more importantly, they also apprehend. There must also be an emphasis on strategies that ensure when students graduate from university they are experts and not novices. Einstein (1940) said that

> Science is an attempt to make the chaotic diversity of our sense-experience correspond to a logically uniform system of thought. In this system single experiences must be correlated with the theoretical structure in such a way that the resulting coordination is convincing. The sense-experiences are the given subject matter. But the theory that interprets them is man-made. It is the result of an extremely laborious process of adaptation; hypothetical, never completely final, always subject to question and doubt. (p. 1)

In this statement, Einstein is reaffirming that the process of learning science isn't about learning content and facts but is instead a process of developing convincing mental schemas that explain the world we observe. It is a fluid ongoing adaptive process where the focus is more on conceptual understanding rather than knowing the "right answers." Constructivism is an approach to knowledge that fits well with Einstein's definition of science. According to Von Glaserfeld (1993) constructivism is "a theory of knowing rather than a theory of knowledge" (p. 12). In a constructivist classroom learning takes place on the foundation of prior knowledge and skills that students bring with them. They develop their ideas by interacting with their peers, the teacher and the environment (Taylor, 1996). So constructivism begins the learning process with finding out what students already know. "Children have their own ideas, some are correct and some are not and if the misconceptions are ignored or dismissed they will hold to their original beliefs" (Rutherford &Ahlgren, 1990, p. 4).

The Conceptual Change Model was developed by Stepans in the mid 1980s in order to provide a methodology that can be used by teachers that encompasses constructivist philosophy (Schmidt, Saigo, & Stepans, 2006). There are six phases incorporated into a Conceptual Change Model Lesson (Schmidt, et al., 2006) and include the following:

1. Students commit to their ideas about a concept before the lesson begins. They need to identify or describe their reasoning and become aware of their own thinking.

2. Students expose their beliefs to others through discussions with the teacher or their peers. They can share and discuss in groups and communicate to others so that everyone becomes aware of the differences in beliefs within the class.
3. Students confront their beliefs through a series of constructivist based activities and experiments. They need to be given the opportunity to challenge their preconceptions.
4. Through teacher facilitated discussion and sharing with other their peers, students can then accommodate new information and can reconstruct their previous conceptions.
5. Students are then encouraged to try out their newly constructed mental schema by making connections to other experiences and situations and to apply their thinking to new contexts.
6. The last and final phase involves allowing and providing opportunity for students to extend their thinking beyond the confines of the lesson. This could be by having the student posing questions that might be explored in a future lesson or independent research project. (Schmidt, et al., p. 18-19)

The success of conceptual change instruction depends on the ability of the learner to reflect on their own thinking and a classroom that promotes this. "The emphasis should be more on discovering rather than memorizing, teaching should be on questioning rather than telling. There should be time allotted for open-ended investigations, dialogues between the instructor and individual student as well as small group discussions" (McDermott, 1996, p. IV).

In the 1990s a new focus developed for teaching science in the United States.

National education reform documents e.g., American Association for the Advancement of Science, 1990; National Research Council, 1996; have advanced a vision for K-12 science instruction beginning in the earliest elementary grades.

> This vision entails using an inquiry-oriented teaching approach and creating a classroom environment in which students take responsibility for their own learning through active engagement in extended and collaborative inquiry-based science activities. This approach aims to help students internalize a scientific worldview; acquire scientific habits of mind, build an understanding of scientific concepts, and develop facility in intellectual and manipulative skills necessary for engaging in scientific inquiry both within and beyond classroom contexts. (Schwartz, 2000, p. 1)

This vision for reform is very much in agreement with the strategies outlined by McDermott (1995), Hewson and Hewson (1988), and Fosnot (1989). However in efforts to implement these reforms several obstacles have been identified. One obstacle is that many elementary programs of study do not allocate enough time for science instruction. The International Association for the Evaluation of Educational Achievement conducted a survey that included more than half a million students from forty-five different countries and found that science is taught for less than two hours a week in half of the countries surveyed. A study done through the University of Berkeley on Bay Area Schools in California found that 16% of elementary teachers spent no time on science at all (Dorph, Goldstein, Lee, Leopori, Scneider, & Venkatesan, 2007). A second obstacle, perhaps related to the first, is the attitude that elementary teachers may have towards teaching science and the challenges they face in implementing activities for students that involve experimentation and constructivist-based activities. Elementary teachers are faced with the challenge of having to prepare for five different subjects and often do not have time and resources available for setting up experiments. They also often do not have the educational background in science to feel confident in teaching it. The University of Berkeley study found that 41% of teachers do not feel adequately prepared to teach science when compared to other subjects such as the reading/language arts where only 4% felt they were not adequately prepared (Dorph et al., 2007).

Many science educators have suggested that experienced science specialists are more likely to achieve reform visions than are elementary teachers (Schwartz and Lederman, 2000). They assert that employing specialists to teach science in equipped science rooms would abate the constraints of priority, time, equipment, knowledge and experience. Elementary science specialists usually have a degree in science or science education and since their primary focus is only in one area, unlike elementary teachers who have to cover other subjects, they are better equipped to develop innovative and conceptually relevant science lessons (Schwartz, 2000). In order to effectively follow through with the implementation of the Conceptual Change Model in an elementary school classroom;

> a science specialist may be better able to identify children's misconceptions, to recognize invalid or dead-end questions, to clear up confusion, to diagnose students' new interpretations, and to direct students' inquiry. The greater the science content knowledge, the better teachers are at identifying key points, developing instructional representations and analyzing student thinking. (Rice, 2005, p.10)

A study done by Dharmadas (2000) found

> that many elementary teachers had difficulty thinking of questions to ask students in order to promote children's thinking to higher levels because they were not conversant with the content material to make effective contact with the children at different thinking levels. In the same study teachers expressed the need for help in preparation and assembly of materials. The teacher needs to be knowledgeable to select appropriate materials and to plan activities for children to master concepts. (p 11)

In conclusion, the research clearly indicates that elementary students begin school with many preconceptions regarding scientific phenomenon. The Conceptual Change Model provides an effective methodology that can be used by teachers to help students through the process of identifying and experimenting with these preconceptions. Students can validate or invalidate their preconceptions using a constructivist process. Newly constructed conceptions become more believable than any misconceptions that students started out with. Beginning this process in elementary is crucial because as students enter adulthood the process of dispelling misconceptions become more difficult (Rice, 2005). Elementary teachers may face obstacles that prevent them from being able to effectively address student misconceptions. The use of a science specialist could help to facilitate and implement science lessons using the Conceptual Change Model most effectively.

METHODOLOGY

I worked in collaboration with a group of fourth grade elementary school teachers in order to conduct this research project. There were four classes with a total of 63 students and four classroom teachers. The elementary principal signed a consent form for all students who participated in this study (Appendix A). The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix B).

The four classroom teachers agreed that they preferred that I construct and teach all of the lessons. Since this was a new unit for them, they did not feel confident in their knowledge of the content and were quite happy to allow me full access to teach and develop the entire unit. I had to incorporate all of the standards and benchmarks (Appendix C) for the new AISB curriculum. This unit had to include all of the benchmarks for Properties of Matter (PS 1.1 C and 1.1 E), Forms of Energy (PS 1.3 A, 1.3 B, and 1.3 D), and Biogeochemical Cycles (3.6 A). There were seven lessons in total and I had each class come up to the high school science labs (where I normally teach) once a week for a 45 minute lesson. After each lesson, the teachers followed up in their own classrooms with discussions and any unanswered questions that students still had. I administered the Teacher Attitude Survey (Appendix D) at the end of the unit in order to collect some data to address two of my focus question subtopics which relate to the issues that impact elementary teachers in their effective implementation of the CCM in the classroom. Teachers were also asked to pass out the Parent Questionnaire before the unit began (Appendix E). The purpose of this parent questionnaire was to assess student attitudes about science during the treatment phase. Data from these questionnaires was used to address my focus question subtopic regarding the impact of the CCM on student curiosity and enthusiasm. The Student Attitude Survey was also used to ask students directly about their attitudes in regards to science (Appendix F). This survey was given to students before and after the unit. Both the Teacher Attitude Survey and the Student Attitude survey were analyzed using a Likert scale. Teachers and students were given five categories to choose from; strongly agree, agree, somewhat agree, disagree, and strongly disagree. I analyzed this data by calculating percentages and looking at the percentage difference between pre and post data for positive responses and negative responses. Two groups were formed in order to look at overall change in attitude. I grouped all of the positive responses (strongly agree, agree) and the negative responses (disagree, and strongly disagree) and calculated the percent change for each question. I also looked at individual changes or shifts for each category to see if any significant patterns could be identified.

After the distribution of the questionnaires, the treatment phase was started. I used the Conceptual Change Model (CCM) as the methodology for developing and teaching each lesson (Schmidt et al., 2006). I taught seven CCM lessons all together and grouped them into three conceptual blocks or sub-units. The first sub-unit, the CCM Energy Subunit (Appendix G) was one lesson on types of energy. The second subunit, the CCM Chemical Energy Subunit (Appendix H) was two lessons on burning and fossil fuels and the third subunit, the CCM Heat Subunit (Appendix I) was four lessons on heat energy.

There are six steps or phases in a CCM lesson (Schmidt et al., 2006). The first step is to assess the students to see of they have any misconceptions in regards to the concepts involved in the unit. The method for doing this was to use the Student Misconceptions Diagnostic Interview (Appendix J) and Pre-Assessment Probes (Appendix K). The Pre-Assessment Probes were given to all 63 students in the fourth grade. Three students for each class were chosen for the interviews. Because most of the students at AISB are ESL students and some do not speak English fluently, I asked teachers to choose students who are the best English speakers so that language skills did not become a variable. I also asked teachers to consider students who are the most willing to talk rather than shy students who may not say much during an interview. These student interviews were tape-recorded and transcribed to ensure the written notes that I took during the interviews were accurate. The data collected from these interviews was used to support and illuminate the student thought process for themes established through the other data collection instruments. After diagnosing student misconceptions and identifying them in the Student Misconception Identification List (Appendix L), I devised a list of activities or experiments that addressed the misconceptions. I also devised a list of Eyes Closed Questions to be asked during each lesson in order to extend student thinking by using a Socratic Dialogue method (Appendix M). I tried to use only experiments as a means to address misconceptions, but in the case of the CCM Heat Subunit, I used a simulation exercise for kinetic molecular theory. I have outlined below one example of a lesson in the CCM Heat Subunit that follows the six phases of a CCM lesson.

One misconception that was revealed through the Pre-Assessment Probe was that many students believed that objects at thermal equilibrium have different temperatures. The plastic part of their chairs must have a warmer temperature than the metal part of the same chair because the metal feels colder when touched. I then set up an experiment with a series of different materials such as wood, plastic, glass, metal, etc, and I also created a worksheet that students used to make predictions and record their data. The first phase of a CCM lesson is to get students to commit to their beliefs before the lesson begins. I asked the students to pick up each object briefly and then to write down their predictions on the worksheet.

The second phase of the CCM lesson involves students sharing their beliefs with their classmates so that they can see the differences in beliefs (Schmidt et al., 2006). After students had written their predictions down I followed with one or two questions that I asked verbally. I used Socratic Dialogue questions to help them focus their thinking. I called these Eyes Closed Questions (Appendix M) and the purpose of these questions was to extend student thinking and provide a format for students to share their thinking with each other. I had them answer by raising their hands with their eyes closed. By closing their eyes they could feel free to express their ideas without influence or scrutiny from their peers. If it was a question that couldn't be answered by voting or raising hands and required a longer response, I passed out index cards. In the thermal equilibrium example I asked them how many people thought the metal would record the coldest temperature, how many thought it would be wood, and how many thought both objects would be the same temperature. I then shared the ideas of the class by telling them the percentage of students who answered for each question.

I then implemented the third phase of the CCM lesson, which is to provide students with constructivist-based activities in order to the challenge their pre-conceptions (Schmidt et al., 2006). I had the students measure the temperature of each object using a temperature probe with a Vernier Lab Quest unit (www.vernier.com/labquest) During this phase I had the students record their data. They measured and recorded the temperatures of each object. I then went around the room and had each group share their findings with the class to see if there was overall agreement between groups. If there were any outliers we had those groups repeat their experiment and continued until everyone had data that was in agreement.

In the fourth phase of the CCM lesson, students should be given a chance to accommodate new thinking and restructure their thinking (Schmidt et al., 2006). We explored possible reasons as to why it is that they had misconceptions in the beginning of the lesson. Each lesson was 40 minutes in length and so due to time restrictions I tried to continue the fourth phase with a second lesson the following week. Since lessons were grouped into subunits based on common conceptual themes, each lesson was followed with a second or third lesson that would help them to further extend and explore the previous concept. So for example, in the CCM Heat Subunit (Appendix I), I first covered two lessons on thermal equilibrium and then followed with two lessons on heat transfer. All four lessons continued to develop the concepts of thermal equilibrium and heat transfer. If students came to understand the concepts of heat transfer then they would have a mental schema to help them think through the reasoning involved in why it is that a metal object feels cold when you touch it.

Before each lesson I had students review the previous lesson with a couple of questions and after each lesson I had students make connections between the lessons with a couple of questions. So, for example after the CCM Heat Subunit Lesson #3 (Hot Hands/Cold Hands), I asked them to go back to touching their chair and explain what happens in terms of heat transfer when they touch the plastic part and the metal part.

Depending on time, I had them either write down their answers or I chose a few students to share their answers verbally with the class.

The fifth and sixth phases of the Conceptual Change Model Lesson require that students try out their newly formed mental schema to new situations and contexts (Schmidt, Saigo, & Stepans, 2006). By cycling the lessons in subunit groups as described above, I gave students more than one opportunity to try out their newly formed mental schema to new situations. For example, in the CCM Heat Subunit Lesson #2 (Appendix I) students were asked if a thermometer placed inside a mitten would record a higher temperature or the same temperature as a thermometer placed outside the mitten. This provided a completely different scenario but involved the same concepts as the first lesson. Therefore students should be able to answer correctly if their new mental schema is firmly established. At the end of the entire unit we did two culminating activities where students could apply their thinking to new contexts. The first activity included a competition where students designed a thermos that loses as little heat as possible and the second culminating activity was a series of demonstrations with liquid nitrogen.

After completing the unit, I administered the same Assessment Probes (Appendix K) and Student Attitude Survey (Appendix F) to all of the students (*N*=63) and the Student Misconceptions Diagnostic Interview (Appendix J) to the same three students from each class (*N*=12) that I had used previously. I used the same tools as I used in the beginning in order to assess if there had been any change between pre and post treatment. The data from the Assessment Probes was analyzed by calculating the percentage change for each identified misconception. In order to validate the data collected and ensure that primary and secondary research questions have been sufficiently addressed, I summarized the data using the triangulation matrix (Table 1) listed below.

Table 1
Triangulation Matrix for Data Sources

Research Questions	Data Source		
	1	2	3
1. Current Misconceptions	Pre-treatment Student Misconception Diagnostic Interviews	Pre-treatment Assessment Probes	Eyes Closed Questions
2. Effectiveness of Constructivist Teaching Methods	Post-treatment Student Misconception Diagnostic Interviews	Post-treatment Assessment Probes	Parent Questionnaire and Teacher Attitude Survey
3. Student Attitudes	Student Attitude Survey	Parent Questionnaire	Teacher Attitude Survey
4. Teacher Attitudes	Teacher Attitude Survey		

DATA AND ANALYSIS

After applying the first phase of the Conceptual Change Model (CCM), the data collected from the Pre-Assessment Probes and the Student Misconceptions Diagnostic Interviews revealed that most students had fundamental misconceptions regarding energy and heat concepts at the beginning of the unit. Before the CCM Energy and the CCM Heat subunits, all students correctly predicted that when a hot object touches a cold object, heat should move into the cold object. However, 86% also incorrectly predicted that cold would move from the cold object into the hot object (N=63). Only 6% of students thought that both metal and wood should have the same temperatures under conditions of thermal equilibrium (Figure 1) and only 10% thought that a thermometer placed inside a mitten should record the same temperature as a thermometer placed outside of a mitten (Figure 2). For the CCM Chemical Energy Subunit, student misconceptions included 67% of students who were unable to identify an apple as a form of energy and 45% of students who predicted that oxygen would increase during burning (*N*=62).

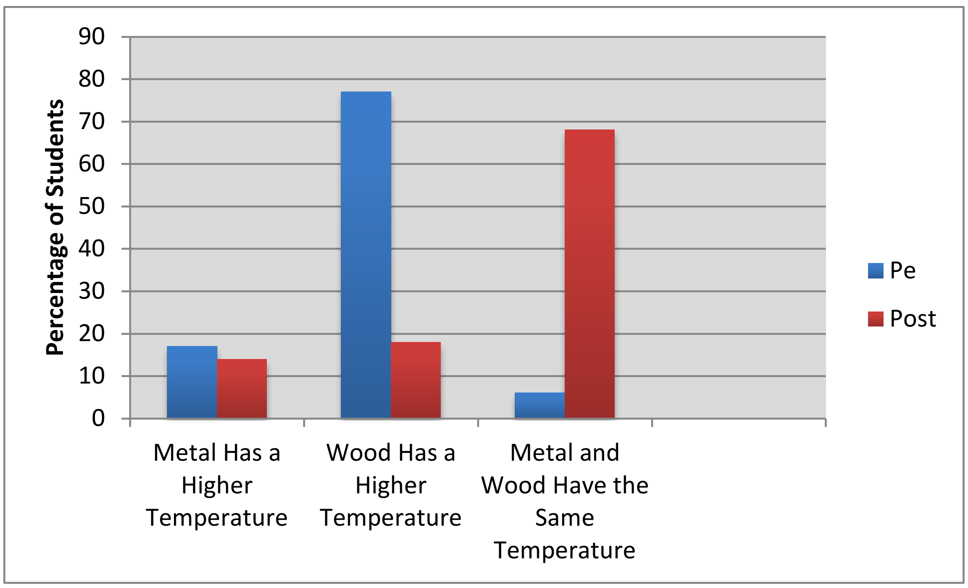

Figure 1. Student Responses to Questions on Thermal Equilibrium, (*N*=63).

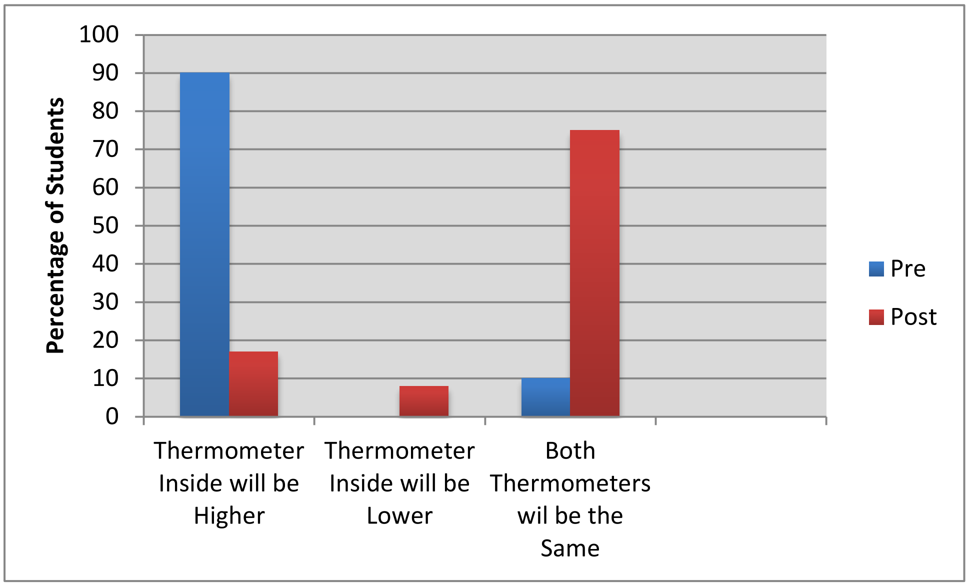

Figure 2. Student Responses to Question: Will a thermometer inside a mitten record a higher, lower, or same temperature reading when compared to a thermometer lying beside it outside of the mitten, (*N*=63).

In addition to the identification of misconceptions it also became evident that for many students these were naïve concepts and they had no mental schema in place at all (Vosniadou, 2002). When asked in the Student Misconceptions Diagnostic Interviews to define what energy is, 92% of students simply gave examples of energy or similes for energy. The same was true when asked to give definitions for heat and cold, where only 8% identified that heat is a form of energy and no one could define coldness (*N*=12). When asked, *why is it that some things burn and others don't*, none of the students could explain although 33% did identify that the type of material an object is made of is important.

During the third and fourth phases of the CCM treatment students explored their ideas through experiments. During the early part of these phases there were often contradictions in the data that may indicate that although some students gave a correct answer, they did not fully understand the concepts. They were still exploring their ideas and not yet sure about the validity of these ideas. For example, most students could easily identify that oxygen was needed for burning (92%). However, when asked to predict what would happen in an experiment using a Vernier oxygen probe to measure the oxygen levels of a burning object in a flask, 45% of the students predicted that oxygen levels should increase. During the same lesson only 12% of students identified that carbon dioxide was produced and released in burning even though they had just watched a video with their classroom teachers the day before on the burning of fossil fuels and global warming (*N*=63).

During this time period I found that the Eyes Closed Questions during lessons were very effective in helping students to extend their thinking and to share their thinking with one another. Often it seemed that students didn't think through questions very well initially. One of the teachers I worked with also commented on this and said, "students need to get warmed up first. Sometimes they know it but they don't know how to talk about it." For example in the beginning of the CCM chemical subunit when I asked the Eyes Closed Question, *do all things burn when placed into a fire,* 23% of students answered yes (*N*=63). I then extended their thinking with the question, *is water a "thing" that burns and is a rock a "thing" that burns.* They all agreed that rocks and water do not burn and therefore changed their previous answer. When asked if water, sand, and soil will heat up the same amount when put under a heat lamp for a 15 minute time period, 32% of students thought that water would heat up the most (*N*=63). I then asked them, the following question, *imagine it is a hot day in the sun and you are* *running around barefoot. Where should you stand if you want to keep your feet from burning*? All students voted for the water and not the sand. One student pointed out, “if water were to get hotter than sand, we would swim in the sand instead of the ocean to stay cool on a hot day.” In this example the students were drawing on a mental schema that was already in place due to life experiences. but as their teacher had pointed out they needed a little time to “get warmed up” in order to fully access it.

In support of the CCM being a methodology that encourages students to develop enthusiasm and curiosity for science, the Teacher Attitude Survey revealed that students were very excited about the unit and the experiments (*N*=4). In answer to the question, *did the methods used (CCM) stimulate student interest in science,* one teacher wrote, “one hundred percent yes” and another wrote, “absolutely, very much,” and another wrote, “students were very excited.” In the Parent Questionnaire, 91% of parents said that their child talked about experiments at home and many added the comment that the child was “very excited” about doing these experiments (*N*=27). When asked, how many times the child discusses something at home relating to our science unit, 52% said daily, 33% said once a week, 15% said a couple of times, and no one said none (*Figure* 3).

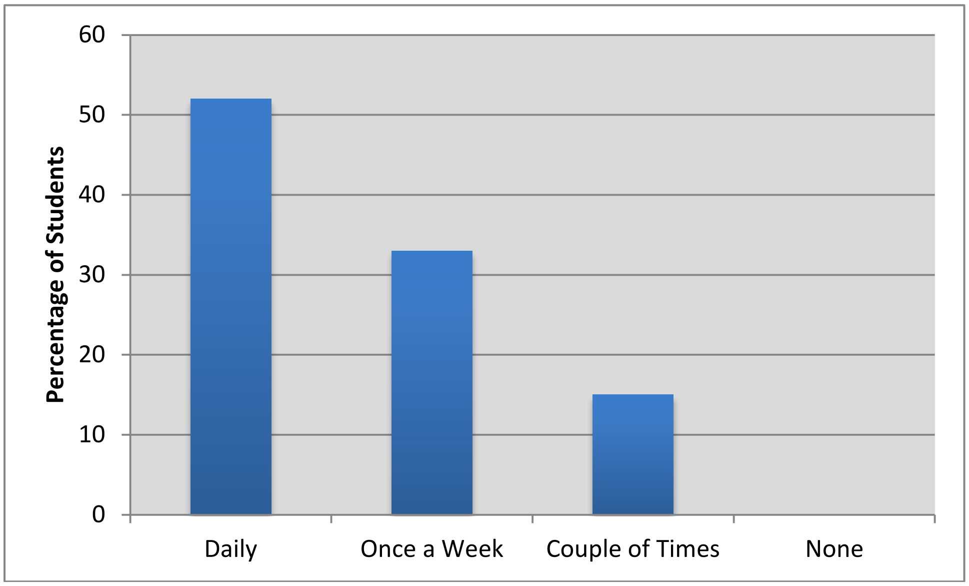

Figure 3. Parent Questionnaire: Frequency of Student Initiated Discussion About the Science Unit at Home, (*N*=27).

Data collected from the Student Attitude Survey did not show much change. For the question, *I like science*, there was only a one percent positive change between pre-treatment and post-treatment. Likewise, there was no change for the prompt, *I have a good understanding of science* (*Figure* 4). The biggest change in positive values was to the prompt, *I think science is difficult*, with a 16% change. The biggest change in negative values was 75%, in answer to the question, *I know how to conduct experiments*, (*Figure* 4).

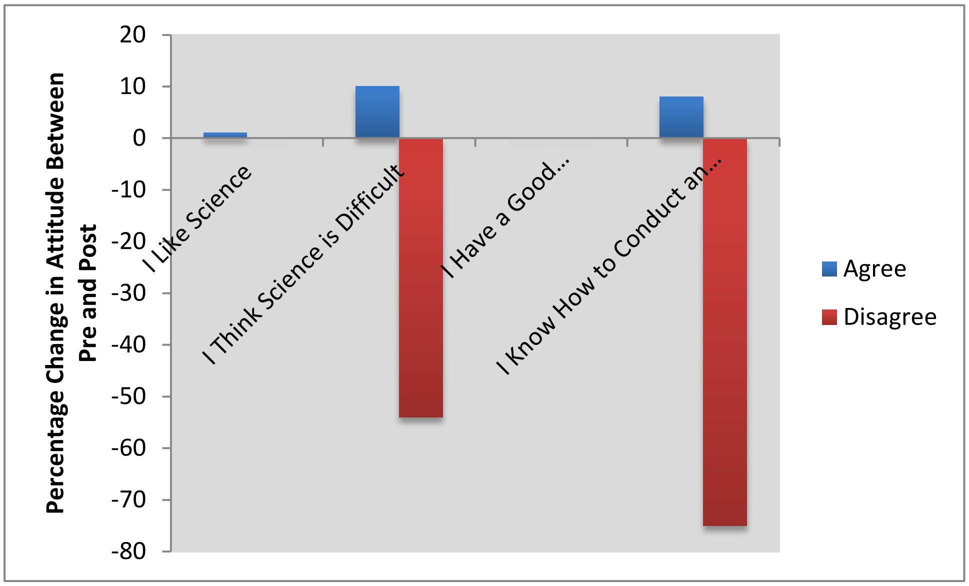

Figure 4. Percentage Change in Student Attitude Between Pre and Post Treatment, (*N*=63).

The data collected from the Teacher Attitude Survey reveals that lack of time is the biggest issue. All of the teachers commented on the survey that time was an issue, especially given the number of benchmarks that had to be covered in one six week unit. One teacher wrote, “students need time just to learn the vocabulary in addition to the science concepts, otherwise they won’t be able to communicate what they know” and another teacher commented, “more time is needed for elementary students to review again and again.” At AISB the fourth grade elementary program only devotes a total of 14 hours per year for science and this time is grouped into two six week units. For this unit I met with each class for one 40 minutes session each week and then teachers devoted two to three more 40 minutes sessions throughout the week in the their own classrooms. This unit was extended to eight weeks, but the teachers still felt that there were too many benchmarks to cover in this time period.

The second biggest issue was lack of resources. When asked if they felt prepared with the necessary resources to teach the benchmarks 75% of the teachers reported that they did not (N=4). One teacher elaborated with, “the challenge for many elementary teachers is we often lack space, set up and instructional time and access to equipment and materials.”

In answer to the questions that targeted the issues of academic and methodological preparedness 50% of teachers felt they were well prepared and 50% felt they were somewhat prepared. Two of the teachers were very enthusiastic about science and did have a good background, but even one of the better prepared teachers said, “I found the high school teacher to be much more knowledgeable about energy than I was. I would not have known what equipment to use and how to set up the experiments.” One of the teachers felt very unprepared academically and said, “I have to spend a lot of time preparing a science lesson because I have never been to a science workshop since becoming a teacher and did not study science much in university.”

Data collected from the Parent Questionnaire shows that 61% of parents said that their child mentioned having a wrong idea about something (*Figure* 5). One parent said, “He found out in an experiment that the temperature inside the glove was the same as the temperature outside the glove which he expected to be more.”

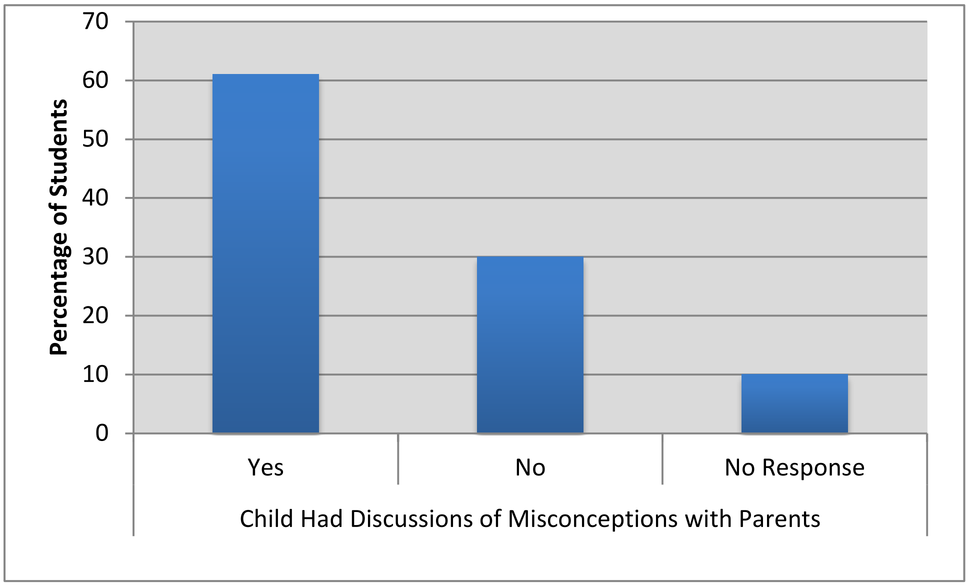

Figure 5. Percentage of Students Who Discussed Their Misconceptions with Parents, (*N*=27).

In answer to the question, *Do you see any evidence in your discussions with your child that there has been any growth or change in their ideas about some of the concepts we have been learning about in regards to heat and energy,* 73% of parents said yes, 11% said no, and 16% didn't respond (*Figure* 6).

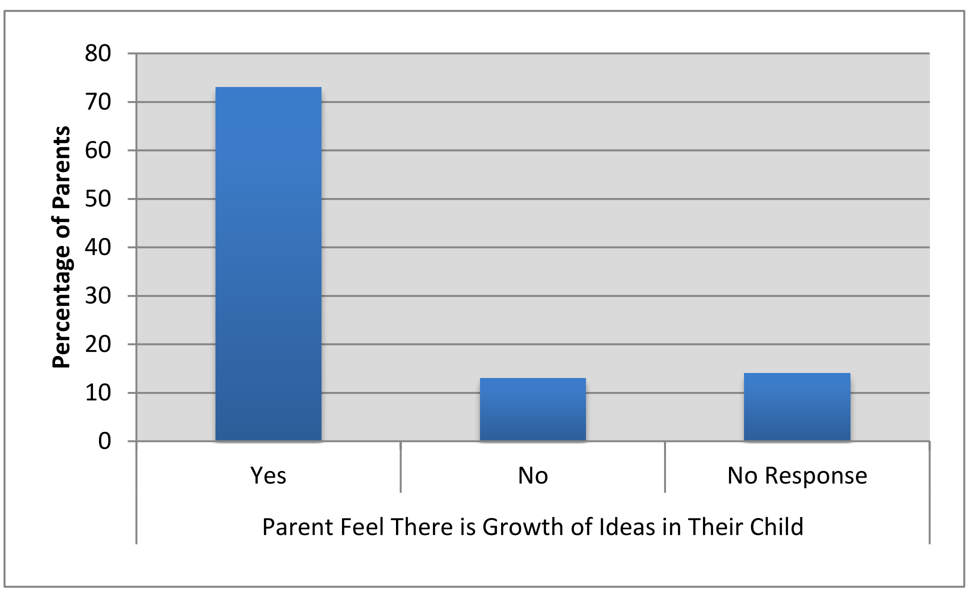

Figure 6. Parent Response to Question: *Do you see any evidence of growth of ideas and /or change in ideas during the course of this unit?, (N=27).*

In addition to parent opinion, the differences in answers between pre and post Assessment Probes and pre and post Student Diagnostic Interviews also showed considerable change in student thinking. The Post-Assessment Probe indicates that the misconception of objects having different temperatures at equilibrium was dispelled by 62% of students. Only 6% of students had answered letter C (metal and heat will be equal temperatures) in the Pre-Assessment Probe compared to 68% in the Post-Assessment. A similar question targeting the same concept indicated that this misconception was dispelled by 65% of all students.

In both of the questions shown above in Figure 1 and Figure 2, there are still some students who have not restructured their thinking. In Figure 1, there are still 32% of students who think that metal or wood should have different temperatures at thermal equilibrium. In Figure 2 there are still 25% of students who think that the two thermometers will not be the same temperature.

In addition to the numerical data represented in the graphs above, there were also student comments that revealed growth in thinking between pre and post treatment. In the pre-treatment Student Misconception Diagnostic Interviews, only one student out of 12 defined heat as a form of energy. In the post treatment comments all of the students used the word energy when they were describing heat. The definitions of energy in general showed more depth as 83% of students gave characteristics of energy such as, “energy can change from one type to another” rather than giving just examples or similes (*N*=12).

There was only one concept from the unit where 100% of all students effectively dispelled their misconceptions. When asked if coldness could move from a cold hand to a hot hand when two people are holding hands, 86% of students responded *yes* in the Pre-Assessment Probe. However in the Post-Assessment Probe, 100% of all students responded *no* (*Figure* 7).

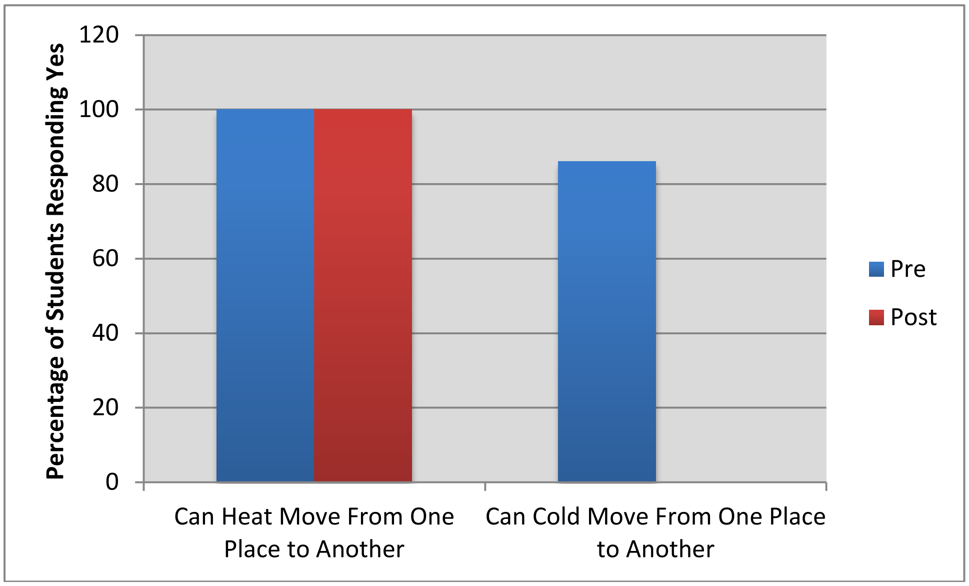

Figure 7. Percentage of Students Who Responded "Yes" to the Question, *Does Coldness Move From a Cold Hand into a Hot Hand*, (*N*=63).

INTERPRETATION AND CONCLUSION

The focus of my research was to investigate the effectiveness of the CCM in dispelling student misconceptions. The first step was therefore to identify these misconceptions and there were some basic ones that I expected students to have. Therefore, I was not surprised when none of the students could define coldness and when 86% of students said that coldness from a cold object could move into a hot object. For every misconception I targeted, I had a plan for an experiment that I knew would allow the students to see contradictions between what they thought would happen and what actually did happen. This was necessary in order to move students beyond comprehension and towards true apprehension. According to Corbern (1993), “It is not that students fail to comprehend what is being taught- it is that they simply do not believe it” (p. 1).

I do not think the elementary teachers would have targeted these misconceptions as easily due to their lack of experience with the content and also with the laboratory equipment and knowledge of experiments that would work well. I asked teachers to list what they thought their students misconceptions would be for this unit, but none of them contributed anything to that list. One teacher told me she did not know what the misconceptions would be for this unit and another teacher told me she would have had no idea about what experiments to use. All the teachers commented frequently that having a “science person” who had access to and experience with the equipment was very beneficial. The feedback I got from the teachers supports the research done by Dharmadus (2000), Schwartz (2000), Rice(2005), and Hounshell (1984) who all maintained that a science specialist will be better prepared to identify student misconceptions and direct the process of inquiry with effective instructional opportunities.

In the process of probing for misconceptions I found the interviews to be the most enlightening. I tried to use the same probing questions for all students in order to control this variable and ensure more reliability in the data collection. However I found that this was difficult because students gave very different answers. My primary focus in these interviews was to probe as deeply as I could in order to obtain a complete picture of each student's mental schema on every targeted concept. Some students just locked me out with an "I don't know" and were unwilling to pursue any thinking. Other students could be enticed with further questioning to ponder and sometimes even eventually figure out that their thinking was flawed. For example when I asked the question, *why is it that some things burn and other things don't burn*, one student told me it is because only strong things like metal burn. So I asked him if wood is strong and he agreed that it is. I then asked him why it is that wood burns but metal does not even though they are both strong. He changed his mind about the strength hypothesis but then ran out of ideas and just said, "I don't know." I used only Socratic style questioning when doing the interviews. I only asked questions and never gave answers. However the most interesting part of this process was that I found that the method of using Socratic questioning became a learning tool for some of the students. So that even before we began the experiment phase, some of the students who did the interviews with me had already figured a few things out. In fact, because I used the same or similar questions in the Pre-Assessment Probes that I used in the Student Misconception Diagnostic Interviews, some of the data that came from the Pre-Assessment Probes was skewed. The graph shown in the *Figure 5* shows 10% of students understood that metal and wood have the same temperature at thermal equilibrium. However those 10% may very well be the students I had interviewed since the interviews took place before the Pre-Assessment Probes were handed out.

In the future I would be sure to do the Pre-Assessment Probes first before the interviews in order to collect more reliable data in terms of pre- treatment misconceptions. I also think it would have been interesting to record the number of questions used for each student and analyze the data to see if there is a correlation between the number of questions asked and the success of each particular student in dispelling their misconceptions in the post-treatment phase.

I did feel that the process of getting students to commit to a belief by putting it in writing or raising their hand in a vote, naturally set the stage for stimulating their curiosity. They always seemed really eager to find out if their idea was correct and they were often genuinely surprised when they were wrong. When they were wrong they were really motivated to do it again and explore further. They were also eager to discuss their results and their ideas. I was continuously impressed by the number of hands that were up all of the time during this process. I did not collect any data for classroom observations and I think it would be interesting for a future study to count the number of hands that go up in this type of lesson compared to a more traditional teacher directed lesson. This type of data could have been used to evaluate student interest level.

The data collected from the Student Attitude Surveys did not indicate significant change between pre and post treatments in the Likert scaled questions regarding interest in science. However, the reason that not much change was indicated could be due to the fact that students answered the, *I like science* question very high to begin with. There were 43% of students who gave it the highest rating of *I strongly agree* and 32% who answered *agree.* Therefore with 75% of students already giving such a high rating it is difficult to show improvement in this attitude. All of this data however may simply be related to science in general and not necessarily relevant to the use of the CCM methodology. The excitement level of the students was already heightened when they walked into my room for their science lessons. It was an entirely different environment being in the high school and being in a “real lab” as they called it, with lots of interesting “stuff.”

The concept of heat transfer is the only concept that was 100% effectively dispelled in this study. This heat transfer concept is also the only concept where I applied the use of a kinesthetic simulation in addition to an experiment. So it is also possible that the use of a kinesthetic simulation helped students to build a mental scheme more effectively than the experiments did. During the Post-Assessment Student Misconception Diagnostic Interviews I had a few students who started to go back to their previous misconception of coldness moving into a hot object. However each one of them corrected themselves. One student started by saying, “cold can move if there is a lot of cold and a little hot, no wait….coldness can’t move, like the people with no energy it can’t move, so no coldness doesn’t move only heat can move because hot things have energy.”

All of the instruments I used allowed me to triangulate my data and make comparisons between pre treatment and post treatment. Analysis of the changes between pre and post treatment data supports the outcome of my primary research question as being positive for the impact of the CCM methodology on dispelling misconceptions in this group of fourth graders.

VALUE

On a school-wide level I believe my research has had positive impact. I do think a science specialist was helpful to the elementary teachers by being better able to target misconceptions with appropriate questions and experiments. So hopefully the elementary and high school teachers in our school will continue to collaborate especially with designing and implementing new units of study. Working with the elementary teachers also helped us all to re-evaluate the existing benchmarks and time issues and consider some possible changes that will improve this unit in the future.

This project has also opened up communications and engendered collaborative relationships between teachers at very different grade levels, who normally would never see each other or work together. This allowed genuine professional development to take place for all teachers involved. The elementary teachers developed a better understanding of the concepts involved for the heat and energy unit and they were introduced to the CCM methodology as an effective tool for directing and planning instruction. I in turn learned many valuable things from the elementary team including some strategies for working with young children.

In support of the elementary teachers, I also agree that time was the most difficult issue and overall I do not feel that I was able to follow all of the stages of the CCM effectively. There were so many benchmarks to cover, that I had to compromise between following all stages of the CCM with instead making sure I covered every benchmark given for the unit since that was the directive of our school administration. I tried to work the benchmarks into common conceptual themes and for each theme I followed the first four stages of the CCM as outlined by Schmidt, Saigo, Stepans, (2006).

The fifth and sixth phases of the CCM requires that students try out their newly formed mental schema to new situations and contexts. Due to time issues these are the stages that I did not get to for any of the concepts except for that of heat transfer. It follows that for the concept of heat transfer the data supports that students were the most successful in dispelling their misconceptions. This could be due to the full application of all phases of the CCM. It is also possible that the use of a kinesthetic simulation had a positive impact on students in helping them to construct a valid mental schema.

Throughout the time period of this research I have changed some of my own preconceptions and have gained some valuable insights that I have begun to apply with my high school students. One of the aspects that has most impressed me about the use of the CCM is the first step where students are asked to really commit to an ideas and own it before the lesson begins. I have been using Eyes Closed Questions and I have found that high school students, much like elementary students, become really invested when they have committed to a belief. This simple first step of the CCM engages students and it directs the planning of my instruction because it allows me to identify what my students know and don’t know. I can then more effectively set up experiments (or simulations) that allow students the opportunity to contrast their ideas with their observations and also with the ideas of their classmates. Students also seem to be more invested and engaged when they aren’t simply given an answer, but are asked to figure it out themselves, especially when the validity of their preconception is being tested. I feel that the use of this methodology has helped me to build better relationships with my students because it is far more interactive and gives them opportunities to reveal themselves more to me than other methodologies I have used in the past.

I am currently teaching IB biology and the one aspect of the CCM that I have struggled with the most is in trying to find purely experimental experiences for students to construct knowledge for many of the concepts I teach. The problem is that students have no previous knowledge at all for some of the concepts I teach and some of these concepts cannot be developed through experimentation. So this year I have been using a lot more kinesthetic simulations similar to the one I used in the heat transfer concept described above. I recently had students simulate the female hormone cycle using ping-pong balls to represent hormones. I have been impressed with the level of enthusiasm these activities generate and the depth of conceptual understanding that results.

In summary of my research I have found that the CCM is a very effective methodology in dispelling misconceptions. It is equally effective for enabling students to construct entirely new conceptual schemas when students have no previous ideas in place. By forcing students to commit to their ideas and then validate or invalidate those ideas through experimentation, the CCM stimulates student interest and investment. I also feel that the CCM engenders respectful relationships between teachers and students.

I enjoyed the process of collecting data and formally doing research while applying one focused methodology. I usually use a blend of different methodologies in my teaching. Because I had to isolate and focus on the CCM methodology I came to appreciate it more. I also saw that often the elementary teachers drew students away from the full impact of the methodology by revealing information before students had a chance to experiment with it. I came to appreciate that mixing methodologies may negate the effectiveness of those methodologies. Using the CCM exclusively directed my teaching and gave it more focus. I also found that the process of collecting and analyzing data forced me to look more in depth at student thinking than I normally would. Although much of the student thinking was what I expected there were many unexpected insights as well. Some questions that came out of this research that I would like to explore further include:

- Does the use of kinesthetic simulations help students to develop valid mental schemas?
- Does the use of the CCM create more respectful relationships between teachers and students?
- Once students have a new mental schema in place how many new opportunities need to be provided for students to apply this schema to novel situations?
- Does the process of Socratic questioning used exclusively in isolation of the CCM or any other methodology effectively dispel student misconceptions?
- Can elementary teachers make accurate predictions regarding student misconceptions?
- How does the amount of time devoted to science education in elementary school impact the presence or absence of student misconceptions in upper grade levels?

- How does the amount of time devoted to science education in elementary school affect the attitudes that students have about science in the upper grade levels?

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APPENDICES

APPENDIX A

CONSENT FORM

Appendix A

Consent Form

Informed Consent Form for Students in the Study

The purpose of this research project entitled "Conceptual Change Model in Elementary Education" examines the effectiveness of identification of student misconceptions and focused experimental opportunities that allow students to prove those misconceptions invalid. For this project, students will be asked to complete the Matter Unit Misconceptions Diagnostic Interview and the Matter Unit Misconceptions Pre-Assessment and Post-Assessment Probe Questionnaire. All of these data collection instruments fall within the area of common classroom assessment practices.

Identification of all students involved will be kept strictly confidential. Most of the students involved in the research will remain unidentified in any way, and their levels of environmental interaction will be assessed and noted. Eight students will be randomly chosen for the interviews by their classroom teachers. Nowhere in any report or listing will students' last name or any other identifying information be listed.

There are no foreseeable risks or ill effects from participating in this study. All treatment and data collection falls within what is considered normal classroom instructional practice. Furthermore, participation in the study can in no way affect grades for this or any course, nor can it affect academic or personal standing in any fashion whatsoever.

There are several benefits to be expected from participation in this study. This project will help to facilitate a union for shared resources and expertise between the elementary and high school divisions. It will give the elementary teachers and myself an opportunity to practice a new methodology with measured results that can be evaluated in more depth than most everyday practiced methodologies.

Participation in this study is voluntary, and students are free to withdraw consent and to discontinue participation in this study at any time without prejudice from the investigator.

Please feel free to ask any questions of Sheri Gates via e-mail, phone, or in person before signing the Informed Consent form and beginning the study, and at any time during the study.

Principal signature: ______________________

Date: ______________________

APPENDIX B

IRB EXEMPTION

Appendix B

IRB Exemption

MONTANA STATE UNIVERSITY

MEMORANDUM

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

960 Technology Blvd. Room 127
c/o Veterinary Molecular Biology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
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Chair: Mark Quinn
406-994-4707
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-6783
cherylj@montana.edu

TO: Sheri Gates

FROM: Mark Quinn, Ph.D. Chair *Mark Quinn cy*
Institutional Review Board for the Protection of Human Subjects

DATE: November 30, 2010

SUBJECT: *"Action Research: Identification of Misconceptions in Elementary Children Using the Conceptual Change Model"* *[SG113010-EX]*

The above research, described in your submission of November 29, 2010, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal Regulations, Part 46, section 101. The specific paragraph which applies to your research is:

___ (b)(1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

___ (b)(3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

___ (b)(4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

___ (b)(5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

___ (b)(6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX C

ASIB CURRICULUM STANDARDS AND BENCHMARKS

Appendix C

ASIB Curriculum Standards and Benchmarks

Science
Grade 4

Standard 1 – Physical Science
Students will develop an understanding of the concepts, models, theories, universal principles, and facts that explain the physical world.

PS 1.1 Properties of Matter
Students will develop an understanding of the characteristic properties of matter and the relationship of these properties to their structure and behavior.

PS 1.1 C By the end of Grade 5, students will be able to identify and describe the physical and chemical properties of a substance.

I. Collect and organize data about physical properties in order to classify objects or draw conclusions about objects and their characteristic properties (e.g., temperature, color, size, shape, weight, texture, flexibility).

PS 1.1 E By the end of Grade 5, students will use measures of weight (data) to demonstrate that the whole equals the sum of its parts.

I. Select the appropriate metric system tools for measuring length, width, temperature, volume, and mass.

PS 1.1 F By the end of Grade 5, students will use observations of magnets in relation to other objects to describe the properties of magnetism (i.e., attract or repel certain objects or has no effect).

I. Observe and sort objects that are and are not attracted to magnets.
II. Predict whether or not an object will be attracted to a magnet.
III. Describe what happens when like and opposite poles of a magnet are placed near each other.
IV. Determine the relative strength of various magnets (e.g. size, number of paper clips attracted, etc.).
V. Describe the physical properties of magnets.

PS 1.3 Forms of Energy
Students will develop an understanding of the characteristics of energy and the interactions between matter and energy.

PS 1.3 A By the end of Grade 5, students will predict the observable effects of energy (i.e., light bulb lights, a bell rings, hands warm up) when given a specific example or illustration (e.g., simple closed circuit, rubbing hands together), (e.g., a test item might ask, "what will happen when…?").

I. Observe how energy does things (e.g., batteries, the sun, wind, electricity).
II. Explain that energy comes from different sources, such as electricity and water, and is utilized in many common objects.
III. Describe how energy produces changes (e.g., heat melts ice, gas makes car go uphill, electricity makes TV work).

IV. Identify the various forms of energy, such as electrical, light, heat, sound and explain that these forms of energy can affect common objects and are involved in common events.

PS 1.3 B By the end of Grade 5, students will experiment, observe, or predict how heat might move from one object to another.

I. Classify objects in terms of their relative temperature (e.g., hotter and colder).
II. Identify some examples where heat is released (e.g., burning candles, rubbing hands, running).
III. Describe that heat can be produced (e.g., burning, rubbing, mixing some substances).
IV. Explain that heat moves more rapidly in thermal conductors (e.g., metal pan) than in insulators (e.g., plastic handle).
V. Describe the effectiveness of different insulating and conducting materials with respect to heat flow.
VI. Classify a variety of materials on whether they conduct heat (conductors) or do not conduct heat (insulators).
VII. Classify a variety of materials as which can reflect or absorb light.

VIII. Classify a variety of materials on whether they conduct electricity (conductors) or do not conduct electricity (insulators).

PS 1.3 D By the end of Grade 5, students will use observations of light in relation to other objects/substances to describe the properties of light (can be reflected, refracted, or absorbed).

I. Describe the effects of the sun's energy on different materials.
II. Identify the sun as the main source of the Earth's light and heat energy.
III. Compare the heating and cooling rates of air, land, and water.
IV. Analyze data to explain the heating and cooling rates of air, land, and water.
V. Describe how the Sun, a major energy source for the Earth, affects the planet's surface.

PS 1.4 Energy Transfer and Conservation
Students will develop an understanding of the transfer, transformation, and conservation of energy.

PS 1.4 A By the end of Grade 5, students will demonstrate and explain the movement of electricity in closed and open circuits.

I. Identify the use of electricity.
II. Construct and explain a simple electric circuit.
III. Demonstrate that electricity flowing in circuits can produce light, heat, sound, and magnetic affects.

PS 1.6 Forces Affecting Motion
Students will understand forces, their forms, and their effects on motions.

PS 1.6A By the end of Grade 5, students will use data to predict how a change in force (greater/less) might affect the position, direction of motion, or speed of an object (e.g., ramps and balls).

I. Explore the effects some objects have on others even when the two objects might not touch (e.g., magnets).

II. Describe the properties of magnetism and demonstrate how magnets can be used to move some things without touching them.
III. Explain that electrically charged material pulls on all other materials and can attract or repel other charged materials.
IV. Use observations of magnets in relation to other objects to describe the properties of magnetism (i.e., attract or repel certain objects or has no effect).

Standard 3 - The Earth

All students will gain an understanding of the structure, dynamics, and geophysical systems of the earth.

ES 3.6 Earth Sciences (Biogeochemical Cycles)

Students will understand that Earth systems have a variety of cycles through which energy and matter continually flow.

ES 3.6 A By the end of Grade 5, students will explain that the supply of many resources is limited, and that resources can be extended through recycling and decreased use.

I. Distinguish between and provide examples of materials that can be recycled/reused and those that cannot.
II. Describe how some resources can be used and reused.
III. Explain that the supply of many resources is limited but the supply can be extended through careful use, decreased use, reusing and/or recycling.
IV. Explain that the supply of many non-renewable resources is limited and can be extended through reducing, reusing and recycling but cannot be extended indefinitely.
V. Describe ways Earth's renewable resources (e.g., fresh water, air, wildlife and trees) can be maintained.
VI. Identify examples where human activity has had a beneficial or harmful effect on other organisms (e.g., feeding birds, littering vs. picking up trash, hunting/conservation of species, paving/restoring greenspace).

APPENDIX D

TEACHER ATTITUDE SURVEY

Appendix D

Teacher Attitude Survey

Name____________________

Part 1: Please answer the questions below with one of the following;
strongly agree, agree, somewhat agree, disagree, strongly disagree

1. I enjoy teaching science.

2. I feel I am academically prepared to teach the science benchmarks stated in the curriculum. (I have enough understanding of the essential scientific concepts)

3. I feel I am strategically prepared to teach the science benchmarks stated in the curriculum. (I have enough knowledge and experience in strategies that will work well to help students understand the scientific concepts)

4. I feel I am prepared with the necessary resources needed to teach the science benchmarks in the curriculum.

Part 2: Please answer the following open response questions.

1. Were the methods used in teaching this unit different or the same as the methods you would normally use?

2. Did you feel that the methods used in this unit effectively helped students to understand the concepts outlined in the standards and benchmarks of the AISB curriculum?

3. Did you feel that the methods used in this unit stimulated student interest in science?

4. Do you think that your students had any misconceptions at the beginning of the unit? Did this surprise you, or were these misconceptions what you had expected based on your previous experience?

5. How do you feel the activities and materials used in this unit compare to the FOSS kits in regards to targeting student misconceptions?
   (a) they are equal
   (b) the FOSS kits are better for targeting student misconceptions
   (c) the activities in this unit were more focused in targeting student misconceptions.

APPENDIX E

PARENT QUESTIONNAIRE

Appendix E

Parent Questionnaire

Introduction:

My name is Sheri Gates and I am the high school IB Biology teacher. I normally work with much older children (juniors and seniors) but currently I am conducting a research project through a course I am taking at Montana State University. I am interested in using a teaching strategy that first identifies any misconceptions that students might have and then allows students to experimentally expose their misconceptions and rebuild a new conceptual framework. I have chosen to work with elementary students because it is at this young age that many misconceptions begin to take root and sometimes remain unchallenged for many years. This is also a wonderful opportunity to merge the elementary science program with the high school, share resources and collaborate in our teaching. With new changes in the standards and benchmarks it is an appropriate time to re-evaluate some of the units we are teaching in order to make sure we have the proper strategies and resources in place to best achieve our objectives. I have been working with the fourth grade teachers to develop a unit for energy and heat transfer. The teaching methodology we are using is a called the Conceptual Change Model and it involves pre-assessing student thinking before a lesson and setting up experimental opportunities for them to then explore their ideas and determine if their thinking is valid or invalid. Students have been conducting experiments; collecting data and making observations in a series of activities that have helped to guide them towards a valid conceptual understanding of energy and heat transfer. I would appreciate your feedback through the questionnaire below so that I can determine if this teaching methodology we have been using has been effective. I am hoping through conversations with your children you have seen some evidence of their thinking throughout this science unit.

Questionnaire:

1. We have been working on this unit since mid-January (six weeks total). Could you please estimate how many times your child has brought up anything that has to do with our science unit. You can record an actual number if you wish or just circle one of the following:

    a. no mention at all of science
    b. a couple of times it was talked about
    c. once a week there was something mentioned
    d. daily there was talk about science
    e. several times a day

1. If your child did talk about science, how did he or she feel about it? Did your child feel that it is difficult, boring, exciting, interesting, etc?

2. Did your child mention anything about having a wrong idea about something or finding out that something is different from what he or she expected?

3. Did your child mention anything about doing experiments? If so, what was your child's attitude about these experiments?

4. Do you see any evidence in your discussions with your child that there has been any growth or change in their ideas about some of the concepts we have been learning about in regards to heat and energy?

Thank you so much for taking the time to complete this survey!!!

APPENDIX F

STUDENT ATTITUDE SURVEY

Appendix F

Student Attitude Survey

Please rank the following questions on a scale of 1 to 5. Circle a number.
1 = strongly agree
2 = agree
3 = somewhere in the middle
4 = disagree
5 = strongly disagree

1. I like science
   1 2 3 4 5

2. I feel we should study more science in school
   1 2 3 4 5

3. I think science is a difficult subject
   1 2 3 4 5

4. I think I have a very good understanding of science and how it works
   1 2 3 4 5

5. I have done a lot of experiments in science in the past
   1 2 3 4 5

6. I like experiments.
   1 2 3 4 5

7. I know how to conduct an experiment.
   1 2 3 4 5

8. Doing experiments helps me to find out if my ideas were right or wrong.
   1 2 3 4 5

APPENDIX G

CCM ENERGY SUBUNIT

Appendix G

CCM Energy Subunit

Lesson 1: What is Energy? (Benchmarks: PS 1.3 A I-IV)

1. Ask students to get into groups of 3 and come up with a definition of energy. What is it? How will you know it when you see it? Can you list examples of energy. Ask them to write down a definition of energy on an index card and collect the cards.

2. Summarize: Write student responses on the board, (people moving around, running, etc) Then put the answers into categories; all those involving movement call mechanical, heat, electrical, sound, nuclear, light, chemical, etc. Finalize a definition; what do all of these things on the board have in common? (they cause changes, do something,) Energy is something that causes a change or does some type of "work.." When energy acts on an object it is transferred to that object and changes it in some way. For example; when you clap your hands where does the energy start? (have students clap and think about it) wait for student responses (energy comes from arms or muscles or hands to create clapping motion) then what happens to that energy? (it changes to sound energy). Sound is the evidence that energy is being transferred; it starts with mechanical (your arms and hands) and changes to sound (the clap).

3. Stations: Each station has a task for students to do. Have students read the instructions and do the task described. Then ask them to decide what type of energy they are observing (from the list created above). Is there a transfer in energy? Is one type of energy being changed into another? (Use worksheet for students to fill out)

   A. wind up toy: Mechanical (you turning the knob) to mechanical (the toy moving)
   B. fry an egg: heat causing a chemical change in the egg.
   C. Mad Cow (toy): mechanical to mechanical (vibrations) and sound
   D. solar heat lamp: heat to mechanical
   E. generator: mechanical to electrical
   F. wind up music box: mechanical to another type of mechanical and sound

4. Ask them if heat can be changed to mechanical energy. Ask for an example from the stations of this (D). Ask them if mechanical energy can be changed to electrical. Ask for an example from the stations of this (E). Now ask if they can think of a way that heat energy from the sun might be used to create electricity (if D and E are put together; heat from the sun causes mechanical energy and this is used to create electricity like in the generator)

Energy Stations

Names of Group
Members____
_

Instructions: In each station do the task described and answer the questions. Use the word list on the board for the different types of energy.

Station A: Wind-up Toy
Wind up the toy and watch what it does.

1. What type of energy did you put into the toy to make it go ?_______________
2. What type of energy was produced by the toy?______________
3. In the wind-up toy, __________________ energy was changed into ____________________ energy.

Station B: Fry an Egg
Crack an egg into the pan and watch what happens to it.

1. What type of energy was put into the egg?__________________
2. What type of energy was produced in the egg?______________
3. In the egg, ________________energy was changed into__________________ energy.

Station C: Mad Cow
Press the button on the Mad Cow.

1. What type of energy did you put into the cow by pressing the button? _____________
2. What type of energy was produced?________________
3. In the cow, _______________energy was changed into __________________energy.

Station D: Solar Heat Lamp
Turn on the switch to the heat lamp and watch what happens.

1. What type of energy went into the metal pieces that caused the dial to spin?
2. What type of energy was produced? _______________
3. In the solar heat lamp, the _______________energy was changed into ____________________ energy.

Station E: Electrical Generator
Turn the wheel and watch what happens.

1. What type of energy went into the wheel?______________
2. What type of energy was produced?_______________
3. In the Electrical Generator, ___________________energy was changed into ___________________energy.

Putting it all together:

1. Can heat energy be changed to mechanical energy? ___________(yes or no)

   A. If you said yes, can you give an example from the above stations where this happened?
   ____

2. Can mechanical energy be changed into electrical energy?___________(yes or no)

   A. If you said yes, can you give an example from the above stations where this
   happened.?____

3. Can heat energy be changed into electrical energy?___________________ (yes or no)

   A. If you said yes, can you give an example from the above stations (hint: you may have to consider two steps or two stations)

   ____

4. Can you think of a way you could make an invention that would use heat from the sun to create electricity? Draw or explain below how it would work.

APPENDIX H

CCM CHEMICAL ENERGY SUBUNIT

Appendix H

CCM Chemical Energy Subunit Lesson #1

Lesson #1: What is Burning? (PS 1.3 B II and III) (ES 3.6 A I-VI)

1. Ask students to get into groups of three and have them answer the following questions:
   A. Where do we get most of our energy to heat our homes and power our cars? Where does this energy come from?
   B. Fossil Fuels are things that burn. Do all things burn? Are there things that don't burn? Why do some things burn and some don't?
   C. Make a list of some things that burn and some things that don't burn.

2. Collect index cards form each group and using their answers, make a list on the board of things that burn and things that don't burn.

3. Put students into stations. Each station has: paper, cotton fabric, metal, rock, clay, an almond and a marshmallow. All of these objects are equal in mass. There are also tongs, a bunsen burner and white tile plate.

4. Ask students to make predictions for these objects before they begin using the worksheet on the following page. Have students put these objects into categories: things that burn and things that don't burn.

4. Ask students to put on goggles and using the tongs, pick up each object and make observations using the worksheet provided.

5. When each group is finished, ask them to look up at the board where they wrote their predictions. Ask each group to give share their experimental results and revise the list on the board.

6. Ask the students what all of the objects that burn have in common. See if they can identify that these things are all objects that were once living (fossil fuels). If they can't identify that, use leading questions to help them. Ask them what each object is made of or where it came from. Where did the wood come from? Where did the almond come from? Answer: they are all made of living things (were once living). Do things that are still living burn? Why don't they burn as easily? (have water in them).

7. Ask them to use the data table from their worksheet and decide which object made the biggest flame (burned the brightest) and which object burned the longest. After a few students give answers, have them close their eyes and vote. Put the winning vote on the board. The almond should have burned the longest and the marshmallow, the brightest. Explain to the students that each piece was of equal mass and ask them which object would be the most

useful for keeping their house warm if they had to choose one. If they pick the almond, then ask them why it is that we don't heat our homes using almonds. What do we use instead? Introduce the concept of Fossil Fuels and the choices involved in why we use wood, gas, oil, coal, etc.

8. Ask students to look at their data table and describe what all of the things that burned looked like after they were finished burning. Was there anything left? Would it be possible to get this object that burned back again?

Summary of Concepts to be Extended Further in the Classroom and in Lesson #2:

1. Things that are living and were once living burn. Things that were once living burn best because (no water). Fossil fuels are things that were once living.

2. Burning living things produces heat energy.

3. Living things contain chemical energy. When you eat food, you are taking in chemical energy, and if someone ate you, they would take in chemical energy, etc.

4. Inside the cells of your body this chemical energy is "burned up" and used to provide us with heat energy, mechanical energy, etc. Ask students if they have heard the expression: "to burn up calories."

5. In burning chemical energy is changed into heat energy.

6. Burning fossil fuels is a nonrenewable source of energy because once something is burned, you can't get it back.

7. Have students estimate how long they think it would take to get a tree back again (how long it takes to grow) and how long it would take to get coal and oil back again. Discuss what renewable and nonrenewable means.

Burning Experiment #1:

Instructions: Pick up an object and put it into the flame from the candle. Keep it in the flame for about one minute and then pull it out again. Observe carefully and write you observations in the table below.

WEAR YOUR GOGGLES AND DON'T TOUCH SOMETHING THAT IS HOT OR BURNING.

Name of Object	Behavior in Flame (does the object do anything, does the flame change?)	Behavior Out of Flame (does it keep burning by itself after it is pulled out of the flame?)	Describe what is left after the object is pulled out of the flame. What color is it? What does it look like?
Paper			
Glass			
Marshmallow			
Metal			
Wood			
Peanut			
Potato Chip			

Questions:

1. Which of the above objects do you think "burned?"

2. Which of the objects do you think melted?

3. What is the difference between "burning" and "melting?"

4. What do all of the objects that burned have in common?

CCM Chemical Subunit Lesson #2

Lesson #2: A Closer Look at Fossil Fuels (PS 1.3 B II and III) (ES 3.6 A I-VI)

Concepts:

- Burning (combustion) is a chemical reaction that doesn't always involve flames.
- Combustion takes place inside of our bodies (cells) and is the way we use our food.
- Food is chemical energy that is "burned" up inside of cells in order to give us energy:
- $C_6H_{12}0_6 + 0_2 \rightarrow CO_2$ and H_20 Burning up food is the reason we need lungs; to bring in 0_2 and get rid of $C0_2$.
- $C0_2$ is a waste product that we need to get rid of (lowers blood pH; it is acidic)
- Most carbon gets ***recycled*** as $C0_2$ (plants will use it in photosynthesis)
- Some carbon doesn't get recycled and becomes buried and compressed and forms "fossil fuels" that later get extracted from the earth as coal, oil, and gas.

Pre-assessment questions:

1. What do breathing and burning have in common?
2. Why do we have lungs? Why do we need to breath?

Part I: Burning releases carbon dioxide. When we exhale we release carbon dioxide.

1. Put the equation for "burning" on the board.
2. Show students the Vernier carbon dioxide probe. Display a graph from Logger Pro that generates the values collected from the probe onto a screen. Record the number for normal carbon dioxide levels in the air. Ask students how many people think that the carbon dioxide levels will rise and how many think they will decrease and how many think they will remain the same. Have students close their eyes when these questions are asked and record the number for each answer on the board. Burn a piece of paper inside of a flask so students can see that carbon dioxide is being produced. Record the new number so they can compare before burning and after burning.
3. Do the same thing with exhaling. Record the carbon dioxide value in the air. Have one student volunteer to come up and breath into the flask. Record the value. Compare the two values. Ask students: "what do breathing and burning have in common?"
4. Repeat #2 above but this time with an oxygen probe. Again, ask students how many think that the levels of oxygen will increase, decrease or remain the same. Record the initial oxygen value and burn a piece of paper. Record the final value and have students watch the graph.

Part II: Carbon Dioxide is a waste product (causes problems if we don't get rid of it)

1. Pass out flasks (10 mL inside each flask of .04% NaOH solution and a few drops of phenolphthalein indicator). NaOH is a base and the solution will turn clear when it becomes acidic.
2. Have students blow into the flask. Carbon dioxide becomes acidic in solution (in our blood). The pink solution will turn clear due to the lower pH.

Part III: Molecular models

1. Pass out one glucose "molecule" to each group. Explain that this molecule represents some type of food you just ate. (explain food as a molecule that has carbon in it and H and O). Ask each group to break the molecule apart and build water and carbon dioxide molecules with the black, red and white pieces.

Burning Experiment #2

Describe 2 things you already know about burning (from our last lab)

1.

2.

Part 1: Burning in air

Record the numbers recorded by the carbon dioxide probe.

$C0_2$ Before Burning	$C0_2$ After Burning	Change in CO_2
0_2 Before Burning	0_2 After Burning	Change in 0_2

1. Did the amount of carbon dioxide increase or decrease due to burning?

____

2. Did the amount of oxygen increase or decrease due to burning?

____

3. Is there anything left over after burning? ____________

What color is it?_________________.

This is carbon and this is the stuff that gets buried deep into the earth and eventually (2000 years later) becomes fossil fuels.

4. Burning is an example of ____________energy being turned into ____________ energy.

Part 2: Burning inside of cells (in a liquid)

The burning that happens inside of cells doesn't make a fire, but instead makes energy that can be used by you to move, think, etc. (energy for living!!)

When you blow into the straw the $C0_2$ from your lungs is going into the liquid and turning it into an acid (that is why the pink color turns clear).

1. Where did this $C0_2$ come from? (why is it in your lungs?)

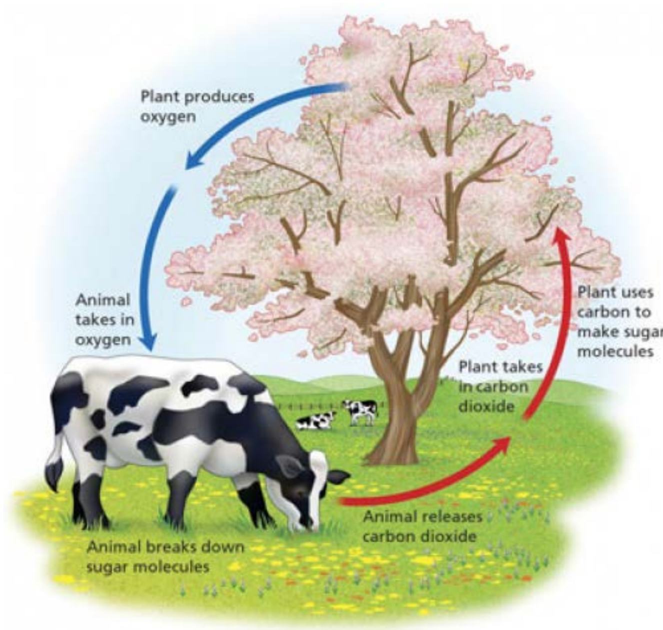
____

2. Where does this $C0_2$ go when you breath out (exhale)?______________________

3. The carbon in the $C0_2$ that you exhale and the $C0_2$ from burning gets recycled.

It is used by plants to produce _________________.

4. Why is burning a tree considered to be a ***renewable*** source of energy, but burning fossil fuels is considered to be ***nonrenewable***?



APPENDIX I

CCM HEAT SUBUNIT

Appendix I

CCM Heat Subunit Lesson #1

Lesson #1: Thermal Equilibrium and Conductivity (PS 1.3 A, 1.3 B, 1.3 B)

Concepts:

- Objects at thermal equilibrium all have the same temperature even though some objects may feel colder to touch than other objects.
- Objects differ in their ability to conduct heat energy. Some objects (ex; metal) conduct better or more quickly than other objects (ex; wood)
- Objects that are better conductors get cold or hot faster than objects that are not good conductors.

Part 1: Thermal Equilibrium

1. Give four objects (plastic, wood, metal, glass) to each group and put them in the center of the table. Each group should also be given a Vernier temperature probe and a Lab Quest unit.
2. Instruct students on how to use the temperature probe. Have them hold the probe against their hand to see how the numbers change. Use the graph function for a more visual display.
3. Ask students to pick up each object and then to pass it around.
4. Ask students to make predictions on their experiment worksheet as to which object will have the coldest temperature, hottest, etc when measured with the Vernier temperature probe.
5. Have students to close their eyes and then ask them the following:
    a. How many people think that the metal will give the highest reading with the temperature probe? How many people think the wood will give the highest reading (compared to the metal)? How many people think the wood and metal will read the same?
    b. Tell the students what percentage or number of people voted for each category and write the numbers on the board.
6. Instruct students to begin recording temperatures for each object and then to write the numbers down in the data table given on the worksheet for experiment #1.
7. When they finish ask each group to share their results and then see if all the groups agree. If there is a group that does not agree, help that group to repeat their measurements. Give students some time to look at their predictions on their paper and on the board and ask them if their experimental results surprised them.

Part 2: Conductivity

1. Have students take the same four objects they used in Part 1, measure their temperatures (thermal equilibrium) , and record in the data table for Experiment #2.
2. Ask students (again with eyes closed); how many people think the metal will cool down the fastest, and how many people think the wood will cool down fastest, and how many people think they will cool down at the same rate.
3. Have students bring the objects up to the pot of boiling water and immerse them for 5 minutes. Carefully with the tongs take out each object and give to the group to measure with the temperature probe at 10 second intervals for 120 seconds.
4. Give students a chance to summarize their data and compare their results with their predictions.

CCM Heat Subunit Lesson #2

Lesson #2: Differences in Conductivity and Heat Transfer (PS 1.3 A, 1.3 B, 1.3 B)

Concepts:

- The materials that make up the earth's surface differ in their conductivity
- Water absorbs heat energy much slower than sand and soil
- Colors in paints and paper, etc are made from pigments that also vary in their ability to absorb or conduct heat energy. Some pigments (ex; black) absorb heat energy more quickly than other colors (ex; white).

Part 1: Review from Lesson #1

1. Set up a oven mitten on each table and a Vernier Lab Quest unit with a temperature probe attached.
2. Ask students to predict what the temperature of the probe will record when put into the mitten. Ask students to close their eyes and ask them to raise their hands if they think the temperature of the probe will record higher when placed into the mitten. Ask them how many people think it will record a lower reading and how many people think it will record the same reading as it is recording now (on the table, outside of the mitten).
3. Have students put the probe inside the mitten and wait 10 minutes and then remove the probe and record the reading. Compare to the original number.
4. Go around to each group and have them share their findings with the class. If any group is in disagreement, have them repeat the experiment until everyone agrees that there is no change in temperature when the probe is put into the mitten.

Part 2: Earth's Materials and Differences in Conductivity

1. Give students 3 cups; one filled with soil, one with sand and one with water. Point out that each cup is filled with the same mass or amount of material.
2. Ask students to make predictions in their data table for Experiment #3 for which material will heat up the fastest when put under a heat lamp.
3. Ask students (again with eyes closed), how many people think the water will heat up the fastest, and how many people think it will be the sand or the soil.
4. Have students measure the temperature of each material with the Vernier probe and record in their data table. Put the cups under the heat lamp for 15 minutes and then measure them again and record the temperature.
5. Give students a chance to summarize their data and compare their results with their predictions.

Part 3: Color Pigments and Differences in Conductivity

1. Give each group of students 3 different colored paper sleeves that fit over the temperature probe. Show them how to cover the metal part of the probe carefully so that no metal is left exposed.
2. Ask students to make predictions before they begin as to which color will absorb heat the fastest and result in a higher temperature reading. Ask students to write down their predictions in their data table for experiment # 4. They will use the same heat lamp they used in Part 3.
3. Ask students (again with eyes closed), how many people think the black covered probe will heat up the fastest ad how many people think it will be the white paper covered probe. Ask if anyone thinks they will heat up the same amount.

4. Have them record initial temperatures, cover the probes with the papers and put under the hat lamp for 5 minutes.
5. Have students record their results in their data table and compare with their predictions.

CCM Heat Subunit Experiments (1 – 4)

Experiment #1

Pick up each object and feel its temperature. Make a guess about which object should record a higher temperature and which should record a lower temperature.
Or do you think they will all have the same temperature? Write what you think below.

I think the __________________________will be the highest temperature and the __________________________will be the lowest temperature.

OR I think all the objects will have the same temperature.

Now measure the temperature of each object by placing your thermometer on the top of the object. Fill in the table below.

Wood	Metal	Styrofoam	Plastic
Temp =	Temp =	Temp =	Temp =

Look at your chart above. Was the guess you made correct?

What is the correct answer based on your measurements?

Experiment #2

4 objects will be heated. Measure the temperature of each object after it is removed from the boiling water. Keep recording the temperature every 10 seconds for 60 seconds.

	Wooden	Metal	Styrofoam	Plastic
After heating				
10 sec				
20 sec				
30 sec				
40 sec				
50 sec				
60 sec				

1. Which of the objects above cooled down the fastest (temperature got lower after less time)_______________________________________

2. Which object took the longest to cool down?_____________________________

Experiment #3

Three cups have been filled with earth materials (water, soil, and sand). They will be put under a hot lamp and heated. Which material do you think will heat up the fastest? Which materials will heat up the slowest? Write down your guess below:

1. __________________will heat up the fastest.

2. __________________ will heat up the slowest.

Record the temperature of each before heating and then again after heating.

	Temperature Before Heating	Temperature After Heating	Change in Temperature
Soil			
Sand			
Water			

Was your guess correct? (yes or no)

Which material heated up fastest?____________________ (earth, soil or sand)

Which material heated up the slowest?___________________(earth, sand or soil)

CCM Heat Subunit Lesson #3

Lesson #3: Hot Hands / Cold Hands

Concepts:
- Heat is a form of energy but coldness is not.
- Coldness is the lack of heat energy.
- Heat energy always moves from warmer objects to colder objects and not the other way around.
- Heat will continue to move between two objects as long as one object is warmer than the other.
- Eventually the objects will reach equilibrium and the temperature of both objects will be equal.

Pre-assessment questions:
1. Why do some things "feel" colder than others even though they are the same temperature?
2. Does heat move? (from a warm object to a cold object). Does cold move? (from a cold object to a hot object)

Lesson:
Students will work in groups of four. Each group will have two temperature probes (thermometers) hooked up to a computer or portable interface. Each group will also have one hot pack and one cold pack.

Part I:
1. Have students "calibrate" their probes. They dip both probes into the same beaker of water and see if the readings are the same. If they are not the same, the difference in the temperatures should be written down. This difference should be subtracted in the future from all readings taken with the higher reading instrument.
2. Have one student be the "cold" hand person. They will hold onto the cold pack for 5 minutes or until their hand feels very cold.
3. At the same time as the cold handed person is holding the cold pack have a second person hold a hot pack for the same time period. This person will be the warm handed person.
4. Have both students put down their packs and quickly hold a thermometer and record the temperature on their thermometer.
5. Have both students repeat steps 2 and 3, but this time they will put their hands together being careful to not touch the probes, but to only touch their hands. They should record the temperature of their probe every 5 seconds until both probes are reading the same temperature.
6. Using logger pro software a graph will be shown using an overhead projector so that everyone can clearly see a graph that shows the data as it is being

recorded. A blue line represents the cold-handed person and a red line represents the warm-handed person. When the two hands are touching the blue line can be seen going upward and the red line going downward. Thermal equilibrium can be seen when both lines remain together for an extended period of time.

7. Students will collect and record their own data and make a graph.

Part II: Kinetic Demonstration

1. Pick four students to stand inside a circle (tightly bunched together with no space between). Outline the circle with chalk on the floor. This represents a solid. Draw a picture on the board. Tell students that they represent cold molecules and since cold means they have no energy, they cannot move and have to stand as still as possible.

2. Apply heat. Heat gives particle energy. Tell students to respond to the words “warm” and “hot” by moving and jumping. Warm means some energy and hot means they have to move and jump with a lot of energy. Look at the tape boundary and see how many students are no longer inside after warm and hot instructions are given. Tell them to stop and ask them to stand where they are when they hear the word “stop.” Using chalk outline the new boundary around all four students. What happened when they jumped? (they needed more space, they spread apart). This represents melting or the change from a solid to a liquid. Have the four students sit down and allow everyone to clearly see the original chalked circle and the new chalked boundary.

3. Now have four students stand in a tight square and tell them they are not allowed to move. They represent cold molecules. Pick another four students to stand around the circle. They will represent hot molecules. Then have the hot group move. Look and see if the cold group was affected. Did the movement of the hot group cause the cold group to move?

4. Have students answer the questions in the Experiment worksheet for Part 2.

CCM Heat Subunit Experiment #5

Part I: Hot Hands/Cold Hands

1. One person in the group will be the cold person. Another person can be the hot person. Have the cold person hold onto an ice pack and have the hot person hold onto a warm pack. Begin at the same time and hold your object for 2 minutes. Put the cold or hot pack down and pick up a thermometer. Hold the thermometer in your hand and record this temperature.

2. Now put both hands together. The hot-handed person and cold-handed person must hold hands. Keep the thermometer in place and be careful to hold hands so that the two thermometers don't touch. Record the temperatures of the hot and cold thermometers every 10 seconds. Keep going until both thermometers stop changing much.

Hot-Handed Person	Temperature (C)	Cold-Handed Person	Temperature (C)
Temperature before holding hands		Temperature before holding hands	
Temp after holding hands 10 sec		Temperature after holding hands 10 sec	
20 sec		20 sec	
30 sec		30 sec	
40 sec		40 sec	
50 sec		50 sec	
60 sec		60 sec	
70 sec		70 sec	
80 sec		80 sec	
90 sec		90 sec	

1) What happened to the temperature of the cold handed person after holding hands?____________________________________

2) What happened to the temperature of the warm handed person after holding hands?____________________________________

3) What happened to the temperature of both hands after 60 to 90 seconds?________________________________

Part II: Heat is a form of energy that moves. (Kinetic Demonstration)

1. Heat is a form of energy and it can move from a ____________ object to a _____________ object. (from a hot hand to a cold hand)

2. Coldness cannot move because____.

3. An object gets cold because it is _____________heat energy. Heat moves away from it or out of it.

4. A glove all by itself will not be warm because _________________________.

Part III: How does Heat Move?

1. Draw in pictures in the boxes below:

Cold (no energy)	Warm (some energy)	Hot (lots of energy)
Solid	Liquid	Gas

2. What happens when a hot object touches a cold object? Can you draw a picture to show this? Draw dots to represent the cold molecules and dots to represent the hot molecules.

Before Touching	After Touching

APPENDIX J

STUDENT MISCONCPETIONS DIAGNOSTIC INTERVIEW

Appendix J

Student Misconceptions Diagnostic Interview

1. When you put something into a flame (have a candle to demonstrate), do all objects burn?

2. Why do some objects burn and some do not?

3. Give students three objects and have them touch the objects. Ask them if all the objects are the same temperature or are they different temperatures. Touch the objects with a temperature probe to show them that the objects all have the same temperature. Ask them why it is that some objects feel colder than other objects.

4. Does heat move? Can it go from one place to another? Ask them for examples in their life when they have observed this.

5. What happens when a hot object touches a cold object (like a cold hand touching a hot hand); does the heat move from the hot hand into the cold hand? Does the coldness move from the cold hand into the hot hand?

6. Why is it that some objects heat up more quickly than other objects when put into a flame or fire? Demonstrate this by heating metal, ceramic and plastic.

7. On a hot day are all of the materials that make up the earth's surface (sand, water and soil) heated up at the same rate? Do some of these materials heat up more slowly t than others?

APPENDIX K

PRE-ASSESSMENT PROBES

Appendix K

Pre-assessment Probes

CCM Energy Subunit:

1. What is energy?

2. Can one type of energy be changed to another type (for example heat energy into electrical energy?)

3. How is the electricity that is used in our houses made?

4. Is sound a form of energy? (yes or no)

5. Is light a form of energy? (yes or no)

6. Is an apple a form of energy? (yes or no)

7. How could you use the suns energy to make electricity? Can you describe how that might work?

8. Can you give an example of a nonrenewable energy and a renewable energy?

9. Most scientists think that the expression “create energy” or “make energy” is not really accurate. Do you know why they think this?

10. What is the most important energy source for planet earth? Explain your answer.

Pre-assessment Probes

CCM Chemical Energy Subunit

1. Do all things burn?

2. Why is it that some things burn and other things don't burn?

3. What is the name of the gas that is produced when something burns?

4. What is the name of the gas that is consumed (gets used up) during burning?

Pre-assessment Probes

CCM Heat Energy Subunit

1. What is heat?

2. Can heat move from one place to another? (yes or no)

3. What is coldness?

4. Can coldness move from one place to another? (yes or no)

5. Your teacher will pass around two objects; a piece of wood and a piece of metal. Circle the letter of the answer below that you most agree with:

   A. The metal has a higher temperature than the wood

   B. The wood has a higher temperature than the metal.

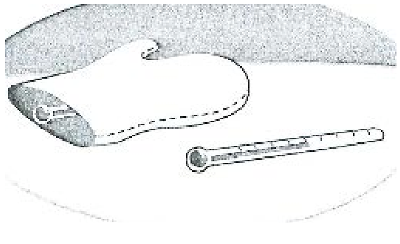
   C. The wood and the metal are both the same temperature

6. Look at the pictures below. Which of the following is true:

   A. The thermometer inside the mitten will have a higher temperature than the thermometer on the table.

   B. The thermometer inside the mitten will have a lower temperature than the thermometer on the table.

   C. Both thermometers will have the same reading.



APPENDIX L

STUDENT MISCONCPETION IDENTIFICATION LIST

Appendix L

Student Misconception Identification List

CCM Energy Subunit

1. Energy cannot be changed from one form to another
2. Confusion about types of energy; apples and sound are not considered to be forms of energy

CCM Chemical Energy Subunit

1. Confusion about what can burn; some students think everything is burnable.
2. Confusion about the role oxygen and carbon dioxide have in burning

CCM Heat Subunit

1. Many students believe that coldness is an entity that can move. Coldness is identified as moving into a warm hand.

2. Most students predicted that objects at thermal equilibrium will not have the same temperatures. Metal objects are predicted to have lower temperatures.

3. Some students predict that water will get warmer at a faster rate than sand under a heat lamp.

4. Most students think that a thermometer put inside of a mitten will get warmer.

APPENDIX M

EYES CLOSED QUESTIONS

Appendix M
Eyes Closed Questions and other Socratic Dialogue Questions

Energy Subunit

1. What is energy (put ideas on board in two lists; to separate out those things that are examples and not definitions)
2. Ask students to pick out those things that are examples and not definitions
3. After the experiment go back to the list and see if students can add anything (energy changes things, can be changed from one form to another, etc)
4. Can energy be changed form one type to another type?
5. What are the types or forms of energy seen in this experiment?

Chemical Energy Subunit

1. Do all things burn?
2. Is water a "thing" that burns?
3. Is a rock a "thing" that burns
4. What do all the things that burned (in the burning experiment) have in common?
5. Which object burned the longest? (almond)
6. Which object made the biggest flame? (potato chip)
7. If you had to choose one of these objects to heat your house, which object would you choose?
8. Why don't we heat our homes with almonds?
9. What will happen to the graph when I burn this object (graph on screen is taking readings from a Vernier oxygen probe)? Will it go up or down?
10. What will happen to the graph when when I burn an object? (graph is connected to a Vernier carbon dioxide probe)
11. What will happen to the graph when I blow into the flask (graph is connected to the carbon dioxide probe)
12. Is there something burning in my body? (after they see carbon dioxide probe going up).

Heat Subunit

1. Which object will record the hottest temperature when we measure it with the thermometer?
2. Will it be the metal? Will it be the wood or will all the objects be the same temperature?
3. A graph is shown on the overhead screen with a blue line (representing the cold probe) and a red line (representing the hot probe). A student volunteer is asked to hold a hot pack and I hold a cold pack. Students are asked to predict what will happen to the red and blue lines when I hold hands with the

student. Will the red line go up or down? Will the blue line go up or down?

4. Which of the earth materials, water, sand or soil will heat up the most in a 15 minute time period when put under a heat lamp?
5. When a thermometer is put into a glove will it record a higher temperature then when it is outside a glove?
6. When you get into a bed with lots of blankets is the bed warm when you first get in? Why not? What makes the bed warm? Is it you (your body) or is it the blankets? Is there a heat source inside the glove? If I put my hand into the glove would it get warm? What is the heat source?
7. What is wrong with the statement: "close the door, you are letting the cold come in."
8. During the kinesthetic simulation: What happened when the hot people touched the cold people? Can coldness move into hotness? What happened to the amount of space needed by the hot people compared to the cold people? (have students look at the circles drawn with chalk around the cold people and the hot people to compare.)
9. What color do you think will get hotter and absorb more heat; black or white or do you think they will all be the same?

Liquid Nitrogen Demonstration

1. What will happen to this balloon when I put it into the liquid nitrogen? Will it get bigger? Will it get smaller?
2. How did the liquid nitrogen turn into a gas? How did the liquid molecules escape and go into the air?