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A CONSTRUCTIVIST APPROACH TO TEACHING A 7TH GRADE MATTER UNIT

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ABSTRACT

A CONSTRUCTIVIST APPROACH TO TEACHING A 7TH GRADE MATTER UNIT

By

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This research project studied the effectiveness of a 7th grade matter unit. The activities and materials in the unit incorporated a constructivist approach – students had many hands-on activities and constructed meaning from these experiences. The objectives of the unit were: 1. Describing and classifying matter and 2. Describing physical and chemical changes. The effectiveness of the unit was evaluated using imbedded assessments and a pre/post test.

Overall the unit was effective. There were many lessons learned which are discussed. These lessons are the basis for further revising the unit. The constructivist approach was successful.

To my wife for her love and patience, and to Jesus who has begun a good work in me.

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Introduction

Why does a massive metal object, a ship for instance, not sink in water when a paper clip does? What is the difference between weight and mass? Does water disappear when it evaporates? What causes combustion or explosions? What causes the "sweat" on the outside of a cold drink in the summer? My seventh grade students were having trouble providing clear, scientific explanation to these and other related questions. Yet these are reasonable questions that a curious mind might ask. The answers to these questions are required knowledge in the Michigan science content standards and benchmarks. The primary reason I chose this unit for development and analysis was to help my students better understand the difficult concepts of matter and energy and changes in matter. Another reason is that the students had been disruptive and disinterested the previous year – evidently not enjoying science. I enjoy science and understanding the world around me, but my students considered it boring. I wanted my students to enjoy studying about even these abstract concepts and realize that science is an interesting field, perhaps even a career field. In summary, the students were not "getting it" and not having fun, so I decided to improve the unit on matter.

The development of this unit was a shift in emphasis in my teaching style. The previous year had been my first year teaching seventh grade science after three years at the high school level. I was new to the material and age level; hence my teaching relied heavily on a textbook. I did a lot of lecturing and student activities were likely to be filling in worksheets. There was limited hands-on science – the experiments that we did were not well connected to the content objectives. In addition, the labs were more for confirmation than exploration of a topic. We would discuss the expected results and then perform a lab to allow students to confirm the class discussion. The math that we used before this new unit was more the "plug and chug" style: just divide the two numbers and get the result. I did not dwell on why the formula gave us a useful number or where the dimensional units came from.

To solve this problem I completely redesigned the matter unit. My hypothesis was that using a constructivist approach would make an effective unit, that is one in which students would understand the key concepts with greater interest. Hence I designed the new unit around this theory, which describes the central role that learners' ever-transforming mental schemes play in their cognitive growth (Brooks and Brooks, 1999). Philosopher D.C. Phillips (1995) identified three distinct roles in the constructivist classroom. The first role is the active learner: knowledge and understanding are actively acquired. Students are not passive receptors of knowledge. Instead they construct knowledge by observing, handling, hypothesizing, and investigating. This is the hands-on component of a constructivist classroom. The next role is that of social learner: knowledge and understanding are socially constructed. Rarely do we construct meaning individually. More often we co-construct meaning. This is the social component of a constructivist classroom. This would require activities in which students worked in pairs, groups of four, and larger groups, including the entire class. This would also require arranging the chairs in groups, instead of rows and columns as I had in the past. Students need to discuss newly constructed meanings in a social environment. The third role is that of creative learner: knowledge and understanding are created or recreated. This is the discovery component of a constructivist classroom. Lowery calls this rehearsal: something new that the brain can assimilate into its prior constructions, thus enriching and extending those constructions (1998). Experience alone is not enough. Levy reports that we do not learn from experience; we learn from reflecting on experience (1999). Students need the opportunity to reflect and construct meaning, and sometimes to rediscover what could easily have been told. It's often been said, "You don't need to rediscover the wheel." But when you do, you gain a much richer appreciation for the benefits and uniqueness of the wheel.

The benefits of using a constructivist approach have been widely documented. The U.S. Department of Education and the National Science Foundation (1992) endorsed curricula that promote active learning, inquiry, problem solving, cooperative learning, and other instructional constructivist methods that motivate students. Rutherford and Ahlgren report that students need to have many and varied opportunities for collecting, sorting and cataloging; observing, note taking and sketching; interviewing, polling, and surveying (1990). Project 2061, a comprehensive effort of the American Association for the Advancement of Science (AAAS) to reshape science, mathematics, and technology education in America, advocates a balanced constructivist approach. At the middle school level, students need to become more systematic and sophisticated in conducting investigations. Further, student investigations ought to constitute a significant part – but only a part – of the total science experience (1993).

Another strength of the constructivist approach is its use of multiple learning styles. In the old unit (described above), students learned primarily through reading and hearing. This engaged visual and auditory learners. But effective teaching usually combines several approaches so the child uses more than one sense at a time while learning (Setley, 1995). Constructivism, with its activity-based learning emphasis, appeals to tactile/kinesthetic learners while still serving the auditory and visual learners. Tactile/kinesthetic learners are students who learn best through actively exploring the physical world around them and may be distracted by their need for activity and exploration (Bogod, 2002). Sandra Rief, whose work includes ADD/ADHD students, has found that students retain 10-20% of what they read or hear. However when information takes other paths (seeing, saying, and doing) into the brain, retention improves. She reports a 90% retention rate for information that students say and do. A constructivist unit should be effective because it appeals to multiple learning styles.

Another component of the constructivist model is the use of inquiry. Inquiry is tickling a student's curiosity and then providing an opportunity for the student to scratch the tickle. Since students construct their own meaning, then certainly learners control their own learning (Brooks & Brooks, 1999). Students must be willing to be active learners. How then do we motivate the student into the role of active learner? Discrepant events tickle the curiosity. Liem describes the discrepant event as surprising, counter-intuitive, unexpected, paradoxical, mind capturing, and intuition-offending (1987). Piaget says the state of perplexity and doubt is a necessary first step in learning (1974). To learn, a person's existing conceptions of the world must be unreliable, unviable. When this happens we create new meaning based on our experiences and the help of those around us (Lorsbach and Tobin, 1997). Festinger explains that the discrepant event produces a mental dissonance, which is psychologically uncomfortable. This motivates the person to try to reduce the dissonance and achieve consonance (1957). This motivates the active learning and cooperative learning components of the constructivist classroom – the learning that takes place is scratching the tickle. Haury comments that inquiry-oriented teaching engages students in investigations to satisfy curiosities. Curiosities are satisfied when individuals have constructed mental frameworks that adequately explain their experiences (1993). Inquiry-based programs at the middle school grades have been found to generally enhance student performance, particularly as it relates to laboratory skills and skills of graphing and interpreting data (Mattheis and Nakayama, 1988).

A final benefit of constructivism theory is the natural connections that are produced. As students construct meaning they make connections to other disciplines and past experiences. One broad connection is between science and math. Integrating these disciplines makes the instruction in both more effective. Indeed, Project 2061 of the American Association of the Advancement of Science (AAAS) recommends that core studies should include connections among science, mathematics, and technology (1993 pXII). Using a constructivist approach would also include making connections with past experiences such as why basketballs are flat on a cold day and why hot air balloons rise. These connections improve student recall and understanding. Levy states that experience forms the vessel for the concept to fill. Connecting concept to experience is at the heart of understanding (1999). Basing this unit on constructivist theory should produce an effective unit.

I used numerous resources to put together this unit. The most useful reference was Invitations to Science Inquiry by Tik L. Liem. The book contains several hundred demonstrations. The procedures are written in such a way to arouse curiosity, hence the title. He also lists several thought-provoking questions for each demonstration. The book was published and revised in the 1980's. Thus some of the chemical usage and precautions are not current. For example, his density column uses gasoline, carbon tetrachloride, and mercury. Another useful resource was the Battle Creek Area Mathematics and Science Center unit Matter Matters (1999). This unit is geared to the Michigan content standards and is activity based. Despite the fact that it is a fifth grade unit, I used or modified several activities from this book. I also used the science book, Matter: Building Block of the Universe (Maton, 1993). It targets an older audience, but contained some ideas for activities and demonstrations. I used some of the activities and materials that Sheldon Knoespel uses in his Division of Science and Math Education middle school science class at Michigan State University (2000). I also examined a unit developed at University of California at Berkeley called Discovering Density (Barber 1988). And certainly I used the web to get ideas and inspiration for new angles on teaching my objectives through questions and activities. Another resource that I used was the web site "Hands on technology" (Candelora, 2000).

Scientific background and common misconceptions. The first part of the unit is on measurement. Mass measures the amount of matter in an object; it is measured in kilograms or grams. Weight is the force of gravity acting on an object; it is measured in Newtons. Volume is the amount of space an object takes up; it is measured in milliliters or cubic centimeters. Meters, which measure distance, can be used to measure area (m^2 or cm^2) as well as volume (m^3 or cm^3). Density is the measure of how much mass is contained in a given volume; we used the units of g/mL or g/cm^3. The mathematical relationship between mass, volume, and density is: Density = Mass/Volume. Some common misconceptions of middle school students: gasses do not have mass or volume; weight and mass are the same; bigger objects are more dense; mass and volume are the same property because they both describe an amount of matter; and objects sink or rise because of their weight rather than their density (Battle Creek Math and Science Center, 1999).

Atoms are the basic building blocks of matter. There are over 100 known families of chemically similar atoms – called elements. Atoms can be divided, but they are the smallest particle of an element that still has all the properties of that element. Atoms are made of protons, neutrons, and electrons, but are mostly empty space. Atoms link together (bond) to form molecules. If the molecule has atoms that are all the same, the molecule itself is classified as an element. If the molecule contains two or more different kinds of atoms, it is classified as a compound. When different atoms or molecules are mixed without bonding, this is classified as a mixture. Some common examples are copper (element), water (compound), and air (mixture). Some common misconceptions: substances that dissolve in water disappear – the substance no longer exists, and atoms are solid objects.

Substances normally occur in one of three states: solid, liquid, or gas. When the atoms or molecules of a substance are locked in a crystal structure and do not have enough kinetic energy to slide past each other (but are still in motion), they are called a solid. The liquid state is when the atoms or molecules have more kinetic energy, but still stick to one another. When the atoms or molecules have enough kinetic energy to move independently they form a gas. Substances can exist in any of these states depending on the temperature and pressure. Adding heat energy to a solid causes it to melt, forming a liquid. Adding more heat energy eventually causes the liquid to boil and form a gas. When heat energy is removed from a gas it condenses, becoming a liquid. Removing more energy causes the liquid to freeze into a solid. Some substances (e.g. iodine and carbon dioxide) change directly from a solid to a gas: this process is called sublimation. The reverse process, changing directly from a gas to a solid, is called deposition. Some common misconceptions: the "sweat" on the outside of a glass of cold water is water that has leaked through the glass; the cloud that forms over a boiling tea kettle is water vapor; melting and boiling points only apply to water; when heat is added to a boiling liquid, the temperature continues to increase; boiling is the only process in which a liquid changes to a gas; to lower temperature you add "cold"; particles of solids have no motion; and there is no gaseous state of water because liquid water disappears and turns into air.

Changes in state (phase changes) are considered physical changes because the substance remains the same. No new substance is formed. Physical changes also include changing the size and shape of objects, for example ripping paper. Another type of physical change is forming mixtures, for example dissolving sugar in water. Chemical changes are processes that produce new substances. During chemical changes the connections (bonds) between atoms and molecules are broken and reformed in new ways. Matter is conserved in chemical changes, in other words atoms are neither created nor destroyed only the bonds are created or destroyed. Common examples are combustion and photosynthesis. Indications that a chemical change may have occurred include change in color, evolution of a gas, producing or absorbing heat, and producing light. Chemical changes can be described in terms of reactants and products. The reactants always combine in set proportions and the products are always produced in set proportions. For example, the electrolysis of water always produces twice as much hydrogen as oxygen. Some common misconceptions: when matter is heated/cooled it always expands/contracts; separate molecules and atoms of a compound have the same properties as the compound itself; and expansion of matter is due to the expansion of particles instead of increased particle spacing.

The new unit needed to emphasize hands-on science. This would require time to plan the activities and more time to get the materials and equipment ready. I spent five weeks at Michigan State University evaluating labs and activities from a variety of sources. I had to find labs that addressed the unit's objectives: Matter and Energy (Standard SCI.IV.1) and Changes in Matter (SCI.IV.2) (Michigan Teacher Network, 2000). Appendix C-1 details the specific benchmarks and correlates the labs to the benchmarks. I tested the labs to make sure they were practical, and yet challenging for seventh graders. I refined the procedures and readied necessary materials. Finally I prepared the lab sheets and discussion guides that the students would use.

The class that formed the basis for this study was a seventh grade class in Holt, MI. Holt is a middle-class suburb of Lansing, MI. The class had 24 students, 10 male and 14 female. Four students received special education assistance. Six students received free or reduced lunch. They were fairly typical of our student population. (Holt Public Schools' K-12 population in 2000 was 5304. Of that population, 12.9% receive free or reduced lunch. The major ethnic groups are 89% white, 4% Hispanic, 4% black, 2% Asian, and 1% Native American. There are no students with limited English proficiency. (Standard and Poors, 2002) Approximately 60% of Holt graduates attend two or four year colleges or other institutions for advanced training. All 24 students participated in the study, indicating their willingness by their signatures and their parents' signatures on an informed consent form.

Implementation

The unit that I planned and implemented is an Introduction to concept of matter. The unit was designed using a constructivist approach. This is why the unit has many labs, activities, and demonstrations into the unit. Twenty-seven out of forty-nine days in this unit were devoted primarily to student-based activities. (Of course other days had some student activity, but it was not the primary focus.) The emphasis was on observation, questions, and discussion. The activities were from a variety of sources and were keyed to the content objectives. All of the labs were based on one or more unanswered questions. Students were required to observe carefully and construct their own conclusions. I had to resist the urge, and sometimes the students' pleas, to "Just tell us the answer." We had a textbook (Maton, 1993) available as a reference, but rarely used it. Instead, the students developed their own notebooks of important information including discussion guides, activity sheets, and labs. I also made a point to explain the math we used. Some of the math was very challenging for seventh graders. My students worked independently only during the pretest and post test, two quizzes, and the description contest (although they discussed the results with their partner after the contest). During all other activities the students worked with partners or in larger groups. Table 1 is a general outline of the unit. Labs, activities, and discussion guides marked with * were developed for this unit (not used the previous year).

Table 1 – Matter Unit Overview

	Monday	Tuesday	Wednesday	Thursday	Friday
Wk 1	Admin needs Discrepant events* Introduce Description Contest	Edible candle Description Contest* Pretest	Describing Distance*	Describing Volume* Show consumer products	Describing mass and weight* Define matter
Wk 2	Review Mass/volume take home investigation*	Density measurement lab* preview and gather data	Density measurement lab share and analyze data	Density measurement lab graph and discuss	Re-measure suspect data
Wk 3	Graph data	Finish lab questions	Description contest Quiz	Correct lab graphs and questions	Density column lab* preview and Part 1
Wk 4	Density column lab Part 2	Density column lab Part 2	Density column lab Part 3 & 4	Density column lab questions Al foil discrepant events	Atom/element intro Film can inference lab* preview
Wk 5	Finish film can inference lab	Creating model atoms activity*	Discuss atoms, molecules, and compounds	Atoms and molecules model*	Introduce mixtures Video 5374 10 *
Wk 6	Review density and atoms	Reinforce: worksheets	Return and review work-sheets/quiz	Discuss mixtures	Discuss separating mixtures
Wk 7	Separating solids activity*	Matter Concept Map*	Review and grade concept map	Discuss phase change Preview melting ice lab*	Dry Ice day – density and phase changes
Wk 8	Melting Ice Lab	Completed melting ice Lab Thermal expansion demo	Video 5787 18* Phase change quiz	Gas thermal expansion Grade quiz	Physical chemical changes. Dry the shirt worksheet*
Wk 9	Evaporation race Begin long term evaporation lab	Discussed evaporation and condensation Fog Story*	Begin chemical reaction model*	Complete chemical reaction model	Dehydration of sugar demo* Unit review
Wk 10	Candle observation*	Baking soda fire extinguisher	Term test	Fire Dept demo*	

The following is a description of the major labs and activities. Student sheets and teacher notes for the major labs and activities are included in appendix A. Handouts and discussion guides that were prepared for this unit are included in appendix B. The pre/post test is appendix C-2. Photographs of labs and activities are in appendix D.

Discrepant events. The unit started with demonstrations of four discrepant events in the first two days. The first was a Cartesian diver using a dropper for the diver. Initially students could not explain why the dropper was sinking and rising, and then they discovered that squeezing the container controlled the motion. Then I asked them to observe more closely and try to explain why this controlled the diver's location. In the second discrepant event, I then poured water and alcohol into separate beakers. (Both fluids were stored in a bottled water container so most students assumed they were both water.) Then I put a larger candle in the alcohol and a smaller candle in the water. The students thought the larger one sank because of its size. I then put the candles into the opposite beakers and the results were reversed. It wasn't the size, but could they explain why the candle sunk in one, but floated in the other? I didn't allow the students to be close enough to smell the alcohol. I didn't explain what was happening, but promised that by the end of the unit they would be able to explain what they just observed. My third discrepant event was to extinguish a candle by pouring CO_2 from a beaker of vinegar and baking soda onto the flame. The students had a hard time explaining why the flame was extinguished when "only air" left the beaker. The fourth discrepant event was on the second day, before the description contest. I lit a banana candle (slivered almond for wick), then blew it out and ate it. At first, most students thought I was eating wax. When they saw me chewing they recognized their mistake and noticed that it was actually a banana. These demonstrations encouraged careful observation rather than a cursory glance.

Description Contest (Appendix A-1). The next few days were spent describing distance, volume, and mass. The discussion guides are in appendix B. To introduce and assess this topic I had a description contest on Day 2 and repeated it on Day 13. This contest was loosely based on the Write-It Do-It event in the Science Olympiad. The purpose of the contest was to see how well students could describe objects, an important science skill. I put twelve objects (cylinders or rectangular blocks of wood) on each table. The students worked in

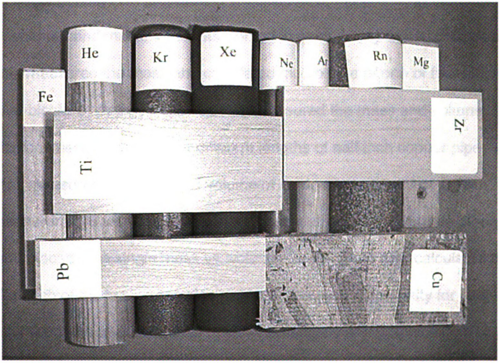


Figure 1: Description Contest Objects

pairs. The first student was assigned six of the twelve objects (Figure 1). These objects were labeled with element symbols (Fe, He, Kr...). The student wrote the symbol and then a description of the object on a form (last page of Appendix A-1) that I provided. I removed the part of the form with the symbol and give the description to the second student. The second student had to read the description and determine which object (of the twelve) was being described. The second student wrote the symbol next to the description. I collated the first student's symbols with the second student's symbols to evaluate how well the team did at encoding and decoding written descriptions.

Density Measurement Lab (Appendix A-2). The first lab activity in this unit was a density lab. We explored the concept of density by answering two questions: 1. Is density different for different substances? 2. Does the size of an object affect density? In preparation we discussed and practiced measuring distance, volume, and mass. Students worked in pairs during this lab. Each pair of students measured the mass and calculated the volume of one of four different rectangular blocks of pinewood. Then they measured the mass and volume (water displacement) of one of four different lengths of half inch copper pipe. Finally they measured the mass and volume of a specified amount of water. These measurements were recorded on a data sheet, shared with three other teams, and placed on a single mass vs. volume graph. They also calculated the density for each of the twelve samples, and then the average density for each substance. Students evaluated their results numerically and graphically. They had one day to redo measurements or calculations for data that appears inconsistent. They discovered that regardless of the length, each copper pipe had the same (nearly) density. They discovered that the density of copper is much different than wood or water. They also discovered how graphing data could quickly point out inconsistent data. The students had the mass and volume of an unknown substance already plotted for them as an example. In the analysis section they were given a table of densities and asked to identify the unknown substance by calculating the density. Besides emphasizing the main points of the lab, the analysis questions also asked students to think about lab errors and why the density graphs would pass through the origin if extended. I measured the effectiveness of the lab in two ways: 1. reviewing their (the students) data tables and the graphs; 2. grading the analysis questions.

Density Column Lab (appendix A-3). The next lab is a qualitative exploration of density. This lab is adapted largely from activity #6, "Exploring Density" of the Matter Matters unit of the Battle Creek Area Mathematics and Science Center. Students complete this lab with a partner, but discuss the results throughout the lab with the other partner teams at their lab station. This lab has four parts and took five days to complete. In part one the students observe a column of six different liquids. The liquids are colored if necessary to make sure the layers and their boundaries are obvious. They sketch the layers and write down their observations. (Many students want to write conclusions about what the liquids are – especially based on color. This makes a great teaching moment for differentiating between observations and conclusions.)

In part two, the students investigate whether two known liquids float or sink when placed in the same test tube. They choose three pairs of liquids, predict which will float on the other, careful put them together, and record what happens. Students watch this distinct boundary form three different times. This does not give any pair of students enough information to identify the six layers from part one. When we pooled the observations of the entire class, we could conclude what each substance was.

In the third part students investigate solid objects floating on the different layers. They predicted and then observed where various familiar objects would float. This demonstrated that each object had its own unique density. Then they took a rubber band of three different sizes and predicted where each piece would float. If the weight determines where the object floats, then the largest piece will float the lowest (this was a common prediction). If density determines where the object floats, then each piece will float at the same level. Students discovered that each piece floats at the same level. In this part I also challenged them to think about a single substance that seemingly had different densities. They each got a chance to make aluminum foil wads and drop them into the column. Could they make a wad float on each boundary? Why can an object made of the same substance float at different levels – what was the difference in the way they made the different wads.

Part four is a series of assessment questions. Students had to use the concept of density to explain the level at which different objects floated in a density column. They had to recognize and refute the misconception that different size pieces of the same soap will float at different levels. I evaluated this lab using their completed drawings, class discussions of Part 2 results, and the assessment questions in part 4.

Film Can Inference Lab (appendix A-4). On Day 20 we moved beyond measurement and density into atomic structure. I introduced the topic using this lab. It is modified from the Shoe Box Atoms laboratory investigation from Matter (Maton, 1993). The purpose is to establish that we can investigate things that we can't see. This allowed students to better understand how scientists have deduced the structure of atoms. In addition the students got a chance to try various methods to investigate unseen object(s). They were quite successful. In this lab students worked in pairs within lab groups of eight. Each pair was given two black film canisters and had to investigate what was inside. They were not allowed to open the canister, but could use a magnet, electronic balance, and manipulate the canister while listening. They had to describe the number of object(s), the shape and characteristics of the object(s), and even sketch what they thought the object(s) looked like. I assessed this activity by reviewing their observation data tables and their sketches. I also made a game out of opening the canisters to reveal what was actually inside. Of course they were curious, and surprised to see how accurate they were.

Creating Model Atoms (appendix A-5). Having established that we can investigate unseen objects, we next investigated the basic structure of the atom. I used an activity called creating atoms from the web site, www.galaxy.net/~k12/matter, last updated March 31, 2000 and copyright D. M.

Candelora. In this activity students built models of the first ten atoms in the periodic table – this kept the models simple while giving a mix of familiar (H, C, N, O) and unfamiliar (Be, Li, B) names. I used packing peanuts (Candelora suggested cotton balls, but packing peanuts were easily acquired and seemed easier to color and glue.) for the nucleons and beads for the electrons on a pipe cleaner, which represented the electron cloud. I did not cover different shells or orbitals; for each element, the electrons all went on one pipe cleaner. The kinesthetic learners used their hands to investigate atomic structure. I assessed this activity with a couple of discussion questions: compare/contrast the model with actual atom and look for structural patterns in the sequence of these first ten elements. The students worked in pairs to make the atoms. Figure 2 shows a

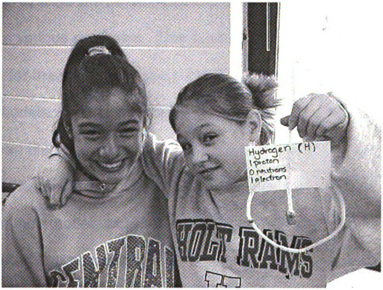


Figure 2: Students with hydrogen model

sample model. Each atom was labeled with chemical name and numbers of protons, neutrons, and electrons. We hung the models from the ceiling and had them to refer back to through the course of the unit. This was especially useful when we talked about chemical reactions and how atoms link up.

Atoms and Molecules Model (appendix A-6). We then discussed how atoms form molecules and compounds. Here I used an activity that expanded on Knoespel's paper clip model of compounds. We used colored paper clips to model atoms. Each color of paper clip represents a different kind of atom. This method seemed much better than the gumdrop model I had used before. It wasn't as messy and it was easy to make and break bonds (link and unlink the paper clips). For example, two blue paper clips (hydrogen) and one yellow paper clip (oxygen) linked together represented H_2O. I did not insist on the correct bonding structure. First I explained the model and used a Power Point presentation to show the difference between elements, compounds, and mixtures and discuss various examples. (The presentation allowed me to enlarge the paper clips for the students to see.) The students then worked in pairs to make their own models. First I classified the substance for them and they explained why it was an element, compound, or mixture. They also wrote the chemical formula for the substance. The second step was for the student to build, classify, and explain their model. I used a worksheet as the record of which models they had completed (the paperclips had to be reused) and to assess their understanding of the differences between elements, compounds, and mixtures.

I also used a 10 min video to help students recognize that matter is made of invisibly small particles. The video was "Molecules: First Film" produced by BFA in 1972. (available from REMC 13 as VH5374). Despite being 30 years old, it provides some fascinating demos that I could not easily reproduce in the classroom. It draws an analogy between the behavior of moving sand and moving water. One demonstration places a steel ball on top of a column of sand and a ping-pong ball at the bottom. When the sand is at rest the steel ball rests on top and the ping-pong ball stays buried. But when the sand particles are put in motion (vibrated) the steel ball sinks to the bottom and the ping-pong ball rises to the top. Because the two balls behaved the same way they would have in water, the viewer may conclude that water is made of small particles in motion. The film also shows Brownian motion (without naming it) and demonstrations that suggest gas, too, could be made of particles in motion. I used the video for several reasons. First, the narrator asks many good questions which allowed us to pause for a class discussion before the answer. Second, the video uses several models and shows how models can be used to help us grasp difficult concepts. Finally the video presents evidence supporting the particulate nature of matter, but requires students to synthesize their own conclusions.

Separating Solids Activity (appendix A-7). As we talked more about mixtures, I used an activity to demonstrate that mixtures can be separated using mechanical methods. This activity was adapted from Candelora's website. The students had a mixture of pepper, sugar, sand, and iron fillings. They had to devise a method of separating them based on their physical properties. I gave a suggested procedure using attraction to static charge to separate the pepper, magnetism to separate the iron fillings, and solubility/filtering to separate the sand from the sugar. As an extension I asked the students to examine the separated substances and see how pure they were (still mixtures). We could also evaporate a thin film of the sugar solution. This let them see the sugar and also foreshadow an upcoming topic: evaporation (phase change). We concluded this portion of the unit with a concept map (included as appendix B-5) that helped the students connect the major ideas of matter and measurement.

The next part of the unit was on physical and chemical changes. After a day of introductory discussion we had a day devoted to fun with dry ice. I did five demonstrations – making connections back to matter and density and also forward to physical and chemical changes (see appendix B-6). First we covered thermal contraction using a brass ball and ring. At room temperature the ball passed through the ring, but after a few minutes of contact between the ring and the dry ice the ball would no longer fit. How could we explain this with our understanding of matter? Next, I put some dry ice into a balloon and measured the combined mass. As the volume changed, did the mass change? Even though we can't see it, CO_2 has volume and mass. Next I used CO_2 as a fire extinguisher. In an open aquarium, with water and dry ice in the bottom, the lower candles went out first. Then I poured "air" out of a beaker containing dry ice and water to extinguish the flame. How does our understanding of density explain these observations? Why does the candle stop burning in the presence of CO_2 – is this a chemical change? When I put dry ice in an aquarium and blew soap bubbles, the bubbles slowly descended until they appeared to hit a barrier or boundary above the water and dry ice at the bottom. Some even remained suspended above the bottom of the aquarium. Again, how does our understanding of density explain these observations? Finally we found and described some phase (physical) changes: dry ice crystals sublime on black construction paper (solid → gas); what caused the "smoke" that they saw (gas→liquid); what happened in the beaker to the water that surrounded the chunk of dry ice (liquid→solid).

Melting Ice Lab (appendix A-8). The next activity for investigating phase change was a lab on melting ice. In this lab we investigated both qualitatively and quantitatively what happens to ice as it melts. I began by asking the students what they think a graph of temperature versus time would look like for ice melting. The majority of students selected a graph showing a constant rise in temperature (this set up a discrepant event). Students were given a test tube with a thermometer frozen into about 4mL of ice. From a starting temperature of about –8° C they put it into their hands and recorded temperature every 30 sec. They also observed the ice-water mixture and recorded what time the ice was mostly gone. They stopped recording at 20° C, which took about 7-10 min. This data was plotted on a temp/time graph. The graphs all showed a constant temperature during phase change followed by a sharp rise in the water temperature. The students' graphing skills were much better at this point than during the measuring density lab. I assessed this lab with the graph and answers to analysis questions about what happened to the ice. One of the tricky things about the melting ice lab is that for water, the solid phase is less dense than the liquid phase. So I repeated the thermal expansion demo (adding heat this time) with the brass ball and ring and with a bi-metallic strip after the lab. To demonstrate that most materials expand when heated.

The next day I showed a video comparing physical and chemical changes. The title of the video is "Changes in Matter" produced by AGC/United Learning and runs for 18 min (REMC 13 code VH10026). The video had a quiz at the end, which I used along with a discussion guide to assess the students' understanding of the activities and discussion to this point. (The quiz and discussion guide are in appendix B.) Another reason for the video was to accommodate the visual learners in the classroom. It started with a description and examples of physical changes. Then it described chemical changes and important indications of chemical changes. The video concluded by comparing and contrasting the two types of changes.

As we moved into investigating evaporation and condensation, I had the students do a quick activity called the evaporation race. We had already discussed the process of evaporation, including factors that affect the rate of evaporation. In addition they had already discussed and written a paragraph on the fastest way to dry a wet shirt. Now working in groups of three they raced to see which group could evaporate a dropper full of water placed on their desk in the shortest time. The winning techniques demonstrated what we'd been discussing in class: spreading out the puddle of water (greater surface area), blowing on the water (removing evaporated water molecules), and trying to warm the water (increasing the kinetic energy of the molecules). To investigate condensation I used a reading/writing assignment from the Battle Creek materials: "A Fog Story". The story is a diary entry in which the writer encountered condensation on nine different occasions. Students fill in a data table and record where the water appeared, what was the source of the water, and how air temperature compared with surface temperature for each of the nine situations. Students discovered a pattern and drew conclusions about the causes condensation. I used the data table and their conclusion to assess students' understanding of evaporation and condensation.

Chemical Reaction Model (appendix A-9). As we moved into the final phase of the unit and explored chemical reactions, I brought back the paper clip model of atoms. Once again the students linked different colored paperclips, but now they also broke the bonds in the reactants and formed new bonds to make the products. I had them make the paperclip models representing these two equations $H_2 + O_2 \rightarrow H_2O$ and $2H_2 + O_2 \rightarrow 2H_2O$. Then they laid the models side by side on their worksheet while I came around and discussed their work. I told them that balanced equations show that atoms are neither created not destroyed, and asked them to consider which equation was balanced. It was clear that both equations said that hydrogen and oxygen react to form water, but that the first equation did not have the same number of oxygen atoms on both sides. I also had them model another equation and explain why it was balanced. As an extension I challenged students to find other chemical reactions (from class discussions, the video, or the internet – perhaps iron and oxygen forming iron oxide) and model them with paperclips. During this exercise I also introduced chemical reaction symbols (+ , $\rightarrow$) and discussed the new terms reactants and products. I used the reaction involving water because it is common substance that we'd used throughout the term and the oxygen and hydrogen pipe cleaner models were hanging from the ceiling for reference. I assessed this activity with the worksheet they completed, which included an additional question about predicting the properties of a compound. This activity was also adapted from Knoespel's materials.

As part of our discussion about chemical changes I chose to do the dehydration of sugar as a demonstration. I did this as a comparison: in one container I combined water and sugar and in another I combined concentrated sulfuric acid and sugar. One was the common physical change, sugar dissolving in water. The other looked the same, a clear liquid added to sugar, but produced a definite chemical reaction. One nice feature of this reaction is that it takes about a minute for the sugar to begin to turn brown. Not all chemical reactions are as rapid as combustion or explosions. Another nice feature of this demonstration is the drama. A column of black frothy mass rises from the container. (The time delay heightens this effect.) Of course the students enjoying the noxious sulfur smell – which necessitates it being outside (or in a fume hood). This reaction also demonstrates several of the indications of chemical reactions: production of a new substance, change of color, production of gas, and production of heat. The idea to do this as a contrast between physical and chemical changes came from Liem (p 135). I also used a discussion guide (appendix B-8) to review chemical and physical changes after the demonstration.

Another activity we did to contrast chemical and physical changes was an

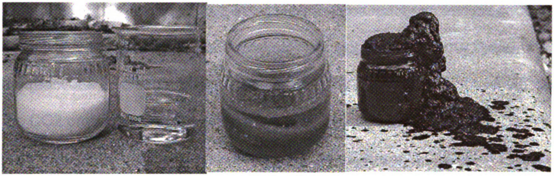


Figure 3: Dehydration of sugar

observation of a burning candle. This activity was adapted from a lab in the Prentice Hall text Matter (p.52). The students carefully observed the candle and documented these observations with a sketch and a written description. They had to identify physical changes (melting wax) and chemical changes (combustion). They also noted indications of the chemical change (light, heat, soot, etc.) I was pleased with how intently the students worked and how detailed the descriptions were. I assessed this activity with the descriptions the students handed in.

We finished the unit with two more fire activities. First, we extinguished candles using CO_2 produced by mixing baking soda with vinegar. After the students did the activity, we discussed two of the chemical reactions. I told the students that the first reaction was vinegar + baking soda → sodium acetate + carbon dioxide + water (in chemistry notation: $HC_2H_3O_2(aq) + NaHCO_3(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(\ell) + CO_2(g)$). We identified the reactants and the products and discussed indications that a chemical change has occurred. The second reaction is commonly called combustion: fuel + oxygen in the presence of heat combine to form carbon dioxide + water + heat. One type of fuel (wax) is

$C_{25}H_{52}$, so in chemistry notation: $C_{25}H_{52} + O_2 \rightarrow CO_2 + H_2O$, or balanced: $C_{25}H_{52} + 38O_2 \rightarrow 25CO_2 + 26H_2O$. Again we identified the reactants and products. Then we discussed why the chemical reaction stopped. I had the students write the reactions on a sheet of paper and answer the question "Why could you pour the CO2 onto the flame?" I assessed this activity with these papers.

My other fire activity was inviting the fire department to come and discuss fire extinguishing. The fire marshal began by describing a fire triangle, which reinforced the previous discussion of reactants. Then he discussed water, CO_2 and powder extinguishers and the different way in which each extinguisher interrupts the chemical reaction. Then he discussed the different classes of fire, which extinguisher to use when, and some personal experiences. Finally he demonstrated the techniques for each extinguisher and we went outside and let the students practice discharging the extinguishers. This provided an outside context to the chemical reactions we had been studying in class. It also gave the students a potentially life saving skill. The students really enjoyed this activity.

Evaluation Tools (appendices C-2 and C-5). To assess the unit I administered a post test at the end of the unit. It was identical to the pretest. The questions are provided in appendix C-2. I also used a student opinion survey at the end of the school year (when the students from the matter unit had returned to my room for an earth science unit). I taught these students only during the first and fourth quarters of the year. This survey is appendix C-5. I asked their opinion of the matter unit and I asked them to compare the matter and earth science units.

Evaluation

An overall evaluation of the unit can be found in the pre and post test data. A copy of the test and a question-by-question breakdown of each of the 24 student's performance on both the pre and post test are in appendices C-2 and C-4. Each of the questions on the test was aligned with the objectives of the unit (this correlation is in appendix C-3). Figure 4 graphically compares the pre and post test average scores on each question. Students made improvements on

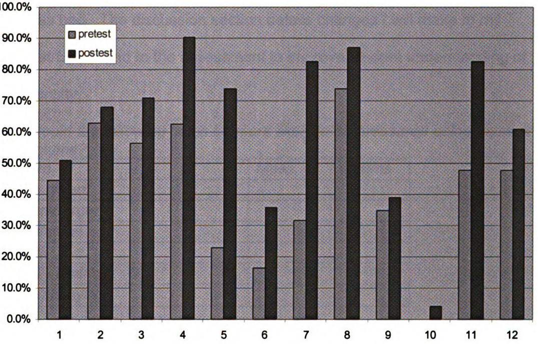


Figure 4: Pre/post test comparison of individual questions

each question, although some of the improvements were minimal. I will list each question and evaluate the results.

1. *When people go fishing, why is lead commonly used for a sinker?* For full credit I required mentioning the higher density of lead compared to water and that this high density would cause it to sink easily. Even by the post

test the average (51%) was failing (< 60%). The question should be explicitly worded to elicit a discussion of density. (For example one student answered that if you didn't use a sinker the hook would just float on top of the water.) Also some students did poorly on the question because they do not fish, so they didn't know what a sinker was. The wording of the question may have hindered students from demonstrating their understanding of density on this question. So either they could not use the concept of density to describe why objects sink or the question was bad. The discussion section details changes I will make to my instruction and to the assessment to improve student understanding of density.

2. *Would the following items be more likely to be measured using mass or volume?*

Item	*Mass*	*Volume*
Ice cream		
Hamburger		
Potatoes		
Milk		
Jelly beans		
Maple syrup		

Table 2: Pre/post test question #2

The post test average was passing, but the gain was minimal. This was disappointing. Students had lots of practice measuring and describing objects in grams and mL. They also had a take home activity in which grocery store items were identified as being sold according to mass or volume. (For example, jam is measured in mass – 907 g.) This connection between science and shopping was not strong enough to be used at the end of the unit and needs to be strengthened.

3. *Classify the following as element, compound, or mixture:*

	Element	*Compound*	*Mixture*
water			
bean soup			
oxygen			
salt			
Pepsi			
hydrogen			

Table 3: Pre/post test question #3

The post test average was passing (71%) while the pretest was failing (56%); students made a reasonable gain on this objective. On the post test most students identified oxygen and hydrogen as elements, but many were unsure about water, bean soup, salt, and Pepsi. One source of this weakness is that students did not know that Pepsi is basically sugar and water. Another cause was a lack of connection between the paper clip models of molecules and what they eat and drink on a daily basis. I was especially disappointed with the inability to classify water and salt because we had discussed and made models of these two compounds.

4. ***In the boxes below draw a model of what you think the molecules in a solid, liquid, and gas would look like. Briefly explain your drawings.***

Solid **Liquid** **Gas**

A full credit answer required that they show increasing spacing and describe increasing motion from solid to gas. Students came into the class with a reasonable understanding of this concept, and improved to significantly (90%

average) by the post test. This is an important concept of matter and I was

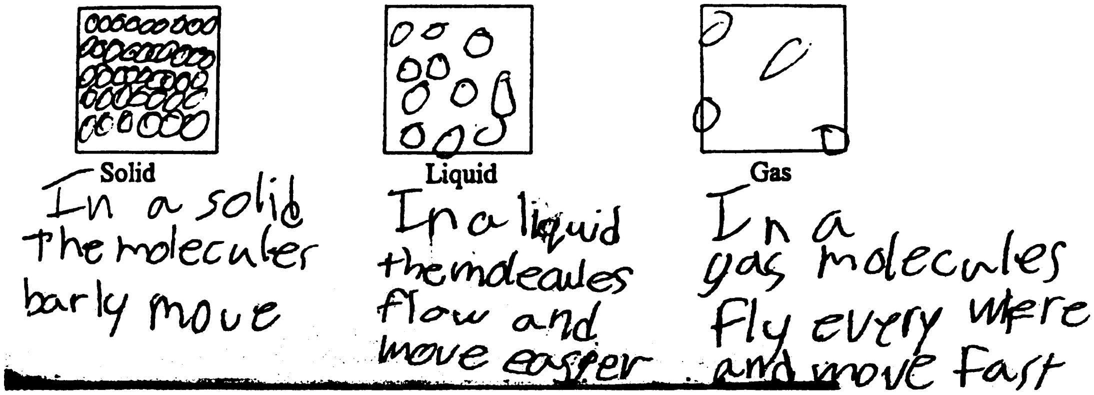


Figure 5: Student work on post test

pleased to see their mastery of it by the end of the unit. Figure 5 shows a student sample from the post test.

5. *Explain why "sweat" forms on the outside of a glass of ice water in the summer.*

A full credit answer required discussion of the difference in temperature between the air and the glass and how this affected the molecules of water vapor. They also had to identify the source of the water. Students received no credit for merely identifying the process ("Due to condensation.") This was a major weakness at the beginning of the unit (23%). Many students left if blank or described how water from the inside got to the outside. Some thought that the hot air made the glass actually perspire and that's where the "sweat" came from. Students made a tremendous improvement (scores up 51%) in this area and could describe how condensation occurs.

6. *Hydrogen gas is given off when hydrochloric acid is added to zinc. The residue that remains is zinc chloride. Scientists might write the reaction like this:*
   zinc + hydrochloric acid → hydrogen gas + zinc chloride.
   Classify these substances as products or reactants.

Products *Reactants*

Students needed to tell me that the reactants were zinc and hydrochloric acid while the products were hydrogen gas and zinc. The pretest score was miserable (16%), the post test average was more than double (36%), but still poor. This was likely the first time many of the students had seen this notation. On the pre test, many students left it blank and I had to minimize their frustration by explaining that this was just the pre test – they weren't expected to know everything on the test. One student expressed her frustration with the answer "I aint this smart!" Even though students had difficulty identifying the products and reactants, they were not overwhelmed by the concept or vocabulary of the question. On the post test only two students left it blank and even the previously mentioned student attempted an answer. I would like to have seen better numerical results. Perhaps emphasizing the terminology more classroom examples and including these terms on the concept map would give better results.

7. *Patrick and Franklin's mother was filling the gasoline tank of her van. Franklin soon smelled gasoline. He asked Patrick how he could smell the gasoline when it went into the tank. Write what you think Patrick said to explain to Franklin how he was able to smell the gasoline. Use the idea of molecules.*

Students received full credit for this question if they discussed evaporation and the movement of molecules in the air. Students made tremendous gains on this question. The pretest showed little ability to discuss the molecular level (average 32%) with a typical answer being, "because the air carys (sic) the smell." The post test showed much greater ability to use these concepts to explain a common phenomenon. The post test average was 83%.

8. *Water freezes at 32°F. What is the approximate melting temperature for chocolate candy bar?*
   a. 20°F   b. 80°F   c. 32°F   d. 212°F

The correct answer was 80 °F. Students had to realize that chocolate, like any other substance melts. For chocolate this occurs at temperatures greater than water freezing, but less than water boiling. Students scored well on the pretest (74% ave) and showed slight gains by the post test (87%). We did not discuss the properties of chocolate in class; this was a question where students had to apply their understanding to a new situation. I was somewhat disappointed with this result. Each student that missed this question selected 32 °F as the correct answer. Water is a common, familiar substance. It is convenient to use as an example in class and labs, but I need to use other substances so that all students realize that other substances have different freezing points than water.

9. *Ice melts at 32°F. What is the approximate freezing point for ice water?*
   a. 20°F   b. 80°F   c. 32°F   d. 212°F

The freezing point for water is approximately 32 °F. To receive credit students needed to realize that the phase change from solid to liquid and the phase change from liquid to solid occur at the same temperature (for the same conditions). Students did poorly on this question on the pretest (35% ave) and showed minimal improvement by the post test (39% ave). This is especially perplexing due to the fact that question #8 states that water freezes at 32°F! Moreover I would think that any student who has been in Michigan in the winter should know that 32°F is the freezing point. The responses to this question show that the unit failed to make the connection between freezing and melting points. A logical place to demonstrate this connection is in the melting ice lab. I may have some students freeze their sample of water using a salt/ice mixture or dry ice. We could compare graphs within the class and notice the phase change occurs at the same temperature, regardless of whether heat is being transferred in or out of the substance.

10. The density of the human body in grams per cubic centimeter is about:
a. 1 g/cc   b. 5 g/cc   c. 10 g/cc   d. 50 g/cc

The density of the human body is approximately 1 g/cc. Nobody answered this correctly on the pretest and only one person answered it correctly on the post test. Both results are worse than just random guessing. Both results surprised me, but for different reasons. This unit was the first discussion of density for most students and certainly the first exposure to the units of g/cc. Thus I would expect little understanding on the pre test, but why 25% of them did not guess correctly is still puzzling. (Another teacher's class took the same pretest and averaged just 13% on this question.) By the end of the unit, we had measured and discovered the density of water (1 g/cc) several times. Either the students did not remember this fact, or they could not connect it with the fact that for the most part the human body is water (which was not covered in class). I have no data to indicate whether it was a lack of recall or a lack of connection – either is bad. I may add another question to the test to help differentiate. Our school has a swimming pool; I may be able to easily measure the density of some student volunteers in the future to help reinforce this point.

11. Lindsay was studying how fertilizer affects plant growth. She planted beans in four containers. Each container got the same amount of sunlight *and water. She put a small amount of fertilizer in the first container, a little more fertilizer in the second container, and lots of fertilizer in the third container. She didn't put any fertilizer in the fourth container. What was the purpose of the fourth container?*

A full credit answer required a discussion of the concept of comparison or control. The pretest average was low (48%) and the post test average was much improved (83%). This was a significant increase. This question is seemingly unrelated to the unit, but tests the ability to design and conduct investigations. This was not overtly taught in this unit, thus I was pleased to see it was learned through the discussions and lab exercises.

12. Frances read that Dr. Zhou linked pollution from a local factory to lung cancer. What further information would cause her to believe the report?

a) Dr. Zhou is a world-renowned expert in the diagnosis and treatment of lung cancer.
b) Other areas without the pollution had lower rates of lung cancer.
c) Frances' friend Chris read the same report in the morning newspaper.
d) Four of her friends had grandparents who died of lung cancer.

The best response was the other areas without the pollution had lower rates of lung cancer. This question showed many misconceptions in the pretest (48% ave) and showed some improvement by the end of the unit (61% ave). This question tested the student's ability to analyze claims for their scientific merit. This concept was not directly taught in the unit. It is common for students to accept without questioning claims from an "expert" (e.g. class brain). Six of the nine students who missed this question selected answer a). I encourage students to discuss results in class and try to convince their peers that they are right. This could probably be covered directly during the discussion of the atom's structure. How do we know what we know? What evidence is adequate to support the claim that the atom is mostly empty? While investigating the unknown film canister, do we rely on personalities or coincidences? This would be a good time to discuss what evidence is credible when supporting scientific claims.

Let me comment on a couple of irregularities in the question-by-question pre and post test analysis contained in appendix C-3. Student X did not take the pretest because he joined the class after the first week of the unit. His post test score is not factored into the overall class gain (20.6%). Student Q took the pretest, but was absent for the post test. His pretest score also was not used to calculate the overall class gain. Thus, the 22 students that took both the pretest and post test generally gained a better understanding of the course objectives during this unit.

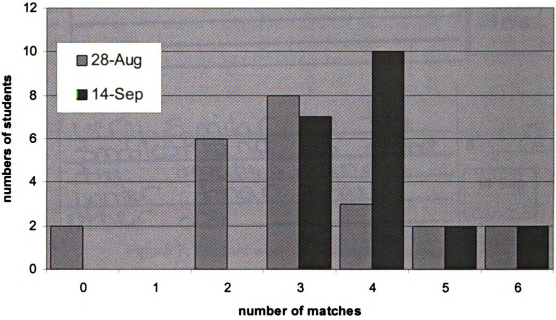


Figure 6: Description contest comparison

I think it is important to evaluate some of the individual activities of the unit. The first activity was the description contest. The objective of this activity was to demonstrate the importance of, and to give students a chance to practice, making detailed descriptions. I ran the contest on the second day of class and repeated it about two weeks later after we had practiced different methods to describe matter. Students worked in pairs. Each pair got a point for each object the second student correctly identified using the first student's description. Figure 6 compares the distribution of points from the first to the second contest. Clearly the distribution of students has shifted to higher numbers of correctly identified objects by the September 14 contest. Notice there are eight students with 0-2 matches in the first contest, but every student had at least three matches

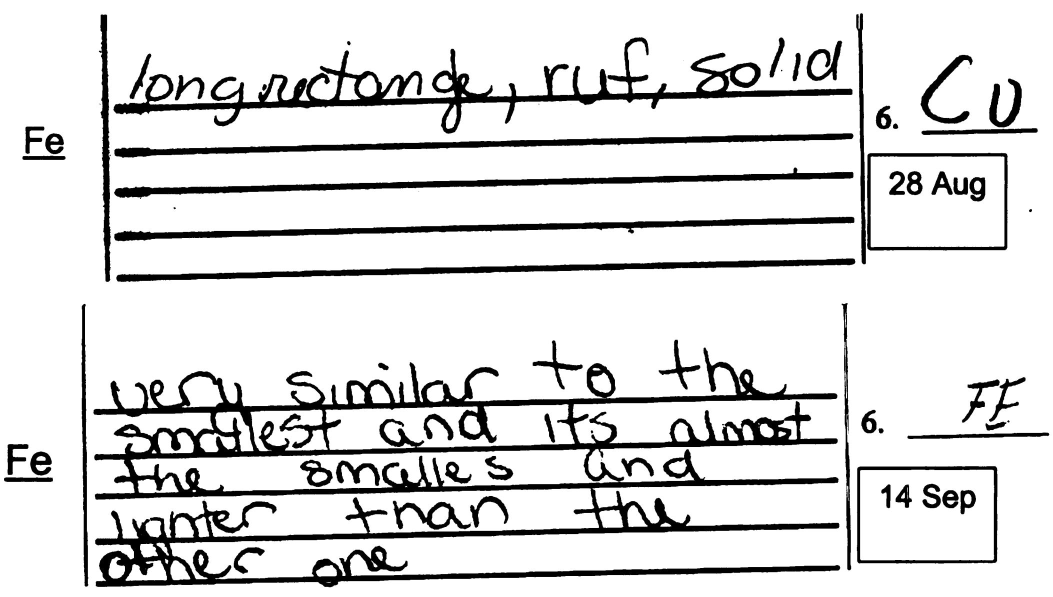


Figure 7: Student work on description contest

by the second contest. In fact the mean increased from 3.04 to 3.95 matches. In general the students' descriptions became more thorough and in a couple of cases even quantitative (mass or length). Figure 7 is a sample of the same student describing the same object on the two different days. On 14 September she included more information and her partner correctly identified the object. My conclusion is that students were more successful at describing objects after this activity.

The next major activity was the measuring density lab, describing density quantitatively. This was a very ambitious lab for the beginning of the school year. I had planned for two and a half days for the lab, but we needed five days to complete the lab and associated work. The major problems included the complexity of the calculations, complexity of instructions, careless measurements, and plotting and interpreting a scatter graph. I had anticipated difficulties so I provided a data table to facilitate taking data and a graph with points from an unknown substance plotted as an example. Students worked in pairs and shared data in a larger group of eight students. Careless calculations (e.g. using mass of water and graduated cylinder instead of mass of water) caused numerous erroneous data points on their graphs. This was a good opportunity to discuss what to do with "bad" data. They learned to spot questionable points and recheck their calculations and measurements as needed. Because each team of two students had to share their data with three other teams, it also provided opportunity to work on group skills. By the end of the data crunching all of the students had data points that were roughly linear. I graded them on final results: all densities about the same and points forming a rough line. The class average for this assessment was 87%. In the second part of the lab the students constructed knowledge from the data. Some of the students had required so much help with the math and plotting that they were puzzled by their data. For example, two pairs of students still answered this question incorrectly: "For objects made of the same substance, does the density change if the object is bigger or smaller?" One team's response was "Yes because when the wood is bigger is bigger density if it smaller the density is smaller (sic)." On the other hand some students showed much better understanding. A middle capability (C students) pair responded to the question about how to use density to determine if pennies are pure copper as follows, "If the pennies are pure copper they would match exactly the graph line for copper." Another team answered, "You could get copper you know is real that is the same size and weigh wich (sic) one weighs more." I assigned a numerical grade to their responses – the class average was 80%. By the end of this lab, most of the students were able to discuss and apply the concept of density.

The next activity was the density column lab. This was the best lab of the entire unit for engaging the students and having them think and rethink their understanding of density. Appendices D-1 through D-3 are unposed pictures that evidence the students' interest and focus. Students worked in pairs. I assessed their understanding based on the lab report they submitted. In part one, students observed a density column, sketched what they saw, and wrote down observations. The sketches were remarkably detailed. Many sketched the bubbles and minute mixing at the boundaries. Several students went beyond observations and wrote guesses (conclusions) about what the substances were.

This was a good opportunity to discuss the difference between an observation and a conclusion.

In part two, each pair chose four liquids and made a miniature density column in a test tube. Before they added each liquid they predicted where the new layer would form. They noted which liquids formed which layers and recorded these observations with words and sketches. Students stayed focused and enjoyed this part of the lab. The subsequent discussion validated the accuracy of their observations. The class combined their observations to discover what the six layers in the original density column were. Students successfully resolved disagreements about which substance floated and which sank. Now we were drawing conclusions. Despite the fact that some of the liquids had been colored, they still they correctly identified each substance! This was also valuable as an exercise in cooperation and teamwork.

In part three, students predicted and observed where various objects would float in the density column. To emphasize that an object's density determines at the level at which it floats, and that objects of the same substance have the same density regardless of size, the students used a rubber band cut into three different sized pieces. Twenty out of twenty-four students predicted that the large rubber band would float at a level below the small rubber band. But every student observed all of the pieces floating at the same level. Figure 8 shows a typical paper. For those 20 students this was a discrepant event: their observation was incongruent with their current understanding. They had to construct a new understanding. And they did. Every student answered a follow

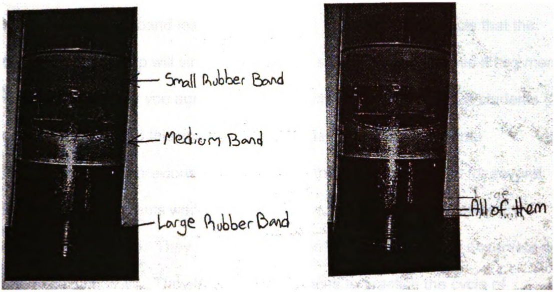


Figure 8: Student work on density column lab

up question by correctly explaining that the density of all three pieces was the same and thus they floated at the same level. Finally they dropped wads of aluminum foil into the density column. The challenge was to get a wad to float on as many different layers as possible, and explain why. This was optional (extra credit), but each group was interested enough to participate. The best groups had aluminum wads floating at five different levels. This was the only part of this lab that I developed. Floating the aluminum wads at different levels caused them to stretch their understanding of density beyond what they had just done with the rubber band. Here identical sizes of foil made of the same substance were floating at different levels. Most students could explain this either verbally (e.g. the one on top was loosely packed so it included lots of air thus its density was less than the liquid and it floated), as I counted their wad levels, or in writing on their lab papers.

In part four, students answered questions using the knowledge they had gained about density. One question gauged how well they understood and applied the rubber band lesson of part three: "One student predicts that the bigger piece of soap will sink lower than the smaller piece because it has more mass. Explain why you agree or disagree with this student." Most students (22 out of 24) answered this question correctly despite having the same misconception the previous day! I evaluate this lab as a success for several reasons. The students were interested and engaged during the different segments of the lab. They practiced and demonstrated excellent observation and sketching skills. They had several chances to practice the cycle of predicting, observing, and constructing meaning. Students were required to cooperate and problem solve in groups as big as eight. Finally, they demonstrated a much-improved understanding of density by the end of the lab.

In the film can inference lab, students investigated objects they could not see. We live in a world where seeing is believing; I wanted the students to discover that you can scientifically investigate unseen objects. Each lab pair was given two film canisters with unseen object(s) inside. They reported the results in a larger group of eight. I assessed them based on their documented observations and how close their conclusions were to the actual object. Every student participated and was ready to share their observations and a prediction. Most were able to extend beyond the tests I provided by suggesting additional tests to learn more. The students enjoyed the activity and were extremely eager to test their predictions by opening the canisters. The students were amazingly accurate. One group distinguished between a quarter and a washer of almost

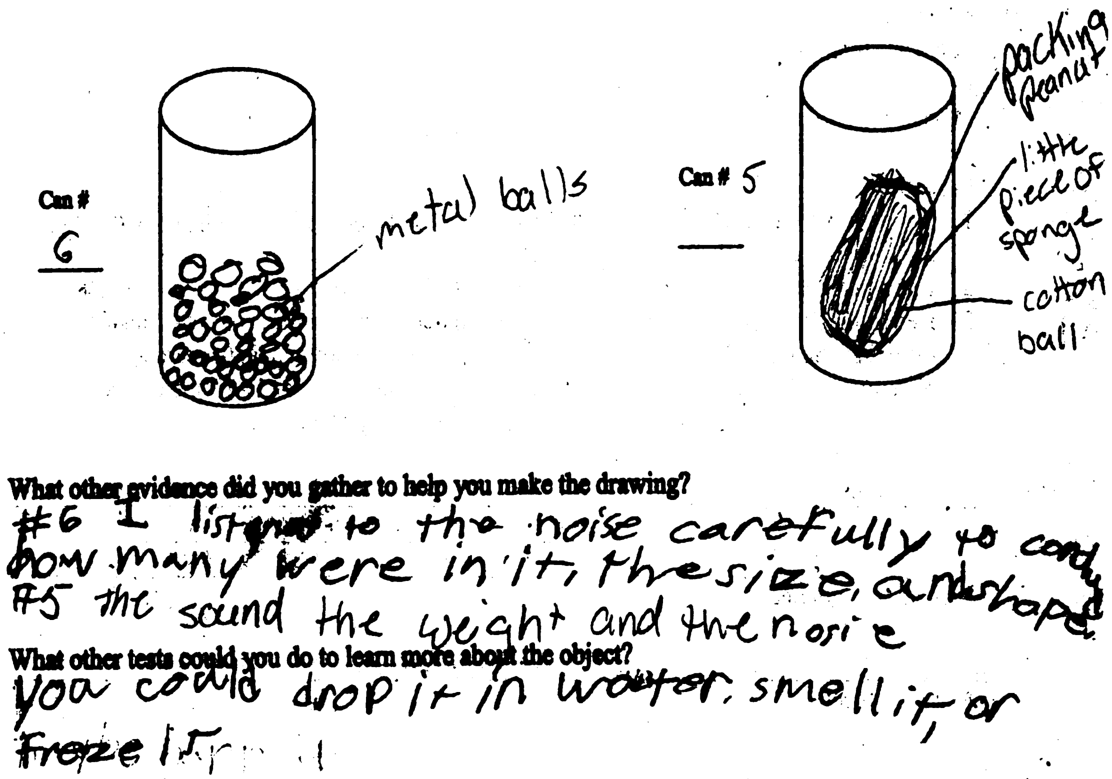
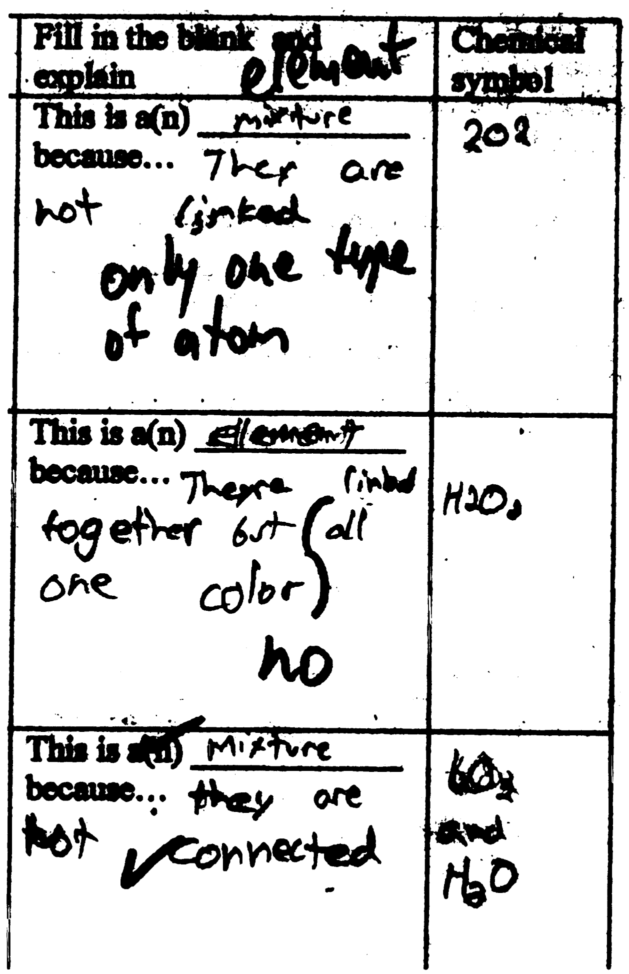


Figure 9: Student work on film can inference lab

identical size. Another group identified a packing peanut by sound and weight. Finally, one group identified not just that the object was a group of paper clips, but the precise number (3). Figure 9 is an example of one of the most accurate predictions. Again the teams worked well in reaching a consensus. I evaluate this as a success because students found out how to investigate and describe objects without being able to see them.

The creating model atoms activity was effective in teaching students the basic structure of an atom. Each pair of students had the correct number of protons, neutrons, and electrons. They also had the electrons in an outer shell and the neutrons and protons in a nucleus. In addition, 19 out of 24 students provided at least two similarities and two differences between their models and the atom they were modeling. All the students noticed the pattern of electrons and protons in the table on their activity sheet.

The next activity to evaluate, modeling atoms with different color paper clips, was used at two separate times. The first time was after we had constructed model atoms and were investigating how atoms bond to form molecules. Then we classified the molecules as either elements or compounds. We also put different types of molecules together to model a mixture. I assessed this in two ways. While they were doing the first part, with lots of guidance, I walked around and checked that each pair of students had the correct paperclip representations and the correct explanations for why they were elements, compounds, or mixtures. In the next part they put together a model that I had specified, classified it as element/compound/mixture, explained



Fill in the blank and explain element	Chemical symbol
This is a(n) mixture because... They are not linked only one type of atom	2O2
This is a(n) element because... Theyre linked together but (all one color) no	H2O
This is a(n) Mixture because... they are not connected	6O2 and H2O

Figure 10: Student work on atoms and molecules model

their classification, and wrote the chemical symbol. I graded these papers; the class average was 81%. Figure 10 is included as a typical sample (the dark marks are mine). They had a reasonable understanding of atoms being linked (bonded) or unlinked and classifying the paper clip models. As has already been noted, the students had difficulty transferring this concept to commonplace substances like Pepsi or bean soup. Despite being hands-on, this activity was very mechanical, more about learning vocabulary than investigating or wondering or even trying to answer a question. It was only minimally successful because they could not apply this understanding to question #3 on the post test. This inability to apply their understanding may have been because they did not identify the common names for their models. For instance they had a mixture of NaCl and H_2O. They knew it was a mixture, but may not have known it was salt water.

The second time we used the paper clips was at the end of the unit as we were discussing chemical reactions. Students modeled different equations and determined why some equations were balanced. We discussed not creating or destroying atoms. They demonstrated an understanding of balanced equations on a followup question, which everyone answered correctly. We finished with a discrepant event for (some students): given the properties of sodium and the properties of chlorine predict the properties of sodium chloride. Some knew it was table salt, but many thought it might explode or give off a poisonous gas. I threw some salt into the water in the sink and jumped back! Then we discussed how compounds could have completely different properties than their component elements. This use of paper clips was better, but still rather mechanical and not investigative. I think it was successful in showing students chemical reactions and what it means to be balanced.

The next activity was separating solids. In this activity I wanted them to gain a deeper understanding of the mechanical means of separating mixtures by using a mixture of pepper, sugar, sand, and iron fillings. This lab was probably too structured. Their handout asked them what physical properties could be used to separate this mixture and how they would do it. The back listed a step-by-step procedure for separating the mixture. When the students brainstormed their own procedure, it looked very similar to the procedure on the back. Thus everyone used this procedure. It became a confirmation lab, lacking an element of discovery. However, the students did a nice job of following the procedure. They saw that pepper really is attracted by a static electricity charge. They practiced folding filter paper. They learned that their separation techniques were far from perfect – would they really use the pepper they had separated out? This activity could be improved, but succeeded in allowing the students to separate a mixture.

The next activity was the melting ice lab. We wanted to investigate what happened to the temperature of water as it changed phase from solid to liquid. I first asked them to predict which of three graphs of temperature vs. time they expected. Only one group made a correct prediction, but I think they all had difficulty interpreting the graphs. However, students did experience an "aha!" when they completed graphing their data. The small amount of ice melted in less than eight minutes, so this lab was easy to finish in one class period. Many of the students had trouble reading the scale on the thermometer. After we worked through this problem everyone got data that showed a constant temperature

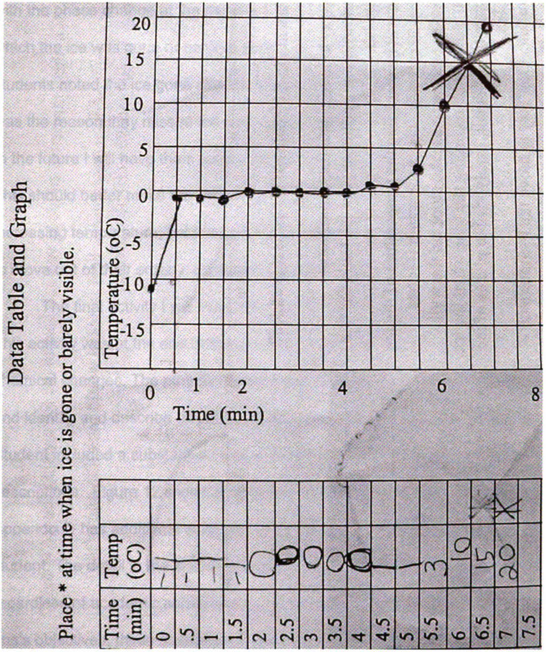


Figure 11: Student work on melting ice lab

during the phase change. Their ability to graph two variables was much improved since the measuring density lab. Figure 11 is a typical data table and graph. This lab was a good chance for students to practice and demonstrate lab techniques and plotting skills. I also assessed the students on their ability to explain the shape of their graphs. Only a few related the constant temperature with the phase change at the molecular level. They were to observe the time at which the ice was gone or barely visible and mark this time on their graphs. Most students noted the ice gone after the temperature was above 10° C. I think this was the reason they missed the connection between 0° C and the phase change. In the future I will have them record the point at which most of the ice is gone. This should better make the connection that the heat that is being added is not increasing temperature, but increasing the kinetic energy to allow the molecules to move out of their orderly, crystalline structure.

The final activity I will evaluate is the observation of a burning candle. This activity was at the end of the unit after we had discussed both physical and chemical changes. The purpose was to have students make careful observations and identify and describe any physical and chemical changes they observed. Student included a substantial amount of detail in their sketches and the written descriptions. Figure 12 shows a portion of a C student's sketch, and was typical. Appendix D has additional samples – one from an A student and one from an E student. The detail in the sketches is evidence of very meticulous observation, regardless of academic achievement. In addition to their understanding of the unit's objectives, these students had also gained powerful ability in an important scientific skill: observation.

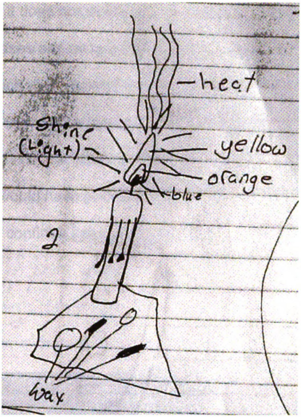


Figure 12: Student work on candle observation activity

Seven months after teaching the unit I surveyed the students and asked them what they liked, what they didn't like, and what I should change. The labs and activities were their favorite part of the matter unit. Of the 24 students, 13 responded that they liked the experiments, or the change they recommended was more experiments. Four other students responded by naming one of the labs as what they like best (3 density column and 1 model atom). Thus 17 of 24 students specifically commented about the labs after seven months had lapsed. When I asked the students to compare the matter unit with the earth science unit the results surprised me. Only four students preferred the matter unit while eleven students preferred the earth science unit (a score of 4 indicated no preference). I think this is because the earth science unit is less abstract than the matter unit. It does not deal with invisibly small particles and processes such as atoms and gases and molecular bonding. Rocks, volcanoes, rivers, and soil are easier to touch and experience. There was no field trip in the matter unit, but in the earth science unit we took a field trip to Grand Ledge. Figure 13 shows this distribution. The first year I taught this unit, I did not ask, but I expect even fewer students would have preferred the matter unit to the earth science unit. I think the survey confirms I studied and revised the unit that most needed improvement.

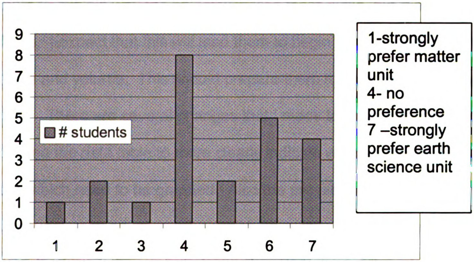


Figure 13: Survey results of unit preference

Discussion

I have already made many changes to the unit based on the experiences gained this year. One major change is switching the order of the two density labs. Next year we will do the density column first and measuring density second; we will start with the qualitative and move to the quantitative. This will provide context and, I hope, additional motivation to lead into measuring density. Also students will begin the density column lab by predicting whether a penny or a block of wood will sink in water. I expect students will use terms like light and heavy, but the piece of wood will have more mass than the penny. I will ask them to explain why the object with less mass sinks, but the one with more mass floats. I expect that this will lead them to begin thinking of a relationship between mass and volume. This should prepare them to investigate density.

There are several changes that I made to the measuring density lab. I revised the data table to more clearly indicate which data are used for calculation and which need to be graphed. Also the pre-plotted points on the graph are removed. Instead, during the prelab discussion the students will calculate the density of the unknown substance (from the given data), plot the three points with the correct symbol, and discuss their linearity. They will also identify the unknown substance and complete that analysis question in class. There is an additional question about the density of water in the required analysis questions. Students need to know the value for the density of water as a reference point. There is also a new optional analysis question about the density of the human body, with the possibility of actually measuring a student. (We would measure the volume of water that spills out as a student gets into a large garbage can filled to the lip with water. Then we would measure their weight and convert to mass. I know other teachers who do this; the students enjoy it and it connects with their experience of floating or sinking in water.

Another lab with several changes is the melting ice lab. Before we collect data I will pass out the thermometers and ask students to read the air temperature. This should help with reading the increments and noting that Celsius is different than Fahrenheit (It's only 23° in here?). Then they will put the thermometer in their hand and practice measuring the new temperature. I may also have some of the class do the experiment with a substance (e.g. chocolate) other than water that melts at a temperature such that body heat alone can cause the phase change. Water is a common substance and we use it as an example throughout the unit, but I want them to experience that other substances change phase. Several students showed the ice molecules more tightly packed than the water molecules. So I modified analysis question #3 to read, "Is ice more or less dense than liquid water? How do you know? Draw a picture and describe the difference between solid and liquid water molecules." Analysis question #4 is changed to read, "What was happening while the temperature was constant (the flat part of your graph)? Why did the temperature not increase during this time?" (*The temperature did not increase because the heat energy added was to break the inter-molecular bonds or break the molecules out of their orderly, crystalline structure*.) This should elicit more of a discussion and understanding of what happens at the molecular level during the phase change and how that affects temperature. I added a new question, "Sketch a graph of temperature versus time for 23°C water that is put into a freezer and label the state in each portion of your graph." to help students understand that freezing is just the reverse process.

I also made changes to the pre and post test. I modified the first question to read, "Which object would sink in water a penny or a block of wood? Explain why." I did this to remove the connection to fishing, which is unfamiliar to some students, distinguish between density and size. There is a new question near the beginning of the test, "The density of water in grams per cubic centimeter is about: a. 1 g/mL b. 5 g/mL c. 10 g/mL d. 50 g/mL" to see if students can recall this important number. Also it will help determine if poor performance on the question about human density is a lack of knowledge of density or an inability to connect human body to water density. Finally, in the questions about temperature the units are changed to Celsius. This is the scale we used in class and I would like to know if they are proficient with this scale.

The unit also needs numerous minor changes. I want to make more of a connection between non-school uses of mass and volume. Next Fall I will use the discussion guide on mass, volume, and density before the density labs (the density portion is deleted). This will provide immediate reinforcement of the connections between mass and volume and items purchased at a store. The concept map (Appendix B-5) I used in this unit already had the bubbles and lines drawn. Student just filled in the blanks. This stimulated some discussion, but is probably best used as an assessment tool. Next year I will have the students make their own concept map and make their own connections. I currently do this in my earth science unit and have been very pleased with the way students discuss the connections and struggle to find the "right" way to arrange the words. Each group finds their own connections and then briefly explains their concept map for the entire class. In the first paper clip activity when we are modeling elements, compounds, and mixtures I would like to make more of a connection between the models and substances familiar to the students. I changed the worksheet to require students to give the common name for each substance. This will help build the connection between their model and substance they are familiar with: water, salt, salt water, carbonated water, etc. I have also added additional questions such as, "Air is mostly composed of oxygen and nitrogen molecules that are not linked together. What would this look like with paper clips? Is air an element, compound, or mixture?" to try and build these connections. Finally, in the separating solids activity students will brainstorm methods for separating the solids before they get the worksheet and a procedure. Students may use their own procedures (or the one provided later) and perhaps compare purity of separated materials to assess whether their procedures were effective. Also I plan to add a demonstration (a match is extinguished when passed near the surface of freshly opened soda pop) of separating carbon dioxide from carbonated water as the students do this activity.

In general, adding more discrepant events, demonstrations, and questions that challenge the students' thinking and motivate them to seek answers will improve the unit. Student volunteers could set up simple demonstrations. The class would benefit from the demo, and the volunteer would benefit doubly through his/her hands-on participation. For example in the measuring density lab, when we have the question of humans floating or sinking, a natural demonstration would be an egg sinking in tap water, but floating in salt water. The demonstration would include appropriate questions to explain the behavior using the concept of density. This also demonstrates why humans float in the Great Salt Lake and Dead Sea. Another example, during the thermal expansion discussion, would be for a student to prepare a pop bottle and straw thermometer for the class. Such mind stimulating exercises are especially needed in the atoms to physical/chemical change portion of the unit. As shown by survey, students preferred the density part of the unit. The atoms portion needs more discovery, wonder, interest. I will be searching for means to tickle their curiosity. I also think the unit would be more effective at producing in-depth understanding by using more frequent assessment and problem solving exercises. For example, use density to determine if a penny is pure copper.

In our teaching unit of approximately 75 students, all three of the core teachers teach a matter unit in the Fall. I shared this matter unit and its activities with both of my colleagues. Teacher A used some of the activities. Teacher B used this unit almost entirely, but didn't get quite as far as I did (and I in turn did not do all the activities that I had planned). Teacher B was extremely enthusiastic about the effectiveness of the unit. She said she had more fun teaching this unit last fall than any previous year. The students were more focused and involved than ever before. Through class discussion and assessments, she felt the students gained a deeper understanding using this unit than her past methods. She feels like this would be a good unit to share with other teachers; we have discussed the possibility of presenting at the MSTA conference. The other unit that she teaches is the hydrosphere and weather. She said that teaching this unit has challenged her to add more activities and hands-on science to that unit. In short, she considers this to be a very effective unit. I also enjoyed teaching this unit last fall. And having reviewed this unit, I feel better prepared and more enthusiastic about teaching it again this fall!

The constructivist approach produced a successful unit. The matter unit incorporated the major tenets of constructivism. Students were put in the role of the active learner. They constructed knowledge by observing, handling, predicting and investigating. They constructed this knowledge as social learners. They shared observations, data, predictions, and understanding while working in groups. They were stimulated and encouraged to be creative learners. Discrepant events and their thoughtful questions sparked their curiosity. The teachers that taught this unit saw students engaged in their work. Students reported they enjoyed the labs and activities. As discussed in the evaluation section, the labs and activities generally accomplished their objectives. Student understanding of the standards and benchmarks improved. Using a constructivist approach requires lots of research and preparation. Nonetheless the benefits outweigh the costs. I plan to use this approach in my other science unit and in the math classes that I teach.

APPENDIX A – Labs and Activities

A - 1 Description contest

A - 2 Density measurement lab

A - 3 Density column lab

A - 4 Film can inference lab

A - 5 Creating model atoms

A - 6 Atoms and molecules model

A - 7 Separating solids activity

A - 8 Melting ice lab

A - 9 Chemical reaction model

Appendix A-1 Description contest

name:________________________ Description Contest

How good are you at describing things? Good scientists make detailed descriptions of what they observe. In this activity you will have a chance to practice and improve on this skill. You will *write* descriptions and then *read* and interpret someone else's descriptions.

Here's how it works:
There are twelve objects. I'll assign you six of those objects to describe. I'll write down the symbols of six objects in the blanks in part 1.

You write your name in the area marked part A. Also write your name on this side of the paper. Then, in part B, describe the object carefully, without describing its color. (If you use a word that describes color your entry will be disqualified.) **Do not use the symbol on the object as part of your description.** You will have 5-10 minutes to finish. Work by yourself because you are competing with your classmates. Give me your paper when you are finished. You are now finished *writing*.

Next I'll detach part A and give your descriptions to another student. That student will be the other half of your team and will be assigned randomly.

You will get the other student's description to read and interpret. Read the descriptions in part B. Decide which object is being described. Write the symbol of this object in part C. You will have 5 minutes to finish. Work by yourself because you are competing with your classmates. Write your name in part C. Hand in your finished paper. You are now finished *reading*.

Be as detailed as possible. The pair that gets the most correct matches wins. Good luck!

Appendix A-1 Description contest

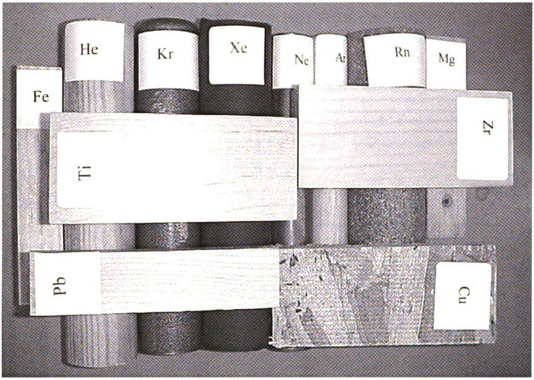
Part A:	Part B:	Part C:
____________ Name		____________ Name
1. ________	________________________________	1. ________
2. ________	________________________________	2. ________
3. ________	________________________________	3. ________
4. ________	________________________________	4. ________
5. ________	________________________________	5. ________
6. ________	________________________________	6. ________

Appendix A-1 Description contest

Notes for the Teacher:

1. The purpose of the contest is to see how well students can describe objects. This is an important science skill; I plan to use this contest more than once.

I plan to use the following objects:



Note: cylinders are all the same length.

He	large diameter wood dowel	Kr	steel table leg
Xe	pipe insulation	Ne	copper pipe
Ar	small diameter wood dowel	Rn	gray pipe insulation

Fe, Pb, and Mg wood pieces same shape and size, but different grain
Ti, Cu, and Zr larger wood pieces, same shape and size, but different grain
* these objects will be the same length (can't be distinguished by length).

2. I plan to label the objects with element symbols. This should prevent the students from using them in their description, because they are not familiar with these symbols. A separate file prints the necessary labels.

3. I hope the competition will prevent students from collaborating on writing the descriptions or reading the descriptions.

4. Each student will describe six of the twelve objects so the reader cannot use process of elimination.

5. One sample description sheet with the symbols already on them is after this page.

Appendix A-1 Description contest

Part A:	Part B:	Part C:
________ Name		________ Name
1. Xe	________	1. ________
2. Kr	________	2. ________
3. He	________	3. ________
4. Pb	________	4. ________
5. Ti	________	5. ________
6. Fe	________	6. ________

Appendix A-2 Density measurement lab

Lab – Measuring Density

Objective: Explore the concept of density.

Questions:
1. Is density different for different substances?
2. Does the size of an object affect density?

Plan:
1. Measure the density of several different substances.
2. Measure several different sizes for each substance.
3. Analyze the information using calculators and graphs.

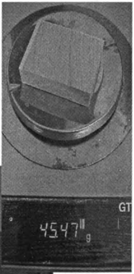
Materials: Each lab group (~8 students) will need:
- four blocks of wood
- four pieces of copper pipe
- two 100 mL graduated cylinders
- four rulers
- access to the digital balance
- supply of water

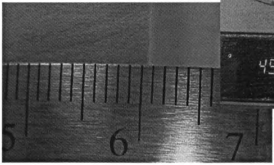
Procedure:

Each student pair will complete and turn in a data sheet, graph, and analysis write-up.

Each student pair will measure the density of a wooden block, a copper pipe, and water. Then share this information with the others in you lab group to complete the data table and analysis questions.

<u>Wood</u>:
1. Select a piece of wood and use the balance to find its mass. Record the mass in grams to the nearest tenth. (45.5g in picture)
2. Measure the length, width, and height of the wood in centimeters. Record each value to the nearest tenth.
3. Calculate the volume by multiplying length x width x height. Record this to the nearest tenth.
4. Finally calculate density as mass ÷ volume. Thus the number will have the unit g/cc or g/mL. Record the value to the nearest tenth.

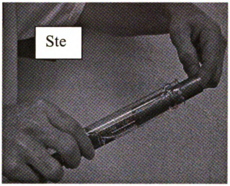




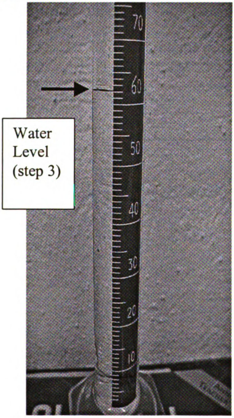
Appendix A-2 Density measurement lab

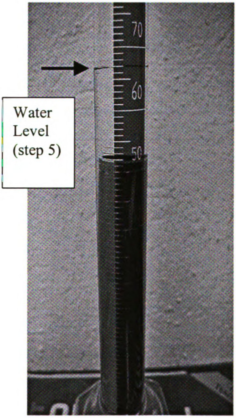
Copper Pipe:

1. Measure the length of your pipe in centimeters. Record your value to the nearest tenth. This will help you identify your pipe.
2. Use the balance to find its mass. Record the mass in grams to the nearest tenth.
3. Put 50-70 mL of water into a 100 mL graduated cylinder. Measure the exact water level in mL (estimate to the nearest tenth). If the water level is not straight across, measure it at its lowest point. Record this as the volume of water.
4. Make sure step 2 is complete. Carefully place the pipe into the graduated cylinder – slide it down the wall of the cylinder as shown in the picture so that it doesn't splash and doesn't hit the bottom with a lot of force.
5. Measure the exact water level in mL (estimate to the nearest tenth) and record this as the volume of water and pipe.
6. Calculate the volume of the pipe by subtracting the volume of the water and pipe from the volume of the water.
7. Calculate the density of the copper pipe as mass ÷ volume. The unit will be g/mL. Record this value to the nearest tenth.



Water:





Appendix A-2 Density measurement lab

1. Measure the mass of the empty graduated cylinder. Round to the nearest tenth and record this as the mass of the empty cylinder.
2. Put about 20-30 mL or 45-55 mL or 70-80 mL or 90-100 mL (depending on which sample your student pair is doing) of water into the graduated cylinder.
3. Measure the mass of the graduated cylinder and water. Round to the nearest tenth and record this as the mass of the cylinder + water.
4. Find the mass of the water by subtracting: (mass of cylinder + water) – (mass of cylinder). Record this value as mass of water.
5. Measure the volume of water in the cylinder in mL, estimate to the nearest tenth. Record this as volume of water.
6. Calculate density of the water as mass ÷ volume. Record the value of density.

<u>Average density</u>:

1. After you have four densities for each substance, calculate the average density by adding the four values together and dividing by four.
2. Record these values in the average density blank.

<u>Graph your data on the supplied graph</u>:

1. Graph each value of volume and mass for wood. (use the symbol ⊙)
2. Graph each value of volume and mass for copper. (use the symbol ⊡)
3. Graph each value of volume and mass for wood. (use the symbol △)
4. As an example the points for an unknown substance are already graphed with the symbol ☆

Volume (mL)	Mass (g)	Density?
3.7	27.8	
6.4	48.6	
9.7	71.6	

Appendix A-2 Density measurement lab

DATA SHEET for Density Lab

Wood:

Mass (g)	Length (cm)	Width (cm)	Height (cm)	Volume = l x w x h (cc)	Density = mass ÷ volume (g/cc)

Average density: ___________

Copper (Cu) Pipe:

Length (cm)	Mass (g)	Volume of water (mL)	Volume of water and pipe (mL)	Volume of pipe itself(mL) [subtract]	Density = mass ÷ volume (g/cc)

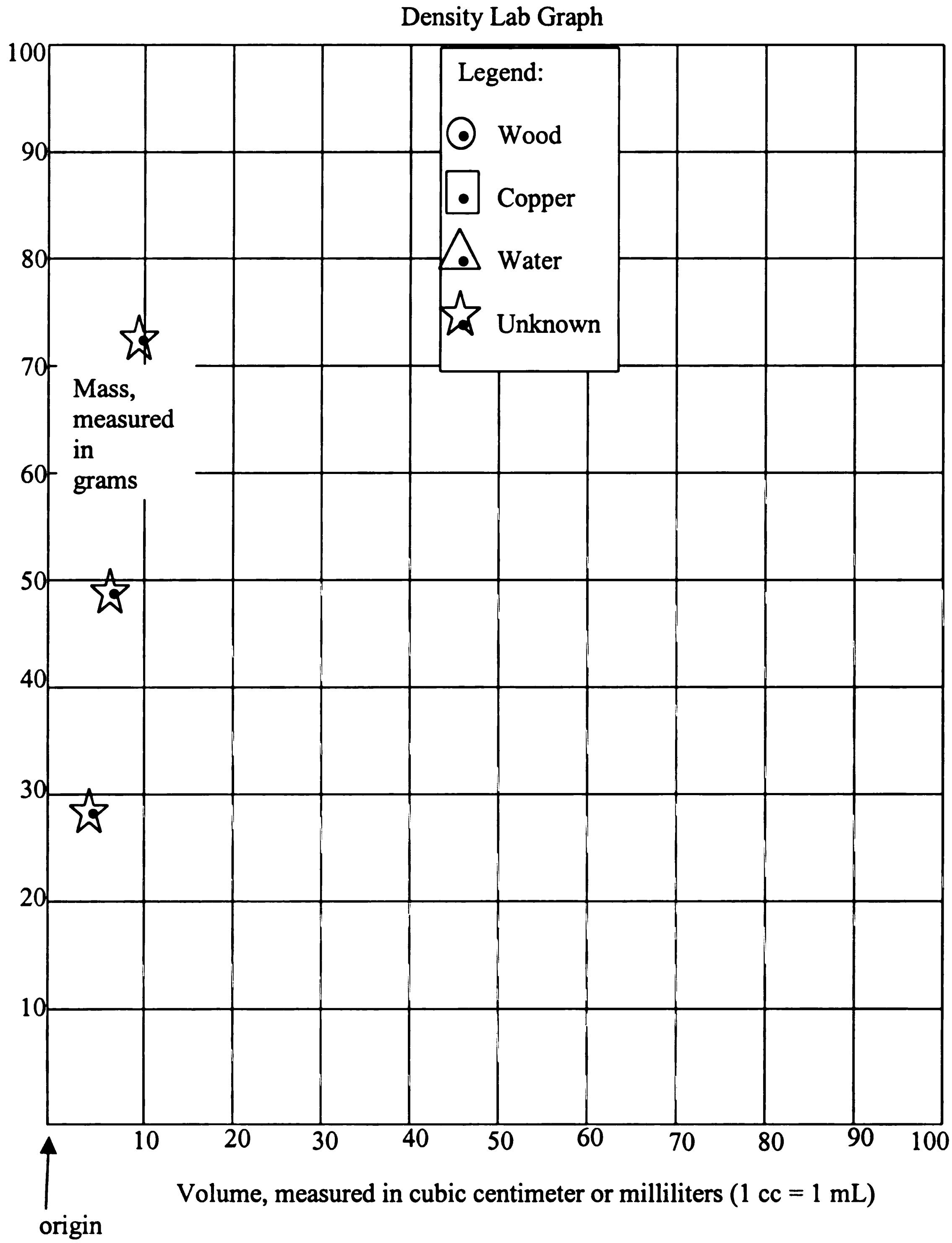
Average density: ___________

Water:

Use about this much water:	Mass empty cylinder (g)	Mass of cylinder + water (g)	Mass of water (g) [subtract]	Volume of water (mL)	Density = mass ÷ volume (g/cc)
20-30 mL					
45-55 mL					
70-80 mL					
90-100 mL					

Average density: ___________

Appendix A-2 Density measurement lab



Appendix A-2 Density measurement lab

Analysis: (learn from the information you've gathered and graphed)
Answer all of these four questions in complete sentences using data you collected in this lab to back up your statements.

1. Do different substances have different densities?

2. For objects made of the same substance, does the density change if the object is bigger or smaller?

3. Draw a straight line through the origin (bottom left hand corner of the graph) and one of your data points for water. The other data points should be close to or on this line. Explain why these points form a line – why don't they curve or bend?

4. What is the unknown substance? The measurements of volume and mass are listed with the graphing directions; also the points are plotted on your graph. Use the data table on page 22 of your book and this data table:

Material	Density (g/mL)	Material	Density (g/mL)	Material	Density (g/mL)
Hydrogen	.000824	Carbon dioxide	.00180	Ethyl alcohol	.789
Table sugar	1.587	Table salt	2.164	Aluminum	2.7
Iron	7.86	Copper	8.94	Silver	10.5
Gold	19.3	Osmium	22.6		

Appendix A-2 Density measurement lab

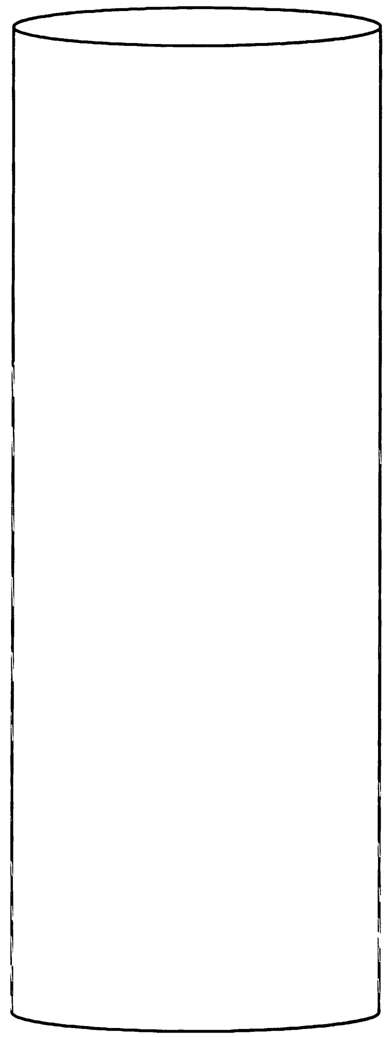
Analysis: (learn from the information you've gathered and graphed)
Answer three of these questions in complete sentences using data you collected in this lab to back up your statements. You may answer more questions for extra credit. Write your answers on the back of the data sheet.

1. Why did the line that contained your data points go through the origin?
2. The data for the copper pipe are scrunched into a tiny portion of your graph. This makes it difficult to graph and analyze accurately. Graph the data for the copper pipe on a separate graph using scales that will spread this data out over the whole page. You may use a computer to make this graph.
3. Describe how you could use the concept of density to determine if pennies are pure copper.
4. What are some sources of error in your lab? In other words, what are some factors that may have caused your results to be a little different from the "book results"?
5. How could you redo the lab to minimize the sources of errors you identified in the question above?
6. You have a piece of wood that has length=200 cm, width=12 cm, and height=8cm. It has mass of 16,320 g (16.320 kg). Is this the same type of wood you used in the lab?
7. What mass would you expect for a volume of water of 42.6 mL? What about 0 mL? What about 150 mL?

Appendix A-3 Density column lab

Part 1 (each student work independently and complete part 1):

1. Look at the density column at your lab group. **Do not tip or shake the container**. Draw and label what you see.



2. Write down anything you observe about the density column. Explain what you are observing.

Appendix A-3 Density column lab

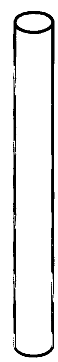
Part 2 (work with one lab partner):

1. Circle the four liquids you would like to investigate:

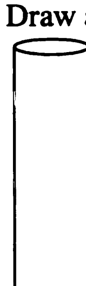
Rubbing Alcohol	Vegetable Oil	Water
Corn Syrup	Baby Oil	Dishwashing liquid

Get samples of the four liquids and bring them back to your table.

a.

(1)What two liquids do you want to put together first? _______________ _______________	(2) What do you think will happen when these two liquids are put in the same test tube?
(3) Put a small amount of each liquid into the test tube. What happened?	(4) Draw a picture of what happened: 

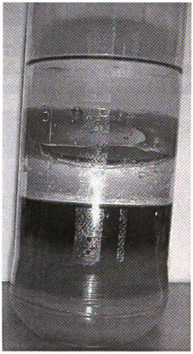
b.

(1)What liquid would you like to add to the test tube? _______________	(2) What do you think will happen when this liquid is added to the two liquids already in the test tube?
(3) Put a small amount of this liquid into the test tube. What happened?	(4) Draw a picture of what happened: 

c.

(1)What is your fourth liquid? ______________	(2) What do you think will happen when this liquid is added to the three liquids already in the test tube?
(3) Put a small amount of this liquid into the test tube. What happened?	(4) Draw a picture of what happened: 

2. Discuss your results with the other lab teams in your group. Can you determine which liquid was at each level in the original density column? (Note: some of the liquids in the original column have food coloring in them.)



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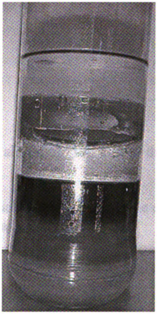
Appendix A-3 Density column lab

Part 3: Where does it float? (complete as a lab group, but your predictions don't have to agree)

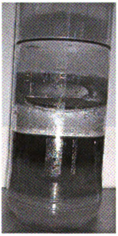
1. You are going to put a paper clip, birthday candle, a piece of film canister, and a rubber stopper into the density column. But FIRST, draw in each object where you predict it will float in the density column. Next, gently place the objects in the density column and draw in where you observe they float.

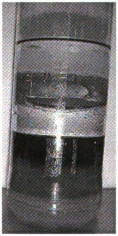
Prediction

Observed



2. Take two rubber bands. Cut one into three different size pieces. Draw in where you predict each piece will float in the density column. Next, gently place the rubber band pieces in the density column and draw in where you observe they float.





Appendix A-3 Density column lab

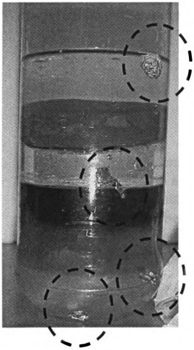
3. Explain what you observed with the rubber bands.

   Why do you think this happened?

4. Where do you predict a larger rubber stopper would come to rest?

   Why?

Extra Credit: In this density column there are wads of aluminum foil at four different levels.



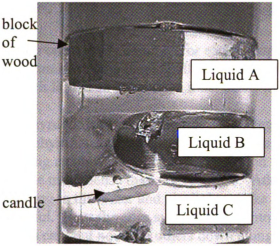
a. 1 point for each level your lab table can get an aluminum wad to stop at.

b. Explain why the same substance can float at different levels.

Appendix A-3 Density column lab

Part 4 (answer these questions on your own):

Use some of the following words to help explain your answers: density, more dense, less dense, sink, float.



1. Using some of the key terms above, describe the position of the block of wood.

2. Using some of the key terms above, describe the position of the candle.

3. Which liquid is the most dense? What evidence do you have that it is the most dense of all liquids in the column?

4. You are looking at a density column. Another student splits a piece of soap into a large piece of soap and a small piece of soap and gets ready to put the pieces of soap into the column. One student predicts that the bigger piece of soap will sink lower than the smaller piece because it has more mass.

   Explain why you agree or disagree with this student.

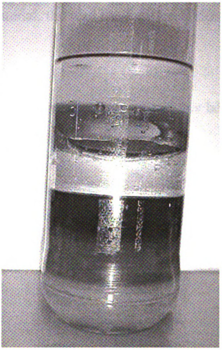
Appendix A-3 Density column lab

Teacher Notes

(this lab is largely from activity #6, "Exploring Density" of the Matter Matters unit of the Battle Creek Area Mathematics and Science Center, copyright 1995, revised 1999)

Part 1:
Set up one density columns for each group. Recommend using tennis ball cans and ~ 100mL of each liquid. In order from most dense to least dense:
corn syrup, dishwashing liquid, water, vegetable oil, baby oil, isopropyl alcohol (if you use rubbing alcohol if may be a 70% solution which will be more dense than the baby oil). Add food coloring to the water and alcohol to make it more colorful. Pour the corn syrup directly into the tennis can, but pour the others down along the wall to minimize mixing.

This column used water colored blue and rubbing alcohol colored green.



Part 2: Have 8 film canisters with each of the six liquids (total of 48). Make sure each canister is labeled. Not all students will get their choice of the four liquids.

Students should be able to put all six liquids in order after their discussions.

Part 3:

Students need to understand that different substances float at different levels because of density.

Appendix A-3 Density column lab

Density does not depend on mass. The different pieces of the rubber band have the same density even though they have different mass. They float at the same level even though they have different masses.

Extra credit: Give the students several pieces of aluminum foil with the same size. Hopefully the students will realize that the difference is how small/tightly/scrunched up they wad up the foil. Even though it's the same material, the wad has a different density because of the air trapped inside.

Part 4:

These questions will show whether the students learned the major concepts of this lab.

Appendix A-4 Film can inference lab

Lab: Film Canister Inferences

Can we investigate something that we can't see?

Materials:
Film canisters, numbered and taped shut.
Balance
Magnet

Procedure:
1. You will work in pairs. Each pair will have two film canisters to investigate. ***Do not open the canister***; do not damage the canister.
2. Use a magnet to determine if the objects in the canister have any magnetic properties.
3. Determine the mass of an empty canister. Then determine the mass of your canister. The difference between the two masses is the mass of the object(s) inside the canister.
4. You may be able to determine something about the object's shape by tilting the canister. Is there more than one object? Does it bounce? Does it flip? Does it roll?

Observations:

Test	Canister number	
Magnet brought near		
Mass of object		
Canister tilted		
Canister shaken		

1. How many objects are in your canister?

2. Describe the object in your canister. Is it soft? Magnetic? Fragile? Flat? Rounded? etc.

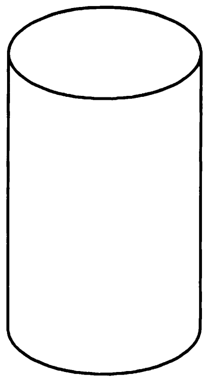
Appendix A-4 Film can inference lab

Analysis and Conclusions:

1. Make a sketch of what you think is in the canister. Draw the object to scale.

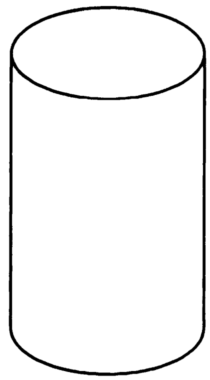
Can #

______



Can #

______



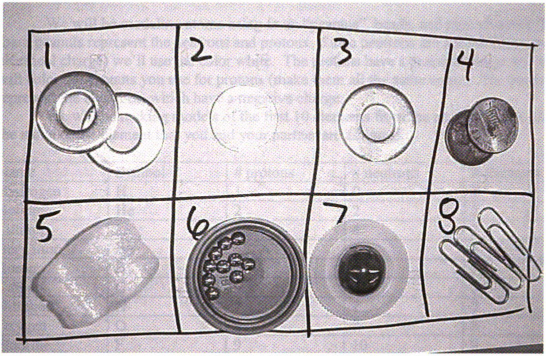
2. What other evidence did you gather to help you make the drawing?

3. What other tests could you do to learn more about the object?

Extra credit: Make a canister with one or two objects you select. Have a parent see if they can determine what is in your canister. Report your results.

Appendix A-4 Film can inference lab

Teacher notes:



The contents of each canister will be:

1. Two magnetic washers about the size of a quarter.
2. One nickel (or a quarter).
3. One magnetic washer about the size of a quarter.
4. Two pennies.
5. One foam packing peanut.
6. Ten BB's – look like copper, but they're steel (magnetic).
7. One glass marble.
8. Three small paper clips.

Appendix A-5 Creating model atoms

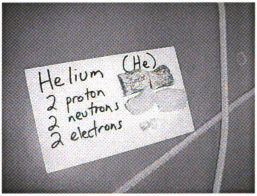
Modeling Atoms

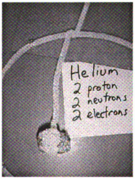
We will be modeling atoms using foam "peanuts", beads, and pipe cleaners. The foam peanuts represent the neutrons and protons. Since neutrons are neutral (have no electrical charge) we'll use the color white. The protons have a positive charge so you will color the peanuts you use for protons (make them all the same color). The beads will represent the electrons, which have a negative charge.

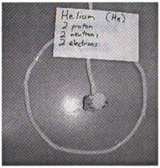
We will be making models of the first 10 elements from the periodic table. Circle the name of the element that you and your partner are assigned.

Name	Symbol	# protons	# neutrons	# electrons
Hydrogen	H	1	0	1
Helium	He	2	2	2
Lithium	Li	3	4	3
Beryllium	Be	4	5	4
Boron	B	5	6	5
Carbon	C	6	6	6
Nitrogen	N	7	7	7
Oxygen	O	8	8	8
Fluorine	F	9	10	9
Neon	Ne	10	10	10

1. Gather the materials you will need: one index card, enough foam peanuts to make the protons and neutrons, beads equal to the number of electrons, and three pipe cleaners.
2. On the index card write the element name, symbol, # protons, # neutrons, and # electrons. Use a marker to color your protons.
3. Glue the neutrons and protons together. Put this nucleus on the end of a single pipe cleaner. Let the glue dry.
4. Twist together the ends of the other two pipe cleaners for the electron shell. String on the appropriate number of beads to represent electrons. Form the pipe cleaners into a circle to make the electrons' orbit; twist the remaining ends together.
5. Connect the pipe cleaner with the nucleus to the electron circle so the nucleus is in the middle of the circle. Staple the card onto the pipe cleaner.







Appendix A-5 Creating model atoms

Discussion Questions:

1. In what ways is your model like a real atom?

2. In what ways is your model unlike a real atom?

3. What patterns do you see in the number of protons, neutrons, and electrons in the table?

extra credit:

1. Make a model of Iron, Cobalt, or Uranium. Make sure you have the correct number of protons, neutrons, and electrons. Label it and bring it into class.
2. Basketballs and atoms, Knoespel p.3-17

Appendix A-5 Creating model atoms

Teacher notes:

Purpose: To reinforce knowledge of the parts of an atom and their relationships. Also reinforces the use and limitations of a model.

Lead a discussion of the questions:

1. In what ways is your model like a real atom?

   relative sizes: neutrons and protons same size, electrons much smaller
   locations: neutrons and protons in nucleus, electrons in orbit
   correct number of particles: neutrons, protons, electrons

2. In what ways is your model unlike a real atom?

   real atom has much more space between nucleus and electrons (diameter of nucleus is ~ 10,000 times smaller than diameter of electron shell). E.c. #2 helps students explore this relationship.
   electrons are not all in the same shell

3. Do you see any patterns in the number of protons, neutrons, and electrons in the table?

   protons and electrons always equal – balance the charges (don't need to mention ions)
   sum of protons and neutrons is equal to atomic weight

This activity is a modification of the activity "Creating Atoms" found on the website: http://www.galaxy.net~k12/matter/atoms.shtml.

Appendix A-6 Atoms and molecules model

Activity: Elements, compounds, and mixtures (adapted from Knoespel p. 4-9)

We are going to construct models of elements, compounds, and mixtures. To do this we are going to use paper clips to model atoms. Each color of paper clip represents a different kind of atom. Use this table:

clip color	clip symbol	element name	chemical symbol
Blue	Bl	Hydrogen	H
Yellow	Y	Oxygen	O
White	W	Sodium	Na
Green	G	Chlorine	Cl
Black	B	Carbon	C
Pink	P	Helium	He

For example one black and one yellow could be joined to form a molecule. Using clip symbols (based on color) this molecule would be represented as BY. This would be a model for the molecule containing one carbon atom and one oxygen atom, called carbon monoxide, and written with chemistry symbols as CO.

Sometimes atoms come into contact with each other, but don't link-up (bond). For example, if carbon and oxygen didn't bond, we would write "B and Y" to represent this mixture (instead of BY). An actual example of two atoms not bonding would be two helium atoms put together. We would write 2 P to mean we had two pink paper clips that were not linked. Using chemical symbols we write 2 He.

Use the paper clips you have to make the following substances (your teacher will walk around and check your work):

Clip symbol	Put model in this box	Explanation	Chemical symbol
2 P		This is an element because…	
Bl_2		This is an element because…	H_2

Appendix A-6 Atoms and molecules model

Bl_2Y		This is a compound because…	
Bl_2Y and WG		This is a mixture because…	

Now try these on your own:

Clip symbol	Put model in this box	Fill in the blank and explain	Chemical symbol
$2Y_2$		This is a(n) ____________ because…	
Bl_2Y_2		This is a(n) ____________ because…	
BY_2 and Bl_2Y		This is a(n) ____________ because…	

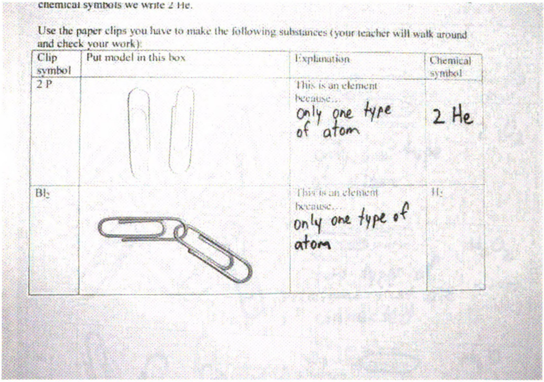
Appendix A-6 Atoms and molecules model

Teacher notes:

Use Power Point presentation: “activity atoms and molecules” for class practice

Really important points:
- correct number and color of paperclips
- paperclips linked when they’re supposed to be
- paperclips not linked when there is no bond

OK even if wrong:
- order of chemical symbols
- molecular structure (e.g. H—O—H vs. H—H—O)



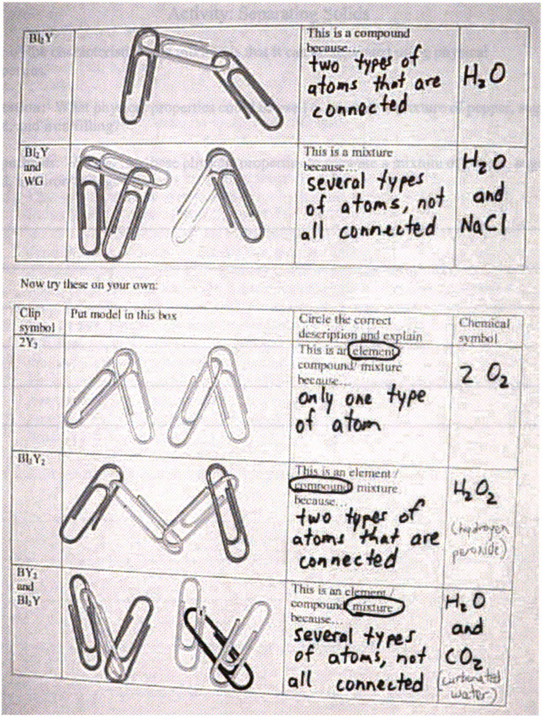
chemical symbols we write 2 He.

Use the paper clips you have to make the following substances (your teacher will walk around and check your work):

Clip symbol	Put model in this box	Explanation	Chemical symbol
2 P		This is an element because... only one type of atom	2 He
Bl₂		This is an element because... only one type of atom	H_2

Student Work

Appendix A-6 Atoms and molecules model



BlY		This is a compound because... two types of atoms that are connected	H_2O
BlY and WG		This is a mixture because... several types of atoms, not all connected	H_2O and $NaCl$

Now try these on your own:

Clip symbol	Put model in this box	Circle the correct description and explain	Chemical symbol
$2Y_2$		This is an (element) compound/ mixture because... only one type of atom	$2\ O_2$
BlY_2		This is an element / (compound) mixture because... two types of atoms that are connected	H_2O_2 (hydrogen peroxide)
BY_2 and BlY		This is an element / compound (mixture) because... several types of atoms, not all connected	H_2O and CO_2 (carbonated water)

Student Work

Appendix A-7 Separating solids activity

Activity: Separating Solids

One of the characteristics of a mixture is that it can be separated using physical properties.

Question: What physical properties could be used to separate a mixture of pepper, sugar, sand, and iron filling?

Hypothesis: We can use these physical properties to separate a mixture of pepper, sugar, sand, and iron fillings:

____

____

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Appendix A-7 Separating solids activity

Materials:

- 2 small jars or beakers
- 3 index cards
- 2 plastic stir sticks
- 1 magnet
- 1 filter paper
- Mixture of pepper, sugar, sand, and iron fillings

Procedure (working in groups of 2-4):

1. Spread out a small amount of the mixture on one index card.
2. Charge the stir stick with static electricity by rubbing it briskly in your hair. Slowly bring it close to the mixture but do not touch the mixture.
3. Brush off the particles that are separated onto a clean index card. Repeat this several times. What particles did you separate out? ____________________
4. Place the magnet **under** the index card with the remaining mixture. DO NOT allow the magnet to come into contact with the mixture or any of the particles. Slowly pull the magnet to the side.
5. Remove the magnet and brush the separated particles off onto a clean index card. What are they? ____________________
6. Prepare the filter by folding it in quarters.
7. Put the remaining mixture into one of the jars. Fill the jar half way with water and stir with the clean stir stick.
8. Pour this liquid through the filter into the other jar.
   What is left on the filter? ____________________
   What do you think is in the beaker? ____________________
9. How could you retrieve the remaining solid from this solution?

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What physical properties did you actually use to separate the solids?

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Appendix A-7 Separating solids activity

Teacher notes:

Purpose: To separate a mixture of solids using physical properties.

Notes:

1. Have students complete the hypothesis before turning to page 2, and working through the procedure.
2. Rubbing the plastic stir stick in your hair charges it with static electricity. It then attracts the pepper more so than the sugar because the pepper particles tend to be lighter weight than the sugar. You will probably pick up some sugar too.
3. The students should not allow the iron fillings to touch the magnet. It's tedious to get them off.
4. Save all the substances the students separate and mix them back together for another class. You'll need to add extra sugar because this is not recovered. It could be if we took the time to evaporate off the water.
5. Remind the students how to fold a filter paper (in quarters). You don't need a funnel; just hold the paper over the jar/beaker.

Extensions:

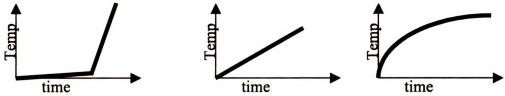
1. Use magnifiers to look at the solids after they've separated them. How pure are the substances?
2. Evaporate a little of the sugar water on a microscope slide to see that they can recover the sugar. This ties in with the evaporation phase change in a couple of weeks.

Appendix A-8 Melting ice lab

Lab – Melting Ice

What happens to the temperature of ice as you add heat to the ice causing the ice to melt?

Do you think a graph of the temperature as heat is added would look like one of the graphs below? Would it have a different shape?



What happens to the molecules of ice as heat is added?

Here's one way to investigate these questions:

1. Work with one partner at your lab table for this entire lab.
2. You will be recording the temperature of the ice every 30 seconds. Use your watch if it has seconds; otherwise use the clock on the wall.
3. You will also be recording the time when the ice is gone or just small, barely visible pieces of ice are left.
4. **Caution**: Don't try to move the thermometer – it is frozen in place and could break!
5. When you are ready to record on the Data Table, get a frozen thermometer/ice/ test tube assembly and immediately record the temperature. That is time 0. Now record the temperature every 30 seconds. Remember to place an asterisk next to the reading when the ice is gone or just barely visible.
6. The source of heat will be your hand. One partner can hold the test tube and observe the thermometer. The other partner can record the data and observations. Switch roles after about 5 minutes.
7. When the temperature is above 20oC, stop recording data, dump the water in the sink, and return the test tube and thermometer.
8. Plot the data and answer the analysis questions.

Appendix A-8 Melting ice lab

Data Table and Graph

Place * at time when ice is gone or barely visible.

Time (min)	Temp (oC)	
0		
.5		
1		
1.5		
2		
2.5		
3		
3.5		
4		
4.5		
5		
5.5		
6		
6.5		
7		
7.5		
8		
8.5		
9		
9.5		
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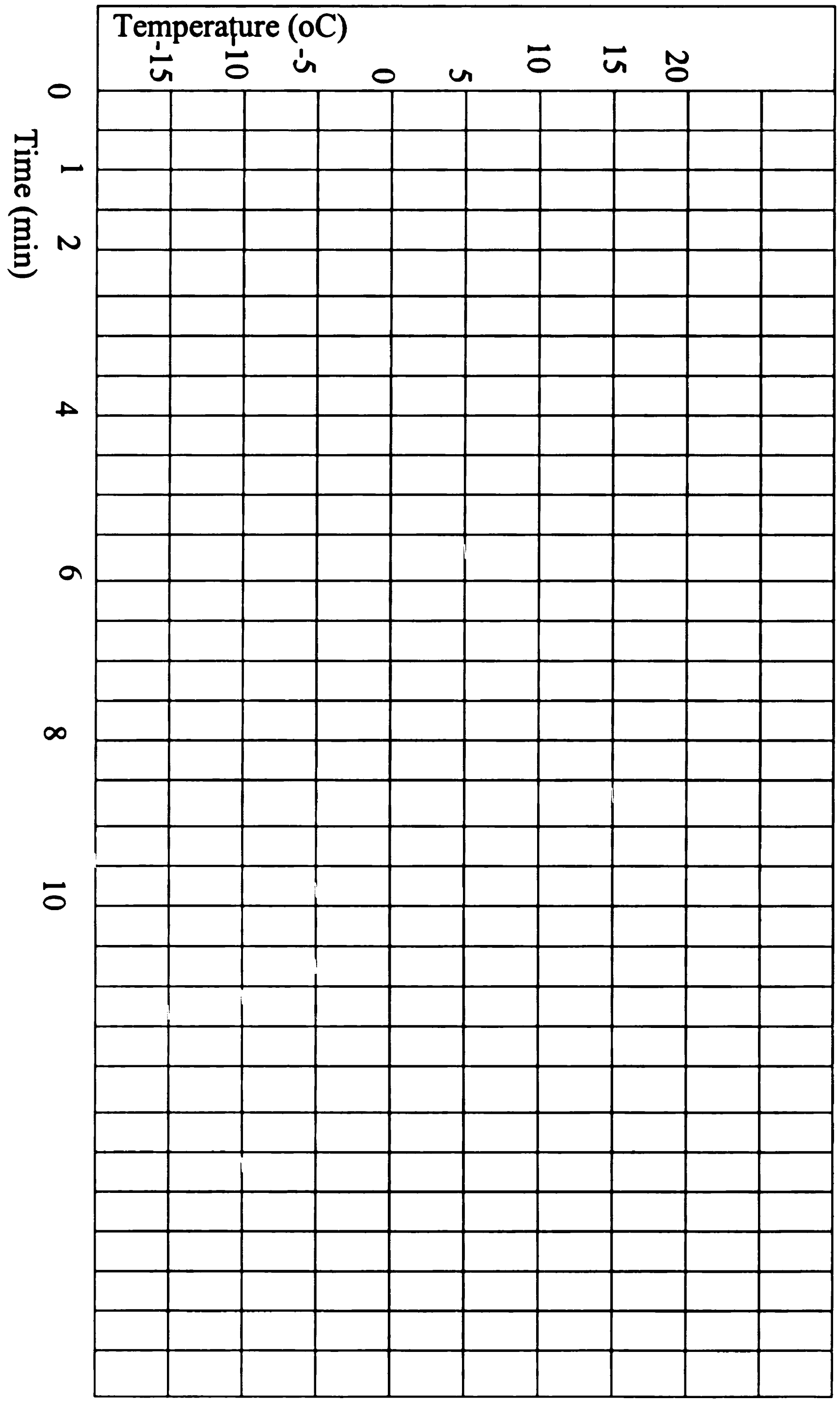
14.5		
15		
15.5		



Observations:

Appendix A-8 Melting ice lab

Analysis Questions:

1. How did your hand feel? Did the ice give off heat or absorb heat?

2. Graph your data. Plot a big "X" at the point where the ice was almost all gone.

3. Draw a picture and describe the difference between the water molecules in the solid or liquid phase.

solid　　　　　　　　　　liquid

4. Can you explain the shape of your graph?

Extension for extra credit:

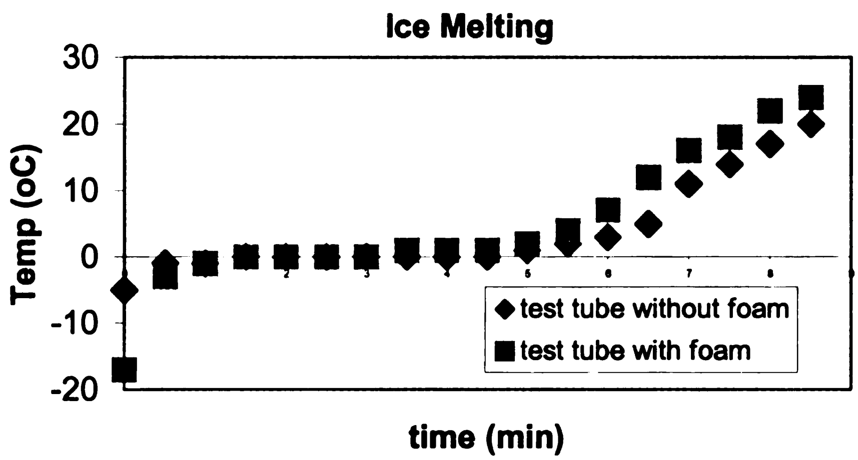
1. Can you predict what will happen to the temperature of water as you add heat to the water and it begins to boil? Draw a sketch. Do this at home with parent's supervision (you may need to borrow a thermometer).

2. What is a question about melting that you would like to study further?

Appendix A-8 Melting ice lab

Teacher notes:

1. Use about 4 mL of water. The bulb of the thermometer should be covered.
2. It will take about an hour to freeze the test tubes. You should be able to have starting temperatures well below zero – maybe –10oC.
3. Make sure the students are observing the samples. An important part of this lab will be missed if they don't observe when the ice is gone. Have them record anything else they observe as well.



time	test tube w foam	test tube wo foam
0	-17	-5
0.5	-3	-1
1	-1	-1
1.5	0	0
2	0	0
2.5	0	0
3	0	0
3.5	1	0
4	1	0
4.5	1	0
5	2	1
5.5	4	2
6	7	3
6.5	12	5
7	16	11
7.5	18	14
8	22	17
8.5	24	20

Here's the data with graph that I got on a couple of trial runs.

Appendix A-9 Chemical reaction model

Activity: chemical reactions (adapted from Knoespel p. 4-9)

We are going to model chemical reactions using paper clips. Remember our model:

clip color	clip symbol	element name	chemical symbol
Blue	Bl	Hydrogen	H
Yellow	Y	Oxygen	O
White	W	Sodium	Na
Green	G	Chlorine	Cl
Black	B	Carbon	C
Pink	P	Helium	He

Here are two new symbols that scientists use: "→" means "reacts to form".
"+" means "and"

For example: <u>hydrogen + oxygen → water</u> means *hydrogen and oxygen react to form water.*

Show this reaction using paper clip model in two different ways:

$H_2 + O_2 \rightarrow H_2O$

$2H_2 + O_2 \rightarrow 2H_2O$

Appendix A-9 Chemical reaction model

One of these equations is *balanced* and one is *unbalanced*. Scientists use balanced equations because they show that atoms are not created nor destroyed. Which of these equations do you think is balanced? WHY?

Model this equation with paper clips: $Na + Cl \rightarrow NaCl$ Is it balanced?

If sodium is a soft, silver shiny metallic element that reacts violently when placed in water and chlorine is a pale green, poisonous gas, can you predict what properties the compound NaCl will have?

Extra credit: Find another chemical reaction and model it with paper clips. Make sure it is balanced!

APPENDIX B – Discussion Guides

B - 1 Describing distance

B - 2 Describing volume

B - 3 Describing mass and weight

B - 4 Mass/volume take home investigation

B - 5 Matter concept map

B - 6 Dry ice day

B - 7 Phase change quiz and discussion questions

B - 8 Dehydration of sugar demonstration

Appendix B-1 Describing distance

Metric Units for Measuring Distance

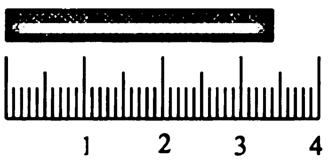
Fill in the blank with the approximate measurement:

Width of paper clip wire _______ Width of your little finger _______

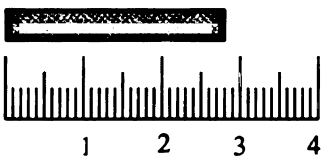
Distance from floor to waist _______ Distance from Hope to High School _______

What do milli, centi, and kilo mean?

We start with a basic unit – in this case the **meter**. [m]
We split a meter into 100 equal parts and call this a **centi**-meter [cm]. (hint: How many cents in a dollar?) A centimeter is bigger/smaller than a meter.
We split a meter into 1000 equal parts and call this a **milli**-meter[mm]. (hint: How many years in a millennium?) A millimeter is bigger/smaller than a meter.
We put 1000 meters together and call this a **kilo**-meter[km]. (hint: A kilometer is 1000 meters.) A kilometer is bigger/smaller than a meter.

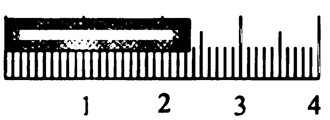


The length of the rectangle is 3.4 cm. Why?



What is the length of this rectangle?

Why is it important to include units?



What would you estimate the length of this rectangle?
2.35m 2.45cm 2.25cm 3.35mm 2.35cm

Measure the width of this paper to the nearest mm. ____________ (include units!)

Measure the length of this paper to the nearest mm. ____________ (include units!)

Why might your neighbor get a different answer? List as many reasons as you can.

Appendix B-1 Describing distance

Circle agree or disagree for the following statements and give a reason.

Example:

1. Agree/Disagree The distance to Elliott is about 2 m.

A meter is about the height of my waist, so 2 m is much smaller that the distance to Elliott.

2. Agree/Disagree The width of a yellow pencil is about 1 cm

3. Agree/Disagree The distance to the high school is about 1000m.

4. Agree/Disagree The width of a piece of notebook paper is about 22 mm.

5. Agree/Disagree The width of my wrist is about 5 cm.

6. Agree/Disagree The height of the tallest student is about 2m.

Extra credit:

1. Make up your own agree/disagree statement:
   Agree/Disagree

2. Measure your height in cm. My height is ________ cm.

Appendix B-2 Describing volume

Volume   Name:

Amount of ________ an object takes up

We will use these units for measuring volume: **1 mL** (milliliter) **= 1 cc** (cubic centimeter)

a 250 cc dirt bike means its engine has a volume of 250 *cubic centimeters*
a 2-liter pop bottle has a volume of 2,000 *mL*.

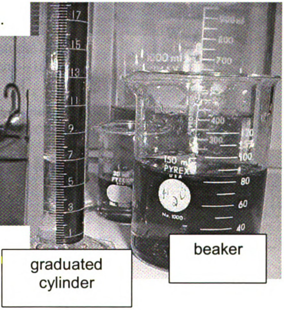
Other common units for measuring volume:

Gallon of ice cream
Cup of milk
Bushel of apples
Teaspoon of medicine
Lung-full of air

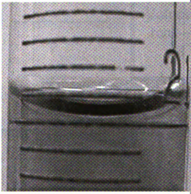
Notice that we can use volume to measure liquids, solids, and sometimes even gases.

We will use three different methods to measure volume. Some methods are simpler than others, but some objects can't be measured using the simple methods.

Method 1: Direct measurement. Pour the liquid into a measuring cup. We will use measuring cups called beakers and graduated cylinders that are marked in mL.



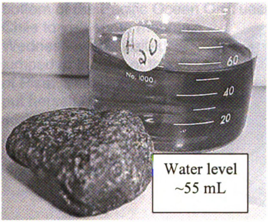
Sometimes the surface of the liquid looks curved. This is called a "meniscus". Read the level of the liquid at the lowest point on the curve. For example, this volume would be 21mL instead of 21.1 mL.



Appendix B-2 Describing volume

Method 2: Use a formula. We will use the formula for the volume of a rectangular solid (6 sides, all corners are right angles): Volume = length x width x height. For example, a block of wood that had length=5cm, width=3cm, and height=2cm has a volume of 5x3x2=30 cubic centimeters. Remember we could also say it had a volume of 30 mL. (This method can be used for other shapes, but we will only use this method for rectangular solids.)

Method 3: Water displacement. This method can be used to measure the volume of a solid of any shape. (It can even be used to measure the volume of a person!) Find a beaker or graduated cylinder that will hold the object. Put some water in the container. Measure the water level. Put the object in the container – make sure the object is completely covered with water. Measure the new water level. The volume of the object is the difference in the water levels.



Volume of rock ~16 mL

Activity:
With a partner in your lab group, measure the volume of the following:

1. What is the volume of the AquaFina bottle? Method to use: ________________

2. What is the volume of the piece of 2x4? Method to use: ________________

3. What is the volume of the piece of steel pipe? Method to use: ________________

Extra credit:
1. Devise a method to measure the volume of your body. Get it approved by the teacher and then do it!

Appendix B-3 Describing mass and weight

Mass measures the amount of _________ in an object.

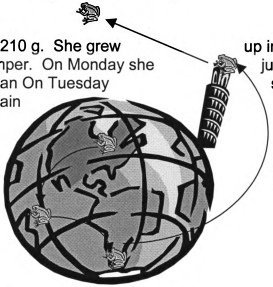
Which object has more matter – a foam peanut or a penny?

More relevant question: Which has more matter – a 16 oz bag of M&M's or two 7 oz bags of M&M's?

Metric units for measuring mass are grams (g) or kilograms (kg)

A small paperclip is a little less than 1 g; a jumbo paperclip is a little more than 1 g.

Weight measures the _________ of gravity between two objects (often one of the objects is earth).



Astro-frog has a mass of 210 g. She grew up in Michigan and became a very strong jumper. On Monday she jumped to the bottom of the Pacific Ocean On Tuesday she hopped to Chile to visit some mountain cousins. On Wednesday she visited Italy and jumped to the top of the leaning Tower of Pisa. Then with a mighty leap, she put herself into frbit. (not drawn to scale)

How did her mass and weight change as she traveled?

Location	Mass	Weight
Michigan	starting value	starting value
Ocean floor	smaller / same / bigger	smaller / same / bigger
Chile	smaller / same / bigger	smaller / same / bigger
Italy	smaller / same / bigger	smaller / same / bigger
Space	smaller / same / bigger	smaller / same / bigger

On the surface of the earth, we usually use weight to measure mass. The two values are closely related. Oftentimes people say "weight" when they actually mean "mass".

The mass of objects (that can be easily moved) is measured quickly and simply by using an electronic balance or a triple beam balance.

Appendix B-3 Describing mass and weight

Measure the mass of your pen or pencil. Remember the correct unit!

____

Which is heavier a kilogram of lead or a kilogram of feathers? Why?

Density is mass per unit volume. A bowling ball is more dense than a volleyball. Lead is more dense than feathers. A box of lead has more mass than a box of feathers. When two liquids mix, the more dense liquid sinks and the less dense liquid rises.

Definition: ***MATTER*** is anything that has mass and volume.

Examples of matter:

Examples of non-matter:

Extra credit:

1. How could you measure the mass of an object in a gravity-free environment?
2. How could you measure the mass of a helium balloon?
3. What is the mass of the earth? How is it measured?

Appendix B-4 Mass/volume take home investigation

Mass – Volume – Density   Name:

1. All matter has mass (measured in grams or kilograms) and volume (measured in mL or cubic centimeter).

Some things are sold based on mass, some based on volume.

Fill in the table. Find three more items in your home that are sold by mass and record their mass. Find three more items in your home that are sold by volume and record their volume.

Mass Item	Mass (grams)	Volume Item	Volume (mL)
Grape jelly		Teriyaki sauce	
Baked beans		Mountain Dew	
Can of tuna fish		Evaporated milk	
		Miracle Whip	
____________	______	____________	
____________	______	____________	
____________	______	____________	

We can use mass and volume to calculate density.

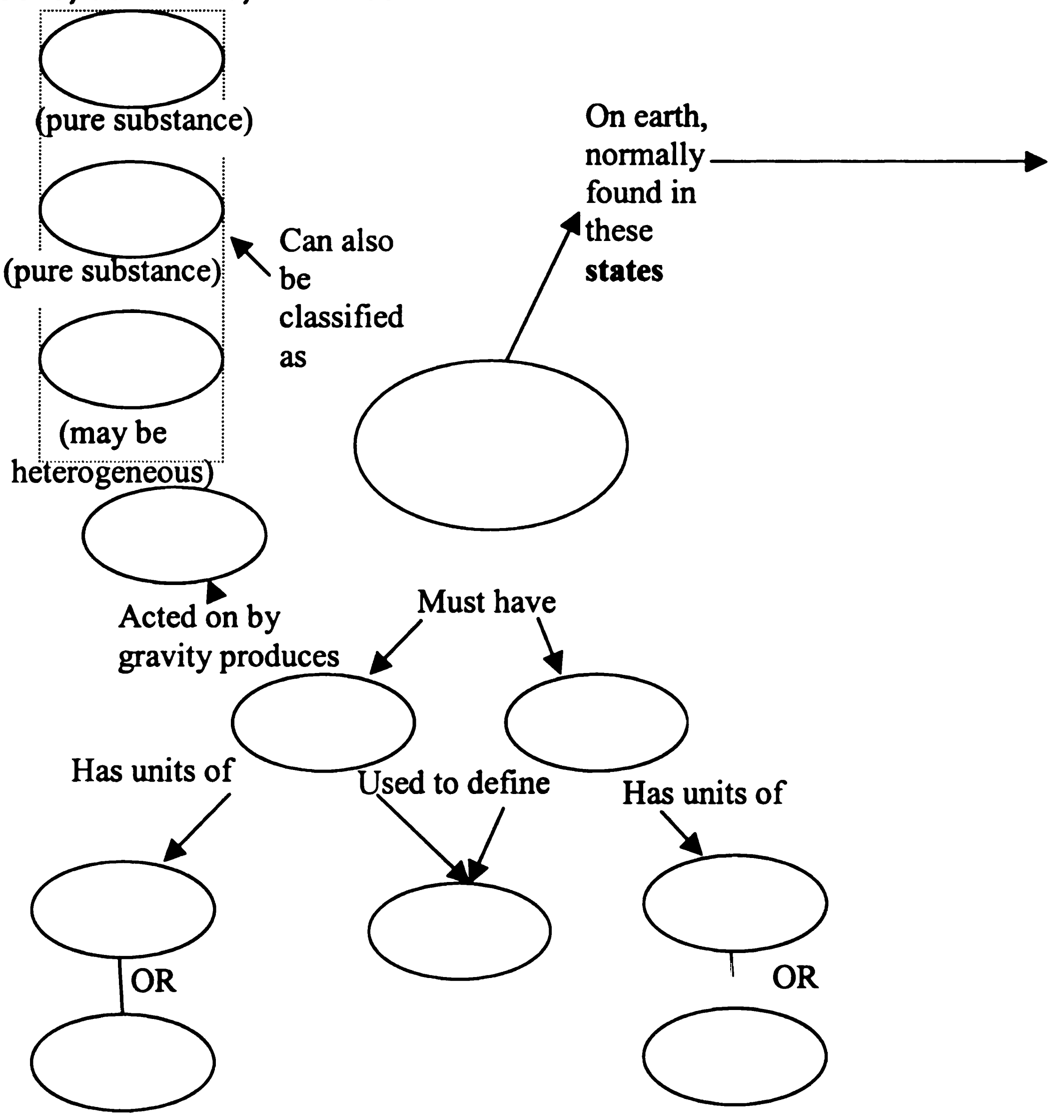
$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

For example: A rock has a mass of 500 g and a volume of 200 cm^3.

Then its density is $\frac{500\ g}{200\ cm^3} = \boxed{2.5\ g/cm^3}$

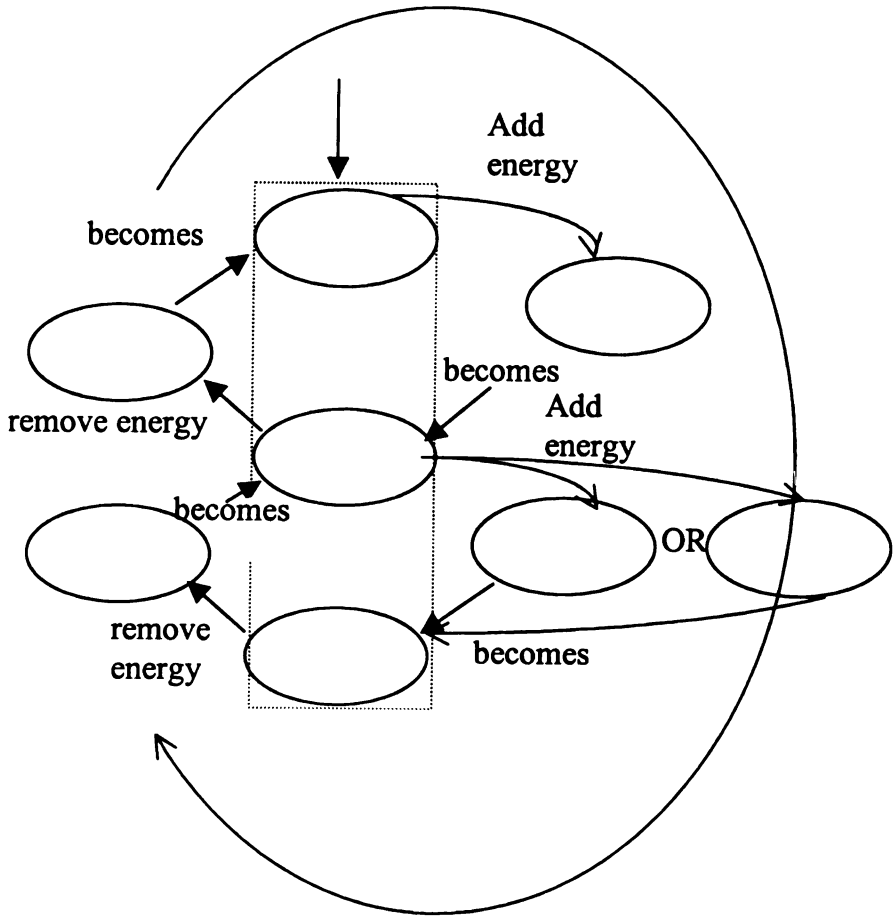
Appendix B-5 Matter concept map

Fill in the ovals in this MATTER concept map with the words:
mass, volume, matter, density, solid, liquid, gas, gram, kilogram, mL, cubic centimeter, weight, melt, evaporate, boil, elements, sublime, compounds, freeze, condense, mixtures



First Half

Appendix B-5 Matter concept map



Second Half

Appendix B-6 Dry ice day

Fun with Dry Ice

Thermal Expansion/Contraction using the ball and ring
- Why will the ball not fit through the ring?
- Why will it fit through later?

Dry Ice has mass and volume
- The gas CO_2 also has mass and volume (even though we can't see it)
- What will happen if I put some dry ice in a balloon?
- Does the mass of the balloon change? Measure it with the balance.

Fire extinguisher
- In aquarium – why does lower candle go out first?
- Outside of aquarium – why can you "pour" the gas?

Bubbles suspended in the aquarium
- Why do they float?

Phase changes – physical, not chemical changes
- Watch the dry ice sublime on black construction paper (solid → gas)
- What is the "smoke" that you see? (gas → liquid)
- What happens to the water in the beaker with the dry ice? (liquid → solid)

Dry ice is frozen carbon dioxide. A block of dry ice has a surface temperature of -109.3 degrees F (-78.5 degrees C). Dry ice also has the very nice feature of **sublimation** -- as it melts it turns directly into carbon dioxide gas rather than a liquid. The super-cold temperature and the sublimation feature make dry ice great for refrigeration. For example, if you want to send something frozen across the country, you can pack it in dry ice. It will be frozen when it reaches its destination and there will be no messy liquid left over like you would have with normal ice.

Many people are familiar with liquid nitrogen, which boils at -320 degrees F (-196 degrees C). Liquid nitrogen is fairly messy and difficult to handle. So why is nitrogen a liquid while carbon dioxide is a solid? This difference is caused by the solid-liquid-gas features of nitrogen and carbon dioxide.

We are all familiar with the solid-liquid-gas behavior of water. We know that at sea level water freezes at 32 degrees F (0 degrees C) and boils at 212 degrees F (100 degrees C). Water behaves differently as you change the pressure, however. As you lower the pressure the boiling point falls. If you lower the pressure enough, water will boil at room temperature. If you plot out the solid-liquid-gas behavior of a substance like water on a graph showing both temperature and pressure, you create what's called a **phase diagram** for the substance. The phase diagram shows the temperatures and pressures at which a substance changes between solid, liquid and gas.

Dry Ice Safety

If you ever have a chance to handle dry ice, you want to be sure to wear heavy gloves. The super-cold surface temperature can easily damage your skin if you touch it directly. For the same reason you never want to taste or swallow dry ice either.

Another important concern with dry ice is ventilation. You want to make sure the area is well-ventilated. Carbon dioxide is heavier than air and it can concentrate in low areas or in enclosed spaces (like a car or a room where dry ice is sublimating). Normal air is 78% Nitrogen, 21% Oxygen and only 0.035% Carbon Dioxide. If the concentration of carbon dioxide in the air rises above 5%, carbon dioxide can become toxic. Be sure to ventilate any area that contains dry ice, and do not transport it in a closed vehicle.

Appendix B-7 Phase change quiz and discussion questions

Physical and Chemical Changes Video Quiz

1.Ice being broken into small bits is an example of a ________change.

2.In a physical change the matter does not change _______.

3.In a chemical change a _______substance is formed.

4. A chemical _________ is a way to describe how matter reacts with other matter.

5. Flammability is the chemical property describing how a substance ___________________.

6. A clue that a chemical change is occurring in a burning flame is that _________________ is given off.

7. Chemical changes occur at _________ speeds.

8. ___________ is the substance produced by iron reacting with oxygen in the air.

9. A chemical _________ is the chemical change in which one or more substances change.

10. ____________ is a chemical reaction in green plants that produces energy and oxygen.

Appendix B-7 Phase change quiz and discussion questions

Physical and Chemical Changes Video Discussion Questions

1. What is a physical change?

2. What are some examples of physical changes in matter?

3. What is a chemical change?

4. What are some examples of chemical changes in matter?

5. What is a chemical reaction?

6. Write out an example of a chemical reaction.

7. What are some physical changes that occur at school? At home? In nature?

8. What are some chemical changes that occur at school? At home? In nature?

Appendix B-8 Dehydration of sugar demonstration

Chemical Reactions

Forms a new substance – a new compound or element.

Clues of chemical reaction taking place:

clue	Example	Exception
Gas produced	Vinegar + baking soda	Dry ice "boiling" in water
Heat energy produced or absorbed	Burning candle	Ice forming on oranges Dissolving barium nitrate(?)
Light energy produced	Burning candle	Light bulb
Change of color	Apple turning brown	

When combining substances, ask these questions to determine if you have a new substance:

1. Can the substances be separated by mechanical means?
   Yes → mixture
2. Do the substances retain their previous properties?
   Yes → mixture
3. Do they combine in any ratio? (tricky to describe without balancing chemical equations)
   Yes → mixture

Compare and contrast:

Sugar and water	Sugar and sulfuric acid (**must** be done outside; see attached page)

Since chemical reactions form new substances we use the terms:

"reactants" substance(s) we start with (what *reacts*)
"products" substance(s) we end with (what is *produced*)

Appendix B-8 Dehydration of sugar demonstration

Teacher notes:

Adapted from Liem p 5.1
Start with about 40mL of concentrated sulfuric acid and amount of sugar shown in a baby jar (this allows the products to be disposed of with the jar)
Do this outside, reaction may be messy and generates noxious gas
Jar will get very hot
Reaction starts very slowly, will be black after ~ 1 min; will be complete after ~ 3 min

APPENDIX C – Assessment Tools

C - 1 Correlation of standards and benchmarks with activities

C - 2 Pre/post test

C - 3 Correlation of pre/post test to standards and benchmarks

C - 4 Pre/post test analysis spreadsheet

C - 5 Student opinion survey

Appendix C-1 Correlation of standards and benchmarks with activities

Matter and Energy Standard SCI.IV.1

Specific benchmarks:

1. Describe and compare objects in terms of mass, volume, and density.

    Describing distance
    Describing volume
    Describing mass and weight
    Description contest
    Density measurement lab
    Density column lab

2. Explain when length, mass, weight, density, area, volume or temperature are appropriate to describe the properties of an object or substance.

    Describing distance
    Describing volume
    Describing mass and weight
    Description contest
    Density measurement lab

3. Classify substances as elements, compounds, or mixtures and justify classifications in terms of atoms and molecules.

    Creating model activity
    Atoms and molecules model
    Separating solids activity
    Video 5374 10

4. Describe the arrangement and motion of molecules in solids, liquids, and gases.
    Atoms and molecules model
    Video 5374 10
    Dry ice day
    Thermal expansion demos
    Melting ice lab

Changes in Matter Standard SCI.IV.2

Specific benchmarks:

1. Describe common physical changes in matter: evaporation, condensation, sublimation, thermal expansion and contraction.

Video 5374 10
Dry ice day
Thermal expansion demos
Video 5787 18
Evaporation race
Fog story

2. Describe common chemical changes in terms of properties of reactants and products.

   Video 5787 18
   Chemical reaction model
   Dehydration of sugar demo
   Candle observation

3. Explain physical changes in terms of the arrangement and motion of atoms and molecules.

   Dry ice day
   Thermal expansion demos
   Video 5787 18
   Fog story

4. Describe common energy transformations in everyday situations.

   Melting ice lab
   Video 5787 18
   Fog story
   Candle observation
   Fire dept demo

Constructing New Scientific Knowledge Standard SCI.I.1

All students will ask questions that help them learn about the world; design and conduct investigations using appropriate methodology and technology; learn from books and other sources of information; and communicate findings of investigations, using appropriate technology. (general)

Discrepant events
Density measurement lab
Density column lab
Film can inference lab

Melting ice lab
Evaporation race

Reflecting on Scientific Knowledge Standard SCI.II.1

All students will analyze claims for their scientific merit and explain how scientists decide what constitutes scientific knowledge; show how science is related to other ways of knowing; show how science and technology affect our society; and show how people of diverse cultures have contributed to and influenced developments in science. (general)

Discrepant events
Density measurement lab
Density column lab
Film can inference lab
Melting ice lab
Evaporation race

Appendix C-2 Pre/post test

1. When people go fishing, why is lead commonly used for a sinker?

2. Would the following items be more likely to be measured using mass or volume?

Item	Mass	Volume
Ice cream		
Hamburger		
Potatoes		
Milk		
Jelly beans		
Maple syrup		

3. Classify the following as element, compound, or mixture:

	Element	Compound	Mixture
water			
bean soup			
oxygen			
salt			
Pepsi			
hydrogen			

4. In the boxes below draw a model of what you think the molecules in a solid, liquid, and gas would look like. Briefly explain your drawings.

Solid	Liquid	Gas

5. Explain why "sweat" forms on the outside of a glass of ice water in the summer.

6. Hydrogen gas is given off when hydrochloric acid is added to zinc. The residue that remains is zinc chloride. Scientists might write the reaction like this:
   zinc + hydrochloric acid → hydrogen gas + zinc chloride.
   Classify these substances as products or reactants.

Products	Reactants

7. Patrick and Franklin's mother was filling the gasoline tank of her van. Franklin soon smelled gasoline. He asked Patrick how he could smell the gasoline when it went into the tank. Write what you think Patrick said to explain to Franklin how he was able to smell the gasoline. Use the idea of *molecules*.

8. Water freezes at 32°F. What is the approximate melting temperature for chocolate candy bar?
   a. 20 °F   b. 80 °F   c. 32 °F   d. 212 °F

9. Ice melts at 32 °F. What is the approximate freezing point for ice water?
   a. 20 °F   b. 80 °F   c. 32 °F   d. 212 °F

10. The density of the human body in grams per cubic centimeter is about:
    a. 1 g/cc   b. 5 g/cc   c. 10 g/cc   d. 50 g/cc

11. Lindsay was studying how fertilizer affects plant growth. She planted beans in four containers. Each container got the same amount of sunlight and water. She put a small amount of fertilizer in the first container, a little more fertilizer in the second container, and lots of fertilizer in the third container. She didn't put any fertilizer in the fourth container. What was the purpose of the fourth container?

12. Frances read that Dr. Zhou linked pollution from a local factory to lung cancer. What further information would cause her to believe the report?
    Dr. Zhou is a world-renowned expert in the diagnosis and treatment of lung cancer.

a) Other areas without the pollution had lower rates of lung cancer.
b) Frances' friend Chris read the same report in the morning newspaper.
c) Four of her friends had grandparents who died of lung cancer.

Appendix C-3 Correlation of pre/post test to standards and benchmarks

Matter and Energy Standard SCI.IV.1

Specific benchmarks:

- ***Describe and compare objects in terms of mass, volume, and density.***

- ***Explain when length, mass, weight, density, area, volume or temperature are appropriate to describe the properties of an object or substance.***

When people go fishing, why is lead commonly used for a sinker?

Would the following items be more likely to be measured using mass or volume?

Item	Mass	Volume
Ice cream		
Hamburger		
Potatoes		
Milk		
Jelly beans		
Maple syrup		

- ***Classify substances as elements, compounds, or mixtures and justify classifications in terms of atoms and molecules.***

Classify the following as element, compound, or mixture:

	Element	Compound	Mixture
water			
bean soup			
oxygen			
salt			
Pepsi			
hydrogen			

Your friend Chris says air is a mixture. Explain why Chris is correct using the words atom and molecule.

- ***Describe the arrangement and motion of molecules in solids, liquids, and gases.***

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

Appendix C-3 Correlation of pre/post test to standards and benchmarks

Solid Liquid Gas

Changes in Matter Standard SCI.IV.2

Specific benchmarks:

- *Describe common physical changes in matter: evaporation, condensation, sublimation, thermal expansion and contraction.*

Explain why "sweat" forms on the outside of a glass of ice water in the summer.

- *Describe common chemical changes in terms of properties of reactants and products.*

Hydrogen gas is given off when hydrochloric acid is added to zinc. The residue that remains is zinc chloride. Classify these substances as products or reactants.

Products Reactants

- *Explain physical changes in terms of the arrangement and motion of atoms and molecules.*

Patrick and Franklin's mother was filling the gasoline tank of her van. Franklin soon smelled gasoline. He asked Patrick how he could smell the gasoline when it went into the tank. Write what you think Patrick said to explain to Franklin how he was able to smell the gasoline. Use the idea of *molecules*.

- *Describe common energy transformations in everyday situations.*

Water freezes at 0°C. What is the approximate melting temperature for chocolate?
a. -10 °C b. 35 °C c. 0 °C d. 100 °C

Ice melts at 0 °C. What is the approximate freezing point for ice water?
a. -10 °C b. 35 °C c. 0 °C d. 100 °C

Constructing New Scientific Knowledge Standard SCI.I.1

All students will ask questions that help them learn about the world; design and conduct investigations using appropriate methodology and technology; learn from books and other sources of information; and communicate findings of investigations, using appropriate technology. (general)

Compare to a control. Why use a control.

Appendix C-3 Correlation of pre/post test to standards and benchmarks

Reflecting on Scientific Knowledge Standard SCI.II.1

All students will analyze claims for their scientific merit and explain how scientists decide what constitutes scientific knowledge; show how science is related to other ways of knowing; show how science and technology affect our society; and show how people of diverse cultures have contributed to and influenced developments in science. (general)

Frances read that Dr. Zhou linked pollution from local factory to lung cancer. What further information would cause her to believe the report?

a. Dr. Zhou is a world-renowned expert in the diagnosis and treatment of lung cancer.
b. Other areas without the pollution had lower rates of lung cancer.
c. Frances' friend Chris read the same report in the morning newspaper.
d. Four of her friends had grandparents who died of lung cancer.

Appendix C-4 Pre/post test analysis spreadsheet

Table 4: Pre test question-by-question analysis

	Pre Test									
que #:	1	2	3	4	5	6	7	8	9	10
pts poss	4	6	6	5	4	4	4	2	2	2
student										
A	2	5	5	5	0	0	0	2	2	0
B	2	0	2	5	0	0	4	2	2	0
C	2	1	4	5	2	0	2	2	0	0
D	0	2	5	3	0	0	0	2	0	0
E	2	6	3	5	2	1	2	2	0	0
F	2	4	4	3	2	2	4	2	2	0
G	2	6	2	5	1	0	2	2	0	0
H	2	5	4	3	1	0	4	2	0	0
I	2	6	3	5	2	0	2	2	2	0
J	2	3	2	0	2	2	0	0	2	0
K	2	5	2	2	0	0	2	2	0	0
L	2	4	2	0	1	0	0	0	0	0
M	2	4	3	2	2	0	0	0	0	0
N	2	0	5	2	0	1	2	0	0	0
O	2	5	3	1	2	2	0	2	0	0
P	2	3	4	5	1	2	1	2	0	0
Q	2	4	4	2	0	4	0	2	2	0
R	2	4	2	3	0	0	0	0	0	0
S	2	5	5	3	2	0	2	2	2	0
T	2	6	3	3	0	0	2	0	0	0
U	0	4	5	5	0	0	0	2	0	0
V	1	5	2	5	1	1	0	2	0	0
W	2	0	4	0	0	0	0	2	2	0
X										
que ave:	44.6%	63.0%	56.5%	62.6%	22.8%	16.3%	31.5%	73.9%	34.8%	0.0%

Appendix C-4 Pre/post test analysis spreadsheet

Table 4: Pre test question-by-question analysis (cont)

			Pre Test	
que #:	11	12	total pts	ave
pts poss	4	2	45	
student				
A	2	2	25	55.6%
B	4	0	21	46.7%
C	2	2	22	48.9%
D	0	2	14	31.1%
E	4	0	27	60.0%
F	4	2	31	68.9%
G	0	2	22	48.9%
H	4	2	27	60.0%
I	2	2	28	62.2%
J	2	0	15	33.3%
K	2	0	17	37.8%
L	2	2	13	28.9%
M	1	0	14	31.1%
N	4	2	18	40.0%
O	2	2	21	46.7%
P	0	0	20	44.4%
Q	0	0	20	
R	0	0	11	24.4%
S	1	0	24	53.3%
T	0	2	18	40.0%
U	4	0	20	44.4%
V	0	0	17	37.8%
W	4	0	14	31.1%
X				
que ave:	47.8%	47.8%	44.3%	44.3%

Appendix C-4 Pre/post test analysis spreadsheet

Table 5: Post test question-by-question analysis

	Post Test									
que #:	1	2	3	4	5	6	7	8	9	10
pts poss	4	6	6	5	4	4	4	2	2	2
student										
A	2	5	6	5	4	4	4	0	2	0
B	2	6	6	5	3	2	3	2	0	0
C	0	0	4	5	4	0	3	2	2	0
D	2	4	5	5	4	0	4	2	0	0
E	0	6	4	5	4	4	4	2	0	0
F	4	6	5	3	3	0	4	2	2	0
G	2	6	6	5	3	0	4	2	2	0
H	4	6	5	5	4	0	3	2	2	0
I	2	5	3	5	4	0	4	2	0	0
J	0	2	2	3	4	0	0	2	2	2
K	3	6	2	4	2	1	3	0	0	0
L	2	6	6	5	2	4	3	2	2	0
M	2	2	4	5	2	0	4	2	0	0
N	4	3	2	3	3	0	4	2	0	0
O	4	5	5	5	2	0	3	2	0	0
P	1	0	2	5	3	0	3	2	0	0
Q										
R	1	4	4	5	3	4	4	2	0	0
S	1	3	5	5	3	3	4	0	0	0
T	1	0	4	3	1	0	3	2	0	0
U	2	5	6	5	4	3	4	2	0	0
V	2	2	2	5	2	4	0	2	2	0
W	2	6	4	3	0	0	4	2	0	0
X	4	6	6	5	4	4	4	2	2	0
que ave %	51.1	68.1	71.0	90.4	73.9	35.9	82.6	87.0	39.1	4.3
average gain % (Post - Pre)	6.5	5.1	14.5	27.8	51.1	19.6	51.1	13.0	4.3	4.3

Appendix C-4 Pre/post test analysis spreadsheet

Table 5: Post test question-by-question analysis (cont)

que #:	11	12	Post Test total pts	ave		Student gain
pts poss	4	2	45			(post - pre)
student						
A	4	2	38	84.4%		28.9%
B	3	2	34	75.6%		28.9%
C	4	0	24	53.3%		4.4%
D	4	2	32	71.1%		40.0%
E	4	2	35	77.8%		17.8%
F	4	2	35	77.8%		8.9%
G	4	2	36	80.0%		31.1%
H	2	2	35	77.8%		17.8%
I	2	0	27	60.0%		-2.2%
J	4	2	23	51.1%		17.8%
K	4	2	27	60.0%		22.2%
L	2	0	34	75.6%		46.7%
M	4	2	27	60.0%		28.9%
N	2	0	23	51.1%		11.1%
O	3	2	31	68.9%		22.2%
P	4	2	22	48.9%		4.4%
Q						
R	4	2	33	73.3%		48.9%
S	2	0	26	57.8%		4.4%
T	3	0	17	37.8%		-2.2%
U	4	0	35	77.8%		33.3%
V	4	0	25	55.6%		17.8%
W	3	0	24	53.3%		22.2%
X	2	2	41			
que ave	82.6%	60.9%	66.1%	64.9%		20.6%
average gain (Post - Pre)	34.8%	13.0%	21.7%			

Appendix C-5 Student opinion survey

Student opinion survey

Remember the first marking period when we talked about density and atoms and compounds and physical/chemical changes…

What did you like best?

What did you like least?

What should I change, if anything?

Compare that unit to this unit (earth science)

Matter unit better			about the same		earth science unit better	
1	2	3	4	5	6	7

APPENDIX D – Photographs and Student Work

D - 1 Density column lab

D - 2 Student work on candle observation activity

D - 3 Various student activities

Appendix D-1 Density column lab

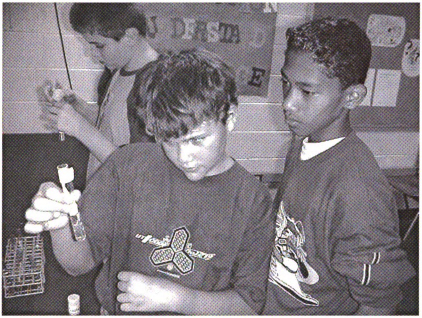


Figure 14: Students comparing liquid density

Figure 15: Students observing density column

Appendix D-1 Density column lab

Figure 16: Students comparing densities of aluminum foil wads

Appendix D-2 Student work on candle observation activity

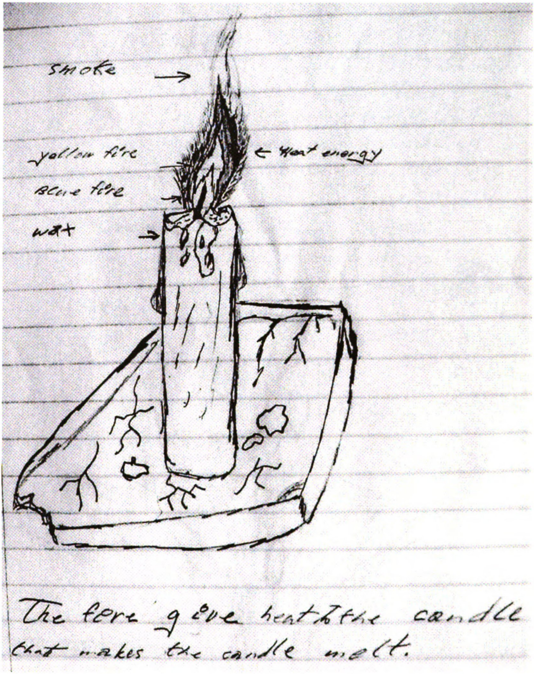


Figure 17: Student work on candle observation activity

Appendix D-2 Student work on candle observation activity

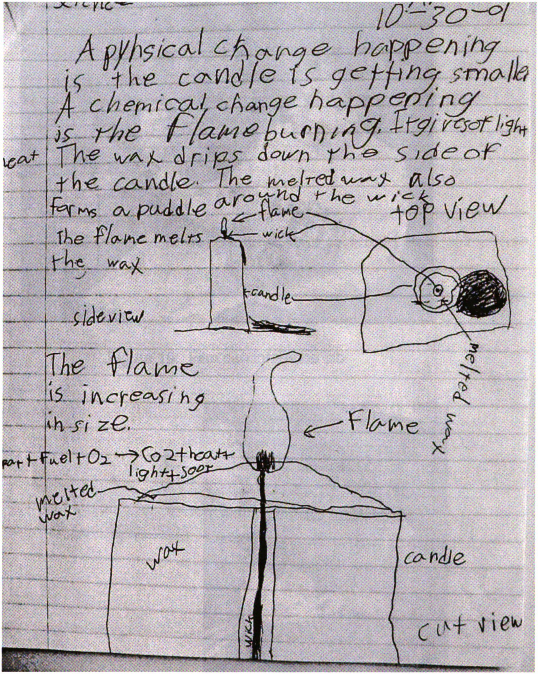


Figure 18: Student work on candle observation activity

Appendix D-3 Various student activities

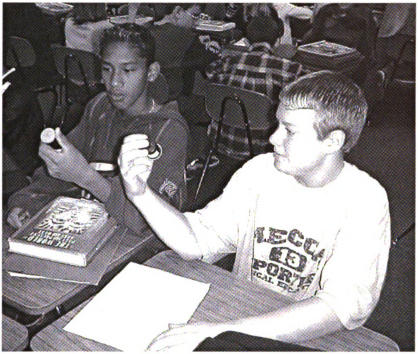


Figure 19: Film can inference lab

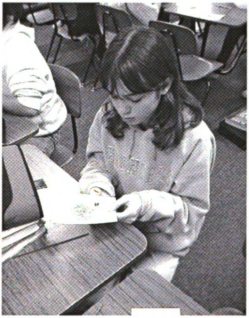


Figure 20: Separating solids activity

Appendix D-3 Various student activities

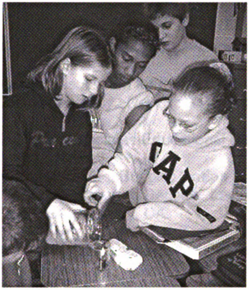


Figure 21: CO_2 fire extinguisher

Figure 22: Fire department demonstration

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