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thesis entitled

IMPACT OF LABS AND ACTIVITIES RELATED TO
THERMODYNAMICS ON STUDENT LEARNING

presented by

John G. Radecki

has been accepted towards fulfillment
of the requirements for the

M.S. degree in Interdepartmental Physical Science

Major Professor's Signature

5 Aug 08

Date

IMPACT OF LABS AND ACTIVITIES RELATED TO THERMODYNAMICS ON STUDENT LEARNING

By

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A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Interdepartmental Physical Sciences

2008

ABSTRACT

IMPACT OF LABS AND ACTIVITIES RELATED TO THERMODYNAMICS ON STUDENT LEARNING

By

John G. Radecki

This study was conducted to determine the impact of labs and activities related to thermodynamics on students learning. Students (n=11) enrolled in a high school physical science class were tested before and after they participated in several laboratory activities that related to heat, temperature, and types of heat energy (conduction, convection, and radiation). Results of the study indicate, based on a paired t-test ($p < 0.05$), that this unit statistical affected the results of only three of the eleven items tested. Students were also surveyed before and after the unit. Results of the survey of students (n=11) reveal that students feel that laboratory experiences are helpful in their learning and play an important part in their learning.

DEDICATION

For Kris

ACKNOWLEDGEMENTS

It has been a long road to the finished product. Many people have contributed much needed encouragement along the way. Thank you to Margaret for being sure that all the paper work was filled out correctly and went to the right places, and for answering every question with a wonderful attitude. Thank you to Merle for the support given through out this endeavor, especially at the end when it was needed most. Thanks to my classmates in the graduate program, there are just too many after six years to mention all of you. I have enjoyed the time spent with you all during the summer months and listening to the wonderful ideas on how to teach well. Thanks to my work colleagues for your support and for listening to my ranting and your continued encouragement. Many thanks to my family, (especially Mary for all the editing), who supported me during the completion of this paper. I love you all. Alex and Nicholas, I love you, thank you for understanding that I had to work on my paper when you wanted to do other things. Thank you all so very much.

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Introduction

At the end of each school year, students are lead in a discussion about how they felt about the topics covered in our classroom. The year prior to this study, the students stated that the unit on heat and thermodynamics was difficult for them. Recognizing that the students did not do as well on the heat and thermodynamics unit as they did on other units in the course, it was decided that many of the activities needed to be rewritten and modified. Modification and revisions had to fit the students' needs in conjunction with the equipment the students have available to use in the classroom. For a long time, teachers of science have generally agreed that hands-on activities, laboratory experiments, and demonstrations are required to help students learn the concepts that are put forth to them within their classrooms. A question for the investigation is: "Do students learn from doing labs and observing demonstrations?" The laboratory experiences which are challenging and enjoyable and which compliment content learning are the best laboratory experiences (McComas 2005). The Michigan High School Science Content Expectations (HSSCE) has set standards for scientific inquiry in each of its science areas (HSSCE 2006). Inquiry needs to be part of the science classroom. It encourages students to challenge their knowledge and understanding of concepts through hands-on experiences (Jarrett 1997). Students need to build a knowledge base and to experience applications of concepts, so that they may build upon previously learned knowledge or replace misconceptions with new knowledge obtained from the experience gained during a laboratory experience or demonstration observation (Baser 2006).

Will having students engaged in hands-on activities and lab experiences help students learn? In a study conducted by Freedman (1998), it was determined that science instruction which includes an opportunity for students to have regular laboratory experiences, does increase students' scores significantly on objective assessments compared to those students not given the opportunity of a laboratory experience. This study also determined that students having the laboratory experience had a more positive attitude towards science. In another study on students' attitudes towards science, researchers determined that students have a higher positive attitude about science if they are engaged in hands-on opportunities in the instructional classroom (Ornstein 2005).

Susan Singer (2005), chair of the National Research Council's Committee on High School Science Laboratories: Role and Vision, wrote in a commentary on Needing a New Approach to Science Labs, about the lab experiences of science students:

> "... labs experiences are often narrow in scope, focusing students more on following procedures than on making meaning from their activities. In contrast, 'integrated instructional units' that sequence lab experiences with other teaching and learning activities and encourage students to reflect on their laboratory observations appear to be more effective."

Students' pre-laboratory instruction is vitally important to the laboratory experience. Having students and the instructor prepare for the laboratory experience before hand by discussing the reason for doing the activity leads the students into having a more active role during the experience (Johnstone 2001). Laboratory experiences can be broken down into four levels based on the levels of instructor direction (McComes 2005). These levels include the following:

Level one - students are given the problem, question, and answer.

Level two – students are given the problem and procedure but do not know the answer in advance.

Level three - students are given the problem and are to develop the procedure and come to a conclusion based on their data.

Level four - students determine a problem they wish to study, develop a procedure, and determine the results dependent upon data.

Laboratory experiences that are completely inquiry based (level four) are difficult to develop and hard to implement. Students are used to the traditional laboratory experience (level one) in which the procedure and outcome is set-up for them. The inquiry based laboratory experience (level four) where students are asked to predict the outcome given minimal instruction and guided towards the goal have been found to profoundly increase the students learning (McComas 2005).

Inquiry laboratory activities have been used successfully to reinforce new concepts in students learning. When inquiry laboratory activities are combined with lecture sessions, which reflect on the experience learned from the laboratory, student demonstrated understanding of the concepts is greatly increased (Bryant 2006).

Students have preconceived knowledge about thermodynamics, heat and temperature in particular, which may cause them to develop misconceptions about basic ideas of thermodynamics (Duit 1990). Some examples of misconceptions that students have are that heat and temperature are the same, the time it takes to heat and cool an object is not dependent on the size or volume, and liquids cool faster than solids. (Baser 2006) It is difficult for students to change their beliefs on heat from those they have held since childhood (Clough 1985). Students have a difficult time learning energy concepts (Kesidou 1993). Challenging the misconceptions held by students will help them to develop their understanding of energy concepts (Carlton 2000). Other studies have shown that individuals have difficulty learning key concepts and distinguishing between terms such as specific heat, heat capacity, and heat transfer (Jasien 2002). According to the Baser study, "One problematic aspect about heat and temperature is that they present abstract and theoretical concepts…The most impressive findings of the research related to heat and temperature concepts have shown that these constructs are usually wrong…Conceptual change methods that were built upon constructivism can be used to take student's misconceptions into account when designing instruction" (Baser 2006).

Thermodynamics, the study of heat and its transformation into mechanical energy (Conceptual Physics 2002), is a difficult subject to teach as well as to learn (Bandyopadhyay 2006). Many teachers also have a difficult time differentiating between temperature and heat (Magnusson 1993). Temperature is a quantity that tells how hot or cold something is compared to a standard; a measure of an objects internal energy (Conceptual Physics 2002). Heat is a measure of the energy that flows from one substance to another because of a temperature difference between the two substances; it is the sum of the kinetic energy of a system (Conceptual Physics 2002).

The goal of this study was to determine if students learn concepts related to thermodynamics from performing laboratory experiments and being actively engaged in demonstrations. The school in which this study took place in is located to the east of Lansing, Michigan. It is a suburban high school with a total enrollment of 943 students. The total students population ethnicity is predominately Caucasian, 87%. Other ethnicities are presented by the following percentages: African-American, 4.7%, Asian/Pacific Islander, 3.9%, American Indian/ Alaska Native, 0.5% (School Matters 2007). The students involved in this study represent students enrolled in the advanced physical science course. The students enrolled this year are typical of the students who enroll in this course every year. The class met for one fifty-five (55) minute class period every weekday during a thirty-six (36) week school year. The study was conducted during approximately a six (6) week period from November 26, 2007 – January 22, 2008.

Implementation

Due to the fact that students struggled with heat and thermodynamic concepts in the previous year these concepts were taught, it was determined that changes were needed in the way the concepts were presented. After researching other studies it was determined that additional hands-on activities might help students succeed in learning thermodynamic and heat concepts. Providing students with laboratory experiences that related to heat and thermodynamics concepts would be the basis of the new unit of study. The development of this unit took place during a five-week period at Michigan State University in the summer of 2007.

This research was conducted during the second quarter of the first semester in a two-semester year course. This was the second unit taught in the advanced physical science course. The advanced physical science course is intended to provide students the opportunity to further their study of physics concepts. It is 'advanced physical science' in name only; the school offers a course titled 'physical science' and therefore a distinction between the two courses is needed. The course is a stand-alone course, meaning that students do not need to have taken 'physical science' before they enrolled in 'advanced physical science'. The course, based on the Conceptual Physics textbook written by Paul Hewitt, and the research study followed the objectives of Unit III Chapters 21-24 (Appendix A). The course is designed for high school juniors and seniors who do not intend on taking the algebra-based physics class but still desire to further their science knowledge.

The main topics taught during this research included temperature, a quantity that tells how hot or cold something is compared to a standard; heat, a measure of the energy change between two substances of different temperature; thermal expansion, when a substance gains heat it expands in all directions; heat transfer, always from hotter objects to cooler objects; convection, a form of heat transfer by currents in a fluid due to the difference in density of the fluid at different temperatures; conduction, a transfer of heat between objects in contact with one another; radiant transfer, heat transfer due to radiation; phase changes, a substance changes from one phase to another determined by whether the substance has gained or lost energy; and, thermodynamics the study of heat and its transformation into mechanical energy.

Each student was required to return letters of assent, as well as letters of consent from their parent or guardian to participate in this study. Students, whether or not they participated in the study, were required to complete all tests, surveys and laboratory assignments. Of the twenty-four (24) students that were enrolled in the class, eleven (11) were included in the study. The other thirteen (13) were excluded from the study for either not returning their assent or parent/guardian consent forms, or not completing one of the required tasks. At the conclusion of the study, the participating students' papers were assigned a letter so that the students' identity was not a factor in the researchers grading of the tests and surveys used in the study.

At the beginning of the study, students were given a pre-test (Appendix B) to determine if there would be a change in their understanding of the concepts being taught during the unit. Students were also given a pre-survey (Appendix C) to determine if there was a change in attitude towards laboratory experiments and their knowledge and use of technology in the laboratory setting. At the completion of the unit, students were given a post-test and post-survey asking the same questions that they answered on the pre-test and pre-survey. The results of the two tests and surveys were not analyzed until after the completion of the unit. The grading rubric for the test can be found in Appendix D.

A schedule of the sequence of activities can be found in Table 1.

Table 1 ACTIVITY SCHEDULE		* = New or modified for this unit
Day	**Objective**	**Activity**
2	Define temperature in terms of KE and describe the common temperature scales.	*Hot And Cold Fingers Parts A&B
3	Define temperature in terms of KE and describe the common temperature scales.	*Thermometer Activity
4	Define thermal equilibrium.	*Hot And Cold Fingers Part C
5	Describe how the quantity of heat that enters or leaves a substance is measured.	*Specific Heat Lab
6	Compare the specific heat capacities of different substances.	*Specific Heat Lab
8	Give examples and applications of thermal expansion of solids.	Linear Expansion Demos - Bimetalic Strip and Ring Se
11	Define thermal equilibrium.	*Mixing Water
12	Explain conduction and its effects.	*Demos: Convection, Conduction, and Radiation
	Distinguish between conduction and convection.	
	Explain how heat can be transmitted through empty space.	
13	Given the color and shininess of two objects, predict which is likely to absorb radiant energy more easily.	*Absorbers and Emitters Lab
14	Compare the ability of an object to emit radiant energy with its ability to absorb radiant energy.	Radiant Heating Lab
16&17	Compare the insulation propreties of different materials.	*Erlenmeyer Flask Lab
24	Explain why water with substances dissolved in it freezes at a lower temperature than pure water	Freezing and Melting Lab
26	Explain why evaporation of water is a cooling process.	Evaporation of Ethanol and Water
27	Explain condensation changes pressure inside the can.	*Collapsing Can - NOT

In addition to these activities, students were also assigned sections of the textbook to read, received lectures and notes from the instructor, completed worksheets, and were assigned homework problems from the textbook. Homework assignments, worksheets, activities and laboratory reports (See Appendix) were all graded for their completeness. (Points were assigned to each assignment and students were awarded to points for completing the assignments.). It was the students' responsibility to make corrections during class discussions of answers and laboratory results. Students were encouraged to discuss their ideas and to challenge their findings together in class both during the time they were working on laboratory experiments and while discussing results as a large group. Students also watched videos related to the curriculum and participated in discussions about the various concepts presented during the course. At the conclusion of each chapter, students took a chapter test.

Descriptions of Activities and Examples of Student Performance

The following are brief descriptions of the activities:

Hot and Cold Fingers Parts A&B (Appendix E)

This activity is designed to introduce students to the idea that their fingers are not a good indicator of temperature. Students placed their hands into different cups of water then removed them from that cup and placed them in a cup having a different temperature water. Average for this activity is 15/15 points.

Thermometer Activity (Appendix F)

Each group of students was given a thin stem pipet and some red colored ethanol in a beaker. Each group was instructed on how to make their own simple thermometer.

They were then asked to place their thermometer into cold and hot beakers of water and to make observations. Average for this activity is 14/15 points.

Hot & Cold Fingers Activity: Part C (Appendix E)

During the second half of the lab, Hot and Cold Fingers, students predicted the temperature of a lab station top and the cabinets. They then used a thermometer to determine the temperature and realized that, even though one felt cooler than the other they were at the same temperature.

Specific Heat Lab (Appendix G)

Students conducted a traditional specific heat lab using washers to determine the specific heat of iron. Average for the activity is 23/25 points.

Demo: Linear Expansion - Bimetallic Strip and Ball and Ring Set

The bimetallic strip is heated in a burner. The strip bends to one side due to the difference in the linear expansion of the two metals bonded on the strip.

The ball and ring demonstration is where a ball that is able to pass through a ring is heated. After heating, the ball is no longer able to pass through the ring. Heating the ring allows the ball to pass through.

Mixing Water (Appendix H)

In this activity, students predicted the final temperature of water when equal amounts of different temperature water were poured into a single beaker. Later on, they are required to predict, by the established pattern, the final temperature of a beaker of water when different amounts of different temperature water are mixed together.

Finally they mixed the same mass of water with the same mass of washers and predicted the temperature outcome of the mixture. Average for this activity is 30/30 points.

Demo: Convection, Conduction and Radiation

A beaker of water is set on a hot plate to heat up. Red food coloring is added drop wise so that the convection current produced in the beaker can be seen.

In another demo a test tube has crushed ice placed at the bottom of the test tube and is held there by steel wool. The top water of the tube is heated and the ice remains cool at the bottom.

Absorbers and Emitters Lab (Appendix I)

In the absorber part of the lab students were asked to predict which of three soda cans (one white, one black and one left silver and not painted) would absorb the most radiant heat from a 100 watt bulb placed 20 cm away for ten minutes. In the emitter part of the lab, the students were to predict which of the cans would emit radiant energy the quickest when 200 grams of 80°C water was allowed to cool for 10 minutes. Average for this activity is 30/30 points

Radiant Heating Lab

The next radiant energy lab the students performed is entitled Insolation Angle. Insolation is the amount of solar radiation received by the planets from the sun. The students placed three temperature probes at 90, 60 and 30-degree angles from a 120 watt light bulb. They were asked to predict which of the probes would rise in temperature the most and the least and to explain their reasoning. Average for the activity is 25/25 points.

Erlenmeyer Flask Lab

The topic covered is insulation. In this experiment students covered Erlenmeyer flasks with different materials and then filled them with warm water and allowed to cool for ten-minutes to see which flask retained the highest temperature. Average for this activity is 25/25 points.

Freezing and Melting Experiment

Students determined the freezing and melting point of water from a graph of the data points collected and plotted by a computer program. Average for this activity is 19/20 points.

Evaporation of Ethanol and Water

Ethanol and water soaked strips of chromatography paper were placed on the ends of temperature probes and allowed to evaporate for a period of time. The data were then collected and plotted for the students so that they could compare the results. Average for this activity is 15/15 points.

Demo: Collapsing Can-NOT

Collapsing Can-NOT is a twist on an old favorite demo. First soda cans with a little water are placed on a hot plate and the water is allowed to boil. Students predicted and explained what would happen if a can was placed into a cool beaker of water. In the new twist students were asked to predict and explain what would happen if a can was placed into a beaker of boiling water.

Results and Analysis

Students were given both the pre-test and post-test during a regular class period. Both tests were graded using the rubric found in Appendix C. Responses were assigned number values based on the points assigned to each question. Questions that were assigned a two point value were assigned a value of zero (0) points for incorrect or no answer given, one point for a slightly correct answer, and two points if the answer was correct. Questions which asked for an answer along with an explanation, were given a four-point scale: two points for the correct answer and two points for the correct explanation. Partial points were awarded to the explanation, two points for a correct answer, one point for a partially correct explanation, and zero points for a wrong explanation or no answer.

Students' responses to both tests were then averaged and graphed. The number of students included in the study was eleven. A paired t-test was performed for each test item to determine if the teaching of the unit correlated with a change in the students' responses on the test items given. A paired t-test value of less than $p = 0.05$ or less would indicate that the unit had some impact on student gains. A higher than $p = 0.05$ result on the paired t-test implies that the unit made no statistical difference.

Test Results

The following figures (Figures 1-11) show the pre-test and post-test average student responses to an individual item on the test. There is a brief summary of the analysis of the data for each item after the figure. In addition there are examples of student responses to the test items. The student responses were selected to demonstrate a range of answers. The student responses are arranged from highest to lowest and were selected randomly from the study group.

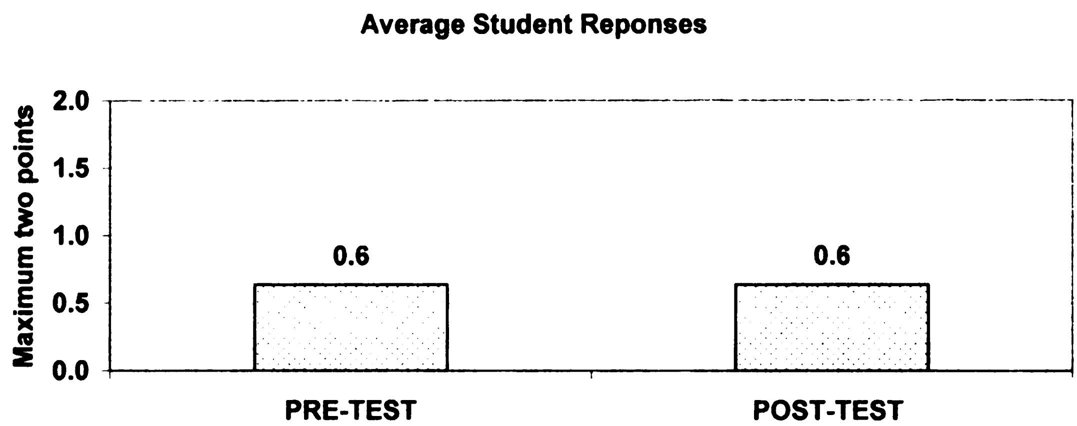

Figure 1 ☐ **1. What causes the liquid in a thermometer to go up and down?**

Figure 1 shows the average score of the students' responses to the pre-test and post-test. Based on the students' averages and a paired t-test result $p = 1.00$ there was no significant change in the results from the students doing this unit as it relates to this question.

Examples of paired responses:

Student I (received two points out of two for both answers)

Pre-test "The excimnet (sic) of the molecules when it's hot causes them to move more and the liquid to expand"

Post-test "The excitement of the molecules in the liquid cause the liquid to expand."

Student A (received one point out of two for both answers)

Pre-test: "It heats up"

Post-test: "The reaction from the heat or cold"

Student E (received zero points out of two points for both answers)

Pre-test "Temperature"

Post test " The difference in pressure inside and outside of the thermometer"

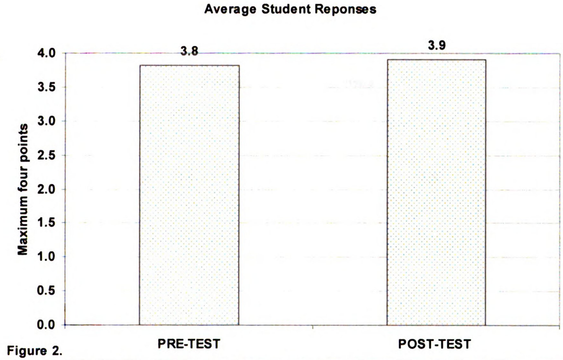

Figure 2.

□2. Which will increase in temperature faster in the sunlight, the interior of a white or a black car? Explain your reasoning.

Figure 2 shows that the average of the students' responses to the pre-test and post-test for this four point question were both quite high. The paired t-test $p = 0.68$ which shows that there was no significant difference in the results that correlate to having completed this unit of study.

Examples of paired responses:

Student N (Four out of four points on both answers)

Pre-test: "A black car because black absorbs all colors-so it would be hotter."

Post-test: "A black car because black absorbs heat (energy)."

Student A (Two out of four points for Pre-test response, Four our of four for post-test response)

Pre-test: "Black car. Darker color."

Post-test: "Black, because it absorbs more heat energy"

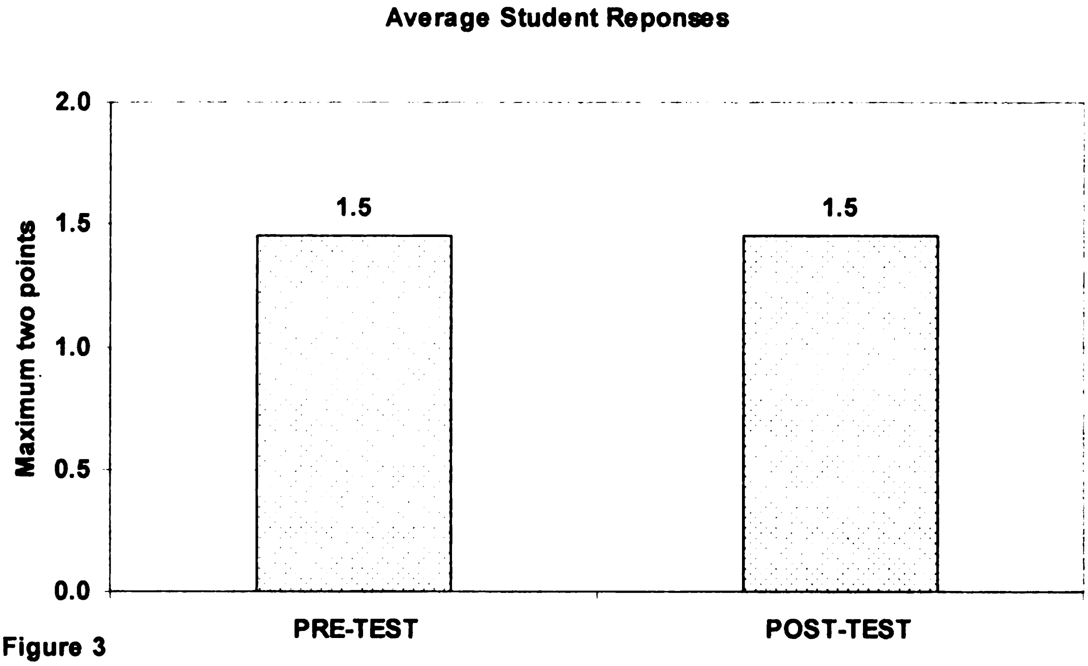

Figure 3

□ 3. On which axis of a graph is the dependent variable placed?

Figure 3 shows that the average students' results are the same before and after the unit was taught. The paired t-test $p = 1.00$ which indicates that the unit did not contribute to a statistical change in the results of this question.

Example of paired responses:

Student M (two points out of two both responses)

Pre-test: "y-axis"

Post-test: "Vertical"

Student G (zero points out of two pre-test, two points out of two post-test)

Pre-test: "x"

Post-test: "y"

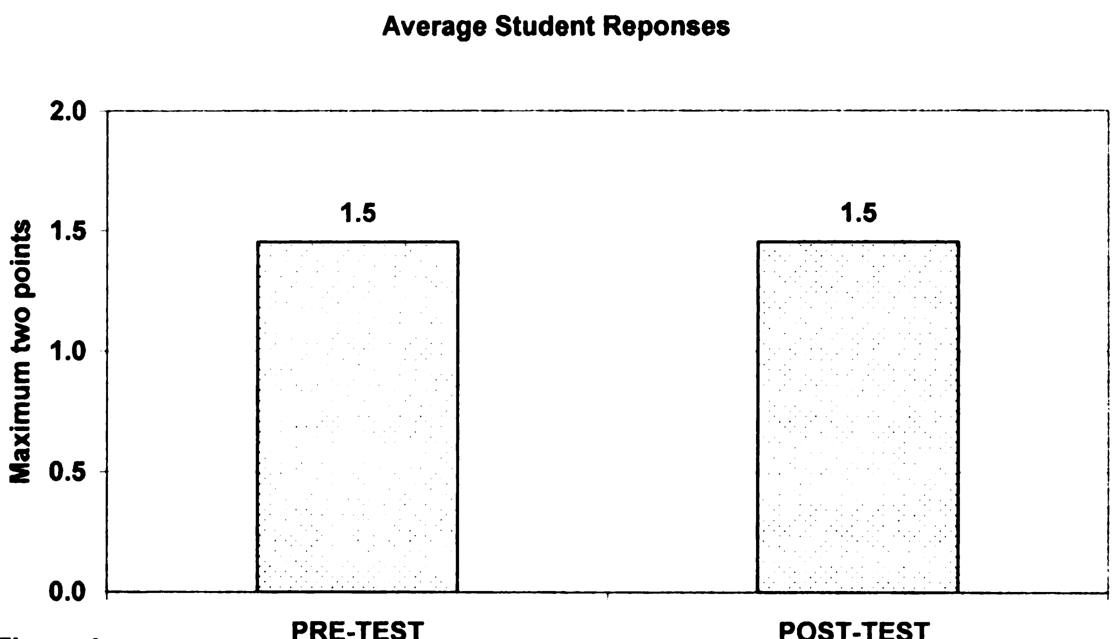

Figure 4

□ 4. On which axis of a graph is the independent variable placed?

Figure 4 shows the average students' response has no change due to the teaching of this unit. Paired t-test p = 1.00 for this question which suggest that this unit did not affect the result of this question.

Student responses to this question:

Student C (two points out of two both responses)

Pre-test: "x"

Post-test: "x-axis"

Student L (zero points out of two pre-test, two points out of two post-test)

Pre-test: "y"

Post-test: "x-axis"

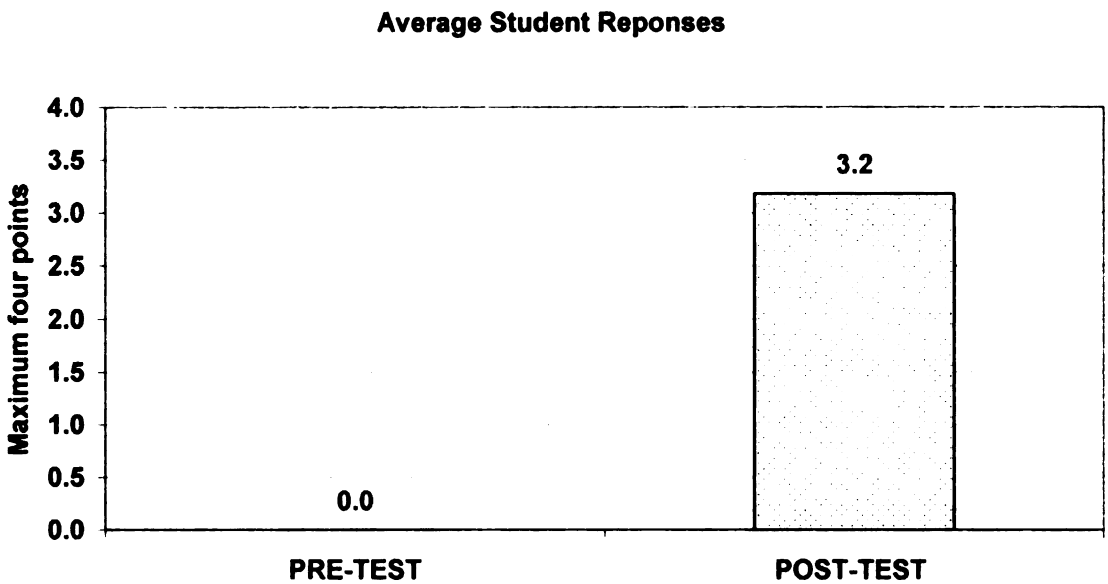

Figure 5

☐ 5. When it is dark outside, which loses it heat faster a white object or a black object? Explain your choice

Figure 5 shows a large increase in the pre-test students' average compared to the post-test average. Paired t-test $p = 0.00$ indicating that the unit of study did correlate to a significant change in students' correct responses to this question.

Examples of student responses:

Student K (zero out of four points pre-test, four out of four points post test)

Pre-test: "a white object, it reflects all colors"

Post-test: "The black object, it absorbs faster, therefore it releases energy faster."

Student B (zero out of four points pre-test, two out of four post-test)

Pre-test: "White, doesn't absorb"

Post-test: "black"

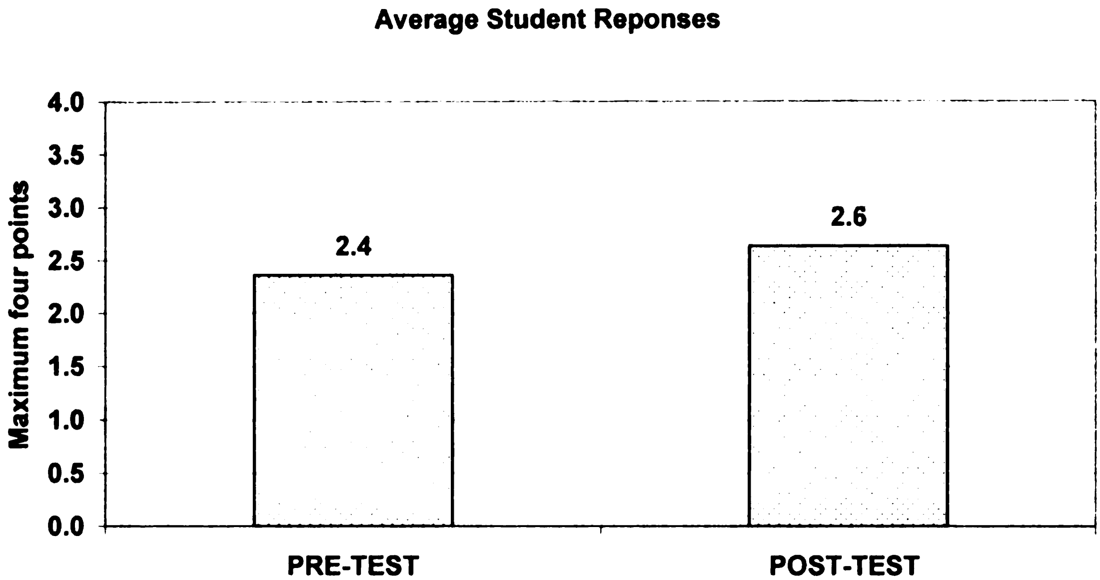

Figure 6

☐ 6. Which gets colder faster in the refrigerator the can or the pop? Explain your choice.

Figure 6 shows little change in the students' average response. The paired t-test p = 0.39 this implies that the unit of study did not statistically affect the result of this question. Examples of student responses:

Student H (two out of four points pre-test, four out of four points post test)

Pre-test: "the can because its (sic) metal."

Post-test: "the can because it has a lower specific heat".

Student B (two out of four points pre-test, three out of four points post-test)

Pre-test: "can it's the outside"

Post-test: "can, specific heat"

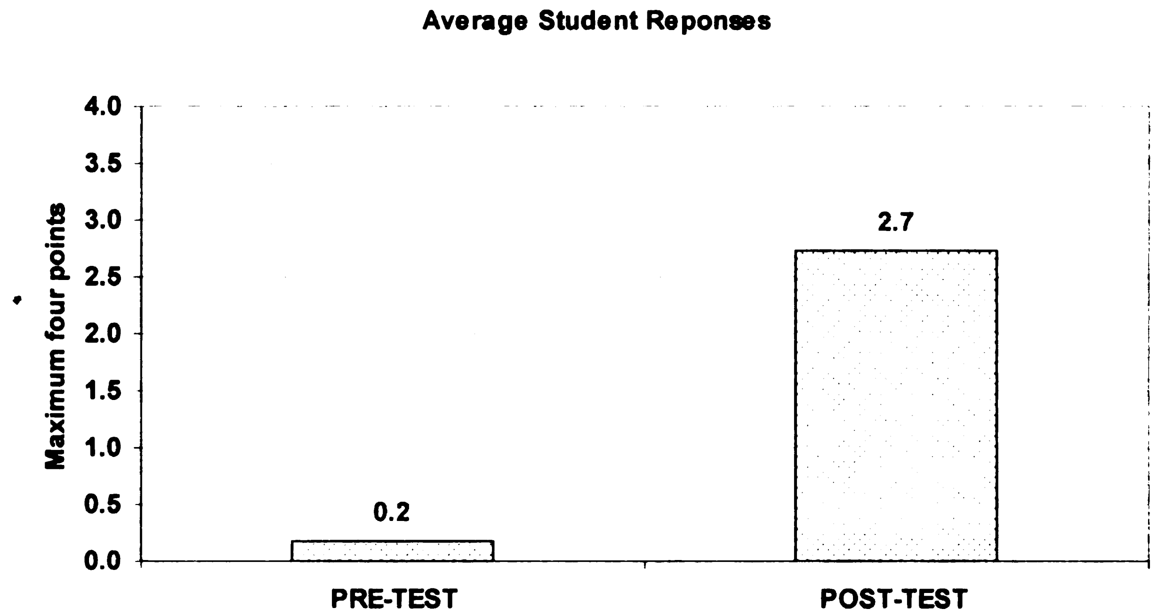

Figure 7 ☐7. Explain convection and give an example.

Figure 7 shows large increase in the students' averages. The paired t-test $p = 0.00$ which indicates that the unit correlates with an increase of the correct responses to this question. Examples of student responses:

Student G (zero out of four points pre-test, four out of four points post-test)

Pre-test: No answer given

Post-test: "transfer heat through different densities ex. oven"

Student I (zero out of four points pre-test, three out of four points post-test)

Pre-test: "I remember that word from something"

Post-test: "heating by molecules moving around, usually gases. Like a convection oven."

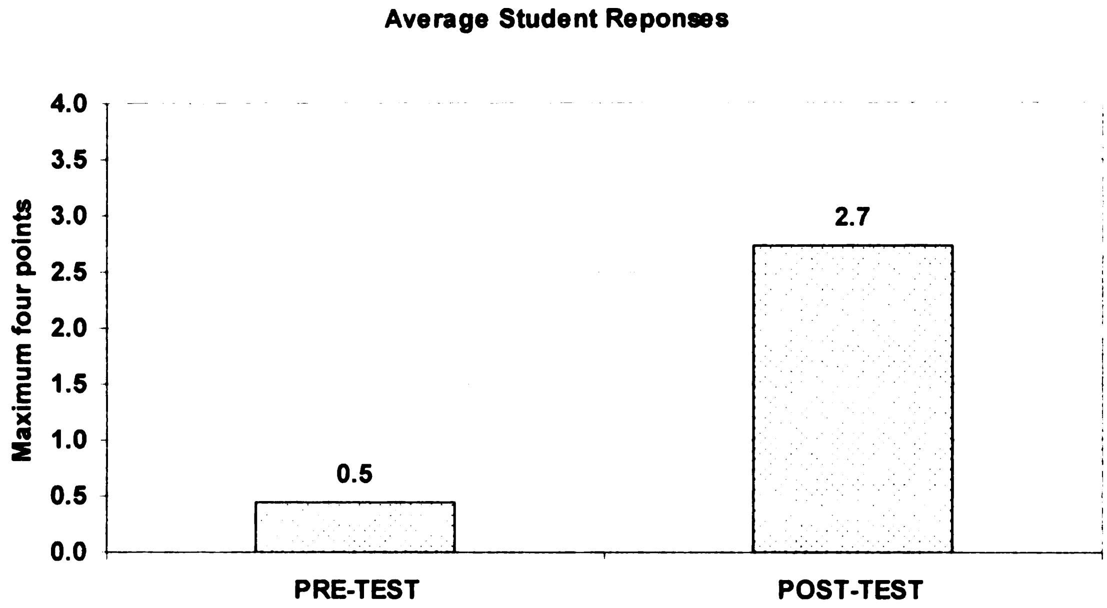

Figure 8 □8. Explain conduction and give an example.

Figure 8 shows that the students' average response increased after the unit was taught. The paired t-test = 0.00 which verifies that the unit of study relates to a change in the students' correct responses.

Example of student responses:

Student C (zero out of four points pre-test, four out of four points post-test)

Pre-test: "Energy"

Post-test: "Passing of heat in which the conductors touch. Touching a hot metal pan."

Student K (one out of four points pre-test, four out of four points post-test)

Pre-test: "when energy passes through a medium"

Post-test: "conduction is a heat transfer by a touch, like a hot spoon in a cup of water."

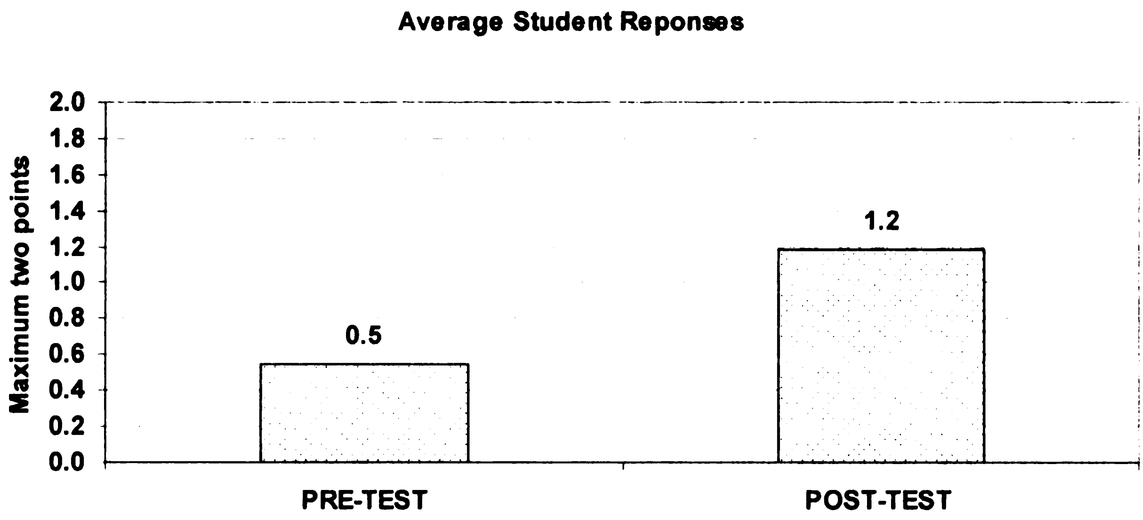

Figure 9 9. How does the sun heat the earth?

Figure 9 shows that the students' average response to this question had little change. The paired t-test p = 0.09 implies that the unit of study made no statistical difference in student responses on the post-test.

Examples of student responses:

Student B (one out of two points pre-test, two out of two points post-test)

Pre-test: "warmly"

Post-test: "solar radiation"

Student H (zero out of two points pre-test, two out of two points post-test)

Pre-test: "with its heat rays"

Post-test: "through heat radiation"

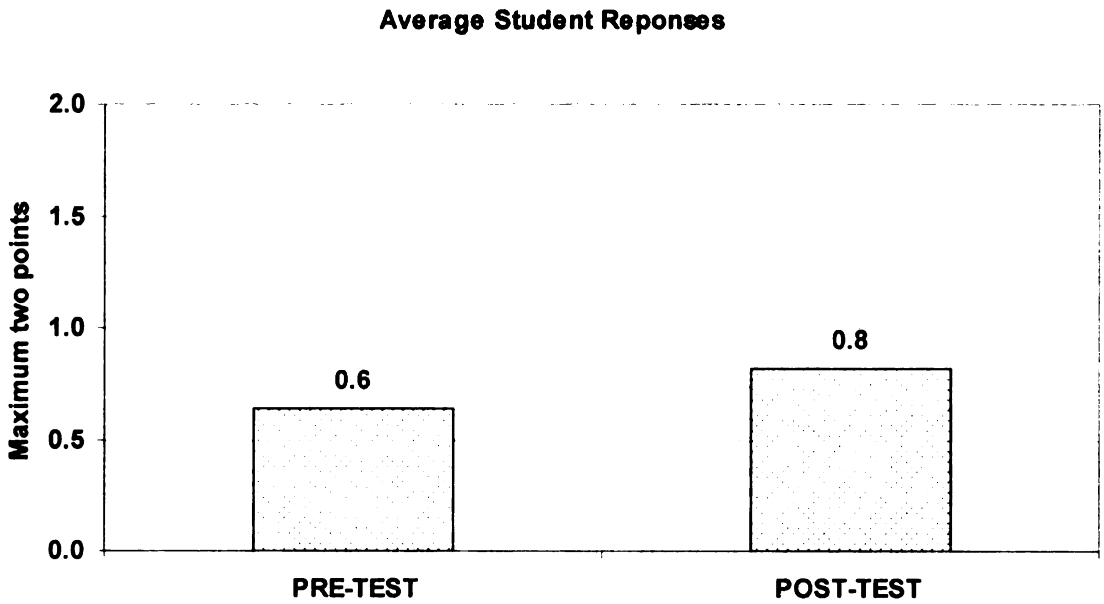

Figure 10 □10. What happens when a substance boils?

Figure 10 shows that the average students' responses did not change very much. The paired t-test $p = 0.59$ which means that the unit of study did not statistically alter the students' response.

Examples of student responses:

Student A (one out of two points for both answers)

Pre-test: "it evaporates"

Post-test: "it reaches its top temp and stays at that temp. until the substance is all gone."

Student B (one out of two points pre-test, two out of two points post-test)

Pre-test: "particles leave"

Post-test: "gains energy"

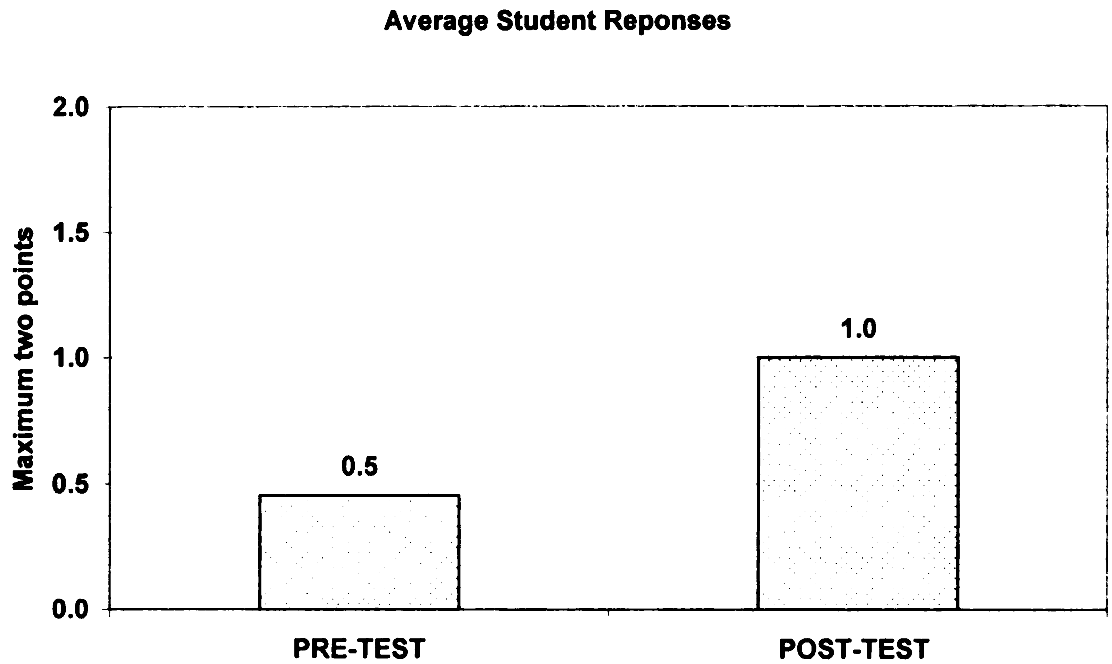

Figure 11 11. What happens when a substance solidifies?

Figure 11 shows the students' responses average increased slightly. The paired t-test p = 0.052 which implies that there is no measurable effect from the unit having been taught.

Examples of student responses:

Student L (one point out of two points both answers)

Pre-test: "gets hard"

Post-test: "the molecules slow down & come closer together"

Student B (zero out of two points pre-test, two out of two points post-test)

Pre-test: "particles stay"

Post-test: "loses energy"

Summary of Test Results

Of the eleven items tested for the eleven students, the students showed t-test score improvement ($p = 0.05$ or less) only on item 5 (figure 5) which asked about emission of energy, item 7 (Figure 7) which questioned them about convection, and item 8 (figure 8) which asked about conduction.

Survey Results

Along with the test students were also given a survey about their attitudes on laboratory experiences. Data were collected and analyzed to see if student's attitude would change after this course of study. (There was a delay in the starting of this unit of study. Students had completed an entire unit prior to taking this survey and had previously engaged in lab activities.)

Question:

1. Do you feel that doing lab exercises help you understand concepts better? Explain.

Pre- test results: Yes: 10/11

Explanation examples: "Hands-on", "Shows me things", "Enhances learning"

No: 1/11

Explanation: "confusing and do not understand how they relate"

Post-test results: Yes: 11/11

Explanation examples: "better then lectures", "sometimes the labs were complicated", "could see and used the labs to explain things"

No: 0/11

2. Do you feel there is adequate time during lab exercises for learning to occur?

   Explain.

Pre-test results: Yes: 10/11

No: 1/11

Explanation: "sometimes"

Post-test results: Yes: 9/11

No: 2/11

Explanation: "ran out (of time) a lot", "rushed"

3. What do you like about doing lab exercises?

   Samples of students responded: "I like hands-on activities"

   "I liked working with others"

   "It was fun"

   "The labs were interesting"

4. What do you dislike about doing lab exercises?

   Samples of student responses: "I did not like it when you assigned groups"

   "Setting the labs up and taking them down got old"

   "There was nothing I did not like"

5. Does what you learn in lab exercises apply to the class work? Explain

Pre-test results: Yes: 11/11

Sample explanations: "That's the point isn't it?

"directly related"

"when it relates"

No: 0/11

Post-test results: Yes: 11/11

Sample explanations: "hands-on kind of person"

"directly related"

"it should"

No: 0/11

Summary of Survey Results

The survey results showed that the eleven students feel that laboratory experiences help them to learn and applies to their class work. The students like doing laboratory work because of its hands-on experience and dislike setting labs up and being assigned to specific groups.

Discussion and Conclusion

As the students were learning the material and the students performed their labs, I observed that the students were actively engaged in the activities and discussing what was happening in the laboratory and activities. When I analyzed the data contained in Figures 1-11, I was surprised to discover that the students did not appear to have a more dramatic increase in knowledge with regards to several of the questions posed.

Convection and conduction (data from Figures 7&8) were taught in a lecture/demonstration activity and reinforced throughout the course. These results showed a significant (paired t-test <0.05) improvement. The question on emission of energy (Figure 5) also showed a large improvement.

One reason for the poor performance on the test may have been in the way in which the questions were asked. I may have interpreted the questions quite differently than the students might have and expected them to write a more detailed answer than many of them did. I should have included some prompts like, "be sure to include examples from labs or activities when answering these questions."

A second reason maybe that for many of the students it was just one more thing they had to get through before they were done with the course. They took the post-test only a few days before they were to take the semester exam in the course. Also, several of the study participants did not continue the course into the next semester for various reasons and they may have no put forth their best effort.

Finally, it was a small group of participates. The class size was twenty-four (24) students but the sample size used in the study was only eleven (11). This was due to the fact many students did not fulfill the requirements to be included in the study. A larger group of data might have generated different results. A larger group might have shown greater differences in the pre-test and post-test data averages, having a small sampling of students, if one or two of the students change their answers the averages can easily.

Unfortunately, due to delays in gaining approval from the university with regard to the parent/ student permission forms, I had to begin the unit later than anticipated. This forced me to teach the unit during the second marking period of the first semester. Because of the delayed start, the learning process was disrupted by several lengthy school break periods. Also, do to the nature of lab work and the time frames needed to cover the material in labs some labs took place over several class periods.

The students seem to enjoy the activities (see results of survey) and liked the simplicity of many of the materials. The students enjoyed the lab where they made a thermometer out of a pipet. Through the discussions I had with the students, they could explain the concept of liquid expansion, but they just did not retain it long enough for it to make a difference on the test. I wonder now if maybe the questions were asked in too broad of terms to elicit the change in the results. I think that the students might have been answering them too simply and I was looking for a greater degree of detail. I should have included specific prompts for the test items such as, "Using heat concepts explain…", to try to obtain a deeper answer from the students.

Some of the students did say, towards the end of the study that they were "tired of doing labs". Some students expressed just the opposite opinion and responded, "…it beats sitting in desks and listening to Mr. Radecki talk…No offense." They also expressed their dislike for the need to set-up the computer (many labs involved the use of a temperature probe, data collection device and a computer) and take it down after the lab period. There may be a need to space the laboratories out between lecture days to give the students a break from laboratory activities. Overall, even though they got tired of doing labs, in the end they expressed in their survey overwhelmingly that they felt they learn more from hands-on activities.

Even though the unit was not the success I had expected it would be, I am going to incorporate several laboratory experiments (Appendices E, F, G, &H) into my teaching. I see now that more time is needed to teach the entire unit. The laboratory experiences generated many discussions amongst the students with regards to concepts covered in the labs. We discussed many times how the knowledge they learned helped them become more informed consumers. For example, after the activity with insulating the Erlenmeyer flask we discussed how a real thermos works and what is the best material for making it. The class had a discussion on whether soda in plastic bottles or aluminum cans would cool faster (see Specific Heat Lab, Appendix G). We also discussed house insulation (Erlenmeyer Flask Lab) and the benefits of heating with water (Appendix H). All of these and other discussions resulted directly from the students having the hands-on experience from which to draw knowledge.

Due to declining enrollment for the advanced physical science course for which this unit was designed, this class has been canceled for 2008-2009. I am also not sure how much of this material will be used in the future, due to the fact that many of the objectives and concepts taught in this unit are not part of the Michigan High School Science Content Expectations for physics or chemistry.

Though the data do not show a dramatic increase of learning from doing these activities, some learning did occur. Many of the ideas and concepts learned were not addressed by the test given as indicated by the discussions we would have in class mentioned previously. Students were actively engaged in learning as observed during their laboratory experiences and activities. The opportunity that these laboratories provided for the students to increase their knowledge and develop their skills in data analysis, reading graphs and predicting outcomes, as well as using technology as a tool for scientific study was worth all the effort given in developing and teaching this unit.

Knowing now what I did not know at the beginning of the unit, there are some things I would do differently. Starting the unit at the beginning of the year would have allowed time for the completion of the unit. Teaching the unit was rushed due to the fact that it was taught before the semester exam and it needed to be completed before some of the students left the classroom. If I had assigned the students into groups based on their ability rather than letting them work in groups of their own choosing, it might have pushed some students to participate to a larger extent than they did during the laboratory experiences.

Overall, this unit was not the large success I had anticipated. The survey results did demonstrate that students enjoyed doing laboratory activities that directly relates to the science concepts being taught. Unfortunately, only a few of the labs and activities had a statistical effect on the students learning concepts related to heat and thermodynamics.

APPENDICES

Appendix A

Objectives

Taken from Conceptual Physics 2002 Teachers Edition
Bulleted objectives are addressed in this study.

Chapter 21 Temperature, Heat, and Expansion

- Define temperature in terms of kinetic energy and describe the common temperature scales.
- Define heat.
- Define thermal equilibrium.
- Distinguish between internal energy and heat.
- Describe how the quantity of heat that enters or leaves a substance is measured.
- Compare the specific heat capacities of different substances.
- Describe how water's high specific capacity affects climate.
- Give examples and applications of thermal expansion of solids.
- Describe the behavior of water as it is heated from 0°C to 15°C.

Chapter 22 Heat Transfer

- Explain conduction and its effects.
- Distinguish between conduction and convection.
- Explain how heat can be transmitted through empty space.
- Given the color and shininess of two objects, predict which is likely to absorb radiant energy more easily.
- Compare the ability of an object to emit radiant energy with its ability to absorb radiant energy.
- Relate the temperature difference between an object and its surroundings to the rate at which it cools.
- Describe global warming and Earth's greenhouse effect.

Chapter 23 Change of Phase

- Explain why evaporation of water is a cooling process.
- Explain why condensation is a warming process.
- Explain why a person with wet skin feels chillier in dry air than in moist air at the same temperature.
- Distinguish between evaporation and boiling and explain why food cooked in boiling water takes longer to cook at high altitudes.
- Explain why water with substances dissolved in it freezes at a lower temperature than pure water.
- Describe how something can boil and freeze at the same temperature.

- Describe how ice melts under pressure and refreezes when the pressure is removed.
- Describe how a substance can absorb or release energy with no resulting change in temperature.

Chapter 24 Thermodynamics

Describe the concept of absolute zero.
State the first law of thermodynamics and relate it to energy conservation.
Describe adiabatic processes and cite examples.
State the second law of thermodynamics.
Define the ideal efficiency of a heat engine in terms of input and output temperatures.
Explain how order tends to disorder.
Define entropy and give examples.

Appendix B

Pre-test and Post-test

1. What causes the liquid in a thermometer to go up and down?

2. Which will increase in temperature faster in the sunlight, the interior of a white or a black car? Explain your reasoning.

3. On which axis of a graph is the dependent variable placed?

4. On which axis of a graph is the independent variable placed?

5. When it is dark outside, which loses it heat faster a white object or a black object? Explain your choice.

6. Which gets colder faster in the refrigerator the can or the pop? Explain your choice.

7. Explain convection and give an example.

8. Explain conduction and give an example.

9. How does the sun heat the earth?

10. What happens when a substance boils?

11. What happens when a substance solidifies?

12. What is an example of adiabatic process?

13. What is the first law of thermodynamics?

14. What is the second law of thermodynamics?

Appendix C

Pre-survey and Post-survey

Answer the following questions to the best of your ability.

1. Do you feel that doing lab exercises help you understand concepts better? Explain.

2. Do you feel there is adequate time during lab exercises for learning to occur? Explain.

3. What do you like about doing lab exercises?

4. What do you dislike about doing lab exercises?

5. Does what you learn in lab exercises apply to the class work? Explain

6. Have you used the LabPro data collector interface and LoggerPro program in other classes? If yes, what kind(s) of exercises did you do using the probes?

Based on a five point scale (5 highest to 1 lowest) rate your skills on the following:

7. Using the computer to collect data. _________

8. Interpreting graphs for relationships of the variables. ________

9. Using the computer to analyze data. _________

10. Working well with others. __________

Appendix D

Pre-test / Post test Grading Rubric

1. What causes the liquid in a thermometer to go up and down?

2pts. The expansion and contraction of the liquid due to the change in heat being absorbed or released

2. Which will increase in temperature faster in the sunlight, the interior of a white or a black car? Explain your reasoning.

4pts The interior of a black car because the black car will absorb all the colors of the spectrum and or black is a good absorber of radiant energy

3. On which axis of a graph is the dependent variable placed?

2pts The dependent variable goes on the y-axis

4. On which axis of a graph is the independent variable placed?

2pts The independent goes on the x-axis

5. When it is dark outside, which loses it heat faster a white object or a black object? Explain your choice.

4pts The black object because good absorbers of radiant energy or good emitters.

6. Which gets colder faster in the refrigerator the can or the pop? Explain your choice.

4pts The can gets colder faster because it has a lower specific heat capacity than the pop.

7. Explain convection and give an example.

4pts Convection is the heat by currents in a fluid. Hot water will circulate because the colder water is denser and the warmer water will rise to the top causes a current to oocur.

8. Explain conduction and give an example.

4pts Conduction is when the molecule actually transfers energy when they collide with each other. A metal spoon in soup heats up because the soup molecules bump into the metal molecules and transfer energy, which cause the spoon to heat up.

9. How does the sun heat the earth?

2pts The earth absorbs radiant energy from the sun and the atmosphere traps the heat energy

10. What happens when a substance boils?

2pts The molecules absorb the energy that goes into heating the substance as they go form a liquid state to a gaseous state the temperature remains constant.

11. What happens when a substance solidifies?

2pts It releases energy and the temperature stays constant until all of the substance solidifies.

12. What is an example of adiabatic process?

2pts A process in which no heat enters or leaves a system when a gas is compressed or the gas expands rapidly.

13. What is the first law of thermodynamics?

2pts Whenever heat is added to a system work must be done on the system (Conservation of energy).

14. What is the second law of thermodynamics?

2pts Heat flows from a hot object to a cold object never the opposite way.

Appendix E

Hot and Cold Fingers

Adapted from Laboratory Manual for Conceptual Physics

Objective: determine how well your hand can determine temperature

Materials: 4 cups or beakers with fill line marked
2 cups labeled room temp
1 cup labeled warm
1 cup labeled cold
Warm water
Cold water
Thermometer

Place the cup so that they are in the order of warm, tap, tap, and cold.
Fill each cup with enough water so that it will cover about half of your fingers when they are submerged but not so much that the water over flows.
In the cup marked **warm** water, pour in warm water.
In the two cups marked **tap**, pour in tap water.
In the cup marked **cold**, pour in cold water.

Are your hands a good indicator of temperature? Explain.

Place your left fingers in the warm water and your right fingers in the cold water for about a minute.
After a minute place each fingers in one of the tap water cups.

Describe how your fingers felt after you placed them from the cold water to the tap water.

Describe how your fingers felt after you placed them from the warm water to the tap water.

Now, take your fingers from the tap water and place your right hand in the warm water and your left hand in the cool water.

Describe how your fingers felt after you placed them from the tap water to the hot water.

Describe how your fingers felt after your placed them form the tap water to the cold water.

How "good" are your fingers at determining temperature?

After wiping your hand off place it on the top of the lab station.
Describe the temperature of the lab station. Give an explanation of your observation.

Place your hand on the drawer of the lab station.
Describe the temperature of the drawer of the lab station. Give an explanation of your observation.

Using a thermometer record the temperature of the lab station and the drawer.

Temperature of lab top_________ **Temperature of the Drawer____________**

How does the temperature recorded by the thermometer compare to the temperature you described previous?

Are your hands a good indicator of temperature? Explain.

After your group is finished pour the water in the cups down the drain. Rinse the cups out so that they are ready for the next group.

Appendix F

Thermometer

Adapted from various sources.

Objective: To create a thermometer using a plastic pipets

Materials:

- Ethanol
- Food Coloring
- Plastic pipets with thin stems
- Two beakers
- Hot and cold water

Fill a beaker half way with warm water
Fill another beaker half way with ice water
Fill an inverted pipet with enough ethanol to completely fill the bulb and a portion of stem near the bulb. If the pipet has measurement lines on it they should be used to keep track of the starting point, if not use a pen to mark to starting point.
Holding on to the stem portion of the pipet carefully lower it into the warm water.

Record you observations.

Write a brief explanation of your observations.

Remove the pipet from the warm water and place it into the cold water.

Record your observations.

Write a brief explanation of your observations.

Appendix G

Specific Heat Lab

Adapted from Laboratory Manual for Conceptual Physics

Objective: To determine the specific heat of a steel washer.

Materials:

250 ml beaker
Hot plate
Washers tied together
Two Styrofoam cups
Balance
Thermometer

Procedure:

Set up about 200 ml of water in the 250 ml beaker on the hot plate to boil.
Mass the washers and record the mass.
Place the washers on the boiling water for at least two minutes.
In one cup, using the balance, place about 200 grams of tap water and record the mass.
Using a thermometer record the temperature of the water.
After the washers have been in the boiling water carefully remove them and quickly place them in the cup of water. Once the temperature of the water and washers reaches equilibrium record the temperature.

Data:

Mass of washers _________

Mass of water in the cup _________

Temperature of water in cup _________

Temperature of water and washers __________

Calculations:

Remembering that the heat lost equals the heat gained

Mass of washers x specific heat x change in temperature = mass of water x specific heat of water x change in temperature

$$m_{washer} \times C_{washer} \times \Delta T_{washer} = m_{water} \times C_{water} \times \Delta T_{water}$$

$$C_{washer} = \frac{m_{water} \times C_{water} \times \Delta T_{water}}{m_{washer} \times \Delta T_{washer}}$$

Compare, by percent error, your result for the specific heat of the washer.

Conclusion:
Write a paragraph summary of your lab results.

Appendix H

Mixing Water

Adapted from Laboratory Manual for Conceptual Physics

Objective: To investigate if there is a relationship between the final temperature of a mixture and the amounts mixed together.

Materials:

Hot plate or a source of hot water
Cold water
600 ml beakers
3 cups
Beaker tongs or heat resistant gloves

On your hot plate heat 400 ml of water to a temperature of less than 100 °C.
In another beaker place 400 ml of tap water and some ice.
Gather three cups, the inside of the cups have marked this is the mark that the cup should be filled to.

PART A
Equal amounts of water

Pour some hot water into a cup and record its temperature ____________
Pour some cold water into a cup and record its temperature _____________

What do you predict will be the temperature of the mixture? Explain your reasoning.

Pour the cups of water into a beaker and record the temperature of the mixture. ____

Which of the waters changed temperature more? Explain or show how you know this.

PART B
Different amounts of water

Part I Two hot and one cold
Pour some hot water into a cup and record its temperature ____________

Pour some hot water into a cup and record its temperature ____________
Pour some cold water into a cup and record its temperature _____________

What do predict the temperature of the mixture will be? Explain your reasoning?

Pour the cups of water into a beaker and record the temperature of the mixture. ____

Which of the waters changed temperature more? Explain or show how you know this.

Part II One hot and two cold
Pour some hot water into a cup and record its temperature ____________
Pour some cold water into a cup and record its temperature ____________
Pour some cold water into a cup and record its temperature _____________

What do predict the temperature of the mixture will be? Explain your reasoning?

Pour the cups of water into a beaker and record the temperature of the mixture. ____

Which of the waters changed temperature more? Explain or show how you know this.

Based on your data do you see a pattern to the final temperature of a mixture? Explain and defend your reasoning.

PART C
Same mass water and solid

Place a cup on a balance and zero it, then pour some cold water in a cup record its mass___________ and temperature _________.

Place a cup on a balance and zero it, then add enough washers so that the mass of the washers is the same as the mass of the water. Remove the washers from the cup and use a piece of string to bundle them together. Replace them in the cup letting the string hang outside the cup. Pour hot water into the cup with the nails and record the temperature after two minutes. Record the temperature _________

Remove the washers from the hot warm and immediately place them into the cold water. Record the temperature _________

Which substance changed temperature the most? Explain or show how you know this. Give a reason for that change.

Did this activity follow the same pattern as the others? Explain.

Explain similarities and differences in the three activities based on your data.

Appendix I

Absorbers and Emitters

Adapted from Physical Science with Computers.

Objective: To investigate which colored can is a better absorber and emitter of radiant heat.

Materials:

- One soda can painted white
- One soda can painted black
- One soda can silver
- Lab Pro data collector
- Three temperature probes
- Logger-Pro program
- Computer
- 100 W light bulb and socket
- Hot water source
- Balance

Absorber

Predict which of the cans you believe will be the better absorber of radiant energy for the 100 W light bulb. Explain the reasoning for your answer.

Place each empty can 20 cm away from the 100 W light bulb.
Make all the necessary connections and open the Logger-Pro program.
Under Experiment, Select Data Collection and adjust the length of time to 10 minutes and the samples/second to two.
Insert a thermometer into each of the cans
Change the labels of the temperature probes to the cans color.
Turn on the light bulb.
Start the collecting data shortly after plugging in the light bulb.
Save the run as "Absorber" in your files.
After the run is complete.
Turn the light off.

Analyze your data by:

- Autoscale your graph
- Statistic Function for each set of data
- Find the change in temperature by subtracting the Maximum value from the Minimum Value.

Place each Statistical box on the graph so that the line can be seen.
Print a copy of your graph for each member of your group.

Change in temperature:
BLACK CAN_________ WHITE CAN _____ SILVER CAN _____

Which can absorbed radiant energy better? Explain your choice using data from the activity.

Emitter

Predict which can will emit radiant energy better when 200 grams of water is allowed to cool for ten minutes in the can. Explain your reasoning for your choice.

Using a balance place about 200 grams of 80 degree water into each of the cans.
Quickly place the cans on the lab station with thermometers and begun recording data using the same time set up form the previous run.
Save this run as "Emitter" in your files.
After the run is complete.
Analyze your data by:
Autoscale your graph
Statistic Function for each set of data
Find the change in temperature by subtracting the Maximum value from the Minimum Value.
Place each Statistical box on the graph so that the line can be seen.
Print a copy of your graph for each member of your group.

Change in temperature:
BLACK CAN _________ WHITE CAN _____ SILVER CAN _____

According to the activity, which color of can emitted radiant energy better. Write an explanation of your results.

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