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A CONSTRUCTIVIST APPROACH TO EXPLORING PHYSICAL AND CHEMICAL CHANGES IN THE JUNIOR HIGH SCIENCE CLASSROOM

by

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ABSTRACT

A CONSTRUCTIVIST APPROACH TO EXPLORING PHYSICAL AND CHEMICAL CHANGES IN THE JUNIOR HIGH CLASSROOM

By

Keith Alan Morris

This research project was designed to study the effectiveness of instructional materials created for a junior high science classroom. I employed a constructivist approach to teaching science that required students to explore concepts through hands-on laboratory investigations and construct meaning based on these experiences. This unit involved the study of physical and chemical changes in matter. The objectives of the unit match the goals and objectives presented in the Michigan Essential Goals and Objectives for Science Education (K-12). The goals of this research were to develop methodology: 1.) To increase student understanding of the scientific principles discussed in the unit. 2.) To improve student interest and attitudes about science, and demonstrate how science relates to their every day lives. 3.) To increase communication about science related issues between students and parents. Students demonstrated a significant improvement in their understanding of the concepts taught in the unit as indicated by pre and post test scores. A survey of students indicated that their overall attitudes concerning science had improved, and also indicated an increase in communication between students and their parents. Overall, students were highly motivated and most of them thought that the techniques used in the unit were effective in helping them learn the material.

To my wife ....for everything

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INTRODUCTION

I. Rationale for Study

As a seventh grade science teacher, I am amazed at the many different explanations students have for what goes on in the world around them. These alternate conceptions prove to be extremely difficult to change. I chose to explore the area of physical and chemical changes to help students with these misconceptions for the following three reasons.

First, the nature of matter is an integral part of our middle school curriculum. It comprises almost 50 percent of what we teach during the year. The kinetic theory of matter is the basis for much of what is learned in subsequent science courses. Second, we have included a unit on physical and chemical changes in our curriculum for the past seven years and our students are still struggling with these concepts on standardized tests such as the Michigan Education Assessment Program (MEAP). Our students have not developed a complete understanding of physical and chemical changes and the impact these changes have on their everyday lives. They use the vocabulary loosely and many times incorrectly. Students might be familiar with the term evaporation, they may even be able to write a definition, but they cannot explain the process on a molecular level or apply the kinetic theory of matter in their description. On a past MEAP test almost a third of our eighth graders answered that water exists only in the liquid and solid states during the Winter. Students were asked what temperature chocolate freezes at and more than fifty percent of them chose an answer below the freezing point of water. When asked what type of change water undergoes when it evaporates from the surface of Lake Michigan, forty-eight percent responded with a chemical change. On the constructed response questions from the 1996 MEAP test

77 percent of the answers from our students received 0 or 1 point, while only 1 percent of the answers given received a score of 3 or 4 points. Some sample MEAP questions are included in Appendix F. These examples show that we need to do something different in the way we instruct students. Finally, students have a great deal of contact with physical and chemical changes both in natural and technological settings. This will enable me to make several different connections to the world outside the science classroom and help students realize how important science is in their everyday lives.

Our current science curriculum is driven by our textbook. Many teachers at the middle school level are not science majors and therefore tend to fall back on the textbook for guidance. This creates several problems. First, it limits the scope of discussions and student opportunities to explore ideas or questions generated during the unit of study. Teachers become limited by the information, or lack there of, that is included in the textbook. Second, it imposes a time constraint because teachers feel they must cover all the topics in any given chapter or unit. Third, the textbook we use does not go into enough detail. It does not afford students enough time or opportunities to construct their own knowledge. For example, our textbook covers phase changes in one day. Physical and chemical properties and changes are designed to be covered in two days. This is not nearly enough time for students to internalize new information, let alone challenge any misconceptions they might have on the topic. Therefore, I wanted to create a unit that allowed students the time to challenge their existing ideas and construct new ones based on experiences and sound scientific principles.

The goals of this unit are 1.) To afford students the opportunity to construct their own knowledge about physical and chemical changes and enable them to develop a deeper understanding based on sound scientific principles. 2.) To improve student attitudes about science both in and out of class. 3.) To increase student communication concerning science related topics outside the classroom with their family and peers.

II. Comparison of Old and New Approaches

In the past my teaching methods have been rigidly structured. I have not afforded students many opportunities to explore their own ideas or questions. Because we had such a large volume of material to cover during the school year, it was impractical to devote valuable instructional time to student exploration. Many of the lessons involved a reading assignment from the textbook and answering questions afterwards. I would lecture to the class and perform some demonstrations to help them understand the concepts. Then students might do a worksheet or other written assignment to reinforce concepts. I did not spend a lot of time exploring concepts in detail. Consequently, it was difficult for students to understand how ideas fit into the larger picture. The lab activities were usually very structured and did not allow for students to explore their own questions about a particular topic. This may be why it is so difficult to get students to talk about their own ideas, they have never been given the chance. Once again, there was little time for lengthy discussions because the curriculum had to be covered. Unfortunately what happens in this scenario is that a lot of topics get "covered" but very little is internalized and understood by the students. Finally, the assessments I used generally focused on vocabulary or very general questions about the concepts discussed, never any real in depth questions that required a deeper understanding of the material. As I look back on what we have done in the past, I can see why our students have been struggling when asked to apply what they have learned to real life situations-they have not been allowed to developed a true working knowledge of the concepts taught.

One of the things that I wanted to accomplish with this unit is to incorporate as many new and innovative teaching techniques as possible. It is very easy for me as a science teacher to get caught up in the subject that I teach and forget that I am an educator first. In trying to cover as much material as possible, I sometimes shy away from trying new teaching techniques that may require more time, but in the long run could yield a greater understanding for the students. Therefore, I want to remain up to date on the most effective teaching strategies available and be willing to employ them as often as I can. A discussion of the techniques that I incorporated into my unit follows.

The central theme of this teaching unit is the constructivist learning model. This model is based on the premise that learning is the social process of making sense of one's experiences in terms of extant knowledge, (von Glasersfeld 1989). As Resnick and Chi (1988) say,

> "Constructivism tells us that people have to build their own scientific knowledge and understanding and that, at each step in science learning, they have to interpret new knowledge in the context of what they already understand. We cannot teach directly, in the sense of putting fully formed knowledge into people's heads; yet it is our charge to help people construct powerful and scientifically correct interpretations of the world."

In this approach, students "construct" their own understanding of the concepts through a carefully developed, step by step process. This process involves six basic steps. The first step is discovering what existing knowledge students have on a particular topic. Then you identify any common alternate conceptions that they might have. After that, a hands-on activity or investigation is used to allow them to challenge their misconceptions and develop new ideas. Students are required to propose explanations and solutions for results of the lab activities. These ideas are shared in small and large group discussions and refined if necessary. Finally, the class develops some conclusions based on the discussions and, ideally, generates other questions to explore. I would like to take this opportunity to discuss in greater detail what these six steps involve.

Learners bring with them to the classroom a diverse set of alternative conceptions that they have developed to explain the world around them. These alternative conceptions are quite consistent across different age groups (Wandersee 1983a). They are also extremely persistent. Studies by diSessa (1982) and Gunstone (1987) showed that even in a high quality educational setting with well prepared college students, alternative conceptions are still present upon completion of the courses. Students have a great deal of difficulty in understanding the particulate nature of matter. Novick and Nussbaum (1978) examined eighth graders' understanding of the particulate nature of matter and found that students had not internalized the ideas of space existing between particles, the intrinsic motion of particles, or the interactions between particles. They reverted back to their own misconceptions to explain the world around them. For example, many of my students believe that the molecules of a substance have the same physical properties as the substance itself. They think that the molecules of a solid are hard, the molecules of a liquid are "soft" and "slushy", and the molecules of a gas are transparent. In my own teaching I have not devoted enough time to examining my students alternative conceptions so that I can develop lessons to help them move

towards more scientific explanations for what goes on around them. In order for students to get the most out of their learning, we have to anticipate and identify any common misconceptions that they might have. One way to accomplish this is to question students both orally and in writing to uncover any alternative conceptions that they might be bringing to the classroom. This can be done through the use of science journals. Howe (1993) states that writing shapes experience and helps in understanding it. Science notebooks or journals should be used by all science students from fifth grade on. Teachers can use these journals to check understanding. Each student brings in a small spiral notebook which can be used in a number of different ways. One of these ways is to have them make predictions about topics that they will explore, and to return to those predictions after they finish a particular laboratory activity to see if they want to change their ideas. This will afford teachers the opportunity to identify misconceptions without using valuable instructional time.

In order for students to give up their previous alternative conceptions about a particular topic, they have to experience something that challenges their misconception and allows them the opportunity to form new beliefs. Smith (1991) makes it clear that in order for conceptual changes to occur, we cannot simply tell the student that their idea is wrong and give them the correct answer. The student must be convinced that the scientific explanation is better than theirs. The best way to do that is through hands on experiences. Rutherford (1993) says that,

> "Hands on learning by experience are powerful ideas, and we know that engaging students actively and thoughtfully in their studies pays off in better learning."

The activities a teacher uses must allow students to examine their misconceptions on a particular topic and afford them the opportunity to develop new ideas that are based on sound scientific principles. Friedler and Tamir (1990) write,

> "The laboratory is a place in which science students have experiences that interact with their existing conceptions and at the same time develop new concepts. Hence, the laboratory can be used as a means of identifying students' preconceptions, as well as a vehicle for extending or modifying such conceptions.

According to Tamir (1975), laboratory work is essential for developing science processing skills like manipulation, organizing ideas, investigation, inquiry and communication. Blosser (1980) found that on average, the level of achievement in science is higher among students who made observations and did experiments. Students are also more motivated when given the opportunity to explore ideas in a hands on manner (Bates, 1978). Students should also be given opportunities to create their own investigations for certain topics. This requires them to design and conduct experiments that could convince others that their ideas were indeed correct.

Along with these in-class activities, students will be given several related take home activities. This will give students the opportunity to discuss science concepts with family and friends and to see that science extends beyond the boundaries of the classroom. It is important that students be given the chance to discuss their ideas because learning is more likely to occur through dialogue and reflection (Kober 1993). These activities will afford students a chance to explore their own ideas or questions.

After completing these different hands on activities, students should have the chance to discuss their findings in both small and large group discussions. During these discussions, the teacher should try to take a back seat to the proceedings. He or she should be more of a facilitator than an instructor. Instead of giving them the information or explaining what happened as I have done in the past, the instructor should give students the responsibility of combining the results into an explanation the entire class can all agree on. This involves a lot more class time, but in the end will be worth it in what students take away from the discussions. Tobin (1990) writes that meaningful learning in the laboratory is possible if students are given the opportunity to reflect on their findings and consult other resources besides the teacher. According to Gunstone and Champagne (1990), learning is an act of construction that involves less time on worksheets and instruction and more time to reflect and discuss ideas.

One of the places for students to reflect and discuss ideas is in their science journals. I have always wanted to include more writing opportunities for students, and these journals are an excellent way for students to record their predictions, observations, explanations, conclusions or questions. Journal writing allows the teacher to examine students' thoughts after school and use the information to plan the next day's discussions or activities. Butler (1991) writes that using the writing process in the science classroom encourages critical thinking among students. Journals also give students an unthreatening avenue through which to share ideas-something extremely important to junior high school aged children. This is one technique that I will be including in all of my teaching next year.

Another technique that I was interested in incorporating into my unit was the use of technology in my presentations. I wanted students to be exposed to information in a variety of ways. By encountering the same material in a variety of modalities, students grasp the richness and depth of the material, (Friedlander 1989). One alternative method of presenting information to students is through the use of multimedia presentations. Evert (1996) found that the use of multimedia presentations has been shown to improve the effectiveness of a lesson.

Finally, in the past I have neglected to perform certain demonstrations due to either a lack of resources or a perceived lack of time. I made it a point to do whatever was necessary to make it possible to incorporate these types of demonstrations. For example, it is not always easy to have liquid nitrogen or dry ice for demonstration purposes. I went through the processes of beg, borrow and ..... until I found the necessary items. If teachers are going to perform these types of demonstrations on a consistent basis, we are going to have to give them the time and the resources to acquire the necessary materials and equipment.

III. Demographics

I teach in a rural district approximately twenty miles from a major city. We have about 3,500 students of which over 90 percent are Caucasian. In our junior high we have approximately 850 students spread out through grades six, seven and eight. I teach both math and science to three classes of 21, 24, and 27 seventh graders respectively. I have each of these classes for two, forty-three minute periods per day. This affords me the opportunity to utilize class time as needed. For example, I am able to use both periods when I have a science activity that requires more time to complete. Of the seventy-two students who participated in this study, thirty-five were male and thirty-seven were female. All of my students were Caucasian. Eleven of my students were receiving services from the special education department.

IV. Scientific Background

Changes in matter fall into three categories; physical, chemical and nuclear. This unit takes an in depth look at physical and chemical changes. Changes in matter which do not result in new substances being formed are physical changes. These include changes in state such as freezing, melting, evaporation, condensation and sublimation and other physical changes such as dissolving. In order to fully understand these physical changes, students must be expert in the use of the kinetic theory of matter. The particles of matter are in constant motion. This motion, along with the distance between molecules and the attractive forces between them determine the state the substance exists in. In a solid, molecules are held together in a rigid array giving rise to its definite shape and volume. As energy is added the molecules are able to break out of the rigid array and flow freely around each other, but they are still held relatively close together by intermolecular forces. These intermolecular forces are either dipole-dipole or ion-dipole in nature. In the liquid state matter still has a definite volume, but takes the shape of its container. Energy must be added or removed for a substance to change phase. As a material goes through a phase change, the temperature remains constant until the change has been completed. This is because the average kinetic energy of the particles remains constant during the phase change. As more energy is added, the liquid molecules acquire enough energy to break away from the surface of the liquid and move into the gas phase. This can occur at the surface of the liquid as in evaporation, or throughout the liquid as in vaporization. In this phase the distance between particles becomes much greater than in the liquid or solid phase. A gas assumes the shape and volume of its container and is much more compressible than either a liquid or solid. Sublimation is the change from solid directly to a gas. Dry ice is an example of a substance that “skips” the liquid phase at standard temperature and pressure. In all of these phases the molecules are separated by empty space.

Chemical changes also involve energy and result in the formation of completely different substances. These new substance(s) can have very different properties than the original material(s). Chemical reactions involve starting materials called the reactants, and ending materials known as products. Chemical changes are easy to recognize because they usually involve greater amounts of heat, light or sound energy than physical changes. A complete list of the resources I used in gathering this scientific information and designing the activities can be found in appendix A.

IMPLEMENTATION OF THE UNIT

I. Overview

The first steps in the teaching of this unit were to determine what students already knew, and identify any misconceptions they might have had. I used the unit pretest as a means of identifying existing knowledge and also to direct the teaching and discussions during the unit. I questioned my students both orally and in writing to uncover misconceptions they might be bringing to the classroom. One of the ways I was able to keep track of where students were in this process was through the use of their science journals. I required each student to bring in a small spiral notebook which we used in a number of different ways. One of these ways was to have them make predictions about topics that we were about to explore, and to return to those predictions after we finished a particular laboratory activity to see if they wanted to modify their ideas. This afforded me the opportunity to identify misconceptions and check understanding without using valuable instructional time. Once I had identified existing knowledge, I then used the activities I created during my coursework and research at Michigan State University to explore and challenge their ideas. These activities allowed students to examine their misconceptions on a particular topic and afforded them the opportunity to develop new ideas based on sound scientific principles. I began each activity with a question to get students focused on the particular topic we were exploring. For example, on one of the days I showed the students a balloon that appeared to have been "sucked" into a flask. The question was to explain how the balloon remained in the flask even though it was not tied shut. Students then worked together in groups of three or four to complete the laboratory activities and discuss the questions at the end of each lab

exercise. During these activities and discussions, I was able to walk around the room and ask probing questions or make certain comments that helped guide students to the scientifically correct conclusions. After all the groups had finished their work, we then came together as an entire class to share and discuss results, conclusions, problems, or questions that they might still have. I found this time to be very rewarding to both myself and my students. It was during these discussions that the students suggested other concepts to explore or possible experiments to perform. These discussions also allowed me to check student understanding and make sure that previous misconceptions were challenged and refuted.

II. Basic Outline

This unit on physical and chemical changes of matter required a total of six weeks of instructional time. All of the activities in this unit are new and are a result of my coursework and research at Michigan State University. The numbers in parentheses after each activity represent the objectives addressed. Those objectives can be found on the following page.

A. INTRODUCTION

1. Vocabulary Exercise

B. PHYSICAL CHANGES

1. Freezing and Melting of Water (1, 5, 6)
2. Conservation of Mass (5, 6, 7)
3. Other Melting Points (1, 5)
4. Other Freezing Points (1, 5, 6)
5. Making Ice Cream (1, 5)
6. Size of Molecules (5)
7. Evaporation and Vaporization (1, 5, 6)
8. Rates of Evaporation (1, 5, 6, 7)
9. Reclaiming a Solid (2)
10. Liquid Nitrogen Demonstrations (1, 5, 6)
11. Condensation (1, 5)
12. Fractional Distillation (2)
13. Exploring Appliances and Designing Machines (8, 9)
14. Chromatography Crimebusters (2)
15. Chromatography T-Shirts (2)
16. Sublimation-Dry Ice (1, 5)
17. Thermal Expansion (1, 5, 8)

C. CHEMICAL CHANGES

1. Exploring Chemical Changes (3)
2. Chemical Changes Demonstrations (3)
3. Classifying Physical and Chemical Changes (4)
4. Multimedia Presentation (3, 4)
5. Making Slime (3, 4)
6. Video Quiz

D. ASSESSMENT

1. Summative Evaluation
2. Surveys, Opinions, and Evaluations Day

III. Unit Objectives

The following objectives were taken from the Michigan Essential Goals and Objectives for Science Education. These are the goals that our district uses to direct science education in our schools. It is also the basis for our new county wide curriculum project that is under way in Eaton County.

1. Describe common physical changes in matter: evaporation, condensation, melting, freezing, dissolving, thermal expansion, size, and shape.
2. Prepare mixtures and separate them into component parts.
3. Describe common chemical changes in terms of properties of reactants and products.
4. Distinguish between physical and chemical changes in natural and technological settings.
5. Explain physical changes in terms of the arrangement and motion of atoms and molecules.
6. Generate scientific questions about the world, based on observations.
7. Design and conduct simple investigations.
8. Describe ways in which technology is used in everyday life.
9. Investigate simple appliances and explain how they work.

IV. Audio-Visual Aids

I used this unit as an opportunity to incorporate the Windows on Science laserdisc resources into my science program. I found this material extremely valuable in helping students construct their knowledge about physical and chemical changes. I liked the laserdisc materials better that other audio-visual aids like filmstrips or videos, because I could focus on one or two concepts and immediately find a certain picture or short demonstration that I could use. I did not have to spend 15 minutes or more watching a video to get a certain point across. It is much more efficient to be able to quickly search for one frame, than to sit through an entire movie or filmstrip. It was also nice to be able to show students demonstrations that I could not do in class because of the lack of materials or for safety reasons. For example, there was a short demonstration on the formation of sodium chloride from sodium metal and chlorine gas-not a reaction I could do in my classroom! There were several examples of physical and chemical changes included on the disc and there was also a video quiz that I used as one of the evaluations. I would recommend this program as an excellent way to improve and augment existing curriculum.

V. HyperStudio Presentation

One of the techniques that I wanted to explore during this unit was the use of multimedia resources in my lessons. Therefore I created a short presentation during my research at Michigan State University using the multimedia program HyperStudio. I recorded videos of the demonstrations I performed for the previous lesson along with pictures taken with a digital camera and included them in the presentation. I used this presentation for eight of my students who were absent for the original demonstrations. I asked these students to come to class during lunch time, and they were more than happy to be a part of my study. The objective of the presentation was that students could identify chemical changes and classify changes as physical or chemical. The students appreciated being able to see the demonstrations they had missed during their absences and all eight of them scored 100 percent on the quiz given to the class. Although this was an excellent way to convey information to students who were absent or to strengthen other students' understanding, the time necessary to create this presentation was enormous. This one presentation took approximately ten hours to create, de-bug, and polish. I would need to shorten that time considerably to make this type of presentation practical to use. I think this would be an interesting avenue to explore, especially if one could align presentations to state objectives.

VI. Evaluation Protocols

In evaluating the overall effectiveness of the unit I compared pre and post test scores for all of my students. These pre and post tests included a combination of multiple choice and constructed response questions. I wanted to include questions similar to those on standardized tests, but at the same time I was interested in whether or not students could formulate answers for questions requiring them to apply the concepts to real life situations. The complete pre and post tests that I used can be found in Appendix B.

In evaluating the individual activities I examined six students, two high achieving, two average achieving and two low achieving students. Their achievement was based on first semester science grades and on their participation in class discussions. The high achieving students both earned A's the first semester, the average students earned a B and a C, and the low achieving students each earned less than a C. There were three boys and

three girls in this sample group. I evaluated their individual responses to pre and post test questions, journal entries, class discussions and laboratory quiz questions. The laboratory quiz questions were similar to those on the pre and post tests. They included both multiple choice and short answer questions. The complete laboratory quizzes are located in Appendix C. I also asked all students to rate the different teaching techniques employed in this unit on the basis of their effectiveness and how well they enjoyed each one.

To evaluate student attitudes towards science and the level of communication among their peers and family I conducted surveys of all of my students both before and after the unit. These surveys can be found in Appendix E. I also collected suggestions, comments, or complaints from the students about the unit when it was over.

VII. Laboratory Exercises: Description and Analysis

Appendix location of each activity is in parentheses.

Activity: Vocabulary (D1)

The first lesson of the unit was a vocabulary activity. I did this for two reasons. First, I wanted students to be familiar with the vocabulary of the unit before we started the laboratory activities. The activity that I created is different from traditional vocabulary exercises. Vacca & Vacca (1989) suggest that in order for students to understand vocabulary well enough to use it, they must be provided with multiple opportunities to build their knowledge of these words. This is especially true of science vocabulary. In normal science vocabulary lessons students look up words, copy down definitions and memorize them for the quiz. The vocabulary activity that I created involved four basic parts. The first part was a glossary of terms written by me. Students were not required to look up and copy definitions. This allowed time for the next three sections. There was a story passage with missing words in which students were required to use the vocabulary words to complete the passage. Next, there was a puzzle page in which students matched definitions to the words and filled in a magic square box. The magic square allowed them to check their work to see if they matched all of the words correctly. The final section involved using each of the words in a sentence of their own. Therefore students were exposed to the vocabulary words four times in different contexts in this exercise. The second reason that I wanted to have the students study vocabulary first, was to give me an opportunity to show that just because students know the definition of a word, it does not necessarily mean that they can use it correctly. To show this I gave each of my students two different quizzes at the end of the lesson (Appendix D-2).

One quiz involved matching the words to the definitions while the other quiz required them to use the concepts to answer questions about happenings in the real world. While the sample group of students I monitored scored an average of 88 % on the matching quiz they struggled with the more in depth quiz. Only one of the six students answered correctly that water evaporating from Lake Michigan goes through a physical change. The rest of the students said it was a chemical change. Two of the six students knew that water exists in all three states in our atmosphere during the winter, while the others thought that only solid and liquid water existed. Finally, only one of the six students could identify the reactants and products of a given reaction even though all of them could give a definition of what a reactant and product was. Overall the average score on the second quiz was only 37 %. So while this vocabulary exercise laid the foundation for me to build on, it was not a substitute for actual hands on, constructivist learning included in the following activities. It was useful, however, in helping me identify misconceptions that students had about physical and chemical changes in a real world context.

Lab: Compare and Contrast Water & Ice (D3)

The first "real" activity for the unit was an opportunity for students to compare and contrast the physical properties of water and ice. I supplied the students with several different samples of ice and water: ice cubes from different containers, ice "sheets", and even some icicles from the gutters on my house. Students were required to write down detailed descriptions of the samples. They also recorded differences in the samples and generated hypotheses as to why these differences were present. The questions in the lab were designed to lead them to the fact that water and ice are made from the same substance but there must be something different about how the molecules are arranged to cause one to be hard and cold and the other to be warmer and flow. The objective of this activity was to get them to realize that water and ice are made of the same kind of molecules, but that these molecules are arranged differently. One of the explanations given by students in their journals was that ice molecules were hard and water molecules were softer and slushier. Another misconception that several of the students possessed was that the molecules of a solid and liquid were the same, there were just different amounts of each. On the pretest, not one of the students from the sample group correctly represented a solid as having its own shape, and all of them showed the molecules in the liquid being much farther apart than the molecules in the solid. None of the students showed the liquid taking the shape of the container. During the activity I found it difficult to get my students to use words other than solid and liquid to describe the samples of ice and water. I had to prompt them to use more descriptive words to describe what they meant by solid and liquid. In the class discussions we reached consensus that water and ice must be made from the same molecules because one "melted" or transformed into the other. We discussed some ideas about what could be different, and I was able to lead them to the hypothesis that the molecules of a solid must be held together tighter than in a liquid. I had them build some models with marshmallows and toothpicks to demonstrate how the molecules themselves were the same, but the way they interacted with each other was different. We were also able to see that the molecules of a liquid were not that much farther apart than those of a solid, and in some cases might even be closer together. On quiz number one that followed the first three lessons the students created more accurate drawings of the solid and liquid phases of water. Two of the six still did not correctly indicate that a solid has its own shape, but all of them now showed the liquid taking the shape of the container. The marshmallow and toothpicks were an engaging way for them to see how the molecules of a solid and liquid could be identical, yet be put together differently to yield ice and water. On the final unit test, all six of these students scored 100 % on their drawings of the solid, liquid, and gas phases of matter. I enjoyed the discussions we had as a class and the students liked being able to make their own observations and develop their own ideas.

Lab: Freezing & Melting Point of Water (D4)

The next lesson was designed to allow students to explore the freezing and melting points of water. The objectives of this lesson were that the learner would be able to state the freezing and melting points of water and be able to recognize and explain why the temperature remained constant during the phase changes. They would also be expected to explain what is happening on a molecular level as a substance freezes or melts and recognize that thermal energy is either added or removed during these processes. In this activity students created a cooling curve and a heating curve for water and ice. We used sidewalk salt in a beaker full of ice to freeze a sample of water in a test-tube while recording the temperature of the water each minute. The students found that the temperature of the water dropped rapidly until 0 degrees Celsius and then it leveled off as the water changed to ice. After the water was completely frozen, the temperature began dropping again. Then we did the reverse and students discovered that the ice began to melt at 0 ° Celsius and stayed at that temperature until all the ice melted and then the temperature of the water began to rise. On the pretest, none of the sample students described the water molecules in ice as being connected together in a rigid array. When asked to describe what happens to molecules of a solid when it melts none of the six students answered that they break apart and move around one another. Several misconceptions were identified during class discussions and in the journals. It was difficult for students to accept that a substance freezes and melts at the same temperature. Many of them said that in order for something to freeze it has to be "cold." They said that in order to freeze or solidify a liquid, you could just put it in the freezer. On the lab quiz the students all answered correctly that the melting and freezing points of water were the same at 0 ° C. Only one person answered correctly that the temperature of the ice and salt mixture we used in the lab was below 0. I found this very strange because the graphs that the students created clearly showed the temperature of the ice in the test tube reached approximately -10° C. Five of six students answered correctly that energy had to be removed in order for a liquid to freeze.

Lab: How Much Water is There? (D5)

Conservation of mass in phase changes is very difficult for students to accept. On the pretest only one of the students said the molecules of water would have the same mass as the molecule of ice that melted. Another question asked what would happen to the amount of water in a closed container if it was frozen. Four students said the amount would decrease, one said it would increase, and one said it would remain the same. I think the reason for this is that students mistakenly use volume instead of mass when comparing the amounts of a substance. This next lesson asked students to design an experiment to test whether matter is conserved or not during freezing and melting. I gave them a scenario in which my nephew says that after water freezes there must be more molecules because the level of the ice is higher than the level of the water he started with. He also used the example of ice cubes in the ice trays being higher than the water he started with. We spent a lot of time studying mass, volume and density earlier in the year and students were able to arrive at the conclusion that the same number of molecules can occupy more space. We discussed the fact that volume measures the amount of space an object takes up, while mass is the measure of the amount of matter. Most of the groups designed an experiment that involved massing an ice cube before it melts and massing the water after and comparing the results. A few groups still used volume in their experiments. They marked off the level of water in a container before they froze it, saw that the level went up after it froze, but then they melted it again to show that the level was the same as when they started. We discussed how they really did not prove my nephew wrong because there still could have been more molecules when the water was frozen and then there were less again when it melted. Eventually I think everyone realized that we should use mass when we are talking about the amount of matter. On the final unit test five of the six sample students answered correctly that matter was conserved during phase changes. One of the students answered that the amount of water would be the same but the mass would not. This showed that some of the students were still incorrectly using volume to measure the amount of matter instead of the mass.

Lab: Melting & Freezing Points of Substances (D6, D7, & D8)

The next lesson addresses the common misconception that something has to be "cold" in order for it to freeze or solidify. This idea was prevalent in many of the interviews with students and in their journal writings. When asked what temperature (0°, -10°, 35° or 100°C) was the closest to the freezing point of chocolate, two of the six students chose the correct answer. The other four students all chose answers below 0° C. Although all of the students knew that salt was used on the roads in the winter to keep them from freezing and we knew the temperature of the ice and salt mixture in the previous experiment, only two of them said that the freezing point of salt water was below 0° C. The objectives of this lesson and the take home activity were to show students that substances freeze and melt at many different temperatures, and to enable them to made educated predictions for freezing points of many common materials. One of the main ideas I wanted to get across was that solid or "frozen" things did not have to be cold. The tables, chairs, and walls around them are all frozen. In this activity the students placed small amounts of different substances around the outside of a tin can lid and held it above a candle flame. They made predictions in their groups as to the order in which they thought the substances would melt. They were instructed to carefully observe each substance and record the order in which they melted. The students seemed to enjoy making predictions and several of them were surprised by a couple of the results. After about 10 minutes the students removed the lid from the flame and recorded the order in which the substances froze or solidified. We had some good class discussions about the questions in the lab and how we know that not all things melt when it gets "hot." The take home activity was designed to create an opportunity for students to involve their parents in their studies and to show the students that science exists outside the boundaries of the classroom. They were asked to collect samples of different household liquids and see in which order they would freeze or solidify. Many of them were surprised to find that not all things they put in the freezer actually would freeze. They enjoyed sharing the results of their experiments with the rest of the class and I felt that they really took ownership of their learning. On the quiz that followed these two activities all but one of the sample students correctly picked the temperature closest to the freezing point of gasoline. All of them were able to explain the freezing and melting processes in terms of the molecules breaking apart or bonding together. All six also answered correctly that energy must be added or removed in order for these phase changes to occur. I was disappointed in some of the results of the unit test. Although five of the six students from the sample group chose the correct freezing point of chocolate, fifteen of my other students still chose an answer below 0° C. We followed this quiz up with a fun activity where we made ice cream in class using two sizes of ziplock bags and an ice and salt mixture to remove energy from the ice cream mixture. This activity worked well with my students. We were able to discuss the energy transfers involved in the process and several of my students went home and tried it themselves. It was enlightening for them to knead the ice cream mixture themselves and feel the transfer of energy and to see the ice melting as energy was absorbed from the ice cream mixture. This activity was thoroughly enjoyed by all.

Lab: Size of Molecules-Micromeasuring

Our next topic of discussion was evaporation. The first activity involved cutting up a piece of aluminum foil into smaller and smaller pieces and having students guess approximately how many atoms of aluminum were in the final piece. Students were amazed when I told them number of atoms in their tiny piece of aluminum. This lead to a discussion about how small molecules must be to fit that number in such a small space. The objective of this lesson was to help students to understand how small molecules really are and how, if they were far enough apart from each other, we would not be able to see them with the naked eye. This concept is important in explaining evaporation because many students hold the misconceptions that molecules soak into the ground or even disappear when something evaporates. I was surprised on the pretest when four of the six sample students explained that gasoline spilled on the pavement soaks into the pavement. Only one of the students used the term evaporation. I then did a demonstration using a large beaker of water and several solids such as glitter, corn starch, cinnamon, and soil to construct a model of what is present in our atmosphere. Students could see the concentrations of nitrogen (water), oxygen (glitter), other gases (corn starch), dust and pollen (soil), and water vapor (cinnamon). We decided in a class discussion that evaporation involved the molecules of a liquid gaining enough energy to break apart into the air. This could occur at any temperature. Students used the fact that we could still smell materials after they had evaporated, so they must be in the air-we just cannot see them. At the end of this lesson, I gave them a problem to work on. I told them that I had left my car window open during the last thunderstorm we had and I needed to dry out the interior as quickly as possible. I told them to bring their ideas to class the next day so we could test them. All six of the sample students answered correctly on the evaporation quiz that the process of evaporation involved molecules breaking away from the surface and moving into the air. Students were still hanging on to the idea that it has to be hot for something to evaporate (it is just more likely to occur.) I gave them a multiple choice question about the temperature at which water evaporates and three of the six chose only the highest temperature. We had to go back and look at examples of evaporation taking place at cooler temperatures again. These ideas that thing have to be cold to solidify or condense, or hot to melt or evaporate were very resistant to change.

Lab: Rates of Evaporation

The next day I had the students share their ideas on how to get my car to dry out faster. They were instructed to chose one of the ideas in their group and prove that it would actually increase the rate of evaporation. Students were required to use the scientific method with which they were familiar to experimentally prove their hypothesis. They really seemed motivated to prove their own ideas. After all of the groups were finished, the class shared their results and discovered three ways to increase rates of evaporation for water. They involved moving the moist air out of the car so more water could evaporate, adding heat energy so evaporation could occur faster, and spreading the moisture over more surface area. We discussed several everyday examples that apply these concepts. Students enjoyed thinking of appliances that used these principles such as clothes dryers, hair dryers, heat lamps, fans, etc. The objective of this lesson was to get the students to give two ways that the rate of evaporation could be increased and everyone in the sample group was able to do that on the quiz and on the unit test. One interesting thing that I did on this quiz was to ask the same question two different ways. I asked the students to respond in a short answer question whether or not it had to be cold outside for evaporation to occur and I gave them the multiple choice question that asked at which temperatures water would evaporate. All six of the students answered on the written response question that it did not have to be hot outside for evaporation to occur. On the multiple choice question, though, half of the sample students picked only the highest temperature for evaporation to occur. This raised an interesting question about how we should test student understanding of concepts. The MEAP test uses multiple choice questions most of the time-is this the best way to evaluate student knowledge on a particular topic? This is something that I would like to explore in greater detail in the future.

Discussion: Evaporation & Vaporization (D9)

The objectives of the next lesson were that students could: 1. compare and contrast evaporation and vaporization, 2. explain why temperature of a substance remained constant during vaporization, 3. explain vaporization in terms of molecules and energy, and 4. identify the gas inside the bubbles as the vapor of that particular substance and not air. For this activity the students created a heating curve for water. They discovered that during vaporization the curve leveled off around 100° C. We discussed as a class how we continued to add energy, but the temperature did not increase. In our discussions it was apparent that many of the students thought that the bubbles rising to the surface contained air and not water vapor. We discussed how evaporation and vaporization are similar and different. Students seemed comfortable with these concepts at the time. However, on the follow up quiz I found some disturbing results. After having performed this experiment in class only half of the sample students knew the boiling point of water. Two of them wrote down 0° C! I interviewed them about this and it seems that they did not read the question carefully enough and gave the melting point instead. I am still not convinced that they fully understand this concept. On the other hand, all of them correctly identified the vapor in the rising bubbles as water vapor. The students also struggled with comparing and contrasting boiling and evaporation. We specifically discussed this in small groups and large groups, but only four of the six could answer this question completely. Once again in my interviews with them I found that they did not fully understand the question itself. I have a feeling that this occurs very often on standardized tests as well. I see the need for more content area reading in science to prepare students for these types of problems. With the emphasis on hands on learning I have neglected this important component to any subject area.

Lab: Reclaiming a Solid (D10)

The next lesson provided a chance to put to use some of the concepts we had studied over the past couple of days. I posed a problem to my students. Someone had added sand to my salt as a practical joke and I needed a way to separate them. The objective of this activity was that students would be able to reclaim a solid by filtering and evaporation or vaporization. I also wanted students to recognize dissolving as a physical change and to be able to explain the process on a molecular level. On the unit pretest none of the students could offer a way to desalinate ocean water if they were stranded on a desert island. All of the students also classified dissolving sugar in tea as a chemical change instead of a physical change. The lab activity required them to add water to the salt and sand mixture and allow the salt to dissolve in the water. They then filtered the sand from the salt water and boiled away the water leaving the salt behind. Students really enjoyed working with the equipment involved in this exercise. By doing this activity they could actually see that the salt was still in the water so it had to be a physical change because nothing new was created. On the final test all of the students classified dissolving as a physical change because the substance was still there in the liquid. They still struggled with the question on purifying salt water though. Once again an activity that we performed in class did not seem to be internalized by the students. They had difficulty applying the concepts from the laboratory to a real life, or novel, situation. This leads me to believe that just doing hands on activities in the science classroom is not enough. Students need to be given opportunities to apply what they have learned in situations unfamiliar to them.

Liquid Nitrogen Demonstrations

The following day was one of my favorites. Students often think that all things evaporate at the same temperature or that something has to be heated up in order for it to evaporate. I wanted them to see that some things actually evaporate at extremely cold temperatures-like liquid nitrogen. I performed several demonstrations I learned about from other teachers and colleagues during my classes at Michigan State University and the students were fascinated by them. I, of course, froze a flower and a rubber ball and broke them. One of my favorite demonstrations was when I put a small piece of a hot-dog and some catsup in the thumb of a rubber glove. I put the rubber glove on my hand (except for my thumb) and stuck the thumb of the glove in the liquid nitrogen. After it was frozen, I removed the "thumb" and smashed it with a hammer. The kids saw the hot-dog and catsup and thought I had smashed my thumb. It was a riot. We

had some good dialogue about what was occurring on a molecular level and the students really seemed to understand that some liquids evaporate at very cold temperatures. They were definitely captivated and interested which was another goal of this unit.

Lab: Condensation-Where Did the Water Come From? (D11)

The liquid nitrogen demonstrations were a good platform for me to introduce the topic of our next discussion, condensation. While I was performing the demonstrations, several students asked why frost was forming on the outside of the beaker or Styrofoam cup I was using to hold the liquid nitrogen. I had them give their explanations for why this happened in their journals. The question I gave them to answer was why do a person's glasses fog up when they come in from the cold in the winter? It was amazing how many different answers I received. Some of the responses were "the cold air hits the warm air making fog." "The quick change from cold to hot causes them to fog up." "The molecules get used to the cold air and the warm air in the house caused them to fog." Not a single student in all of my classes even mentioned water vapor or water molecules for that matter. I got just as many different answers when I asked why glasses do not fog up when a person goes outside into the cold. It was very obvious to me that of the phase changes we were studying, condensation was the least understood. The objective for the next activity was to have students explain the process of condensation in terms of molecules and energy. I wanted students to be able to explain everyday examples of water vapor condensing on different surfaces. The lab required two tin cans with lids. Students put a mixture of ice and water in one can and observed what happened on the outside of the can. We then put warm water in an identical can and noticed that water now condensed

on the inside of the can. We had some good class discussions about what was happening and students generated several examples of condensation occurring in their own homes. I showed them an example of a closed system with a flask of boiling water and a tube for the vapor to travel through and condense in a test-tube on the other end. This seemed to work well because they could see vaporization and condensation occurring in the same set-up. We discussed how water boils at 100° C. so it must be able to condense at that temperature also. I was disappointed in the results on the lab quiz. Only two of the sample students answered correctly that the reason glasses fog up in the winter is that water vapor in the air condenses on the cold surface of the glasses. All of them answered correctly that water exists in all three states in the winter, compared to only one on the unit pretest. The question I was the most concerned about was a multiple choice question in which I gave them a model of a water molecule from a solid and asked them to pick the picture that best represented a water molecule as a gas. Only two of the six picked the picture that was identical. That was disturbing because we had been modeling water in the different states with the marshmallows and toothpicks through the entire unit. I knew this was going to be a tough concept for them to master, but I was amazed at how difficult it was to get them to change their views. I cannot help but think back to my first year of teaching when we covered phase changes in a day!

Lab: Fractional Distillation (D12)

This lab required the students to separate three liquids by fractional distillation. We discussed in class how the petroleum industry uses this process to refine crude oil. I showed them the mixture of water, isopropyl alcohol, and ethylene glycol and asked for ideas on how to separate them. The objective of this activity was to enable students to explain the process of separating two or more liquids by their different boiling points. We discussed how different substances have different boiling points, and how we could condense the vapors back into the liquid phase. The lab involved boiling the mixture in a large test-tube and allowing the vapors to travel through a rubber tube to another test-tube located in a beaker of ice. The groups were required to record temperatures of, and plot a heating curve for, the mixture. The students were excited about this particular activity because of all the equipment involved. They were also interested because of the connections made to the petroleum industry. We had some excellent small and large group discussions concerning when the best time was to switch the collection tubes in order to get the greatest degree of separation. It was good for them to see how difficult it actually was to get pure samples of the three components. Before the lab activity none of the students in the test group could explain how to separate two liquids. Five of them put down a question mark, and the other one wanted to use the principles of density. After the activity, four of the six students scored 75 % on the same question, one scored 100 %, and one scored 25%. Students drew pictures of the apparatus in their explanations and included step by step instructions, something that has proven to be very difficult to get junior high students to do.

Activity: Exploring Appliances (D13)

The objective of this activity was to help students explain how different appliances use the concepts we have been discussing in class the past two weeks. I wanted students to see how the interrelationship between technology and science make our lives more enjoyable. None of the students could explain how a dehumidifier worked on the unit pretest. All of them left that particular question blank. I provided students with pictures of several different appliances and they worked together cooperatively to figure out how they worked. This involved explaining on a molecular level what was being accomplished by the appliance. I personally enjoyed this activity because it required students to apply what they had learned in the previous lessons. After all of the groups had an opportunity to share their findings with the entire class I gave them a list of problems and had them choose one and design a machine or appliance that could solve the problem. An example would be how could you keep your toilet tank from "sweating" during the Summer. I wish I had the opportunity to share all of the ingenious ideas that I received. The students were extremely motivated and were very creative in their designs. Many of the students mentioned that they discussed the problem with family and friends and even had input from them. This was a great activity to get students working outside the science classroom and talking to others about science.

Lab: Crimebusters-Chromatography

The objective of this activity was to show students how to separate a mixture of inks by differences in solubility. I also wanted to show that solubility was a physical property. I showed students a note from the person who put the sand in my salt and told them that I needed to know what type of pen was used. I showed them the process of chromatography and they tested several different pens trying to match the results that I had from the ink from the note. Once again, students were motivated by the use of science concepts to solve a problem. We discussed forensic science and how it uses many of the concepts that were discussed in class. After solving the “crime”, I requested that students bring in a white T-shirt and we made some designs on them using ink and chromatographic techniques. Students were excited about this activity and some of the designs they created were incredible. I evaluated this lab with a performance based assessment. I gave students a pen to test and they were require to match it with samples that I had already made. All of the students were able to correctly identify each pen.

Lab: Thermal Expansion (D15)

The objective of this lab activity was for students to explain thermal expansion in terms of molecular motion and energy. This lab involved placing a penny on the top of a cold pop bottle and warming the bottle with your hands. The resulting expansion of the air in the bottle causes the penny to “dance.” We discussed several examples of thermal expansion in the real world and how this expansion was compensated for. Students had difficulty accepting that solids really expand. This was evident in their journal entries. I did a demonstration with a solid ball of brass and a ring to show them that after the metal ball was heated it would no longer pass through the ring. After it cooled off, it then went through the ring again. Following this activity all of the students were able to explain why sidewalks have spaces between the separate squares of concrete and why railroad tracks have spaces between the rails.

Lab: Observing Chemical Changes (D16 & D17)

The objective of this lesson was for students to generate a list of characteristics of chemical changes. They should also begin to distinguish between physical and chemical changes. Students must also be able to classify the reactants and products of a given chemical reaction. This lab activity required students to observe four different chemical reactions and describe what happened in each one. We then worked together as a class to develop a set of characteristics for chemical changes. Students were very excited about working with different "chemicals." The reactions that I used were simple reactions that students could duplicate on their own. I wanted to make sure that they made the connection with their everyday life. The following day I performed several different demonstrations of chemical changes that were fun for the students. These included the genie in the bottle, several hydrogen explosions, combustion of different gases, and several other eye opening examples. Many of the students at the end of the unit said that this was their favorite part of the unit. Before the lesson, none of the students were able to list the reactants and products for a given chemical reaction. Also none of the students answered correctly that mass is conserved in a chemical reaction. Following the unit, all of the students were able to classify the reactants and products of the vinegar and baking soda reaction. Four of the students correctly stated that mass was conserved in this reaction while two of them said the reactants had more mass because one of the products was a gas. This was disappointing because we had spent several days earlier in the year proving that gases do have mass. Students were reverting back to previously held misconceptions, something I dealt with during the debriefing following the unit test.

Lab: Classifying Physical and Chemical Changes (D14)

In this activity students explored the differences between physical and chemical changes. The objectives were to get students to correctly classify changes as physical or chemical and give a reason for their decision. Students performed some simple physical and chemical changes on pieces of wood and a candle. They were again required to discuss their results in small and large groups. Before this activity, students in the test group correctly classified 60% of the physical and chemical changes they were presented with. Following the lesson they classified 97% of the changes correctly. Following this lesson, I used an alternative form of assessment, a video quiz. Using the Windows on Science videodisc, I showed the students 9 different changes and asked them to classify them as physical or chemical and give a reason why. Students seemed to enjoy this type of quiz and performed extremely well on it. The average score for all 70 of my students was 94%.

Lab: A Fun Chemical Change-Making Slime

There are certain activities that students always remember from the school year and many of them indicated that this was one of them. This activity was an opportunity for them to see how much fun science can be and at the same time solidify understanding of chemical changes. We discussed polymer chemistry and looked at a list of polymers present in our every day lives. We modeled the chemical change when polyvinyl alcohol (PVA) and sodium tetra-borate (STB) are combined with small and large paper clips connected in long chains. We were able to model how the chains of PVA were connected together by shorter chains of STB trapping water molecules in between. This activity was designed to increase students appreciation of science and many of them said that this was their favorite activity.

EVALUATION

I. Pre and Post Tests (Appendix A)

The questions on the pre and post tests were a combination of short answer and multiple choice questions designed to test the students' ability to apply the concepts behind physical and chemical changes to real world situations. The results of these scores indicate that the instructional materials and techniques used were very successful. Students made significant gains over the course of the unit as can be seen in Table 1.

Table 1. Pre and Post Test Data

	Mean Scores	Standard Deviation	Range
Pre Test	28.2	9.4	12-58
Post Test	80.4	13	41-100
Gain	52.2		

Overall, my students performed at the 80% level on the post test. This is quite an accomplishment considering the difficulty of the exam.

In studying the answers given by the six students that I followed through the unit in detail, I notice that the high and average students scored 92% on the multiple choice questions, while the low group scored 64% on the same questions. I looked through the tests of several other students who I considered in the low achieving group based on past experiences and found that they scored an average of 66% on these same multiple choice questions. It would be interesting to see if there is any correlation between the type of questions used to evaluate students and their achievement. I found that in all three groups, the scores went up an average of 60 points

from pre to post tests. All three groups seemed to benefit from the instructional practices used in the unit. I was impressed with the students' ability to apply the concepts we explored in class to real life experiences. For example, one of the test questions asked them to explain why a person's glasses fog up when they come inside from the cold. One of my students responded with the following, "Your glasses are cold from being outside and when water molecules from the air hit the glasses, they lose energy and condensation takes place." That same students wrote on the pretest that, "The molecules in the lenses get used to the cold weather so when you come in, where it is warm, the two temperatures mix and they (the glasses) fog up." This student has made tremendous progress in her understanding of molecules, energy, and phase changes.

II. New Teaching Strategies

The use of the constructivist learning model was very effective as shown by the pre and post test results. This method of instruction forced me to evaluate my students' pre-existing knowledge, something that I have been very neglectful of in the past. The students enjoyed the hands-on lab activities and also the opportunities to discuss ideas and explore their own hypotheses. Many of the students commented on the activities saying such things as, "I personally thought the unit was very fun. The things that I like best were the demonstrations and the labs." Another student wrote, "I liked the group activities and class discussions because you get to see what other people think." I asked all of my students to evaluate each of the instructional techniques individually on the basis of how well they helped them learn, and also on how well they enjoyed it. The students were asked to rate each technique on a scale of one to five, with one being the least helpful or enjoyable, and five being the most helpful or enjoyable. A copy of this survey is in appendix E. The results from all of my students are summarized in Table 2 below.

Table 2. Student evaluations of teaching techniques

Techniques	Effectiveness Mean Score	Enjoyment Mean Score
Vocabulary	4.0	2.9
Class Discussions	4.8	3.9
Group Discussions	4.5	3.8
Take-home Labs	3.3	3.0
Journals	3.1	2.6
Hands-on Labs	5.0	5.0
Demonstrations	4.4	4.5
Laserdisc Videos	3.8	3.3
Alternative Assessments	3.6	3.3

The data shows that students rated the labs, discussions, and demonstrations as the most helpful in learning the material. They also rated the labs and demonstrations as the most enjoyable. These data are consistent with what I found during the individual interviews I conducted after the unit was completed. The hands-on activities were very effective in keeping students interested and motivated. I found that they really got kids talking to each other and asking questions. The discussions that followed each of the labs were helpful to me in gauging where students were in their learning, and what things we still needed to work on. The fact that students were constructing their own knowledge based on what occurred in the labs made it more meaningful to them.

III. Students Attitudes

The other goals of this unit were to increase communication about science related issues between students and their friends and families, and improve the students' overall attitudes about science in general. Once again, I surveyed all of my students before and after the unit (Appendix E). Students were required to respond to each question on a scale of one to four, with one being the lowest rating, and four being the highest. The results of this survey are summarized in Table 3 below.

Table 3. Survey of student attitudes

Question	Initial Score	Final Score	% Increase
Favorite Subject?	2.4	3.4	41.7
How Important	2.4	2.9	20.8
Discuss/friends	1.7	2.4	41.2
Discuss/family	2.1	2.8	33.3
Science Job?	2.5	3.2	28.0
Rate Yourself	2.6	3.0	15.4
Usefulness	2.6	3.3	26.9

The results of the survey show that my students' opinions about science improved, as did the amount of communication between students, friends and family concerning science related issues. The hands-on investigations and demonstrations were among the things that students discussed with family members and friends from other science classes. I was very pleased to see that the largest increase occurred on the question asking students to rate where science fits on their list of favorite subjects. I also requested that students write down any comments, suggestions or concerns about the unit as part of the final survey. Over 90% of their comments were positive. One of the students wrote, "I enjoyed asking questions because it took a long time and it led to new experiments." Another student wrote, "I thought I would have trouble understanding this science unit, but the way we had labs and discussions helped me out a lot."

DISCUSSION

I. What was Effective

The constructivist learning model was an effective way of instructing students. The fact that it requires teachers to gather information concerning students' misconceptions, is extremely helpful in structuring the lab activities and guiding class discussions. It is well worth the extra time and effort necessary to find out what your students already know, and what alternate conceptions they are bringing to the classroom. Another aspect of this unit that I found helpful was that I assessed students after each activity. In the past, I may have given one or two quizzes before the unit test. It is far more effective to do short, simple evaluations of student understanding more often. This can be as simple as having them answer a question in their journals at the beginning or end of class. I also found it helpful to walk around the room and listen to the groups discussing the results of a particular activity or answers to lab questions. By doing these things I was able to focus discussions towards those concepts that were presenting the most problems for students. The questions that I used on the pre and post test and the quizzes were effective in discovering whether or not students really understood the concepts. I used both multiple choice and constructed response questions and both types were useful in their unique ways.

The laboratory activities were an excellent way to keep students motivated and interested in the material. By giving students the opportunity to actually perform experiments and even design their own, I found that they learned a great deal more than they have in the past. I also enjoyed these lab activities because I was free to move around and share, or discuss, ideas with small groups of students at a time. These small group discussions were very effective in allowing me to address any misconceptions students had.

I felt that by giving students lab activities to try at home, I increased their level of communication with parents and friends concerning science. Students were excited the following day to share the things that they had tried or discovered the night before. This required extra time, but the results were well worth it.

The multimedia presentation that I created was effective in conveying information that students missed while absent. I was thinking that this type of multimedia approach could also be used as a form of remediation. In putting together this presentation I collected photographs, videos, and diagrams and imported them into my HyperStudio presentation. This was an extremely time consuming and frustrating process. I would like to have programs like this available to my students, but I am not the one to create them.

II. Changing the teaching of other units

As I speak with teachers from around the area, the term "constructivist learning" is coming up more and more. I personally plan to incorporate this instructional model in all of my science units. Although the science units that I have been using have been successful in the past, my standards for student achievement were not high enough. I want to include more in depth analyses of the topics we cover in our curriculum. This is going to mean that we have to adjust our curriculum to allow students the time and resources necessary to develop a deeper understanding of science. I also plan to assess my students continually throughout each unit. This is necessary to gauge where students are in the construction of ideas and concepts and how they are making the connections to every day life. One of the assessment tools that I plan to incorporate into all of my units is the use of a journal. I was surprised at the willingness of students to write their predictions, explanations, and conclusions in these journals. This was an excellent source of information for me to use to guide the next activity or discussion and I want to continue to use them.

III. Aspects of the unit that need improvement

Many of the lab activities need to be adjusted to allow for more student input. Many of the labs are still too "cookbook." I want students to feel free to ask questions and explore their ideas as often as possible. I want to include a cooling curve lab for a substance other than water. One of the concepts I was trying to convey in this unit was that not everything freezes at 0° C. Although we did melt and freeze different materials and found qualitative evidence of this concept, I still think students need quantitative results as well. It has been difficult to find a suitable material for use in a classroom with poor ventilation.

The lessons on condensation need to be improved. As I pointed out in the evaluation of the individual activities, students were not as comfortable with this concept as they were with the others. This stems from the fact that we cannot see vapors in the air. Students still want to say that air forms the drops of liquid on a cold container. This needs to be addressed in a way that allows them to challenge this idea and replace it with the scientific one.

IV. Conclusions

I have come to the conclusion that teaching is the toughest job in the world. The amount of materials and research available concerning education is overwhelming. It was disappointing to me that I have been teaching for eight years, and I was not familiar with the constructivist learning model. If we are going to be successful in educating our children in the next century, then we have to find ways to keep teachers abreast of the most current and effective teaching techniques available.

Before I began this project, I used to cover many concepts in a short period of time. If students are going to construct meaning and make connections to the world around them, then they must be given time to explore ideas in several different ways. To really understand the molecular structure of matter, students must be allowed to experience physical and chemical changes and be given time to discuss their ideas with peers and adults. It is important to assess student understanding of concepts often and in as many different ways as possible. Rather than telling students how things work or what is going to happen, let them try it for themselves.

Finally, I was very pleased with the overall success of this unit. At the same time I was amazed at the amount of work required in creating opportunities for students to become responsible for their learning. I would like to see more science textbooks employ the constructivist model in their programs.

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APPENDICES

APPENDIX A

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Appendix B

Pre and Post Tests

Pretest-Physical & Chemical Changes

Directions: Answer the following questions as completely as you can. You may use diagrams or pictures to help explain your answers. Remember that this is a pretest to see what you already know about physical and chemical changes. Do the best that you can, but remember that you will not be graded.

1. In the boxes below draw a model of what you think the molecules in a solid, liquid, and gas would look like.

solid	liquid	gas

2. Describe what happens to the molecules of something when it:

    a. Freezes:

    b. Melts:

    c. Evaporates:

    d. Condenses:

3. What do you have to do to a substance to get it to:

    a. Freeze?

    b. Melt?

    c. Evaporate?

    d. Condense?

4. Compare and contrast the molecules of water in the solid, liquid and gas states.

5. Water freezes at 0° C. What temperature is nearest to the temperature chocolate freezes at?
   A. 0° C. B. -10° C. C. 35° C. D. 100° C.

6. When gasoline is spilled on the ground it soon disappears. Where did it go? Explain your answer.

7. Your friend wears glasses and they fog up every time he or she comes inside during the winter. Explain why this happens using molecules in your answer.

8. Why don't your friends glasses fog up when he or she goes outside into the cold?

9. If a closed container of water is frozen, what will happen to the amount of water in the container?

A. The amount of water will increase
B. The amount of water will decrease
C. The amount of water will stay the same.
D. None of the above.

10. When ice melts, its molecules:

A. weigh less because the ice melts into a puddle.
B. weigh less because liquids weigh less than solids.
C. have the same weight but break apart from each other.
D. weigh more because the puddle is more dense that the ice.

11. A dehumidifier removes moisture from the air. Explain how this works using what you know about molecules and phase changes.

12. You are stranded on a desert island with no fresh water. Design a way you could turn ocean water into fresh water. Explain how your method works in terms of molecules. You may draw pictures if you like.

13. How could you separate a mixture of alcohol and water? Be specific.

14. List five everyday examples of phase changes (changes from solid to liquid to gas.)

15. When a substance freezes, the molecules:

A. get harder and colder.
B. slow down and stick together.
C. change from being soft and slushy into ice molecules.
D. All of the above.

16. You spilled a whole glass of water in your lap at lunch time. Give two things you could do to make it dry faster?

17. In a sample of pure water what is between the molecules?

A. Air B. Empty Space C. Ice D. Impurities

18. Pure water freezes at 0° C. At what temperature do you think salt water freezes at?

A. 0° C. B. -10° C. C. 5° C. D. All of these.

19. When you add vinegar to baking soda you get carbon dioxide gas, sodium acetate, and water. List the reactants and the products for this reaction.

Reactants	**Products**

20. In the reaction of vinegar and baking soda which would be greater, the total mass of the reactants or the total mass of the products? Explain your answer.

21. Classify the following changes as physical or chemical. Give a reason for each answer.

A. Breaking a glass:
B. A burning building:
C. Digesting a hamburger:
D. Dissolving sugar in your tea:
E. Fireworks exploding:
F. Melting ice cream:

Name:_____________ Date: ________ Hour: _______

Test-Physical & Chemical Changes

Directions: Answer the following questions as completely as you can. You may use diagrams or pictures to help explain your answers.

1. In the boxes below draw a model of what you think the molecules in a solid, liquid, and gas would look like.

solid	liquid	gas

2. Describe what happens to the molecules of something when it:

   a. Freezes:

   b. Melts:

   c. Evaporates:

   d. Condenses:

3. What do you have to do to a substance to get it to:

   a. Freeze?

   b. Melt?

   c. Evaporate?

   d. Condense?

4. Compare and contrast the molecules of water in the solid, liquid and gas states.

5. Water freezes at 0° C. What temperature is nearest to the temperature chocolate freezes at?

   A. 0° C. B. -10° C. C. 35° C. D. 100° C.

6. When gasoline is spilled on the ground it soon disappears. Where did it go? Explain your answer.

7. Your friend wears glasses and they fog up every time he or she comes inside during the winter. Explain why this happens using molecules in your answer.

8. Why don't your friends glasses fog up when he or she goes outside into the cold?

9. If a closed container of water is frozen, what will happen to the amount of water in the container?

A. The amount of water will increase
B. The amount of water will decrease
C. The amount of water will stay the same.
D. None of the above.

10. When ice melts, its molecules:

A. weigh less because the ice melts into a puddle.
B. weigh less because liquids weigh less than solids.
C. have the same weight but break apart from each other.
D. weigh more because the puddle is more dense that the ice.

11. A dehumidifier removes moisture from the air. Explain how this works using what you know about molecules and phase changes.

12. You are stranded on a desert island with no fresh water. Design a way you could turn ocean water into fresh water. Explain how your method works in terms of molecules. You may draw pictures if you like.

13. How could you separate a mixture of alcohol and water? Be specific.

14. List five everyday examples of phase changes (changes from solid to liquid to gas.)

15. When a substance freezes, the molecules:

A. get harder and colder.
B. slow down and stick together.
C. change from being soft and slushy into ice molecules.
D. All of the above.

16. You spilled a whole glass of water in your lap at lunch time. Give two things you could do to make it dry faster?

17. In a sample of pure water what is between the molecules?

A. Air B. Empty Space C. Ice D. Impurities

18. Pure water freezes at 0° C. At what temperature do you think salt water freezes at?

A. 0° C. B. -10° C. C. 5° C. D. All of these.

19. When you add vinegar to baking soda you get carbon dioxide gas, sodium acetate, and water. List the reactants and the products for this reaction.

Reactants	**Products**

20. In the reaction of vinegar and baking soda which would be greater, the total mass of the reactants or the total mass of the products? Explain your answer.

21. Classify the following changes as physical or chemical. Give a reason for each answer.

A. Breaking a glass:
B. A burning building:
C. Digesting a hamburger:
D. Dissolving sugar in your tea:
E. Fireworks exploding:
F. Melting ice cream:

Appendix C

Laboratory Quizzes

LAB QUIZ: Freezing & Melting

1. What is the freezing point of water?

   A. -10° C   B. 0° C   C. 3° C   D. 10° C

2. What is the melting point of ice?

   A. -10° C   B. 0° C   C. -1° C   D. 1° C

3. What temperature is closest to the temperature of the ice and salt mixture we used in the lab?

   A. -10° C   B. 0° C   C. 3° C   D. 10° C

4. To freeze a liquid you must

   A. Add Energy
   B. Remove Energy
   C. Neither add or remove energy

5. Draw a picture of the molecules in a solid and a liquid.

solid   liquid

Name: ____________________ Date: _______________ Hour: _______

LAB QUIZ: Freezing & Melting #2

1. What do you have to do to a substance in order for it to:

   A. Freeze:

   B. Melt:

2. Explain what happens to the molecules of a substance when it:

   A. Freezes:

   B. Melts:

3. Many people think that in order for something to freeze it has to be cold. What do you think?

4. Pick the temperature closest to the freezing point of gasoline.

   A. 100° C
   B. 50° C
   C. 0° C
   D. -50° C

Name: ____________________________ Date: ____________ Hour: ____________

LAB QUIZ: EVAPORATION AND VAPORIZATION

1. When a substance evaporates the molecules

   a. move slower and closer together
   b. break apart and move into the air
   c. break apart and disappear
   d. break apart and soak into the ground

2. You spilled a glass of pop all over the couch. Give two ways that you could get it to dry faster.

3. My nephew thinks that evaporation only happens when it is hot outside. Do you agree with him? Why or why not?

4. At what temperature will water evaporate?

   a. 50°C b. 25 °C c. 5 °C d. All of These

5. At what temperature does pure water vaporize?______________

6. What happens to the temperature of water as it vaporizes?

7. As water vaporizes, what is in the bubbles rising to the surface?

8. Compare and contrast evaporation and vaporization.

9. Draw a picture of the molecules in a solid, liquid and a gas.

Name: ______________________ Date: ________________ Hour: ____________

LAB QUIZ: CONDENSATION

1. Water vaporizes at 100 °C, what temperature does water condense at?

   a. 0 °C   b. 50 °C   c. 95 °C   d. 100 °C

2. In the winter time in Michigan water is present as

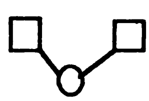
   a. Solid, liquid and gas
   b. Solid and liquid only
   c. Liquid and solid only
   d. Solid only

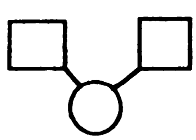
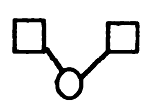
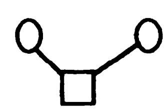
3. Eyeglasses "fog" up in the winter time when

   a. slow moving a i r molecules lose energy and condense on the cold surface
   b. fast moving a i r molecules gain energy and condense on the cold surface
   c. fast moving water molecules lose energy and condense on the cold surface
   d. slow moving water molecules gain energy and condense on the cold surface

4. In my basement I found two copper pipes side by side. I noticed that one of the pipes had liquid dripping all along it, but the other one did not. I quickly called the plumber to come and fix my leaky pipe. Was this a good idea? Why or why not?

5. Explain how you would separate a mixture of three liquids that boil at 50, 75 and 95 degrees Celsius. Be specific. You may draw a picture to help you explain your answer.

6. If this represents a molecule of ice,  which picture below best represents a molecule of water vapor?

a.  b.  c.  d. 

Appendix D

Labs, Activities & Demonstrations

Vocabulary: Physical & Chemical Changes

Condensation	Chemical Change	Chemical Reaction	Vaporization	
Physical Change	Evaporation	Freezing	Melting	Molecule
Reactants	Products	Sublimation	Phase Change	
Phases (States) of Matter	Dissolving	Law of Conservation of Mass		

Chemical Change: Occurs when a new substance is formed.

Chemical Reaction: Process that changes a substance(s) into another.

Condensation: Phase change from a gas to a liquid.

Dissolving: Occurs when the molecules of a solid occupy the spaces between the molecules of a liquid.

Evaporation: Phase change from liquid to gas, occurs at the surface.

Freezing: Phase change from a liquid to a solid.

Law of Conservation of Mass: Law that states that matter cannot be created or destroyed.

Melting: The change from solid to liquid state.

Molecule: Two or more atoms bonded together.

Phases (States) of Matter: Forms in which matter can exist: solid, liquid, gas and plasma.

Phase Change: Occurs when matter changes from one state to another because energy is added or removed. It is a physical change.

Physical Changes: Are changes in the physical appearance of a substance without changing the identity of the substance itself.

Products: The substance(s) formed during a chemical reaction.

Reactants: The substances that are being changed in a chemical reaction.

Sublimation: The change of a solid directly into a gas.

Vaporization: Phase change from a liquid to a gas throughout the liquid.

Part 1. Using the vocabulary words, fill in the blanks in the following passage.

Mr. Morris' class is beginning a new unit on physical and chemical changes. They will be performing several different experiments where they change the state or phase of a substance by adding or removing energy. These changes are called ____________________. All matter can exist as solids, liquids, gases or plasma. These forms of matter are called the _____ ____________________. There are examples of phase changes all around us. The candy coating on M&Ms stops the chocolate in them from ___________. This is the change from solid to liquid. Sometimes the chocolate has already melted and we need to cool it down to get it to _______________ back into a solid again. Have you ever noticed that when you spill water on the ground it soon disappears. This is an example of ______________ because the ________________ of water are leaving the **surface** of the puddle. Sometimes we want to heat a liquid up so that it changes into a gas all throughout the liquid. This is called __________________________. Another example of a phase change happens when you take a hot shower and the bathroom mirror becomes all fogged up. This is caused by water vapor cooling off and changing into a liquid on the mirror. This process is called __________________________. Have you ever noticed that even when the temperature outside is below freezing, snow still seems to disappear without melting. This is the process known as _______________________.

We will also be doing some experiments in which we change what a substance looks like, but not the substance itself. These types of changes are called ______________________. Whenever we add sugar to our ice tea the molecules of sugar are ________________________ in the liquid. This is an example of a physical change because the sugar is still there. (How do you know it's there?) ____________________________ on the other hand, occur when new substances are formed. We will have to be careful because Mr. Morris plans on demonstrating several different __________________ ______________. These reactions start with substances called ____________ and end up with new substances being made called the _________________. Whenever a chemical reaction takes place, we always end up with the same amount of matter that we started with. This is stated in the______________ __________________. The amount of matter also stays the same during phase changes as well. Good luck, I hope we survive!

Part 2: Magic Square
Put the number of the word from column I next to the appropriate letter in column II and in the square at the bottom of the page. If everything is correct, you should get the same sum down each column and across each row of the magic square.

Column I

1. Chemical Change
2. Sublimation
3. Products
4. Dissolving
5. Physical Change
6. Freezing
7. Law of Conservation of Mass
8. Molecules
9. Melting
10. Phases (States) of Matter
11. Phase Change
12. Evaporation
13. Reactants
14. Condensation
15. Chemical Reaction
16. Vaporization

MAGIC NUMBER = _______

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

Column II

____ A. Change from liquid to gas that happens throughout the liquid.

____ B. The change from solid to gas.

____ C. Substances formed during a chemical reaction

____ D. The substances that are being changed in a chemical reaction.

____ E. Changes in the appearance without changing the identity.

____ F. When matter changes from one state or phase to another.

____ G. Solid, liquid, gas and plasma are examples.

____ H. Two or more atoms bonded together, tiny particles of matter.

____ I. The change from solid to liquid.

____ J. States that matter cannot be created or destroyed.

____ K. Change from liquid to solid.

____ L. Change from liquid to gas that occurs on surface of the liquid.

____ M. Happens when a solid occupies space between molecules of a liquid.

____ N. Phase change from gas to a liquid.

____ O. Process that creates new substances.

____ P. Change in which new substances are made.

Part 3: Use each of the vocabulary words in a sentence. You can use more than one word in each.

1. ________________________________

2. ________________________________

3. ________________________________

4. ________________________________

5. ________________________________

6. ________________________________

7. ________________________________

8. ________________________________

9. ________________________________

10. ________________________________

11. ________________________________

12. ________________________________

Name:____________________ Date:______________ Hour:_________

Vocabulary Quiz: Physical & Chemical Changes

Directions: Match the word with the correct definition.

1. Molecules
2. Products
3. Sublimation
4. Dissolving
5. Physical Change
6. Melting
7. Law of Conservation of Mass
8. Chemical Change
9. Freezing
10. Phases (States) of Matter
11. Phase Change
12. Vaporization
13. Reactants
14. Condensation
15. Chemical Reaction
16. Evaporation

____ A. Change from liquid to gas that happens throughout the liquid.

____ B. The change from solid to gas.

____ C. Substances that are formed during a chemical reaction

____ D. The substances that are being changed in a chemical reaction.

____ E. Changes in the appearance without changing identity.

____ F. When matter changes from one state or phase to another.

____ G. Solid, liquid, gas and plasma

____ H. Two or more atoms bonded together tiny particles of matter.

____ I. The change from solid to liquid.

____ J. States that matter cannot be created or destroyed.

____ K. Change from liquid to solid

____ L. Change from liquid to gas that occurs at surface of the liquid.

____ M. Happens when a solid occupies the spaces in between molecules of a liquid.

____ N. Phase change from gas to a liquid

____ O. Process that creates new substances.

____ P. Change in which new substances are made.

Multiple Choice and Short Answer Questions

1. When water evaporates from Lake Michigan, does it go through any kind of change?

A. It goes through a physical change
B. It goes through a chemical change
C. It does not change since it is still water
D. It goes through a physical change then a chemical change

2. During January in Michigan, which states of water are in the environment

A. Solid only
B. Gas and liquid
C. Solid and liquid
D. Solid, liquid and gas

3. Ryan decided to use a chemical paint stripper to strip all of the paint off his bike. After a few weeks he noticed brown spots appearing on the bare metal. Ryan should conclude that a

A. Physical change has occurred because the metal has dissolved
B. Physical change has occurred because the metal changed color
C. Chemical change has occurred because a new substance was formed
D. Chemical change has occurred because the paint stripper contained chemicals

4. Which of the following is **not** an example of a chemical change?

A. Burning paper
B. Boiling water
C. Baking bread
D. Digesting food

5. When ice melts, its molecules:

A. will weigh less because ice melts into a puddle
B. will weigh less because liquids weigh less than solids
C. will weigh the same but break apart from each other
D. will weigh more because the puddle is more dense than the ice

6. Explain the difference between evaporation and vaporization.

7. When zinc and hydrochloric acid are combined together they react to form zinc chloride, hydrogen gas, and water. Please list the reactants and products in the spaces provided.

Reactants Products

What is the Difference Between Ice and Water?

1. Observe the samples of ice and water. Write down your descriptions of each in the space below.

2. What are some differences between ice and water that you observed?

3. What do you think is different about ice and water that causes these differences?

4. Do you think ice and water are made of the same materials? Explain your answer.

5. Draw a picture of what you think the molecules of ice and water look like.

Name: _______________ Date: _______ Hour: ________

FREEZING & MELTING POINTS OF WATER

SAFETY:

Wear your safety goggles at all times. If you spill any chemicals on your body wash right away with plenty of water and notify the teacher. Clean up any spills with plenty of water and notify the teacher. Be careful with all glassware, report any breakage to your teacher.

PURPOSE:

To observe water as it freezes and melts and create graphs of the temperatures of water as it changes from liquid to solid and from solid to liquid. To begin developing an explanation of what happens to molecules when a substance freezes or melts. To find the freezing & melting point of water.

INTRODUCTION:

Remember from our class discussions that the two main differences between ice and water were that ice is cold and hard while water is warmer and can flow. We also reasoned that ice and water had to be made of the same kind of molecules because ice melts into water and water freezes into ice. In this lab you will look closely at what happens when water begins to freeze and observe the temperature before, during, and after the water freezes completely. As you are performing this activity, try to develop a model of what is happening to the molecules of water as it turns to ice.

MATERIALS:

Safety Goggles	Water	Stirring Rod
Styrofoam Cup	Ice	
Graduated Cylinder	Salt	
250 mL Beaker	Thermometer	
Test Tube & Rack	Graph Paper	

PROCEDURES:

Record all of your results and answers in the OBSERVATIONS section.

PART I: FREEZING POINT OF WATER

_____1. Fill the styrofoam cup 2/3 full with ice and add 2 scoops of salt. Mix thoroughly and place the styrofoam cup in the beaker for support.

_____2. Measure 5 mL of water in the graduated cylinder and pour into the test tube.

_____3. Measure the temperature of the water in the test tube and record in the data table provided. Note the time and immediately place the test tube of water into the ice and salt mixture. Make sure that the water in the test tube is below the top of the ice and salt mixture.

_____4. Measure the temperature of the water every minute and observe the water in the test tube. **ONCE THE WATER BEGINS TO FREEZE, DO NOT PUT ANY PRESSURE ON THE THERMOMETER OR IT WILL BREAK!!!!!!!!!**

_____5. Make sure to mark the times when the water begins to freeze and when it becomes completely frozen. You may need to stir the ice and salt mixture by using the test tube. **BE CAREFUL OF THE THERMOMETER!!!!**

_____6. Continue recording the temperature for 5 minutes after the water has completely frozen. Remove the test tube with the themometer still in the frozen water and place it in the test tube rack.

PART II: MELTING POINT OF ICE

_____1. Record the temperature of the ice in the second data table and note the time.

_____2. Take turns holding the test tube in the palms of your hands and record the temperature of the water in the test tube every minute. Make sure to mark the times when the ice first begins to melt and when it has completely melted.

_____3. Continue recording the temperature of the water for 2-3 minutes after it has completely melted.

_____4. Return all materials to the proper areas and clean up your work space.

DATA AND OBSERVATIONS:

Time (min.)													
Temp. (°C)													

Time (min.)													
Temp. (°C)													

1. Graph the information from the data tables above on the same piece of graph paper. Use a different color for each set of points.

2. At what temperature did the water first start to freeze at? __________

3. What happened to the temperature of the water as it was freezing?

____

4. What happened to the ice in the styrofoam cup as the water in the test tube was freezing?

____

5. What happened to the temperature of the water in the test tube after it had completely frozen solid?______________________________________

6. What happened to the ice in the test tube while you were holding it in

your hand? ______________________ How did your hand feel?_________

7. What happened to the temperature of the ice as it was melting in the test tube?

____

CONCLUSIONS:

1. What do you have to do to a liquid in order to get it to freeze?

____

2. What do you think is happening to the water molecules as the water

freezes?____

3. What do you have to do to a solid in order to get it to melt?_________

____

4. What do you think is happening to the water molecules as the ice was

melting? ____

5. What is the freezing point of water? What is the melting point of ice?

6. Draw a picture of what the molecules of pure water would look like as a liquid and as a solid.

solid

liquid

How Much Water is There?

My eight year old nephew noticed that when he put a container of water in the freezer that after it froze, the level of ice was higher than the level of water that he started with. He concluded that there must be more water after it freezes than before, when it was a liquid. He backed up his claim by saying that ice cubes are always higher than the level of water in the ice cube trays before they freeze.

1. Do you agree with what my nephew is saying? Why or why not?

2. What does the law of conservation of mass tell us?

3. Write an explanation to my nephew about why the amount of water should be the same before and after freezing.

4. My nephew always wants to be shown how things work. Design an experiment that will prove your explanation to him. Make sure that you include step by step instructions that my nephew can follow.

Name: ________________ Date: _______ Hour: ________

MELTING POINTS OF OTHER SUBSTANCES

SAFETY:

Wear your safety goggles at all times. If you spill any chemicals on your body wash right away with water and notify the teacher. Clean up any spills with plenty of water and notify the teacher. Keep desk clear of any books and papers while using candles.

PURPOSE:

In this activity you will observe different substances as they melt and compare the temperatures that they melt at.

MATERIALS:

Large tin can lid
Tongs
Candle and matches
Wooden splint
Paper towel
Substances to test:
Chocolate Chip
Small piece of wax
Salt
Sugar
Sulfur
Soldering wire

Procedures:

1. Place a small amount of each substance around the outer edge of the metal lid.

2. Predict the order in which you think the substances will melt.

1. _______ 2. ________ 3. ________ 4. ________ 5. _______ 6. ________

3. Place the candle on the index card and light the candle.

4. Holding the lid with the tongs, heat the center of the lid by holding it directly over the candle flame.

5. Observe the substances carefully and record the order in which they melt.

1. ________ 2. ________ 3. _______ 4. ________ 5. ________ 6. ________

6. When you have heated the metal lid for at least 10 minutes blow out the candle and carefully set the lid down on the desk.

7. Observe the substances as they cool. Record the order in which the substances freeze.

1. ________ 2. ________ 3. ________ 4. ________ 5. _________ 6. _______

8. With the wooden splint carefully scrap the substances from the metal lid onto the paper towel and discard in the container provided. Return the rest of the materials to the proper locations.

Observations and Conclusions:

1. How did your predictions compare with the actual results? ___________

____

2. Did all of the substances melt? __________ If not, which ones did not

melt? __________________

3. What do you think is happening to the molecules of these substances as

they melt?____

4. Why do you think that these substances melt at different temperatures?

____

5. Many people think that all things melt at the same temperature that ice

melts at. How do we know that this cannot be true? ____________________

6. We know that ice melts at 0° C. What temperature is nearest to the temperature chocolate melts at?

A. 0° C B. -10° C C. 35° C D. 100° C

7. We know that water freezes at 0° C. What temperature is nearest the temperature that wax freezes at?

A. 0° C B. -10° C C. 50° C D. 100° C

8. What do you have to do to a substance in order to get it to melt? _____

Try This at Home

Question: Do all substances freeze at the same temperature?

Procedures:

1. Gather several liquids from around the house. Make sure that you do not use anything that is toxic. Items that could be used are; milk, juice, water, rubbing alcohol, hydrogen peroxide, salt water (dissolve table salt in water), sugar water, etc.

2. Find a container that can hold several different liquids such as an old ice cube tray, an empty styrofoam egg carton, or several small dixie cups.

3. Fill each container with the same amounts of the different liquids and place in the freezer. Make a prediction about the order you think the liquids will freeze in. Are there any liquids you think will not freeze?

Predictions:

4. Check the containers every 15 - 30 minutes for 2-3 hours to see which, if any, of the liquids have frozen.

5. Record the order in which the liquids freeze. Note any liquids that do not freeze.

6. Compare the results with your predictions. Were you surprised about any of the results?

7. Many people think that all things "freeze" at 32° F or 0° C like water does. Do you agree with them? Why or why not?

Name: __________________ Date: _______ Hour: ________

A Tasty Phase Change

PURPOSE:

To explore the phase changes involved in making ice cream

MATERIALS:

Ice cream mixture:
- 4-beaten eggs (optional)
- 2 cups sugar
- 4 cups half and half
- 2 teaspoons vanilla
- 1/2 teaspoon salt
- Whole milk

Ice and Salt
small and large re-sealable bags

PROCEDURES:

1. Place the eggs, sugar, half and half, vanilla and salt in a gallon milk jug and fill to the top with whole milk. Shake well.

2. Fill your large re-sealable bag approximately half full with ice. Add 1/4 cup of salt to the ice.

3. Obtain from the teacher a small bag filled with 3/4 cup ice cream mixture. Seal the bag and place it in the large bag with the ice and salt and then seal the large bag also.

4. Take turns in your group squeezing and kneading the bag so that the ice cream mixture comes in contact with the ice and salt.

OBSERVATIONS:

1. What is happening to the ice in the large bag? ________________

2. How long do you think it will take the ice cream to freeze? _____

3. What is happening to the molecules in the ice cream mixture as you

kneed the bag? ____

4. What purpose does the salt in the large bag serve? ____________

____

5. Explain what is happening in terms of energy to both the ice and

salt mixture and the ice cream mixture. _______________________

____

6. When the ice cream has completely frozen remove the small bag and dump the ice and salt mixture in the container provided. Then enjoy!

Name: ________________ Date: _______ Hour: ________

Vaporization of Water

SAFETY:

Wear your safety goggles at all times. If you spill any chemicals on your body wash right away with water and notify the teacher. Clean up any spills with plenty of water and notify the teacher.

PURPOSE:

To explore the vaporization of water and recognize heating curves and phase changes. To compare vaporization to evaporation.

MATERIALS:

Bunsen burner	ring stand	beaker tongs
matches	250 mL beaker	wire gauze
water	thermometer	themometer clamp
graph paper		

PROCEDURES:

1. Set up the apparatus like the one on the instructor's desk.

2. Pour 150 mL of water in the beaker and place on the wire gauze.

3. Record the starting temperature and begin heating the water. Record the temperature every minute until the water begins to boil.

4. Continue recording the temperature for 5 - 10 more minutes.

5. Shut off the gas and allow the equipment to cool down. Plot the time vs. temperature on the graph paper. Put the equipment in the proper location.

OBSERVATIONS:

1. What happened to the temperature as heat energy was added to the

water? ____

2. What happened to the temperature as the water was vaporizing? ______

____

3. Describe the graph you made of the time and temperature. __________

____

CONCLUSIONS:

1. At what temperature does water vaporize? _______________

2. If energy was still being added while the water was boiling, why did the temperaure remain the same? ______________________________

3. What do you have to do to get a substance to vaporize? ____________

4. What is in the bubbles rising in the water as it vaporized? __________

5. Draw a picture of the molecules in a solid, liquid, and gas.

6. How are evaporation and vaporization the same? _______________

____

How are they different? ____

____

7. Explain what is happening to the molecules during vaporization.______

____

Name: ____________________ Date: _______ Hour: ________

Reclaiming a Solid

SAFETY:

Wear your safety goggles at all times. If you spill any chemicals on your body wash right away with water and notify the teacher. Clean up any spills with plenty of water and notify the teacher. Observe all fire safety rules.

PURPOSE:

To use filtering and vaporization to separate a mixture of salt and sand into there component parts.

MATERIALS:

Bunsen burners	ring stand	beaker tongs
matches	2-100 mL beaker	evaporating dish
water	funnel	filter paper
graduated cylinder	stirring rod	small iron ring
safety goggles	sand/salt mixture	

PROCEDURES:

1. Obtain a sample of the salt and sand mixture from the teacher.

2. Add 25 mL of water to the mixture in a beaker and stir.

3. Fold a piece of filter paper as instructed by your teacher. Wet the sides of the funnel and place the filter paper in the funnel. Place the funnel in the iron ring on the ring stand so that the tip of the funnel barely touches the inside edge of the empty beaker beneath it.

4. Slowly pour the mixture of salt, sand and water into the funnel. Allow enough time for the water to flow through the filter paper into the beaker.

5. Carefully remove the filter paper and throw it in the trash.

6. Pour the remaining liquid in the evaporating dish and place the dish on the iron ring. Light the Bunsen burner and begin heating the contents of the dish. When the remaining solid in the dish begins to splatter, turn off the heat.

OBSERVATIONS & CONCLUSIONS:

1. When all of the water has vaporized, what do you see in the dish?

____

2. What is the probable identity of the substance in the dish? ______

3. Do you think that you could separate a mixture of salt and sugar in this manner? Why or Why not? ________________________

____

4. Could you separate two liquids this way? ______________

____

Where Did the Water Come From?

In this activity we will try and prove to my nephew that the water on the outside of a pop can did not mysteriously appear by leaking through the can. While performing this experiment, try to keep in mind what the molecules are doing and be prepared to explain the results to my inquisitive nephew.

1. Take one of the cans and fill it 2/3 full with ice and water. Dry off the outside of the can and put the lid on.

*Why did we dry off the outside of the can?

*Why did we put the lid on the container?

*After a few minutes what do you notice about the outside of the can?

*Where do you think this moisture came from?

*Why did it form on the outside of the can?

My nephew still would say that the water leaked through tiny holes in the can just like sweat come through pores in our skin. What do you suggest we do to show him that the cans do not leak?

2. Take the second can and have the teacher fill it with hot water. Dry off the outside of the can and put the lid on.

*Where do you see the moisture now?

*How do we know that water is not leaking through the can with the ice water in it?

*Where is the new moisture coming from and how is it getting there?

*Give a scientific explanation using what you know about molecules and energy to describe what is happening with both cans of water.

*In your group think of as many different examples of "fog" or water appearing on different things like the water on the bathroom mirror after a hot shower.

Name: ___________________ Date: _______ Hour: ________

Fractional Distillation

SAFETY:

Wear your safety goggles at all times. If you spill any chemicals on your body wash right away with water and notify the teacher. Clean up any spills with plenty of water and notify the teacher. Fire safety rules apply.

PURPOSE:

To separate a mixture of three liquids with different boiling points.

MATERIALS:

Bunsen burner	ring stand	3 large test tubes
matches	400 mL beaker	Crushed ice
water	thermometer	2 hole stopper
graph paper	glass elbow	test tube clamp
test tube rack	rubber tubing	isopropyl alcohol
ethylene glycol		

PROCEDURES:

1. Set up the apparatus as shown on the teacher's desk. Obtain a sample of the mixture from the teacher and add 2-3 boiling chips to the test tube before putting in the stopper.

2. Light the Bunsen burner and **SLOWLY** heat the mixture in the test tube. Try not to let the material boil too rapidly. If some of the mixture boils through the rubber tubing, then turn off the burner, return all liquids to the original test tube and begin again. Record the temperature of the vapors every minute in a data table.

3. When the temperature levels off, you should see the first liquid collecting in the tube in the beaker of ice. Mark this temperature on the data table. **CAUTION:** Do not let the rubber tubing touch the liquid collecting in the tube.

4. When the temperature begins rising again, switch the test tube and place it in the rack.

5. When the temperature levels off again you should see the second liquid condensing in the tube. Mark this temperature on you data table. When the temperature begins to rise again, turn off the heat. Allow the apparatus to cool before taking it apart.

6. Make a graph of temperature vs. time from your data table.

OBSERVATIONS & CONCLUSIONS:

1. At what temperature did the first liquid begin to collect in the tube?

____

2. At what temperature did the second liquid Begin to collect in the second tube? _______________

3. Carefully smell the two liquid and describe the odors.

____

4. Describe all three remaining liquids. _______________

____

5. Can you identify the three fractions? _______________

6. Were you able to get pure samples of the three liquids in this activity? Explain. _______________

____

7. Can you think of any circumstances in which this type of separation might be more difficult to do? _______________

____

8. How do you know if this was a physical change or a chemical change?

____

____

Name: ____________________ Date: ______________ Hour: __________

Take-Home Quiz

You have been hired by an engineering firm to design a machine to solve one of the problems listed below. Your solution should include a picture of the machine you designed and an explanation of how it works. This explanation must include details on how molecules are behaving and how energy is being used.

1. How could you stop pipes in the basement from "sweating?"

2. How could you keep your drink container from getting wet on the outside on a hot Summer day?

3. How could you keep your toilet tank from getting all wet?

4. How could you keep moisture from collecting on your car windows during the night?

5. How could we keep the classroom from getting too dry in the winter?

6. Solve a problem of your own that involves adding or removing moisture from something.

Name: __________________ Date: _______ Hour: ________

Recognizing Chemical Changes

SAFETY:

Wear your safety goggles at all times. Keep all flammable materials away from the candle flame. If you spill any chemicals on your body wash right away with water and notify the teacher. Clean up any spills with plenty of water and notify the teacher.

PURPOSE:

To explore physical and chemical changes and to recognize the difference between these two types of changes.

MATERIALS:

2 wood splints
Candle
Metal spoon
Small pieces of wax
Metal jar lid
Matches
Safety goggles

PROCEDURES:

1. Take one of the wood splints and break it in half. Continue breaking it in half until you get the smallest pieces possible. Place these pieces in the metal jar lid.

Was this a physical change or a chemical change? ____________________

How do you know? ____________________

2. Place two or three small pieces of wax in the bowl of the spoon. Light the candle and hold the spoon over the flame.

What happens to the wax in the spoon? ____________________

Was this a physical or chemical change? ____________________

How do you know? ____________________

3. Remove the spoon from the flame and let it cool.

What happens to the wax in the spoon? ____________________

Is this a physical or chemical change? ____________________

4. Observe the candle as it is burning. Is this a physical or chemical change? Explain? ______

5. Light the other wood splint with the candle flame and then use the burning splint to light the pieces of wood in the jar lid.

What happens to the pieces of wood in the lid? ______

Is the material in the lid still wood? ______

Was this a physical or chemical change? Why? ______

______

6. Clean out the jar lid and the metal spoon and return materials to the proper location.

CONCLUSIONS:

1. Explain to my nephew how you tell the difference between a physical and chemical change.

______

______

______

2. List 5 physical changes that occur in your life outside of school.

______

3. List 5 chemical changes that occur in your life outside of school.

______

Name: ____________________ Date: ________ Hour: _________

Thermal Expansion Lab

PURPOSE:

To explore what happens to molecules as energy is added.

MATERIALS:

Cold Glass Pop Bottle
Penny
Beaker with Water

PROCEDURES:

1. Obtain the materials listed above. The teacher will give your group a pop bottle after you have picked up the other materials.

2. Wet the penny and place it on the top of the bottle. Make sure that it is directly over the opening and a good seal of water is around the penny. You can drip water around the penny if necessary.

3. Have one student place his or her hand on the bottle. What Happens? Keep adding hands to the bottle and observe what happens.

OBSERVATIONS & CONCLUSIONS

1. What happened to the penny as the bottle warmed up?

2. What do you think caused the penny to do this? Be Specific.

3. Describe what is happening in terms of molecules and energy.

4. Draw a picture of the bottle before and after you warmed it up. Be sure to include the molecules of air inside the bottle and show what they are doing.

5. What do you think would happen if we put a balloon on top of a cold pop bottle? Explain.

6. Can you make a prediction on how I got the balloon inside the flask?

7. Tonight I would like you to design and conduct an experiment to see if temperature has any effect on the size of a balloon. Make sure to write down your procedures step by step and include your results. If you need a balloon, let me know. Have Fun!!!!!!!!!!!!!!!!

Name: ___________________ Date: _______ Hour: ________

Exploring Chemical Changes

PURPOSE:

To explore some simple chemical changes and develop a list of characteristics. To identify the reactants and products of a reaction.

MATERIALS:

Vinegar	baking soda	250 mL Beaker
3M HCl	Marble Chips	Petri Dish
Steel Wool	100 mL Beaker	Paper Towel
Salt	2 wire leads	2 pencil leads
6 Volt Battery	water	

PROCEDURES:

In this activity we explored four different chemical changes. I talked the students through the steps together. They recorded observations, predictions, reactants and products in their journals.

1. Vinegar + Baking Soda (in 250 mL Beaker)
2. HCl + Marble Chips (in petri dish)
3. Rusting Iron (wash steel wool in vinegar, dry and set out on towel.)
4. Hydrolysis of water (in petri dish. Hook wire leads to battery and pencil leads. Place pencil leads in dish of salt water.)

We discussed each of these reactions and developed a list of clues to help us identify chemical changes. We also listed the reactants and products for each reaction.

Tomorrow we will observe several chemical changes and identify reactants and products.

Chemical Change Demonstrations

Here is a list of demonstrations designed to entertain and excite students about chemical changes. I have students list or describe the reactants and products as we go through the demos.

1. Vinegar and baking soda
2. Pour carbon dioxide on a burning candle
3. HCl + Zinc
4. Fill pringles can with hydrogen and ignite
5. Methanol in 5 gallon water bottle, ignite
6. Potassium permanganate and glycerin
7. Genie in a Bottle- Manganese Dioxide + 30% Hydrogen Peroxide
8. Hydrolysis of Water. Notice the different volumes of gases
9. Test for hydrogen and oxygen
10. Sodium in water
11. Potassium in Water
12. Sulfuric Acid in sugar
13. Soap Bubbles filled with burner gas. Ignite
14. Steel wool on 9 volt battery. Mass before and after
15. Elephant toothpaste (Flinn Scientific)
16. Several examples from laserdisc, Windows on Science
17. Different types of hand warmers (physical and chemical)

Appendix E

Student Surveys

The following questions are about the last unit on physical and chemical changes. Please answer them as completely and honestly as you can.

1. On a scale of 1 to 5, with 1 being the least helpful and 5 being the most helpful, please rate the following on how well they helped you learn the material.

Vocabulary Assignment ______

Journal Entries ______

Demonstrations ______

Hands on Lab Activities ______

Class Discussions

Group Discussions ______

Laserdisc Videos ______

Take home labs ______

Alternative Assessments ______

2. On a scale of 1 to 5, with 1 being the least enjoyable and 5 being the most enjoyable, please rate the following as to how well you enjoyed them.

Vocabulary Assignment ______

Journal Entries ______

Demonstrations ______

Hands on Lab Activities ______

Class Discussions ______

Group Discussions ______

Laserdisc Videos ______

Take home labs ______

Alternative Assessments ______

3. Overall, how well do you think you understand physical and chemical changes now that you have completed this unit?

4. Please give any thoughts, opinions, comments, suggestions or concerns that you may have concerning the past 6 weeks of instruction about physical and chemical changes. Be sure to include the things that you liked the best and the things you liked the least and why. Be honest and constuctive in your remarks.

Student Survey-General Science

Please answer the following questions as accurately as possible. This survey will be done anonymously. Please do not put your name on this paper.

1. Where does science fit on your list of favorite subjects?

1	2	3	4
least favorite			most favorite

2. How important is science in your life outside of school?

1	2	3	4
not at all	a little	important	very important

3. How often do you discuss science topics with your friends?

1	2	3	4
never	monthly	weekly	daily

4. How often do you discuss science topics with your family?

1	2	3	4
never	monthly	weekly	daily

5. Would you like to work in a science related job someday?

1	2	3	4
never	not likely	possibly	absolutely

6. How good are you in science?

1	2	3	4
below average	average	above average	excellent

7. How much of what you learn in science class do you actually use?

1	2	3	4
none	25%	50%	more than 75%

Appendix F

Sample Meap Questions

1. When water evaporates from the surface of Lake Michigan, does it go through any kind of change?

43% A. It goes through a physical change.
15% B. It goes through a chemical change.
9% C. It does not change since it is still water.
33% D. It goes through a physical change and then chemical change.

2. Constructed response questions were a major problem (6 questions)

0 pts.-34% 1pt.-44% 2 pts.-21% 3 pts.-1%

3. During January in Michigan, which forms of water are in the environment?

04% A. solid only
05% B. gas and liquid
21% C. solid and liquid
70% D. gas, liquid, and solid

4. Classify the four substances listed below as either reactants or products of the reaction that takes place while a candle burns.

carbon dioxide	water vapor
oxygen	candle wax

69% received 0 pts. 14% received 1 pt. 16% received 2 pts. 0% received 3 pts.

5. Which best describes the motions and arrangement of molecules when a liquid turns into a gas?

18% A. fixed vibration with molecules farther apart

56% B. random motion with molecules farther apart

13% C. fixed vibration with molecules closer together

13% D. random motion with molecules closer together

6. Ryan decided to use a chemical paint stripper to strip all the paint off his bike. After a few weeks he noticed brown spots appearing on the bare metal. Ryan should conclude that a:

12% A. physical change occurred because the metal dissolved

12% B. physical change occurred because the metal changed color

45% C. chemical change occurred because a new substance was formed

31% D. chemical change occurred because the paint stripper contained chemicals

7. A drinking glass contains ice water. Liquid has collected on the outside of the glass. What is the BEST explanation of how liquid is formed?

35% A. Water molecules from the air slowed down as they hit the cold glass and stuck together to form a liquid

26% B. Water molecules from the glass escaped into the air and slowed down as they hit the cold glass and stuck together to form a liquid

10% C. Water molecules in the ice water shrank, then traveled through the glass to the outside surface

29% D. Air molecules turned to liquid on the surface