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ELL AND NON-ELL STUDENTS’ MISCONCEPTIONS ABOUT HEAT AND TEMPERATURE IN MIDDLE SCHOOL

by

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B.S. University of Arizona, 2000

A thesis submitted in partial fulfillment of the requirement for the degree of Master of Education in the Department of Teaching and Learning Principals in the College of Education at the University of Central Florida Orlando, Florida

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ABSTRACT

All students come to the classroom with their own ideas about a number of science phenomena. In the classroom setting, English language learners may have ideas about heat and temperature that present additional challenges for teachers. In fact, their ideas can stem from many different influences and English language learners (ELL), in particular, may have misconceptions about topics and language barriers, or misconceptions, that are culturally or language-based (Lee, 2001).

This action research thesis was performed to explore the research questions: How did my use of formative assessment affect ELL students’ misconceptions about heat?, How did my use of formative assessment uncover students’ misconceptions about heat? Formative assessments were used in the classroom to uncover students’ misconceptions about heat and temperature. The students performed labs based on the formative assessment activity sheets. The students answer before and after questions related to the labs. Data were collected and analyzed to examine changes in ELL students’ conceptions of heat and temperature. Data showed that some ELL students changed their ideas about heat and temperature but other misconceptions remained. Time allotted to instruction and alignment of laboratory activities with formative assessments need to be further explored to address changing students’ ideas about heat and temperature.
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CHAPTER 1: INTRODUCTION

Purpose

Students come to the classroom with background knowledge about most topics in science (Clough & Driver, 1985). Their background knowledge, however, can lead to ideas that are not scientifically correct (Driver, Squires, Rushworth, & Wood-Robinson, 2000). The ideas can stem from many different influences and English language learners (ELL), in particular, may have misconceptions about topics that are culturally or language-based (Lee, 2001). If students do not understand English, they may have more difficulties understanding scientific concepts in English. ELL students who have misconceptions may also have difficulties expressing the ideas, and may resist a conceptual change. The purpose of this thesis was to address the misconceptions that ELL students have about heat. Most ELL students are influenced by language and culture that can cause misconceptions (Lee, 2007). Many students have misconceptions about the concepts of heat and temperature (Wiser & Amin, 2001). The framework used to address the misconceptions was a social constructivism approach, which was to help students feel that their ideas are equally important to those of others and to improve academic learning (Atwater, 1996). Formative assessments were used to uncover the students’ misconceptions.

Research questions

Two guiding questions were used in this action research study:
1. How did my practice of using formative assessments affect the ELL students' understanding of heat?

2. How did my use of formative assessments uncover the students’ misconceptions about heat?

Rationale

ELL students may present unique challenges in middle school science classrooms. That is, students may have misconceptions and teachers may find it difficult to address them because of language barriers. In lab sessions, teachers may have difficulties in finding out what the ELL students are learning. For example, a Hispanic student may not have sufficient English vocabulary to communicate what happened during a lab, although they might be able to communicate the information in Spanish. Misconceptions can easily arise from translations, since non-English words may not directly translate into English. The idea for this thesis originated from my observations of ELL students who only write in their notebooks what I told them to write. Typically, they would write down answers, without believing the answer I gave. The students may need to visualize the information to aid their understanding of the ideas. Thus, their misconceptions had to be specifically addressed for them to grasp the scientific explanation.

In facing this challenge of teaching science to ELL students, I used formal formative assessments to expose students’ misconceptions, which was followed by a discussion of the ideas.
Students often have misconceptions about heat, (Wiser & Amin, 2001) which are compounded for ELL students, since some languages have words that cannot directly be translated into English. For example, in science textbooks, heat is translated as *calor*, but is also related to *caliente*. The meanings of these terms may be the source of confusion since the first word means aura of warmth and the later mean an object’s heat. In summary, students’ misconceptions present problems during instruction, which may be compounded for students who speak English as their second language. In this study, I used formative assessments and discussions to identify students’ misconceptions about heat. Once student misconceptions were identified, they were addressed through instruction.

In the section below, I presented definitions relevant to this study.

**Definitions**

*Calor*  
Spanish. An aura of warmth.

*Caliente*  
Spanish. An object’s heat or being hot.

ELL student  
English Language Learner, English is not the student’s first language. (District, 2008)

Energy  
Ability to do work or cause change (Littell, 2006).

Formative assessment  
Encompassing all those activities undertaken by teachers, and/or by their students, that provide information to be used as feedback to modify the teaching and learning activities in which they are engaged (Black & William, 1998).

Heat  
The flow of energy from an object at a higher temperature to an object at a lower temperature. The energy that is transferred from a warmer object to a cooler object (Littell, 2006).

Kinetic energy  
The energy of motion. A moving object has the most kinetic energy at the point where it moves the fastest (Littell, 2006).
Misconceptions  Ideas that are at a variance with accepted views (Stein, 2008).

Thermal energy  The energy an object has due to the motion of its particles; the total amount of kinetic energy of particles in an object (Littell, 2006).

Temperature  A measure of the average amount of kinetic energy of the particles in an object (Littell, 2006).

Thermometer  A device used to measure temperature (Littell, 2006).

Social Constructivism  Based on Vygotsky’s Zone of Proximal Development. It is defined as the distance between the actual developmental level as determined by independent problem-solving, and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers (Vygotsky, 1978).

Limitations of the study

One limitation of the study was the time constraint. The curriculum calendar for the district recommended that the concept of heat had to be covered within two weeks. This is not a lot of time to address the many misconceptions students likely had about heat and temperature. I tried focused on a few important concepts that could be covered by the formative assessment activity sheets and labs.

Another limitation was due to the condition and difficulties students had when using the equipment. Some students had problems with the thermometers and hot plates. One of the hot plates did not warm-up quickly. It did not work during the class.

The thermometers used for the Ice Water assessment activity sheet lab were old, and were imprecise. They only had a level of significance of .5 °C, and they were small, so the students had a hard time reading them.
Overview of thesis

In Chapter 1, the study purpose and research questions were presented. I then explained the rationale behind the thesis, presented definitions, and explained the limitations of the study.

In Chapter 2, the literature review began with an overview of social constructivism and how it can be used in the ELL classrooms. This led into other studies that have been conducted with ELL students in science classes and how vocabulary and the student’s home language can affect their misconceptions. Specific misconceptions about heat were discussed, and research on formal and informal formative assessments was presented.

Chapter 3 presented the methodology of the study. This section included the classroom setting, school information, formative assessment information, the assessment sheet written by Keeley (Keeley & Tugel, 2009), and lab and discussion format. The explanation for using each activity sheet and their order was also included.

The data analysis was presented in Chapter 4. Students’ comments and written responses to the focus questions, along with formative assessment sheets were analyzed to determine whether or not the assessments had helped students shift away from misconceptions towards scientifically accepted ideas. The misconceptions of non-ELL students were documented through formative assessments.

Chapter 5, the concluding section, reviewed the ideas presented in the previous chapters. The research findings were presented along with the final conclusions and implications for addressing the ELL students’ misconceptions about heat.
CHAPTER 2: LITERATURE REVIEW

Introduction

Students in the science classroom often have misconceptions about heat (Wiser & Amin, 2001), which can be especially problematic when the students are learning English as a second language. Lee (2007) states that ELL students have language and cultural influences that contribute to their misconceptions. In this chapter, I present different views on social constructivism, discuss ELL students in the science classroom, their misconceptions, and the use of formative assessments. According to constructivism, students need to construct ideas about the world around them to learn; simply telling them does not work (Hewson & Hewson, 1998). Reconstructing ideas is a cognitive process. Students need to do more than simply learn new ideas, since interventions that directly conflict with their misconception may not change their beliefs (Chi, 2005). Teachers need to first understand the misconceptions that exist before they can address them, so that the students can explore new ideas.

Social constructivism

One process that has been used to help dispel misconceptions is social constructivism, which is based on the idea that students can learn more through interacting with others than what they can learn on their own. Vygotsky (1978) developed an idea and labeled it the zone of proximal development. Students leave their zone of learning and expand into a larger zone because of their interactions with more knowledgably adults or peers.
By discussing and defending their ideas, students deconstruct and reconstruct science concepts (Mason, 2001). When students listen to their peers, they may change their point of view (Mason, 2001). The construction of new information thus depends on students discussing and processing the information and learning to assimilate it (Riberio, 2002). Through scientific argumentation, students learn to defend their own ideas and listen to those of others. Science students may struggle with this process if they have never been taught how to look at evidence for their own ideas, or to examine the evidence from others (Driver, Newton, & Osborne, 2000). ELL students may find that discussions with their peers are too difficult, because they lack a mastery of the language (Riberio, 2002). Consequently, ELL students may digress into an earlier stage of development, to understand a science concept that appears to be too difficult, going back to what is described as speech for oneself. ELL students may also need more time to gain self-control, to process a concept in English, and then to discuss the idea with others (Riberio, 2002).

Social constructivism is not limited to just speaking, but may be applied to modeling activities and to writing. The idea also considers that students cannot learn in a vacuum, but need to interact with others, which for example, could involve the imitation of a technique, like modeling a lab (Smith, 2001). This kind of modeling can lead to growth and can help students assimilate new information. They can also model the teacher and ways for performing an activity as a way to learn to do it on their own.

In a classroom, where students are not homogenous and are at different levels, in language acquisition or in cognitive abilities, social constructivism can help all students
grow (Ben-Ari & Friedrich, 2000). In a heterogeneous classroom, non-ELL and ELL students may have more discussions because of their differing ideas due to language (Ben-Ari & Friedrich, 2000). In any case, all students in the classroom should have equal voices, and social constructivism works if all the students feel they have a voice (Atwater, 1995). If minority students do not feel they have a voice in a science classroom, they often shut themselves off from the teacher and from their peers (Atwater, 1996). Teachers must be able to make students, especially ELL students, feel secure in their interactions with others, to help them break down ideas and rebuild them.

In this thesis, social constructivism is used as the theoretical framework because discussion and modeling in the science classroom are used by students to construct new ideas. Many ELL students learn how to speak English before becoming proficient in reading or writing English. Using social constructivism, the aim is to expand on the students’ natural desire to discuss ideas and learn from one another. This study uses the lab set-up for modeling the concepts presented in formative assessment activity sheets. Students’ ideas about heat and temperature could differ, because of their language differences, and classes that facilitate students’ interactions and discourse can help them build ideas through participation.

**The English language learner**

ELL students may have background knowledge of science in their home language, but most teachers would not be able to call upon that knowledge. ELL students may also have misconceptions, based on their home language (Luykx, Lee, & Edwards, 2008). Teachers must be able to consider what resources the students might be bringing
with them to the classroom (Warren, 2000). This question was raised by Warren in a study of ELL students, where the author concluded that teachers were paying too little attention to the students’ background knowledge (Warren, 2000). ELL students learn in the same manner as do non-ELL students; they interact with their environment and process scientific concepts in relation to their everyday experience. Nevertheless, the ELL student may have different everyday experiences with regards to the science concepts (Ash, 2004).

Both parents and teachers play a role in ELL students’ learning. Parents are the students’ life-long teachers. Furthermore, the interactions between language, culture, science, and speech play roles in the ELL students’ informal science learning (Ash, 2004). Teachers play a large role in the overall science lessons for ELL students’ success in science. The attitudes and overall content knowledge of teachers can also affect student learning. Teachers of ELL students need to realize that the students’ home language and culture are relevant when teaching science (Lee, 2001, 2007). Teachers are often unaware of the influence that language and culture have on science, since science is thought to be universal (Lee, 2007). This was an important aspect in this study, as the students’ home language can influence their learning of science.

When ELL students translate science lessons into their home language, they may have misconceptions about science principles (Luykx, Lee, & Edwards, 2008). Science concepts are not always exactly translated from English into foreign languages, and even if a student has a co-teacher or an ELL aid, the translator may not have science content knowledge for translating the ideas (Luykx, Lee, & Edwards, 2008). While students do
not have to know English to do hands-on activities, they must have an understanding about what the activity is showing, which may be lost if the student does not have an accurately translated scientific description (Lee, 2007).

Overall, the language and culture of ELL students must be considered in the science classroom. Since translations between English and a student’s first language may not be direct, the student’s background knowledge of science should be considered when addressing their misconceptions of science.

**Misconceptions in science**

Students often have misconceptions, also called alternative conceptions, about science. “Students hold a surprisingly wide range of ideas which diverge from accepted explanations” (Hewson & Hewson, 1988). Some of the ideas held by students are not random, and many hold similar misconceptions about a science topic. Students tend to construct their ideas from day to day experiences, and may go directly against the scientific explanation, with little flexibility to change (Hewson & Hewson, 1988; Stein, Larrabee, & Barman, 2008). Often, a conceptual change is needed for students to understand new ideas. Misconceptions in the physical sciences can be more difficult to address than those in other science areas (Stein, Larrabee, & Barman, 2008); hence, students’ ideas about heat may present an even greater instructional challenge.

Two views have been used to explain how misconceptions occur and how they lead to conceptual change (Duit, 2003). Conceptual changes can be defined as “pre-conceptual structures of the learners have to be fundamentally restructured in order to allow understanding of the intended knowledge, that is, the acquisition of science
concepts” (Duit, 2003). The idea of students restructuring concepts ties in with the framework of constructivism, or reconstructing science ideas. The epistemological view is based on the idea that students never really let go of their original idea, but become dissatisfied with the original idea and reconstruct it to fit with the correct view point (Duit, 2003). Student will then accept the new view, depending on if it is believable and if it can help them understand other problems (Duit, 2003).

The ontological view addresses how students might view an idea. A misconception about science may be caused by how students categorize the scientific topics (Chi, Slotta, & Leeuw, 1994). Students might assign a concept the attribute of being matter, when really it is a process. Thus, students will have to change the attributes of a given scientific idea for a conceptual change to occur (Slotta, Chi, & Joram, 1995).

The idea is to reconstruct how students classify the natural world, from a material to a process for a given misconception (Slotta, Chi, & Joram, 1995). Slotta (1995) gives the example of student classifying electricity as a material, but after learning the concept of electricity, it is classified as a process. The way students classify the natural world may be the root problem as to how they come to understand science. Chi (2005) uses such terms as direct and emergent processes to explain why some misconceptions are difficult to correct.

To understand emergent processes, one must treat all the components as a uniform collection in which all individual components should not be differentiated from each other. As a collection, therefore, the individual components can interact with any other component. The pattern that one observes
is the process emerges from the contribution of interactions of all the components, as they occur over time (Chi, 2005, p. 180).

These kinds of misconceptions can be difficult to correct and present significant challenges during instruction.

Heat is a science concept which many students, even at a young age, have misconceptions about (Clough & Driver, 1985). Often, young students classify heat as a substance, and later as a fluid material. A misconception also exists about heat and temperature. Temperature is described as characteristic of the material (Clough & Driver, 1985). Three misconceptions about heat and temperature were described by Driver (2000) “The idea that heat is hot, but temperature can be cold or hot- you can have something freezing, whereas heat-you tend to think of something being hot. Heat…it’s the warm end of the scale. The idea is no difference between heat and temperature. The idea that temperature is a means of measuring heat: temperature- you can measure heat with, but heat is hot-you can feel heat” (Driver, Squires, Rushworth, & Wood-Robinson, 2000).

With the ontological view, Wiser and Amin (2001) studied student ideas about heat. In the study, students were first introduced to the idea of “everyday heat” and “scientific heat.” The students performed several of computer activities to help them shift their ideas that “everyday heat” was matter; both types of heat were actually the same concept.

For ELL students, misconceptions about science can be tied to their culture and home language. ELL students may not have the sense- making resources from their
home language (Warren, 2000), and their home language can hinder their ability to change their concepts of science (Luykx, Lee, & Mahotiere, 2007). Some students, based on their home language and cultural background, may have different ways of expressing their ideas. The language, and not the understanding of words or topics, may cause a problem in accurate translation. According to Luykx, Lee, and Mahotiere (2007) the problem may be “languacultural” where language and culture are tied together to create misconception about a science topic. These factors can have an impact on ELL students, as their misconceptions can be due to differences in culture. Teachers need to be aware of the misconceptions that stem from language and cultural issues (Lee, 2007).

Formative assessments

Assessments can occur in many different forms in the classroom, from state testing, to everyday classroom questioning. Assessments can be any type of activity that students do to show their learning and thinking, such as benchmark tests, a short quizzes, lab assignments, or teacher questions (Herman, Osmundson, Ayala, Schneider, & Timms, 2006). Formative assessments have been defined recently as “activities that help students learning” (Wang, Wang, Wang, & Huang, 2006). In earlier studies, these were defined as “encompassing all those activities undertaken by teachers, and/or by their students, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged” (Black & William, 1998). Formative assessment often differ from summative assessments in that the former are performed by teachers to uncover misconceptions, help students achieve the learning goals of a unit, and close the gap between scientific knowledge and misconceptions (Yin, Shavelson, Ayala, Ruiz-Primo,
Brandon, & Furtak, 2008). Summative assessments are those that give students rank and scores based on performance (Yin, Shavelson, Ayala, Ruiz-Primo, Brandon, & Furtak, 2008). Formative assessments are done by teachers to gather information on their students learning process.

Formative assessments have been divided into two groups: formal and informal. They are also called planned formative assessments and interactive formative assessments (Bell & Cowie, 2001). Interactive formative assessments occur when the teacher is “noticing, recognizing and responding to students” (Bell & Cowie, 2001), and are also responsive to student learning. Informal formative assessments are unplanned and based on student needs. Ruiz-Primo and Furtak (2006) studied how conversation and teachers eliciting information during a discussion, as a formative assessment, can improve overall student learning. The authors saw improvement in student learning when teachers not only gathered information, but also responded to the students’ answers. In informal formative assessment situations, teachers need to have a strong content knowledge, otherwise, the teacher may be unable to notice the students’ gaps in knowledge and be unable to lead the discussion accurately (Ruiz-Primo & Furtak, 2006).

Planned formative assessment, or formal formative assessment, is a planned lesson that gathers information about what students think about a topic. The formal formative assessment is comprised of: eliciting, interpreting, and acting, on the part of the teacher (Bell & Cowie, 2001). Often, this kind of assessment is in response to the teacher’s curriculum, and is to help the teacher learn about the students’ ideas about the curriculum (Bell & Cowie, 2001). Teachers may use activities designed to reveal the
students’ ideas about an area in science where common misconceptions might develop. The success of implementing formal formative assessments has been studied to determine their fidelity (Furtak, et al., 2008). The studies reveal that the formal formative assessments were designed to be used in classrooms and students were asked to justify their answers. The success of these assessments depended on how well the teacher used the formative assessment, as designed by the author (Furtak, et al., 2008).

Both formal and informal formative assessments can be used in classrooms to help guide the teacher’s instruction (Crumrine & Demers, 2007). Teachers should know what a unit is covering and what stumbling blocks may be in the way of students. Either through questioning techniques or through student work, teachers can move the classroom towards the learning goals (Herman, Osmundson, Ayala, Schneider, & Timms, 2006). Teachers should also be well educated about the content to be effective at using formative assessment. If they change their instruction because of an informal formative assessment, they need to have a “deep and broad knowledge of science” (Keeley, 2005).

Herman (2006) suggests that formative assessments should be used so that they will lead to “more successful teaching and learning than simply administering assessment, scoring assessments, and sending data to researchers” (Herman, Osmundson, Ayala, Schneider, & Timms, 2006, p. 33). The formative assessments chosen for this thesis were designed to uncover student misconceptions, and not necessarily designed to be lab procedures. Also, questioning techniques and discussions are to guide students when they are participating in the lab setting.
In summary, Chapter 2 described the literature about social constructivism, ELL students, misconceptions in science, and formative assessment. In chapter 3, methods used to address the research question were presented.
CHAPTER 3: METHODOLOGY

The overarching question guiding this action research project was, how effective was my teaching method for addressing ELL students’ misconceptions about heat and temperature when I used formative assessment during science instruction? In this chapter, I presented the design of the study, setting, instruments, data collection, methods, data analysis and triangulation of data sources.

Design of study

The study was an action research study. I looked at my teaching methods in the classroom. Action research is a type of research focused on a specific local problem and resulting in an action plan to address the problem. In examining my own teaching methods, I collected data, the data were analyzed, and I looked for emergent themes. (Fraenkel & Norman, 2009).

Setting

The study was done in an 8th grade physical science classroom. The school is located in a rural part of central Florida where students are bused in from suburban communities. In the school, about 12% of 8th grade students are ELL. The Hispanic population in the school district is 29%, but the percentage of Hispanic students at the school, during the time of this study was 51.6%. The school uses a 6 class daily schedule, and every class meets for 49 minutes 4 days a week, and for 39 minutes 1 day a week. The class that participated in this study was an advanced 8th grade science class. Most Algebra 1 students were placed in honors science classes, most advanced math
students were place in advanced science, and most regular math students were placed in regular science.

**Classroom setting**

A total of 13 students were in the class: 3 chose not to participate in the study. Of the remaining 10 students, 4 were ELL students. Of the 4 ELL students, 3 had been dismissed from ELL classes, so that only one ELL student remained. Students learning English as a second or other language can be dismissed from ELL classes if they score above 3 on the FCAT or another specific ELL measurement test. Such students are monitored academically for two years. Of the 4 ELL students, 3 were Hispanic, and 1 was Vietnamese. Two of the students who were in the class were classified as students with exceptional needs. One of these students had a 504 plan for ADHD. The class for this study was classified as advanced Physical Science, so that all students were in pre-Algebra or Algebra 1. All of the students were in the 8th grade, and their age ranged from 13-15 years. The class was small, students seemed to be comfortable with each other, and enjoyed discussing ideas. The ELL students were able to communicate in English, though it was not their home language, a different language was spoken at home.

**Instruments**

Two different formative assessment instruments were used to gather data. Focus questions used were based on the misconceptions identified in *Targeting Students Science Misconceptions* (Stepans, 2003). The questions were formulated from a list in the book about students’ misconception about heat, and references for the sources of the list are provided (Appendix A). The questions that were chosen were about
misconceptions that could be exposed by the formative assessment activity sheets
(Keeley, Eberle, & Farin, 2005; Keeley, Eberle, & Tugel, 2007; Keeley & Tugel, 2009). The formative assessment activity sheets were based on research by Keeley on misconceptions, and were piloted by students in Maine, New Hampshire and Vermont. A list of references and acknowledgments is shown in (Appendix B).

Focus questions

The focus questions were chosen from a list of common misconceptions that students have about heat and temperature. The list was comprised of 19 common misconceptions, and since not all of the misconceptions could be addressed in this study due to time constraints, 7 misconceptions were chosen to be restated as questions (Stepans, 2003). The criteria for choosing a misconception were based on how well the misconception could be addressed in a lab setting, and whether or not it aligned with the other formative assessment activity sheets. When the misconceptions were chosen, usage of Spanish words, such as caliente and calor had not been considered in connection to this study. The following focus questions (Appendix C) were administered in class:

1. Is cold the opposite of heat?
2. Is heat a material that can move through an object?
3. Is there a difference between heat and temperature?
4. If I add more heat do I raise the temperature?
5. Is heat maintained at a source?
6. Is heat a material that can be added to an object?
7. Is metal colder than plastic?
The questions were designed to expose student misconceptions about heat, and possibly expose language misconceptions about heat when *calor* and *caliente* were considered, as well as guide the discussion about heat and temperature. The same questions were given again at the end of the unit to determine what changes had occurred, if any.

*Formative assessment activity sheets*

Five formative assessment activity sheets were used. These assessments were chosen because they addressed the focus questions, and the presented labs could be done in the classroom setting.

The first activity sheet was *Ice Water* (Appendix D), which dealt with adding ice to water when ice is already present in the glass. The students had two misconceptions about the cold: 1) how cold temperatures are not related to heat, and 2) if there is less energy, the temperature will always decrease (Stepans, 2003). This assessment activity sheet was selected because it could address the question, “Is cold the opposite of heat?”

The second activity sheet was *Turning the Dial* (Appendix E), which was about turning down the heat when water is boiling, to cause it to boil less rapidly, but still be at boiling point. *Turning the Dial* was designed to show the misconception that increasing thermal energy means that temperature will increase. At a phase change the temperature does not change. This formative assessment also addressed the idea that heat deals with energy, not matter. *Turning the Dial* was chosen to address the questions: 1) “If I add
more heat do I raise the temperature?”, and 2) “Is heat a material that can move through an object?”

The third sheet was Warming Water (Appendix F), which dealt with radiation energy from the sun that warms cold water, and whether or not cold water has energy. The Warming Water activity sheet addressed the question: “Is heat a material that can be added to an object?”

The next assessment was Objects and Temperature (Appendix G), which addressed the question: Is metal colder than plastic?” The assessment activity sheet, The Mitten Problem (Appendix H), was not originally chosen, but was used because the misconception was revealed during the introductory discussion for Objects and Temperature. It addressed the idea of insulation and the idea of temperature objects have because of the material they are made from.

Notes/questions sheet

To help students organize their ideas, a handout was given for review of some of the labs, and to see what the students were learning. Simply reading the students’ answers provided little in the way of usable data, and more specific information was needed. The notes/questions (Appendix I) asked students to re-write the information about heat and temperature, and to describe what they had learnt from the activity sheet (Ice Water, Turning the Dial, The Mitten Problem, and Warming Water). The Objects and Temperature activity sheet had not been used at the time the handout was given to the students.
Data collection

The UCF IRB was contacted at the beginning of the study for permission to use human subjects for the study. The IRB said that parental permission (Appendix J) was required, but the formal permission was not needed, since the study did not include any procedures that were outside those of the regular classroom (Appendix K). The District was contacted for permission to collect data, and permission was granted (Appendix L).

The focus questions were designed on the basis of misconceptions identified in research studies about heat (Wiser & Amin, 2001). The students’ specific misconceptions about heat were identified using Paige Keeley’s formative assessments, with her permission (Appendix M). The activity sheets were chosen because of their straight-forward language, the use of pictures with questions, and the space allowed for writing answers or explaining ideas. The assessment could be used by ELL students even if they had limited English vocabulary. The discussion and focus questions were used before the class began their assessment activity sheets. Five assessments were used in the class and a graphic organizer for notes/questions sheet was designed to help students organize their thoughts after being given the fourth activity sheet. The discussions after the focus questions and assessments were to help students re-construct their ideas about heat and temperature.

Methods

To begin, students were asked to answer focus questions that were based on the list of student misconceptions about heat and temperature (Stepans, 2003). The list had been narrowed further to fit with the available assessments. The focus questions were
each discussed in a whole group setting. Students had opportunities to discuss their ideas about heat and temperature in a think-pair-share activity and as a whole class. On the following day, after realizing that two Spanish words can be used for heat, the terms temperature and thermal energy were introduced and defined at the beginning of class. Students were not allowed to write hot and cold on their papers, but were asked to use scientific terminology when discussing assessments. Students were also instructed to use the science descriptions of molecules moving faster or slower, and if the energy was increasing or decreasing. The students were asked to describe how particles were moving when energy was added.

*Ice Water data collection*

The students were introduced to the first assessment, *Ice Water*. This activity sheet was used to address the students’ ideas about temperature, energy and molecular movement. Students began by filling in an activity sheet about what they thought would happen to ice water when five ice cubes were added. Students were then given thermometers, ice water, and beakers, and asked to record the water temperature before the ice was added, and again after five ice cubes had been added. Students recorded the temperatures and wrote about their ideas for what was going to happen, with comparison to what actually happened. A discussion followed the experiment about their expectations for the experiment in relation to what actually happened.

*Turning the Dial data collection*
Students were introduced to the second assessment, Turning the Dial, and given activity sheets to complete and write about their ideas. Turning the Dial was used as an assessment in connection with increasing heat and increasing temperature. The assessment addressed two of the focus questions about heat and temperature. Students were given a 250 mL glass beaker and asked to fill it with 150 mL of water. Students place the beaker onto a hot plate, turned the dial to high and placed a thermometer into the water. The students waited for the water to boil rapidly, and then took the temperature of the water, and then they turned the dial to med-high and waited until the water was boiling less rapidly. Again, the students took the temperature of the water. The results were recorded and the findings were compared to what the students had originally expected to happen, as recorded on their activity sheets. The students shared their results with the class and discussed their explanations for what had happened.

_Warming water data collection:_

Student began by reading the formative assessment, Warming Water, and answered the activity sheet provided. This activity sheet addressed the students’ ideas about thermal energy and radiation from the sun. It also addressed ideas about of objects and molecules being in motion and having energy. Students were given thermometers and bowls containing 200 mL of water. They recorded the temperature of the water on the activity sheet. Then the students went outside to a sunny area and placed their bowls of water into the sunshine for five minutes. They recorded the temperature of the water after five minutes. Students then returned to the classroom and compared their findings to the original expectations. They were asked to re-examine the definition of temperature.
and discuss their findings without using the words the terms warming up or cooling
down, but instead referring to what had happened to the energy.

*The Mitten Problem data collection:*

Students were given *The Mitten Problem* activity sheet and they were asked to fill
it out. This activity sheet and following lab addressed the concept of insulation and room
temperature. On the first day, the students discussed what they thought would happen, 
and what was affecting the temperatures of a thermometer if it was inside a jacket. A
student place a thermometer inside of a jacket to see what would happen. The next day,
students were provided with mittens and hats, into which they placed thermometers.
Temperatures were recorded initially and after five minutes. Students also wrote what
they thought was going to happen and what actually happened. The students discussed
the findings in a whole group discussion.

*Objects and Temperature data collection:*

Students were given the *Objects and Temperature* activity sheet, and wrote their
predictions about objects located in the same room and what their temperature was in the
room. This assessment was to address the misconception about objects and temperature
with reference to the focus question. The class discussed their predictions before doing
the experiment. Students were given a metal pot, a glass beaker, a wood frame, and a
wool hat. Thermometers were taped onto the various items so that the bulbs would be
touching the material. The students waited five minutes and recorded the various
temperatures. The results were written down and discussed.

*Notes/questions*
The students were given a graphic organizer to help them organize what they learned. They were asked to answer the questions using the information they had gathered during the labs data collection. The questions were discussed together as a class discussion.

*Final data collection:*

Students were asked to answer the final focus questions, which had been given at the beginning of the data collection to see if their conceptions about heat and temperature changed.

**Videotaping/confidentiality**

Students’ submitted their permission slips to be videotaped which were placed in a locked drawer in the teacher’s desk. The videos of the students were transferred to a DVD, and the original videos were erased. The DVD’s were viewed for data and then destroyed.

**Data analysis**

The purpose of this study was to look for changes in how students viewed heat, thermal energy, and temperature. Students’ answers to the initial focus questions were collected and the formative assessment activity sheets were analyzed for changes in wording or in the descriptions of ideas before and after the formative assessment. The answers to the initial focus questions were compared to the answers given after the formative assessments activity sheet and the lab investigation to see the effect, if any, that the formative assessment activity and lab had on students’ misconceptions. The answers were analyzed in terms of changes in student ideas. The discussions were observed and
analyzed for whether they supported or not students written assessments. Finally, the answers to the final focus questions were examined to find any changes in their ideas expressed by students. Findings of this analysis were reported as themes in Chapter 4.

**Validity and reliability**

Validity and reliability were addressed in the study. First, a triangulation of data sources was included. The questions and assessment sheets and discussions were used to help triangulate the students’ ideas. The students works were analyzed, and compared to what they had said in class (on the video), and in terms of their responses to the initial focus question, the written responses on the activity sheets. After the final answers to the focus questions were given the responses were compared to the answers in the formative assessment activity sheets and the answers to the initial focus questions. Second, content alignment was addressed through establishing a congruence of purpose with assessment sheets, research questions and laboratory activities. Third, I used the same procedures were used with each laboratory to maintain consistency in procedures used.

**Summary**

In this chapter, I described the design of study, setting, population, and methods used and how data were analyzed and triangulated. In Chapter 4, the results of the data analysis were presented.
CHAPTER 4: RESULTS

Introduction

This action research thesis focused on students’ misconceptions about heat and temperature. The data were collected from the following sources: focus questions, formative assessment activity sheets, questions about formative assessment sheets, and videotaping. Presented in the chapter were data to answer each research question. There were two guiding question in this action research study:

1. How did my practice of using formative assessments affect ELL students understanding of heat?
2. How did my use of formative assessments uncover students’ misconceptions about heat?

The first step in the research process was giving the students seven focus questions to answer about heat. Then the students worked on five formative assessment activity sheets that were used to model a lab related to the misconceptions. Students were given the notes/question graphic organizer to answer, and then the focus questions were given at the end of the unit.

Ell misconceptions about heat

To start the unit, I gave each student seven focus questions and five assessment activity sheets to identify misconceptions they had about heat and to be able to find any conceptual changes about heat and temperature. At the beginning of the research for ELL students were participating. Three of these students were from various Spanish-
speaking countries; all were born outside the U.S., and they spoke Spanish at home. One student was born in the U.S., but his home language was Vietnamese. One student did not finish the unit and left the school.

_Ice Water_

_Ice Water_ was the first assessment activity sheet given to the students. For this activity sheet, students decided if the temperature of the water was going to increase, decrease or stay the same if ice was added to ice water. Two of the four ELL students wrote that the ice water temperature would decrease, exposing a misconception about temperature and particle movement. Kurt\(^1\) wrote, “I think the temperature of the water will decrease and the particles will slow as well.” Edgar wrote, “I think the temperature of the water will drop only two degrees and then the water will stay the same temperature.” The other two students wrote the correct answer, that the temperature would not change.

Kurt and Edgar’s misconceptions did not change. After Kurt did the experiment, he recorded that the temperature dropped two degrees when the second ice was added. In response to this, he wrote “What I thought would happen did happen. I knew this because if you add more particles the temperature lowers.” When he answered the question on the questions/notes sheet, he wrote, “Thermal energy produces heat or speed up molecules. The ice water started off with slow molecules, and then they speed up to meet room temperature”(Appendix N). Edgar wrote after the experiment, “I thought the temperature dropped -5° so I was wrong.” The water must not have been at zero, so the

\(^{1}\) ALL STUDENTS NAMES ARE PSUEDONYMS
temperature could still drop. There was no basis for their conceptions to change. The students did not observe water at the freezing point, where temperature does not decrease.

Before the Ice Water experiment, the class had a discussion about cold water, energy, and particle movement.

During the discussion, Edgar asked “Do cold water molecules move faster or slower? Slower right?”

My response was, “Correct.”

Then Ryan asked, “If I keep hot water out, the particles start moving slower and it cools off?”

This time I responded, “Energy moves from high speeds to low speeds and the molecules bounce into each other.” I was hoping that the students could visualize it, but when I looked over their final answers, they had not visualized cold water bouncing into ice and realizing it was heat.

This discussion was related to the idea that heat is a transfer of energy, and it can happen at cold and hot temperatures. Regardless of the discussion, all ELL students answered that cold is opposite of heat in both times they answered the focus question, “Is cold the opposite of heat?” Ryan wrote for his first answered, “No cold is not opposite of heat, because hot is, hot is different from heat like its next step.” For his first answer, Edgar wrote, “Cold is the opposite of heat because hot are molecules [sic] that are warm and cold is something near to frozen.” For the first answer, Kurt wrote, “Cold is the opposite of heat because heat involving warm objects like fire is cold needs ice.” The follow up answers for the students were very similar. Kurt wrote for his second answer,
“Cold is not the opposite of heat because cold is what we feel and heat is what we feel.” Ryan wrote the second time, “Yes, when it is cold the temperature goes down, when it is hot the temperature goes up,” and Sam wrote for his second answer, “Heat has more kinetic energy than coldness, the heat gets hotter or its kinetic energy increases.” According to student responses, heat is tied to hot, and one student thought heat is what we feel, not the transfer of energy. None of the students realized that energy transfers take place even if both objects are cold.

*Turning the dial*

For the *Turning the Dial* activity sheet, three of the students had misconceptions about the water’s temperature changing when boiling at different rates. According to the activity sheet the students were supposed keep the water boiling throughout the entire experiment. The answers on the activity sheet were similar to the focus questions, “Is heat a material that can move through an object?”, and “If I add more heat do I raise the temperature.” According to written responses before the lab, Sam wrote, “I think the boiling temperature will increase when the dial is set on high, because the dial controls the fire that boils the water.” He was working with Ryan, who wrote, “The boiling temperature is greater when the dial is set on high, because it’s higher.” Kurt wrote, “I think the water boils differently at different levels of temperature.” These all showed that they thought the temperature would continue to go up even when boiling.

Ryan and Sam experiment did not work correctly, and Kurt had technical problems. Ryan wrote, “When it was on high, it was 98° then I put it on low and the temperature went down to 94°.” Sam and Ryan did not get the water to 100°C, the
boiling point of pure water. This changed the outcome of the experiment. Sam wrote, “The temperature did increase when the dial was on high, the higher kinetic energy in the hot plate was, the higher the water kinetic energy got. I think when you raise the hotplate kinetic energy; it affects the water kinetic energy.” He was using the term energy, so he was possibly beginning to understand the heat is not matter but energy. When he answered the question, “If I add more heat, do I raise the temperature?” for a second time, he wrote, “Yes, since temperature is a measure of kinetic energy, the more heat there is the more temperature.” Ryan wrote, “If you add more heat, the temperature will rise.” Sam may be having a conceptual change about heat being particles moving faster and bumping into each other, causing other molecules to move faster.

Kurt did not get the water to boil, so his misconception about the topic was not addressed. He wrote on the questions/notes page, “I learned that heat transfers energy into the water, causing the water molecules to speed up. When there is less energy, the molecules slow down.” Like Sam, he was beginning to view heat as energy and not as matter. To the second focus question, “If I add more heat, do I raise the temperature?” he wrote: “Yes, because the energy from one object is transferring to another object.” His answer was still based on background knowledge.

The focus question, “Is heat a material that can move through an object?” was addressed in this activity sheet. Students use the analogy of a microwave or stove making heat that moves into an object. Edgar’s answer for the beginning focus question, “Heat is a material that can move threw an object cause when popcorn is in the microwave the heat travels through [sic] the bag and moves to make the popcorn pop.”
Kurt wrote for his first answer, “Yes, because when you cook the heat from the stove goes through the pan into the air.” Sam wrote, “Yes, heat can move threw objects because heat moves around the air.” The students thought heat is a material, or matter, that moves through and object.

Overall, misconceptions of two students changed, while the misconception of the other student did not change. Sam wrote for his second answer, “No, objects that are near the heat get hotter or its kinetic energy increases.” Kurt wrote for his second answer, “No, because it causes the particles to move faster in one object and causes it to move other particles to move faster,” These answers are both improvements in their mental image of heat. “Yes, because it heats up the object and will make it hot inside and outside,” was Ryan’s answer. Ryan really did not show any conceptual change in his answer.

**Warming Water**

Warming Water was an activity sheet used to expose students’ ideas about the energy an object has, and if heat is added to an object. The activity sheet exposed two ELL students’ misconceptions about energy in objects. Edgar wrote, “I think Ambra is right because [sic] the water does not have energy. The suns heat warmed up the water almost like the water was on the stove.” Sam wrote, “I think cold water doesn’t have energy. If it did it wouldn’t be cold, it would be hot. The sun gave water energy.” Sam changed his mind after the experiment, Edgar did not. Sam wrote after the experiment, “I think it should be outside for a longer period of time, but the water did have energy.” He explains better during on the questions/notes sheet, “The water had energy. The sunlight
only gave the cold water more energy.” He had realized that all substance have energy, even if it is cold.

During the discussion that followed the lab, I asked, “What is coming from the sun to warm up the water?”

One student answered, “Heat”, but Sam was more specific, “Heat waves.”

I asked, “What does that mean about the molecules?”

Sam answered, “They are moving faster.” This indicates Sam’s conceptual change. After the experiment, Edgar wrote, “The water temperature went up 5 degrees.” Unfortunately, he had left school by the last focus questions.

“Is heat a material that can be added to an object?” was the focus question associated with the activity sheet. Kurt wrote, “No, because heat moves through an object.” In his second answer, he changes his answer to identify a different misconception, “Yes, because you can add energy to an object making the particles go faster.” It seems like there is a slight conceptual change, but it still is worded like energy is matter. Ryan’s answers also change. Ryan first wrote as an answer to this focus question, “No, it’s not.” After the activity and the discussion he wrote for his answer to the focus question, “Yes, heat can be added to an object.” It is almost as if the Warming Water activity sheet and discussion caused a misconception.

The Mitten Problem

The Mitten Problem activity sheet was done based on a question I asked during the discussion for Objects and Temperature.

I had asked, “If I put a jacket on a thermometer, will it heat up?”
The chorus response from the class was, “Yes.”

Edgar pointed to the jacket and said, “It has heat on there.” This was the evidence to address this misconception.

The Mitten Problem activity sheet had three different options, and the three participating ELL students wrote three different answers. Sam wrote the correct answer, “Both thermometers will have the same temperature reading.” Edgar wrote, “The thermometer inside the mitten will have higher temperature reading than the thermometer on the table.” Kurt wrote, “I think the temperature will be lower inside the mitten.” After we did the experiment, the ELL students realized that an object in a room will be at room temperature. Kurt wrote after the experiment, “Most things on the outside are at room temperature.”

Sam shared his idea in the class before the experiment, “I think all objects will have the same room temperature because the air particles are hitting them.” After the experiment, Sam explained that, “The mitten and the table were affected by room temperature which means everything in the room has the same temperature.” After the experiment, Edgar wrote, “The thermometer had the same temperature as the thermometer on the table.” Overall, this experiment led to a conceptual change for the ELL students.

Objects and Temperature

The Objects and Temperature activity sheet was aligned with the focus question, “Is metal colder than plastic?” This activity sheet led to the most discussion, and was the springboard for doing The Mitten Problem activity sheet. During the first focus question
discussion, a student picked up thermometers and began to take the temperature of objects in the room. Sam was working with the student that day, so he remembered the findings when we started the discussion about this activity sheet. Sam wrote, “All objects have the same temperature. All material is at room temperature.” During the discussion, he talked about Aiden taking the temperature of the different objects in the room. He said, “When Aiden was taking the temperature of the table and the chair leg, they were the same temperature, the chair leg just felt colder.” The other students who were not working with Aiden had different ideas. Ryan wrote, “None of the objects will have the same temperature” (Appendix O). Kurt wrote, “Three of the objects will have different temperatures.” Some of the ELL students thought that the temperature of an object is not dependant on room temperature. When we did the experiment, the temperature of the objects were all 23.5° C or 24°C. The metal was the same temperature as the hat. This led to the students indicating a conceptual change. Sam indicated, “I was correct, the items were at room temperature.” Kurt also indicated after the experiment, “The objects were all at room temperature.” Ryan indicated on his activity sheet, “All objects were around the same temperature,” but the following day on his focus questions, he still indicated that metal was colder than plastic.

The focus question “Is metal colder than plastic?” was tied to the activity sheet Objects and Temperature. When Ryan first answered the focus question, “Is metal colder than plastic?” he wrote, “Yes, because it (metal) freezes up and it (metal) will hold up the cold.” When we did the experiment, the objects’ temperatures were all at room temperature. Kurt’s first answer to the focus question was, “No, because you can freeze
the plastic and it would be colder.” He was saying that normally metal is colder than plastic, unless you place plastic in a colder environment. Edgar’s idea about the questions is similar to Kurt’s response. He wrote for his first answer, “Metal is not colder than plastic cause it all depends on where you put the metal or plastic.” Kurt’s response after the experiment for the focus question was “No, it is the temperature of the environment surrounding it.” Ryan did not have a conceptual change, he wrote, “The metal kind of absorbs the heat.” For the follow-up answer to the focus question he wrote, “Yes, metal is colder than plastic.” He saw the experiment and it did not lead to a conceptual change.

Overall, the activity sheets showed the misconceptions ELL students had about the topic, but after doing the experiment there was not a conceptual change for all the ELL students. For the Ice Water activity sheet, 50% of the ELL students had the correct answer to start the activity, and 50% of the ELL students chose a response that identified a misconception about the water continuing to decrease. After the experiment, 50% of the students identified the correct answer, and 50% of the students still chose the incorrect response, saying the water’s temperature will continue to decrease. None of ELL students’ showed a conceptual change for focus question one. All of the ELL students still specified that cold is the opposite of the first time and the second time they answered the focus questions. There was no change in student understanding for this misconception.

For the Turning the Dial activity sheet, 100% of the ELL students identified with the misconception that the temperature will decrease when the water was still boiling.
After the experiment, 100% of the ELL students identified the misconception that the temperature would change when still boiling. There was no conceptual change indicated by the ELL students, and most likely because of the students’ experiment did not mirror the activity sheets procedure. For the focus question, “If I add heat the temperature will increase,” 100% of the students identified the misconception that the temperature will continue to increase before the experiment, and 100% of the students identified that the temperature will continue to increase with increased heat after the experiment. There was no evidence of a conceptual change, and again it was most likely caused by the experiments procedure not being followed. For the focus question, “Is heat a material that can move through an object?” 100% of the ELL students identified that heat can move through and object before the experiment. When answering the question after the experiment, only 33% of the ELL students wrote that heat can move through an object. This did indicate a conceptual change by part of the ELL students.

For the Warming Water activity sheet and the focus question, “Is heat a material that can be added to an object?”, 66% of ELL students identified with the misconception that cold water does not have energy. After the lab, 33% of the students still identified with the misconception that cold water does not have energy. For the focus question number 6, “Is heat a material that can be added to an object?”, 33% of the ELL students identified the specific misconception that heat can be added before the experiment. After the experiment, 66% of the students wrote that heat can be added to an object. There was an increase in the students’ misconception about heat being a material that can be added
to an object. It may have been caused by the description of the molecules moving faster when the heat rays hit the water.

For The Mitten Problem, 66% of the students identified on the activity sheet the misconception that the mitten would impact the temperature of the thermometer before the experiment. After the experiment, 0% of the students identified with the misconception about the thermometers temperature changing because it is in the mitten. The students’ answers did suggest a conceptual change based on the experiment.

For the Objects and Temperature activity sheet, 66% of the ELL students identified with the misconception that the objects will have different temperature in the same room before the experiment. After the experiment, 0% of the students identified with the misconception about temperature. For the initial response to the focus question, “Is metal colder than plastic?” 66% of the students identified the misconception that metal is colder than plastic before the experiment. After the experiment, 33% of the students wrote that metal is colder than plastic. A conceptual change may be difficult for a student, even when presented with the correct scientific concept. Students did not incorporate the scientific concept into their knowledge.

**Exposing students misconceptions about heat and temperature**

All ten students had misconceptions about heat and temperature. The activity sheets and focus questions exposed misconceptions the students had regarding both heat and temperature.

*Ice Water*
The students worked on both the **Ice Water** activity sheet to reveal their misconceptions about water at its freezing point, when the temperature does not change. Also, the focus question asked, “Is cold the opposite of heat?” Andrew wrote, “The temperature of the ice water will decrease to 19° I think.” Kelly wrote, “The temperature will drop even more and the water will rise.” Daniel wrote, “I think the temperature will decrease maybe about the same as the first time, the particles will slow down which is making it colder in the water.” For the **Ice Water** activity sheet, 86% of the students exposed misconceptions on the activity sheet.

The first time they answered the focus questions exposed misconceptions as well. For the focus question related to the **Ice Water** activity sheet, “Is cold the opposite of heat?” Andrew wrote, “No, it’s not, heat is something you create.” Daniel wrote, “Cold is opposite of heat because cold has a different feeling and effect than heat.” Kelly wrote, “Yes, because if you’re not hot then you’re cold. If you’re not cold you’re hot.” For this question, 100% of the students’ misconceptions were uncovered.

**Turning the Dial**

The **Turning the Dial** activity sheet was used to reveal student misconceptions about adding heat and increasing the temperature. The activity sheet was associated with two focus questions “If I increase heat, do I raise the temperature?” and “Is heat a material that can move through an object?” The activity sheet uncovered misconceptions the students had about heat and increasing temperature. Ryan wrote, “The boiling temperature is greater when the dial is set on high, because it’s higher.” Daniel wrote, “The boiling is great when the dial is set on high because the molecules are moving faster
it goes to high.” Andrew wrote, “I think the temperature is greater when the dial is on high because on high it will last longer and on low the temperature will go down but then up again.” On the Turning the Dial activity sheet, 88% of the students chose a misconception as their answer.

The focus question, “If I increase heat, do I raise the temperature?” revealed the common misconception that temperature increases when heat increases. Answers ranged. Andrew wrote “Yes” for his answers. Edgar wrote, “Yes, the more the heat the more the temperature goes higher.” Daniel wrote, “If you add more heat you add more temperature because the thermometer measures temperature and heat goes up.” For this focus question, 100% of the students wrote answers that exposed misconceptions about increasing heat means increasing temperature.

In answering the focus question, “Is heat a material that can move through an object?” the students’ responses were the common misconception of heat being matter. Kelly wrote for her first answer, “Yes, because if you put hot water in a sealed jar then the glass of the jar on the outside is going to get hot.” Daniel wrote, “Heat can move through a material such as water.” “Yes, heat can move threw objects because heat moves around the air,” Andrew wrote for his answer. This focus question exposed misconceptions about heat in 100% of the students.

*Warming Water*

The *Warming Water* activity sheet also revealed student misconceptions about objects having energy. It incorporated the focus question, “Is heat a material that can be added to an object?” Some students choose the correct answer for this activity sheet.
Misconception answers identified that the water did not have energy. One student, Anna, wrote, “I think Ambra is correct [sic] when she said that the water did not have energy.” Edgar wrote, “I think Ambra is right because [sic] the water does not have energy the suns heat warmed up the water almost like if the water was in the stove getting boiled [sic].” Andrew wrote, “I think Ambra is right because the warmer it there is more energy.” On the Warming Water activity sheet, 57% of the students chose an answer that was a misconception.

For the focus question, “Is heat a material that can be added to a material?” there were two yes answers that showed a misconception, and two no answers that showed a misconception. Kelly was a no answer, because she related heat to moving through, “No, because if you have cold water and you want it hot without adding more water than your water is staying cold unless you add water.” Edgar answered “You can boil water, the heat is what is causing the water to boil.”, and finally Daniel wrote, “Yes, heat can be added.” For this focus question, 66% of the students wrote that heat can be added to an object.

**The Mitten Problem**

The Mitten Problem was used to uncover students’ misconceptions about heat and insulation. In answering this focus question, three students answered correctly, three wrote that the temperature would be higher inside the mitten, and three wrote that the temperature would be lower inside the mitten. Andrew thought the temperature would be higher. He wrote, “The thermometer inside of the mitten will have a higher temperature reading than the thermometer on the table.” James wrote, “The thermometer inside the
mitten will have higher temperature reading than the thermometer on the table because the mitten will insolate the heat.” Daniel wrote, “The thermometer inside the mitten will have a lower temperature reading than the thermometer on the table. I think this because the jacket or mitten is already cold, it’s just you feel warmer.” Overall, 75% of the students thought that the mitten would increase the temperature of the thermometer if placed inside.

*Objects and Temperature*

The *Objects and Temperature* activity sheet also showed the students’ misconception about an object made of metal having the same temperature as an object made of glass, if they are in the same room. Metals are not invariably colder than plastic. This activity sheet was connected to the focus question, “Is metal colder than plastic?” Kurt wrote, “Three objects will have the same temperature.” Ryan thought, “None of the objects will have the same temperature.”, and James wrote, “None of the objects will have the same temperature because the materials that make them up are different.”

During the discussion, James expands on this, “The molecules are different, so they are moving differently.” He convinced Andrew this misconception was correct. For the *Objects and Temperature* activity, 66% of the students thought that the objects would have different temperatures.

For the focus question, “Is metal colder than plastic.” five of the six students had misconceptions about the metal and plastic. Daniel wrote, “Metal is colder than plastic because it attracts more coldness. Heat comes from something hotness.” Ryan wrote, “Yes, because it freezes up and it will hold up the cold.” Andrew wrote, “No, plastic
become rubber.” I was not sure what Andrew was thinking when he wrote this, and he could not describe it well when I asked. He just commented, “It gets plastic gets harder like rubber.” For this focus question 83% of the students revealed misconception about metal being colder than plastic because of the material it’s made of. The 17% of students’ answers were inconclusive.

The student misconceptions were revealed, and in all cases, the number of students with misconceptions outnumbered the number of students with correct scientific ideas about heat and temperature (Figure 1). Warming Water had the fewest misconceptions, though more than 50% of the students still had misconceptions in this topic.

![Misconceptions percentages](image)

Figure 1: Percentage of misconception of students revealed by focus questions and activity sheets.
Summary

In this chapter, the students’ data were presented and evaluated. The research questions were restated. The first section reported the results of the ELL students’ misconceptions about heat and temperature and the conceptual changes that had occurred. The data were then analyzed to show what percentage of student had a better understanding of heat and temperature after the labs and discussions. The second section reported in the classes’ misconceptions about heat and temperature that were revealed when using the formative assessment activity sheets and focus questions.
CHAPTER 5: CONCLUSION

Introduction

In this chapter, I summarized chapters 1-4 to present complete picture of the research. The research questions and purpose of this study were presented again, and the literature review was summarized. The findings and then the implications of the data were discussed. Then, finally, I concluded with future topics for research.

The purpose of this research study was to examine whether or not if the use of formative assessment activity sheets and focus questions, followed by experiments and discussion could affect the ELL students’ misconceptions about heat and temperature. The research questions that guided this study were:

1. How did my practice of using formative assessments affect ELL students’ understanding of heat?
2. How did my use of formative assessments uncover students’ misconceptions about heat?

Prior studies have shown how a home language can lead ELL students to form different misconceptions compared to those of native English speakers (Luykx, Lee, & Edwards, Lost in translation, 2008). Student misconceptions about heat are often based on the characteristic that heat is described as matter, not a process (Slotta, Chi, & Joram, 1995). In this study, the framework of social constructivism and how it can lead students to learn more as a group instead of independently was supported by research (Vygotsky, 1978). Finally, studies about formative assessments used in science were discussed (Bell & Cowie, 2001). A study on the fidelity of formative assessments in the
classroom depends on whether when used if they are use how they were designed to be used (Furtak, et al., 2008).

The data revealed several themes. First, changing ELL students’ misconception is not an easy task to achieve. In fact, in this study, not all of the ELL students had conceptual changes after their misconceptions were uncovered. Even when a lab had been set up to align exactly like the formative assessment to address specific misconceptions about temperature, one ELL student still did not change his misconception about objects being at room temperature. The Ice Water and Turning the Dial formative assessment labs were also problematic. They did not show the expected outcome, and students continued to hold onto their misconceptions. Second, when looking at each assessment and question individually, some conceptual change had taken place, but a complete change of students misconceptions about heat had not occurred. The formative assessments revealed the students misconceptions about heat, which were similar to those identified previously. Third, generally the students considered heat as matter and struggled to think of it as energy. Also they relate heat to hot, but not to cold.

An implication of the study was that students need to be taught explicitly that heat is a transfer of energy between particles, and this can take place at high and low temperatures. I did not say this. Then, it may help to do the laboratory activities to support this idea. Students did not infer this idea based on other discussions about heat, hot water, and cold water.

Another implication of the study is that the formative assessment activity sheets appeared not to be designed for labs, and thus to make them work in a lab setting was less
effective than doing other labs. Originally, I had thought that working directly from the activity sheet would benefit the students, but the labs had to work out. In the future when teaching about heat, I would choose a variety of labs that are close to the formative assessment activity sheets so that students get enough time and experience working with each particular concept.

Third, implication of the study is that using social constructivism ideas such as students working together and helping each other develop ideas may lead to students’ wrong ideas. Teachers should monitor students’ discussion and bring them together to discuss what they have learned to assist them in making accurate interpretations when doing lab activities. When Sam worked with Aiden and they figured out focus question 7 (about metal being colder than plastic), Aiden tested the different objects in the room and informed Sam about his results, which led Sam to the correct answer. When James shared his information with Andrew about each object being a different material so they would be different temperature, James convinced Andrew of his misconception. Teachers need to be aware of the discussions that taking place in the classroom, so students do not learn or reinforce misconceptions.

Lastly, an implication of the study was that students may observe a lab, but not all students may grasp the ideas. Follow up discussion and experiments were needed for a more complete conceptual change.

This study was limited to a small classroom with a few ELL students who also speak English well, but who have non-English home languages. Students who are non-English speakers may not understand enough English to benefit from only doing lab work.
but may need the teacher actively facilitating the learning looking for gaps in students’ understanding.

One of the limitations in this study was that some students were not present during every day of instruction. At no time, were all ten students present together in the class. And by not experiencing the entire unit, they may have held some of their misconceptions about heat and temperature. The effect of this problem was difficult to evaluate, and it was difficult to know whether if the conceptual change did not take place because of language or because a student was absent.

In the future it would be interesting to do a more detailed study with ELL students and their misconceptions about science topics and the role language plays in their misconceptions. Another suitable project would be to focus on how the students’ view heat and temperature using pictorial models for the words to see how the students relate to the ideas.

**Final summary**

In this action research study, ELL students’ misconceptions about heat and temperature were identified through formative assessments. The research says that getting students to change their conceptions is not easy, which was also the case for students in this study. Conceptual changes did occur took place for a small number of students, though some of the ELL students still had misconceptions about heat and temperature. Overall, the students’ misconceptions were revealed, but a conceptual change did not take place in all cases. This may be explained by the labs, which coincided by did not show the information as explained in the activity sheets. In
addition, social constructivism ideas like fostering student discourse and making sense of ideas themselves may work, but a teacher must be aware of the students’ discussion to guide the development of correct scientific understanding. In the future, there may be some changes in students’ ideas about heat and temperature.
APPENDIX A: REFERENCES FOR TARGETING MISCONCEPTIONS IN SCIENCE
F. REFERENCES


APPENDIX B: REFERENCE AND ACKNOWLEDGMENTS FOR KEELEY

ACTIVITY SHEETS
Next Steps

This book is planned as a series of assessment probe books, each volume describing a new application as well as including new probes. In the next volume of *Uncovering Student Ideas in Science*, we will describe strategies for using the probes during instruction to help your students experience conceptual change. In the third volume, we will address ways to use the probes for professional development.

References


Acknowledgments

The assessment probes in this book have been extensively field tested and piloted with hundreds of students in Maine, New Hampshire, and Vermont by the Maine Mathematics and Science Alliance (MMSA). We would like to thank the teachers in the National Science Foundation–funded Northern New England Co-Mentoring Network (NNECN) (www.nnecn.org), Maine’s Governor’s Academy for Science Education Leadership, and participants in various MMSA professional development programs for their willingness to field test and pilot items, share student data; and contribute ideas for additional assessment probe development. In particular we would like to acknowledge the following teachers for their contributions to this project:

Judith Allard, VT; Dr. Pasco Avery, ME; Julie Barry, ME; Mary Belisle, ME; Anita Bernard, ME; Lise Boefinger, NH; Tracy Bricchi, NH; Ruth Bither-Broene, ME; Linda Brasseur, VT; Nancy Chesley, ME; Gay
APPENDIX C: FOCUS GROUP QUESTIONS
Focus groups questions:

1. Is cold opposite of heat? Explain?
2. Is heat a material that can move through an object? Explain?
3. Is there a difference between heat and temperature? What is it?
4. If I add more heat, do I raise the temperature?
5. Is heat maintained at a source? Explain?
6. Is heat a material that can be added to an object?
7. Is metal colder than plastic? Why or why not?
Ice Water

Christine put five ice cubes in a glass. After 20 minutes, most of the ice had melted to form "ice water." There were still some small pieces of ice floating in the water. Christine measured the temperature of the ice water then added five more ice cubes to the glass. She measured the temperature three minutes later. What do you predict happened to the temperature of the "ice water" three minutes after she added more ice?

A The temperature of the "ice water" increased.

B The temperature of the "ice water" decreased.

C The temperature of the "ice water" stayed the same.

Circle the answer that best matches your thinking. Explain what happens to the temperature of "ice water" when more ice is added.

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Understanding Student Ideas in Science

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APPENDIX E: TURNING THE DIAL ACTIVITY SHEET
Flora is boiling water on a stove. She turns the temperature dial up to high to boil the water. The water is boiling vigorously with large bubbles quickly forming and bursting at the surface. Flora then turns the dial of the stove down to low. The water is boiling gently, with smaller bubbles slowly forming and bursting at the surface. Flora wonders if the boiling temperature changes when she turns the dial. What would you tell Flora? Circle the best answer.

A. The boiling temperature is greater when the dial is set at high.
B. The boiling temperature is greater when the dial is set at low.
C. The boiling temperature is the same at both settings.

Explain your thinking. What “rule” or reasoning did you use to select your answer?
Warming Water

Two friends put a bowl of very cold water outside on a hot sunny day. The Sun warmed the water. They wondered about the energy of the water. This is what they thought:

Ted: "The very cold water had energy. The Sun provided additional energy to warm the water."

Ambra: "The very cold water did not have energy. The energy in the warm water came from the Sun."

Which friend has the best idea? Explain why you agree with one friend and not the other.
APPENDIX G: OBJECTS AND TEMPERATURE ACTIVITY SHEET
Objects and Temperature

Taz and Kyle are comparing the temperature readings of four different objects:

- block of wood
- metal tray
- wool hat
- glass plate

They place the objects on a table in their science classroom and leave them overnight. A thermometer is attached to each object. The next day they record the temperature of each object at the same time.

Put an X next to the statement that best describes your prediction about the objects' temperature.

___ None of the objects will have the same temperature.
___ Two of the objects will have the same temperature.
___ Three of the objects will have the same temperature.
___ All of the objects will have the same temperature.

Describe your thinking. Provide an explanation for your answer.

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Questions/notes

What does temperature measure?

What do you think about solid particles moving?

What do you think about what a thermometer does and about how energy moves?

What evidence have you see about the molecules moving from higher to lower? (this is called heat, but what evidence have you seen that this happens?)

What did you learn about thermal energy in the Ice Water probe?
What did you learn in the turning up the dial probe about temperature and molecules moving? What happens when there is less energy?

What did you learn about temperature and energy from the Warming the water probe?

What did you learn from the mitten probe and the discussion about insulation and body heat?
APPENDIX J: PARENTS PERMISSION SLIP FOR VIDEOTAPING
Dear Parents,

As your child’s science teacher, I am continually striving to become a better teacher. Currently, I am in a Master’s program at UCF. The program is to help K-8 teachers teach science and math better. To finish my degree, I am writing an action-research thesis examining my practice of teaching. My action research project is to examine English language learners misconceptions about heat. Heat is a subject covered in the 8th grade standards, and some students have misconceptions about what heat is and how it is related to temperature. The purpose of the study is for me to examine how to teach your child about heat and thermal energy better by examining how I teach the unit and what misconceptions I address.

**What your child will be asked to do in the study:** Students will be in class as normal. Students will be learning about heat and thermal energy. The students will be asked to write in their notebooks about their ideas on heat and thermal energy, and do experiments about heat and energy. There is a possibility the student may be videotaped, and asked questions about what they learned in the unit about heat and energy.

**Audio or video taping:** Your child will be videotaped during this study. If you do not want your child to be videotaped, your child will not be able to be in the study. If your child is videotaped, the tape will be kept in a locked, safe place. The tape will be erased or destroyed when the study is finished at the end of summer 2010.

**Confidentiality:** The data collected during the study will remain confidential during the study.

Your child is not required to be part of the study. It will not impact the students grade in any way.

Thank you
Leah Torres

Permission to participate in the study

Parent permission
APPENDIX K: IRB RESPONSE LETTER
NOT HUMAN RESEARCH DETERMINATION

From: UCF Institutional Review Board #1
      FWA0000351, IRB0000138

To: Leah Weiss

Date: October 26, 2009

Dear Researcher:

On 10/26/2009, the IRB determined that the following proposed activity is not human research as defined by DHHS regulations at 45 CFR 46 or FDA regulations at 21 CFR 50/56:

Type of Review: Not Human Research Determination
Project Title: Addressing 8th grade ELL students misconceptions on heat
Investigator: Leah Weiss
IRB ID: SBE-09-06374
Funding Agency:
Grant Title:
Research ID: N/A

University of Central Florida IRB review and approval is not required. The information although systematic is part of the routine classroom and will not be used for other purposes other than to improve teaching, etc. There is no expectation that this information will be published or shared outside of the educational setting. Although this study does not fall under IRB oversight the PI is aware that although since human subjects are being studied ethical principles should always be applied. Since parental permission will most likely be secured some type of parental consent process is recommended to ensure the parent is aware of the videotaping and what their child is being asked to do.

This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are to be made and there are questions about whether these activities are research involving human subjects, please contact the IRB office to discuss the proposed changes.

On behalf of the IRB Chair, Joseph Bielitzki, DVM, this letter is signed by:

Signature applied by Joanne Muratori on 10/26/2009 08:37:46 AM EST

IRB Coordinator
APPENDIX L: DISTRICT APPROVAL LETTER
August 31, 2009

Ms. Leah Torres
2912 Oaktree Drive
Kissimmee, FL 34744

Dear Ms. Torres:

This letter is to inform you that we have received your request to conduct research in our School District. Based on the description of the research you intend to conduct, I am pleased to inform you that you may proceed with your work as you have outlined.

I will remind you that all information obtained for the purpose of your research must be dealt with in the strictest of confidentiality. At no time is it acceptable to release any student or staff identifiable information.

I wish you the best of luck in your future endeavors. If I can be further assistance, please do not hesitate to contact me.

Sincerely,

[Signature]

Angela Marino
Director
Research, Evaluation & Accountability
Date: Thursday, July 23, 2009 10:04 AM
From: Page Keeley <pkeeley@mmsa.org>
To: lcmw75@cfl.rr.com
Subject: Re: Permission

Dear Leah,
You have my permission. Furthermore, I would love to read your thesis when you finish it! There may be some interesting findings to share with the field.

Best,
Page

On Wed, Jul 22, 2009 at 10:46 PM, <lcwm75@cfl.rr.com> wrote:

Hi
I was wondering if I could have permission to use your probes for my graduate research thesis. My question is How will my practice of identifying misconceptions of ELL students about heat lead to a conceptual change?
Thank you
Leah Torres

--- pkeeley@gmail.com wrote:
> There have been none as these are formative probes that are not used for measurement.
> From: lcwm75@cfl.rr.com
> To: Page Keeley
> Sent: Jul 19, 2009 7:18 PM
> Subject: Reliability and Validity for assessment probes
>
> Hi
> I am a masters student at the University of Central Florida, and I was going to use the probes you wrote as an instrument in my masters thesis research. Could you tell me if there has ever been a reliability or validity studies on the formative assessment probes. I'm specifically studying misconceptions ELL students have about heat.
>
>
> Sent from my BlackBerry® wireless device from U.S. Cellular. Please excuse the typos and brevity of my message as I type on this tiny keyboard.
APPENDIX N: STUDENT WORK #1
What does temperature measure?

Temperature measures the amount of energy.

What do you think about solid particles moving?

I think solid particles move around, but don't completely stop.

What do you think about what a thermometer does and about how energy moves?

A thermometer measures the temperature of objects, and energy moves in a continuous motion.

What evidence have you seen about the molecules moving from higher to lower? (This is called heat, but what evidence have you seen that this happens?)

The evidence I've seen is boiling water. Boiling water is molecules heated up or sped up and transferred its energy into the glass to the water. The water's molecules sped up and became a boil.

What did you learn about thermal energy in the Ice Water probe?

Thermal energy produces faster or sped up molecules. The Ice Water started off with slow molecules, then they sped up to meet the room temperature.

Temp is related to particles' movement because the slower they go, the lower the temp.
APPENDIX O: STUDENTS WORK #2
Objects and Temperature

Taz and Kyle are comparing the temperature readings of four different objects:

- block of wood
- metal tray
- wool hat
- glass plate

They place the objects on a table in their science classroom and leave them overnight. A thermometer is attached to each object. The next day they record the temperature of each object at the same time.

Put an X next to the statement that best describes your prediction about the objects’ temperature.

X  None of the objects will have the same temperature.

Two of the objects will have the same temperature.

Three of the objects will have the same temperature.

All of the objects will have the same temperature.

Describe your thinking. Provide an explanation for your answer.

[Explanatory text]

Uncovering Student Ideas in Science
REFERENCES


