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A Constructivist Approach To Teaching Matter Classification as a Chemistry Unit

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Suzanne Elizabeth Donley

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A CONSTRUCTIVIST APPROACH TO TEACHING MATTER CLASSIFICATION AS A MATTER UNIT

By

Suzanne Elizabeth Donley

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in partial fulfillment of the requirements
for the degree of

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College of Natural Science
Division of Science and Mathematics Education

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ABSTRACT

A CONSTRUCTIVIST APPROACH TO TEACHING MATTER CLASSIFICATION AS A CHEMISTRY UNIT

By

Suzanne Elizabeth Donley

A high school chemistry unit on the classification of matter was designed to provide more thought-provoking, student-designed activities. There were two goals for this new unit. First, the students should be able to distinguish, compare and find relationships between heterogeneous mixtures, homogeneous mixtures, compounds and elements. Second, the students should be able to experience conceptual change about matter by applying their critical thinking skills to hands-on, minds-on activities.

Varied assessments were used, including pre- and post-unit interviews, journal writing, laboratory exercises, group work, student-driven class discussions, and observations. With respect to content understanding, some activities were successful and some were not. All new activities that required mental engagement were effective in helping students stay motivated throughout the unit.

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ACKNOWLEDGEMENTS

I would like to thank my students for giving up their lunch and free time to answer questions for me. I appreciate their honest answers and suggestions.

Dr. Merle Heidemann was my sounding board throughout the project. She was patient as I slowly focused on a topic, she listened supportively while I talked through my frustration on more than one occasion, and she promptly returned emails and phone calls to answer questions. Thank you so very much for your help.

Without my mom's time and stress management advice, I would still be at the bottom of the mountain. Thanks, Mom.

Finally, I need to thank my husband, Ben. He tolerated a very messy office for weeks and fielded phone calls when I was stuck time after time. Thank you for your generous support.

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INTRODUCTION

Statement of problem and rationale of study:

Classifying matter as a mixture or a pure substance, then further classifying it as a heterogeneous mixture, a homogeneous mixture, a compound or an element is a task that many high school students find difficult and confusing. They do not seem to understand why or how chemists do it, let alone how that process relates to everyday phenomena. They seem to miss the correlation between classifying matter samples and chemical and physical changes of matter. In general, a sample of matter that can be separated physically is a mixture, while a sample that can only be separated chemically, if at all, is a pure substance. I want my students to be able to distinguish, compare and find relationships between different classifications of matter because this knowledge will serve as a foundation for understanding basic chemistry principles.

I have used information from two secondary chemistry textbooks (Smoot, Smith and Price, 1990, pp. 41-54 and Tocci and Viehland, 1996, pp. 34-57) to teach a unit on matter. Both texts define the four classifications of matter, and provide a visual aid to help students see the relationships between them. However, neither book offers any activities the students can do to understand these concepts. As a result, my students see classification as a memorization game they must master to earn a particular grade, without really understanding the fundamental concepts behind classifying matter. I wanted to develop thought-provoking activities my students could engage in to apply their critical thinking skills and knowledge in hands-on, minds-on activities with the hope that they would experience conceptual change about matter.

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I have taught basic chemistry at the high school level for three years. The first year (1995-6), each class met 45 minutes everyday for the entire year. I lectured on the differences among the four types of matter, assigned reading and homework problems, and sent the students into the lab to work through cookbook type experiments on chemical and physical changes. At the end of the unit, approximately 50% of my students earned 59% or less on the test. When quizzed many of the students classified Sprite® as both a homogeneous mixture and a compound because both are made up of more than one thing. They obviously did not understand the molecular difference between these two types of matter.

The second year (1996-7), our school went to the 4 x 4 block, which means each class met 90 minutes everyday for one semester. I taught Chemistry both semesters that year, and during the first semester of the third year (1997-8) as well. The new schedule allowed me to incorporate more hands-on activities and facilitate more in-depth discussions with my students on a regular basis. To prepare for the transition to block scheduling, I reorganized my unit to include more journal writing, created new pair and group activities, and designed open and self-contained laboratory exercises. I expected the lessons to give my students improved opportunitities to gain insight into the correlation between classifying matter samples and chemical and physical changes of matter.

The Matter unit followed a general review unit that includes the scientific method, metrics, significant figures, lab safety, and taking measurements in the laboratory. I began the real content of the class with the Matter unit because it provides the fundamental basis for the remaining concepts, such as atomic structure, nuclear changes, periodicity, and chemical

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reactions. In addition, the students should have had some prior knowledge from middle school regarding properties of matter and chemical and physical changes that I could elicit from them during class discussion to begin our detailed study of matter and how it is classified.

Review of pedagogical literature:

The traditional approach to Chemistry teaching - lecture, the assignment of textbook problems, and cookbook style labs - allows students to passively absorb scattered pieces of information without realizing the connections between concepts. They are not encouraged to think critically about the new knowledge, which inhibits the integration of new understandings with prior conceptions about their worlds outside the classroom. The lecture format also does not allow for dialogue that is necessary for internalization and deep understanding. (Richardson, 1997, pp 3) Since students are not given the opportunity to examine their thoughts with peers and the instructor during lecture, students are expected to integrate the new information with their old conceptions on their own. The more motivated students will strive for deeper understanding regardless of the approach the instructor uses. Without the opportunity to verbally analyze their notions via discussion, the high achieving students will become frustrated with their inability to reconcile the old and new conceptions and resort to memorizing facts in an effort to do well on tests. These students "develop a 'passing at any cost' mentality when their frustration level gets too high." (Bunce, 1993, pp 179)

More and more college chemistry professors as well as secondary school teachers are beginning to notice the negative repercussions of using

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the transmission model, commonly called lecture approach, of teaching. Leonard S. Kogut of Penn State Beaver Campus taught a class comprised of science majors in need of remediation in chemistry. He was taken aback when less than half of his students did not even attempt the textbook problems that required critical thinking skills. (Kogut, 1996, pp 218) Jay Worrell of the University of South Florida was surprised to discover that few of his students could demonstrate a proficiency in basic chemistry skills several days after the concepts were presented in a lecture format. (Worrell, 1992, pp 914)

The constructivist model is one alternative to using the lecture approach to teach chemistry. In the constructivist format of teaching, existing ideas which learners may hold are used to make sense of new experiences and new information. Learning therefore occurs when there is a change in the learner's existing ideas, either by adding some new information or reorganizing what is already known. (Appleton, 1997, pp 303) In the constructivist format of teaching, students are actively engaged in generating their own knowledge as they hypothesize, discuss, test, and critically evaluate concepts. The instructor's role is to act as a "facilitator who assists in a process in which the students discover concepts for themselves" as opposed to the primary source of information and explanation. (Lamba, 1994, pp 1073) As Fensham states:

> No longer can science teaching focus only on presenting the scientists' views of physical events, or on covering the subject matter of science. Science teaching also involves understanding the students' views of science concepts. Teaching involves more than showing students the incorrectness of their beliefs that work quite well for them everyday in realistic contexts. It involves more than setting up dissonances between students' models and teacher controlled demonstrations. It involves leading

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> students to test and develop their models and thought processes in familiar contexts, which they believe are real, representative of everyday experience, and under their control rather than subject to manipulation by powerful people who cause clever but false things to happen.
> (Fensham, et al., 1994, pp 32-33)

Many science educators have experimented with implementation of the constructivist model in their own teaching. Richardson suggests that teachers can facilitate student-centered learning by providing events that cannot be explained within a student's existing framework. These events can come from a variety of sources, including images, diagrams, examples, and demonstrations. (Richardson, 1997, pp 34) By using certain forms of questioning, the teacher can help the students turn their beliefs into hypotheses that can be tested. The students then engage in hands-on, minds-on activities that, with teacher coaching, should lead to a reorganization of existing cognitive maps. (Richardson, 1997, pp 5) To encourage critical thinking skills, Kogut has implemented five strategies into his teaching. He asks questions frequently, uses examples and illustrations to reinforce the notion there are many ways to solve a problem in science , promotes discussion among students, uses feedback effectively, and models the thinking process critical to chemistry. (Kogut, 1996, pp 220) Fensham, et al, (1994, pp 42) recommend providing opportunities for students to test open-ended problems in which only general principles are suggested for finding the solution. This forces the students to analyze the problem, derive the best stragegy for solving the problem, test possible solutions, and choose the point at which they think the problem has been solved.

The positive outcomes of employing the constructivist model are overwhelming. Kogut's (1996, pp 220) students became active, responsible, enthusiastic learners as evidenced by favorable comments on student evaluati

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evaluations. According to a rise in homework scores, he was able to help students identify and change their own misconceptions into correct understandings. Three instructors using student-designed experiments at Wellesley College found that a high percentage of their students mastered general chemical principles by explaining what they were doing to one another in the lab. Although initially skeptical about their abilities to plan their own experiments, students reported a stronger sense of self-confidence and authority about the labs at the end of the course. (Merritt, 1993, pp 660).

I taught high school Chemistry for one year using the traditional methodology. I spent most of the time lecturing, assigned several textbook problems, and thought I was doing a good job when I sent the students to lab to perform "recipe" experiments. However, when the students answered lab questions and took tests, they performed poorly. I blamed their performance on lack of effort and insufficient critical thinking skills. After learning more about the constructivist model, I introduced into all units journal writing, paired activities in which the students could converse and write about their thoughts, student-designed lab exercises, and student-centered class discussions. Just like the authors mentioned, I also noticed an increase in critical thinking skills, motivation, and conceptual change across the curriculum.

Review of scientific literature:

Matter can be defined as anything that has mass and volume and is made up of atoms. This includes all solids, liquids and gases. Most students can readily understand the mass and volume requirements because they can take measurements to see them. However, it is often difficult for students to grasp th

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grasp the concept of atoms because, in a typical high school laboratory, students cannot see atoms for themselves either directly or indirectly. They are forced to take the teacher's word for it.

Once the students have a basic definition for matter, we begin to describe its properties. Physical properties are those which can be measured or observed without changing the chemical composition of the sample. These include color, texture, boiling point, density, etc. To determine chemical properties, samples must interact with another material, which will change its chemical composition. Chemical properties include reactivity with acid or oxygen, flammability, oxidation states, etc.

Properties can be classified a second way. Properties that depend on the size of the sample are called "extensive", such as mass and volume. Properties that do not depend on sample size are called "intensive", such as boiling point and density. This is an important distinction to make when attempting to identify a substance. For example, the density of a sample is $2.699\ g/cm^3$, so you can identify the sample as aluminum (assuming other properties fit the aluminum description, too). However, what if you have a larger sample? Will the density change, and therefore be something else? On the other hand, you must measure the mass and volume of your sample to determine its density. Students intuitively understand that the more sample you have, the higher the mass and volume. When faced with the rationalization for classifying density as extensive, some students have a particularly difficult time understanding why it is actually an intensive property.

The next topic we explore is how we can change matter. Matter changes are accompanied by energy changes. For example, the water

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molecules in ice contain a certain amount of potential energy that holds them near each other. When you add heat energy to ice, that heat energy is converted to kinetic energy, allowing the molecules to move faster. Eventually the molecules have enough kinetic energy to overcome the potential energy holding them together, and they are able to move apart. This is an example in which heat energy is transferred from the surroundings to the system. Another similar example of heat transfer is chocolate melting in your hand. The opposite happens when heat is transferred from the system to the surroundings. Examples of this process include the "sweat" that forms on cold pop cans and the formation of ice.

After looking at why changes occur in matter, we attempt to classify the changes we see as chemical or physical. In a physical change, such as a phase change, the particles simply move closer to or away from each other. The individual atoms or molecules do not change shape, and there is no difference in the way the particles are bonded (if at all). Therefore, the substance maintains its chemical composition. During a chemical change, the atoms do not change shape, but there is a change in the bonding pattern among atoms. Sometimes bonds are broken, sometimes new bonds are formed, and sometimes both happen during a chemical change. This change in bonding produces something new that can be identified using chemical and physical properties. The challenge here is helping the students to envision the correct molecular picture to fit the macroscopic properties.

Finally, we address the classification of different types of matter as heterogeneous mixture, homogeneous mixture, compound or element. If a sample is made up of more than one type of atom or molecule, it is a mixture. If not, it is a pure substance. Mixtures can then be classified further. If the different p

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different particles in a mixture are scattered unevenly, the sample is heterogeneous, as in a sample of salt and pepper. If the particles are evenly mixed, the sample is homogeneous, as in a glass of Kool-Aid®. The pure substances can also be further classified. If the sample contains more than one kind of atom, it is a compound, such as sugar or table salt. If it contains only one kind of atom, it is an element, such as lead or chlorine. This sounds very simple on paper or in lecture, but how can we distinguish these categories in the laboratory? A homogeneous mixture looks just like a pure substance, and this causes the most confusion in my classes.

> "The common statement by teachers that 'water consists of hydrogen and oxygen" means to some students that a water molecule is formed by a major rearrangement of the nuclei and electrons from two hydrogen and one oxygen atom. Many other students, however, ascribe to the same statement the meaning that water is a mixture of hydrogen and oxygen. This view is reinforced by their experience in elementary chemistry that this 'mixture' can be disentangled by electrolysis involving simple batteries. Some of them project this view on to what seems like the much more energetic process of boiling, by describing the bubbles of first air and then steam, as bubbles of hydrogen and oxygen. The distinction between pure substances and mixture . . . is thus quite confused even in this most simple of substances. (Fensham, 1992, pp 18-19)

In my first year teaching Chemistry, I gave the students formulas for pure substances so they could distinguish compounds and elements from mixtures. However, that is not a procedure you would see in a true chemistry lab. The second year, I had the students do several physical separation procedures to distinguish mixtures and pure substances. I also demonstrated a chemical procedure to separate a compound into its elements. While the students had a great time in lab, they still did not develop a clear understanding of the difference between the four types of matter during discussion c

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discussion or in their answers to evaluation questions. In the third year, I eliminated a few of the ineffective labs and introduced new labs and activities I hoped would help the students grasp the basic concept of classification of matter.

Demographics of the classroom:

I teach in a suburban area of Flint, Michigan. There are 480 students in the high school, grades 9-12. The student body is 97% Caucasian and 3% Hispanic, Indian and African American. Of our entire student body, 13% are receiving special education services and approximately 40% of the students go on to college. The population is socio-economically diverse.

The two Chemistry classes for this study were taught in the fall of 1997, during my third year at the high school. All 35 students participating in the unit passed Earth Science and Biology prior to enrolling in Chemistry, an elective class recommended for college bound students. The first section was composed of ten males and nine females, one sophomore, fourteen juniors, and four seniors. The second section contained five males and eleven females, fifteen juniors and one senior.

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IMPLEMENTATION OF UNIT

The three years I taught basic chemistry, including three semesters on the block schedule, provided the background information necessary for restructuring the Matter unit. I chose the Matter unit in particular for my research because the knowledge addressed in that unit is fundamental to every other topic in the course. As stated in the Introduction, approximately 50% of my students earned 59% or less when tested on Matter concepts during my first year teaching (1995-6). The low success rate of my students caused me to review my teaching methods. I wondered if using the constructivist approach to teach this unit would help the students be more successful. Over the next two years (1996-8), I decreased the amount time students spent performing recipe-style experiments and listening to me lecture, and concurrently increased their time on activities that should promote critical thinking and cognitive reorganization of matter understanding.

As I looked more closely at the subtopics within the unit, I became confused about how they link together and how I could best guide my students through them. For example, chemists use chemical and physical properties to classify matter, so it makes sense to discuss properties before classification. However, you could also give your students a sample, have them work through a classification flow chart, and then discuss properties and changes in more detail. I drafted several plans, all of which were logical. In the end, I chose the following order because it felt the most comfortable. Based on my prior experience, high school chemistry students tend to remember more from middle school about chemical and physical changes of matter th

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matter than how matter is classified. By teaching changes in matter before matter classification, I could use the students' prior knowledge as a springboard for the rest of the unit.

In addition to reorganizing my unit, I also tried different teaching techniques and/or created new activities. I added journal questions designed to elicit prior knowledge and stimulate discussion or experimentation. I added and revised over time an activity done in small groups that should provide an opportunity for students to discuss and illustrate their understandings about chemical and physical change on a molecular level. I created two open-ended laboratory activities that should promote critical thinking and active mental participation. Finally, I added two cookbook-type experiments so the students could practice common separation chemistry techniques, with the assumption that we would discuss the concepts during class both before and after the experiments. These techniques and activities will be summarized and informally evaluated in the next section.

During the semester I gathered my data (fall of 1997), I used four weeks on the block schedule to teach the Matter unit, which is equivalent to eight weeks on the traditional schedule. Below is a linear description of the revised Matter unit. New activities developed in accordance with the constructivist model format are marked with an asterisk (*). Old activities were left in the unit either because they proved effective over time, or because they allowed students to practice common chemistry techniques. Figure 1, which follows the unit description, illustrates the Matter unit at a glance.

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Week 1: What is matter? How do we describe it?

- * Journal Question: What is matter?
- Journal Question: What does all matter have in common?
- Lecture: Properties (chemical, physical, intensive, extensive)
- Demonstrations: Properties (surface tension, boiling point, alcohol flammability, etc) (Appendix A)
- Paired Activity: Organize properties into a Venn diagram
- Homework: Read/highlight text, practice problems on classifying properties
- Journal Question: Is magnetism an intensive or extensive property and why?
- Demonstration: Penny in nitric acid (Summerlin, et al, 4,5)
- * Lab: Density (Appendix B)
- Activity: Guess densities of solid metal samples based on sight (volume) and feel (mass)
- Journal Question: When floating on a lake, why do you rise when you inhale and sink when you exhale?
- Demonstration: Floating bubbles (Appendix C)

Week 2: How can we change it? What kinds of change can happen?

- Journal Question: How can you change matter? List five ways.
- Lecture: Energy (kinetic, potential, heat transfer)
- * Journal Question: Draw the molecules in a chocolate bar before and after melting.
- Journal Question: Sketch the molecules of water before and after condensing.
- Activity: Phase change/energy transfer flip books
- Demonstration: Phase plates
- Demonstration: Phase changes with dry ice and liquid nitrogen
- Lecture: Chemical and physical changes
- Demonstration: Chemical change - lead nitrate and potassium iodide
- Homework: Practice problems on classifying changes (chemical and physical)
- * Group Activity: Chemical and physical changes transparency

Weeks 3,4: How is matter classified?

Homework: Read/highlight text on classification of matter samples

Lab: Classifying Matter Samples (rotation) (Appendix D)

Journal Question: Classify water, iron and KoolAid® and explain why.

Group Activity: Brainstorm how to separate different mixtures listed on the board

Demonstration: Water electrolysis

Demonstration: Separation of KoolAid® dyes (Appendix E)

Lab: Separation Using Paper Chromatography (Appendix F)

Lab: Perfume (Appendix G)

* Lab: Hotdogs (Appendix H)

* Lab: Properties of Analgesics (Tocci and Viehland, 662)

* Lab: Gold Pennies

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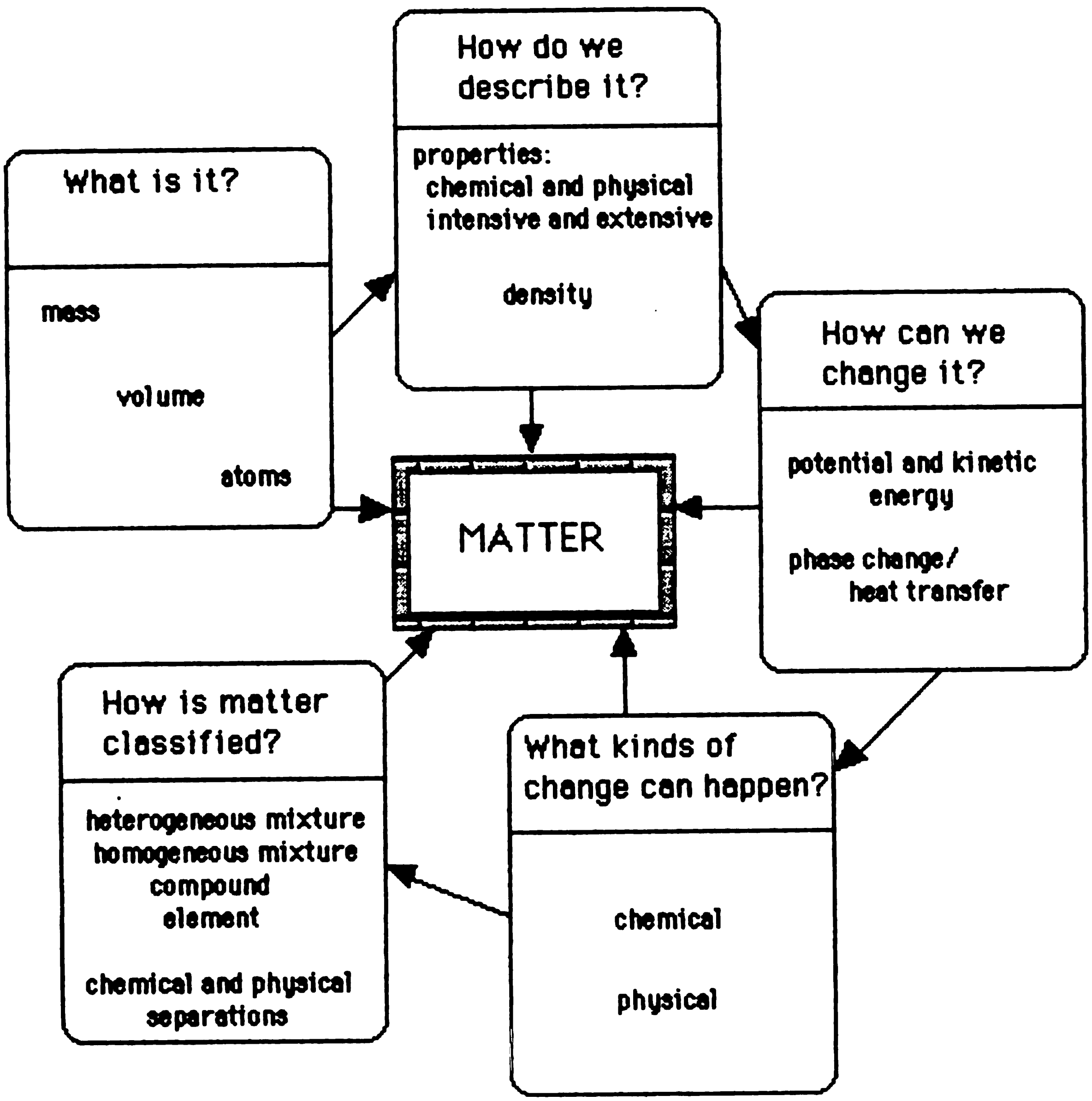
Figure 1: Unit Overview



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IMPLEMENTATION AND EVALUATION OF NEW ACTIVITIES

* Journal Question: What is matter? (Week 1)

One of my goals in the revised unit was to actively engage students in their own learning. One way to do this was to incorporate more thoughtful journal writing. To start the unit, I wrote several terms on the overhead projector and asked the students to group them as "matter", "not matter", or "unsure". The students had no trouble putting "peanut butter" and "trees" in the matter category; however a few had trouble with "water" and about half had real trouble with "carbon dioxide". Some believed that if you can't see it, it isn't matter. A hot debate ensued, during which my role became mediator. Some students also argued that gases do not have mass, which prompted the class to measure the mass of an empty balloon, fill it with air and then measure it again to prove those students wrong. After 45 minutes, one class had come to the conclusion that to be matter, a substance had to have mass and volume and it must be made up of atoms. The other class, thoroughly frustrated, begged for the correct answer. I believe this approach worked well because the students became actively engaged in the debate and thought carefully about peer comments before citing examples to support their own arguments.

* Journal Question: Draw the molecules in a chocolate bar before and after melting. (Week 2)

To begin our study of how matter changes, I wanted the students to call to mind their own ideas about melting. I asked the students to do this individually as I walked around the room to view their work.

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Approximately half of the students showed a deformation of the molecules in their "after" pictures. The students then compared their pictures with a partner to develop a single picture, followed by a class activity in which the students directed me to draw a picture that we could reach consensus on. While this journal question did not stimulate the same energetic response as the first one of the unit, I believe it was effective because the students had to critically review their ideas about melting by talking with a partner and then the class. Once we had a common mental image of the melting process, we began to discuss what happens to cause that change. Specifically, I introduced heat transfer and kinetic and potential energy. The students revisit this concept when we compare and contrast chemical and physical changes.

* Chemical and Physical Changes: Poster/Transparency (Week 2)

Each year I teach Chemistry, I ask the students what the difference is between chemical and physical changes. Every year the students tell me that a physical change is something that can change back, and a chemical change is one that can't be reversed. So many students give this rote answer that I have had a difficult time helping them see their misconception. During my first year teaching Chemistry (1995-6), I simply told them that many chemical changes are reversible. In the second year (1996-7), we talked about how something new is formed in a chemical change. I wanted the students to use that information and illustrate it on a molecular level in the form of a poster. The students were told to choose one example each of a physical and chemical change, none that were discussed in class. They were to draw the atoms/molecules involved both before and after the change. I expected to see the same r

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the same number of particles before and after the changes, different shapes to represent different types of atoms, and a new bonding arrangement after the chemical change but the same bonding arrangement and a different spatial arrangement after the physical change. I was horrified when I collected the posters. Only two of approximately fifty students clearly understood the concept. Most of the students showed a new spatial arrangement in both types of changes. Many showed circular particles before and triangular particles after the chemical change. Except for the two mentioned above, no one showed a change in bonding pattern.

In my third year teaching Chemistry (1997-8, the unit year), I tried a similar assignment. This time I put the students in groups and gave them the examples, a transparency, and different colored markers. The students were to draw pictures as a group and then present them to the class for discussion. Using this method, I was hoping the students would be able to arrive at the correct molecular picture through conversation during this minds-on activity. However, again very few students grasped the concept and I ended up telling them the answer. Either this activity was a disaster, or I did not use it properly. In the future, I plan to model chemical and physical changes by sketching before and after pictures of atoms and their bonding arrangements. Then, I will assign the transparency activity and ask the students to illustrate different examples of chemical and physical change.

* Laboratory Exercise: Density (Appendix B) (Week 1)

We often describe matter in terms of chemical and physical properties. Another useful way to describe matter is in terms of intensive and extensive properties, as explained in the Introduction section of this paper.

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After comparing and contrasting the different classifications of properties and how each is useful to describe and identify matter, the students go to the lab to determine whether density is an intensive or extensive property. I developed this open-ended laboratory activity because in the past many students have stated that since you measure mass and volume to determine density, density must be extensive. They do not seem to understand that as mass increases, volume also increases proportionally. Thus, density is an intensive property and therefore an excellent parameter for identifying any amount of an unknown substance (barring equipment restrictions).

The students were told each lab group would be given 100 mL of sample liquid, a different sample for each group. They were to write a protocol that would prove whether density is an intensive or extensive property. Their procedure should include instructions that would result in at least four data points to plot on a graph. After writing their procedures, the groups would switch papers and a different group would perform the experiment.

Each lab group was given 30 minutes to write an objective, list of materials, hypothesis, step by step procedure, and data tables with headings as a preparation for the experiment. Once all procedures were approved and the papers shuffled, the groups had 20 minutes to perform the experiment.

The following day each group calculated the density of the liquid for at least four different volumes. We compared the data from each group and discussed sources of error that would affect the outcome of the density calculations. At the end of the exercise, the students received a group grade based on their data and conclusions and how easy their own procedure was to follow.

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I found this experiment to be very effective. Six of the nine groups in my classes predicted that density would be an extensive property, and only one group had to conclude the same based on inaccurate data. The students found the task difficult at first, saying things like "We can't write our own lab" and "Just tell us what to do". With minimal prompting, these same students constructed their own procedures and had fun watching other groups follow their work. Nearly all the discussion in the lab was about the topic at hand instead of the social events I hear about during cookbook-type activities. I also noticed that they were highly critical of their peers' work, remarking on every detail that was even mildly confusing.

<u>Laboratory Exercise: Rotation Lab (Classifying Matter Samples)</u> (Appendix D) (Week 3)

In this activity, fourteen stations are set up, each with a sample and a notecard with the name of the sample and the chemical symbol or formula for the sample where applicable. The students work in pairs as they rotate from station to station. The students spend one minute at each station, during which they record the name of the material, the symbol or formula, observations, their classification of the sample, and why they classified it that way. I continue to use the rotation lab because it requires the students to stay focused on the criteria for classifying samples of matter. Although the students find the time constraint frustrating at first, they notice as they go along that mixtures don't have chemical formulas or symbols and the symbols for compounds have more than one capital letter in them. Recognizing these patterns eases their stress and reinforces the lecture and reading objectives.

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Laboratory Exercise: Separation Using Paper Chromatography (Appendix E) (Week 3)

Students perform paper chromatography using different solvents to separate the inks in a variety of washable and permanent markers. The goal of the experiment is to determine which markers are mixtures and which are pure substances. This lab was left in my unit because chromatography is a common chemistry technique.

Laboratory Exercise: Perfume (Appendix G) (Week 3)

The students extract essential oils from plant materials such as orange peels and cinnamon. The protocol provides the student the opportunity to practice extraction and distillation, two common separation chemistry techniques. Again, the activity reinforces the idea that if a sample can be separated using physical means, it must have been a mixture.

* Laboratory Exercise: Hotdogs (Appendix H) (Week 4)

After working through a matter classification flow chart and studying the characteristics of a heterogeneous mixture, a homogeneous mixture, a compound and an element, the students separated the components of regular and fat-free hotdogs using a centrifuge. I created this laboratory experiment during my summer at MSU. There are two straight-forward objectives to this exercise: to determine the percentage of fat in a regular hotdog, and to see if "Fat-free" hotdogs are truly fat-free. The third, deeper objective is to provide an opportunity for students to physically separate a homogeneous mixture into its components using a common separation technique.

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Because the exercise was smelly and visual, and the students were working with a common food, it provoked a strong response from the students. I believe they hated to like this lab. However, I do not think it was effective with respect to the first objective. The students had great difficulty with the math, and the protocol was poorly written which led to inaccurate percentages. By the time they completed the calculations, the main concept was buried under frustration.

This activity is also written in "recipe" format, which made it less engaging and harder for students to understand why they were performing certain steps. The lab itself did not clearly promote critically thinking until the very end when they were asked to analyze their data. During my third year teaching Chemistry, I tried to make this activity model the world outside a high school chemistry classroom by having the students report their conclusions in the form of a business letter. I anticipated that this approach would force the students to assimilate their lab experience, data, calculations, and class discussion into one big picture and report it in a professional way. However, most of the reports failed to show a clear understanding that since centrifugation is a physical separation process, the hotdogs must have been mixtures. In the future, I will eliminate the math and have the students evaluate the data qualitatively instead of quantitatively.

* Laboratory Exercise: Properties of Analgesics (Week 4)

To practice another physical separation technique, students performed an experiment from their textbook in which they used vacuum filtration to separate the active ingredient from the filler in three different analgesics. (Tocci and Viehland, 1996, 662) Upon observation, the students could not tell

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tell whether the tablets were mixtures or pure substances. After grinding the tablets and dissolving the powder in water, the students could see that something was floating on the surface of the water. From the background information for the lab, students learned that filler does not dissolve in water but the active ingredient does. Therefore, the students were able to prove that the tablets are mixtures.

Again, since the experiment was written in a step by step fashion, the students had a hard time explaining why each step was necessary. When I asked each lab group what they were doing, they all told me what step they were on. When I probed further, they said, "I don't know". While knowing how to perform suction filtration is an important skill, the students were more concerned about following the procedure exactly than understanding the objective of the lab as it relates to the Matter unit. In the future, I will have the students read the protocol and sketch pictures of what they think will happen before they go to lab. I can use their pictures as a basis for discussing filtration as a physical separation process, and reinforce the idea that a sample that can be separated physically must have been a mixture.

* Laboratory Exercise: Gold Pennies (Week 4)

To end the unit, I made "gold" pennies for the students. By coating the pennies with zinc and then heating them, the copper and zinc mix to form an alloy called brass. (Dominic, 1995, pp 389) I wanted the students to draw on what they thought they knew about pennies and new knowledge about separation techniques and classification of matter samples from the unit to prove whether or not it was gold. Most students tried to scratch or cut it, after which they could see the silver colored material inside. Since they could see more than one color and the materials were unevenly distributed, they concluded the pennies were heterogeneous mixtures and therefore not pure gold.

I then asked them to tell me what was inside the penny. Nearly all of the groups chose to heat the cut penny over a Bunsen burner. This caused the inner material to melt out of the brass coating and land on the desktop. The students were very excited about this, and called the other groups over to see what was happening to their penny. Each group decided to find the density of the silver colored blob and compare their value to that found in a textbook. Because our equipment is inappropriate for their small samples, none of the groups were able to determine an accurate density value. I had them list the top five possible identities for the material inside the penny and read about them in the CRC Handbook of Chemistry and Physics to match other properties. In the end, only a few groups were able to correctly identify the metal. However, I feel this activity was successful because the students had full control over which procedures they should try and they evaluated each one critically. In the end, they all tried to find the density of the sample, which is a concept we had covered a few weeks earlier. I was impressed with their involvement and how little they needed my input.

IMPLEMENTATION OF EVALUATION PARAMETER

I taught my revised Matter unit in the fall semester of the 1997-8 school year. During that semester I taught two sections of basic Chemistry. To evaluate whether or not the revisions I made to my lesson plan helped my students understand the concepts related to the classification of matter, I chose two students from each section to participate in video-taped interviews before and after the unit. I based my selection on my perception of their cognitive abilities in science. Before the interviews began, I believed I had chosen one above average student, two average students, and one below average student. As the unit progressed, I began to see that I was actually working with two above average students, one average student and one below average student.

EVALUATION

I used two methods to evaluate the effectiveness of the Matter unit. I interviewed two students from each section of Chemistry before the unit began, and again approximately five months after the unit ended. I videotaped both sessions and used the same questions. I also listened and watched carefully for feedback from all students during class discussions, labs, paired activities, and journal entries.

All students participated in this study on a volunteer basis. Each student received a letter at the start of the semester in August explaining my thesis goals and methods of data collection. All students and parents were informed that participation in this study would not affect class grades in any way. Every student in both classes returned a signed permission slip before the unit began. (Appendix J)

The data obtained from the pre-unit interviews told me what misconceptions the students held and what information would be new to them. They also provided direction for me as the instructor to plan appropriate opportunities for the students to change their misconceptions. The post-unit interviews provided information about whether or not the students had improved their thinking about the basic concepts. The list of questions used can be found in Appendix K. Of course, I used additional questions as necessary to probe students to further explain their thinking.

SUMMARY AND EVALUATION OF STUDENT RESPONSES

The following series of tables and figures summarize the student responses obtained from the video transcription. Table 1 includes the answers given to the question "What is Matter?" both before and after the unit. Tables 2 and 3 show how the students arranged word cards to catogorize samples as "Matter", "Not Matter", or "Not Sure". Tables 4 and 5 show how the students further arranged their "Matter" cards into the groups "Mixtures" and "Pure Substances". These tables also include student definitions of mixture and pure substance. Figures 2 and 3 show student illustrations of how molecules of chocolate are arranged both before and after melting. Tables 6 and 7 include student definitions of chemical and physical changes both before and after the unit. Finally, figure 4 shows student illustrations of how atoms are arranged before and after a chemical change.

In each table and figure, the students that participated in the interviews are referred to by letter. Student A was the below average student, students B and C were above average students, and student D was an average student with a tremendous amount of enthusiasm for learning.

Table 1: What is Matter?

	Before unit	After unit
Student A	"Something that has space, mass, solids, liquids, and gases."	"Something that has properties like space, some kind of denseness, solids, liquids and gases, and all things that can change."
Student B	"Something that has mass - like solids."	"Anything that has mass."
Student C	"The amount of mass in an object."	"Anything that has mass, space, liquid, gas or plasma, and it's an object." "Made up of atoms."
Student D	"What things are composed of - what's inside things. Like, solids are matter but liquids are not."	"All matter has atoms and mass."

Before the unit began, three of the four students recognized that all matter has mass, but only one associated volume with matter. I was surprised to see that none of the students listed atoms as part of the definition of matter. In light of the heated debate at the start of the unit, I was even more surprised that only two of the students interviewed after the completion of the unit associated atoms with matter.

These students were given ten notecards with the following words written on them: air, blueberry muffin, carbon dioxide, copper, energy, pop, salt water, silver, 2% milk, water. They were asked to arrange the cards into three piles: "matter", "not matter", and "not sure". Students were then asked to explain why they arranged the cards in that way. This was a follow-up activity to the first question to see if the students would adhere to their own definitions of matter as they decided which pile to put each card into. I also wanted to determine which words would cause uncertainty so I could prepare activities prior to the unit to help clear up misconceptions that might arise during class. Table 2 below shows the students' responses before the unit began. Assume any words not appearing in the table were classified as "Matter". Table 3 shows the students' responses after the unit ended.

Table 2: Matter Classification - Before the Unit

	Not matter	Not sure
Student A		energy
Student B	air, CO_2, energy	
Student C	energy	
Student D	water, 2% milk, salt water, air, CO_2, pop	energy

In each case above, the students' classification schemes matched their stated definitions of matter. Student A thought some forms of energy might be matter, like electrical energy, because she thought that form "takes up mass". Student B said you can't weigh air, CO_2 or energy so they cannot be matter. Student C listed air and CO_2 in the "not matter" category at first, but then changed her mind because she said "air has got to weigh something and CO_2 is part of air." Student D listed all non-solids in the "not matter" category, which is consistent with his definition of matter. He could not explain his uncertainty about energy.

Table 3: Matter Classification - After the Unit

	Not matter	Not sure
Student A		energy
Student B	energy	
Student C	energy	
Student D	energy	

Student A grouped the cards in the same way as in the first interview. She was not sure about energy because she thought "You get it from matter, but it doesn't have 'matter' form." Student B moved air and CO_2 to the "matter" category in the second interview because he remembered weighing the balloon containing air in class, and since it had mass, they must be matter. Student C stayed with her original answers, stating that "energy does not contain atoms." Student D made the most changes to his first classification. He explained that energy is "the only item that does not contain atoms."

The students removed all cards in the "not matter" and "not sure" piles and used the "matter" cards for the next question. They were told that chemists often classify matter into two categories: mixtures and pure substances. They were asked to arrange the cards into those two groupings. Tables 4 and 5 show the results.

Table 4: Mixtures vs. Pure Substances - Before the Unit

	Mixtures	Pure Substances	Definition of Mixture	Definition of Pure Substance
Student A	all cards		"things have been added"	"nothing was added"
Student B	muffin, pop, salt water	water, 2% milk, copper, silver	"mixed"	"not mixed with anything"
Student C	water, 2% milk, muffin, salt water, air, pop, CO_2		"two or more things mixed together"	"something single - not mixed with anything else"
Student D	muffin	silver, copper	"mixed components to get a totally new thing"	"something that doesn't interact with anything"

Student C was "not sure what makes up these metals", referring to copper and silver. Student D explained that to make blueberry muffins you take "eggs, milk and butter and mix them all together to get the final product that is different". He also said that "copper is only copper - nothing else".

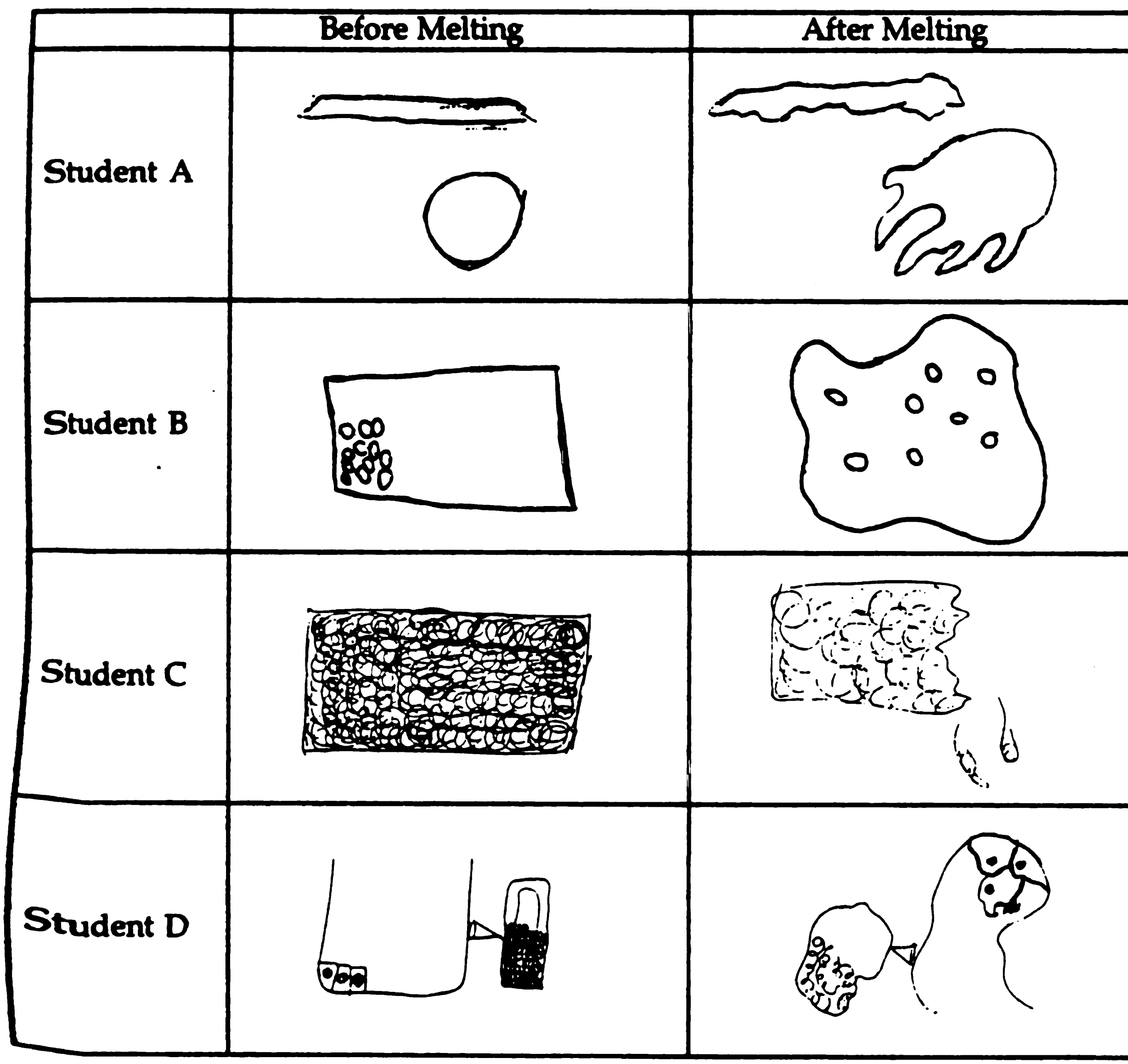
Table 5: Mixtures vs. Pure Substances - After the Unit

	Mixtures	Pure Substances	Definition of Mixture	Definition of Pure Substance
Student A	air, muffin, CO_2,pop, salt water, 2% milk, water	copper, silver	"more than one pure thing in them"	"all itself, nothing else"
Student B	pop, salt water, 2% milk, air, muffin	copper, silver, water, CO_2	"can be separated easily without breaking bonds - separated physically"	"not mixed with anything - just single things by themselves" "atoms chemically bonded"
Student C	muffin, 2% milk, pop	CO_2, salt water, water, air, copper, silver	"different things mixed together that can be separated"	
Student D	muffin, salt water, pop, 2% milk, air, water, CO_2	copper, silver	"more than one thing, don't need to break bonds to separate".	"one kind of atom"

When asked about elements and compounds, Student A said salt water, CO_2 and water are compounds because there were "two or more elements mixed". "They are stable - atoms not all bouncing off each other. They (the elements) change, but both of the things we mixed are still present." Student B did not originally mention bonding, and he classified air and milk as pure substances. He also believed until probed further that carbon dioxide, oxygen, and nitrogen were all bonded together to make air. It was after I asked him to explain the difference between water and salt water that he began to talk about chemical and physical separation. He also clarified the distinction between "mixed" and "bonded". At the end, he further classified carbon dioxide and water as compounds, which he said are "two or more single elements chemically combined". Student C further categorized pure substances into elements and compounds. She said air, CO_2 and water were compounds because they were "two or more elements combined", and silver and copper were elements because there was "nothing else to them". She said salt water was a solution, yet a pure substance. When asked to explain the difference between "mixed" and "combined", she was unable to do so. Student D originally defined mixtures as "not the same all the way through" and "made up of more than one thing". To him, pure substances were "uniform all the way through" and "one kind of atom". When asked to differentiate between salt water and water, he said salt water was "two or more atoms floating around each other" and water was "two or more atoms combined to form the molecule". He remembered separating the hotdog without breaking bonds as a physical change, and he then reclassified his mixture pile. This time, he left the muffin and salt water together, and made a separate pile that included pop, water, CO_2, air, and 2% milk. After further discussion about how to separate pop and 2% milk, he moved them to the pile with muffin and salt water. In the end, he was able to distinguish mixtures from compounds, but he did not see how compounds are also pure substances until I explained it directly.

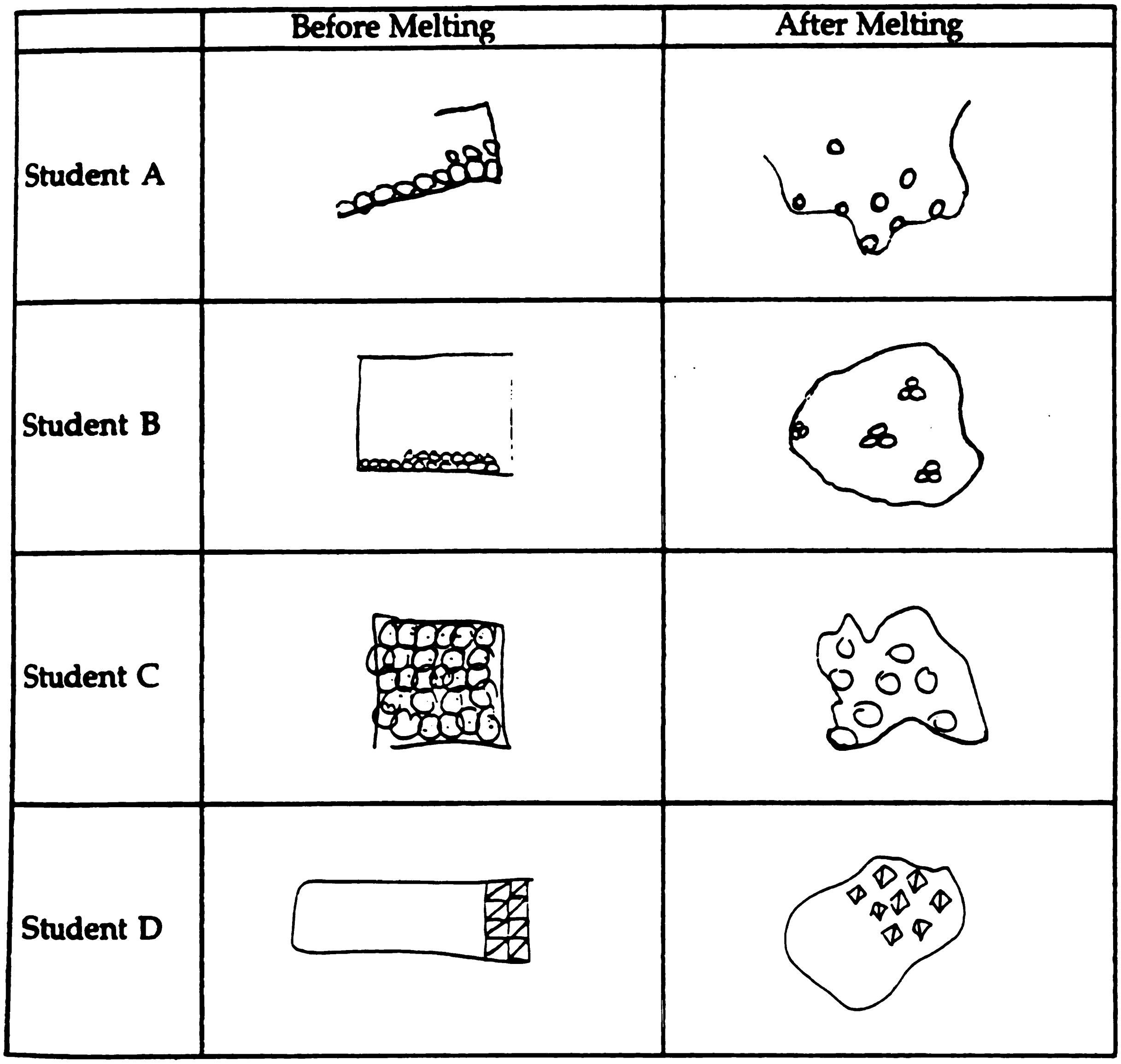
The third concept I tested was what happens during a physical change, such as melting chocolate. Figure 2 shows the students' sketches of a chocolate bar before and after it melts, before the unit began. Figure 3 shows the students' work after the unit ended. In general, circles and curlies (Student C) represent individual molecules and wavy lines represent melting.

Figure 2: Melting Chocolate Bar - Before the Unit



Students A and D seem to have the misconception that whatever happens on the macroscopic level also happens on the molecular level. They are both showing a change in the shape of each molecule similar to the change we see as we watch the entire chocolate bar melt. From their pictures, students B and C seem to correctly understand that the macroscopic shape change is due to the increase in space between individual molecules. However, when asked to clarify her picture, student C said "the particles get smaller and also move farther apart". She, too, held the incorrect understanding that molecules change shape during the melting process. Student D also explained his drawings. Before the unit began, he said the "molecules are changing shape. Each square is a molecule with a nucleus that has protons and neutrons. The molecules take the shape of the outer edge of the candy bar."

Figure 3: Melting Chocolate Bar - After the Unit



From the pre- and post-interviews, I can conclude that two of the four students (Students C and D) correctly changed their misconceptions about what happens to the shape of molecules during the melting process. One student (Student B) continued to hold the correct understanding, and the fourth student (Student A) continued to hold her misconception. Student D also seemed to add an addition of space between molecules to his after melting drawing in the post-unit interview that was not present in the pre-unit sketch.

In the post-unit interview, I asked Student A if she meant to draw identical circles in her before and after pictures. She said "no, that's not right. The molecules do change shape, which changes the overall chocolate bar shape." When asked what happens to the molecules when you add heat to a chocolate bar, Student B said in both interviews "the molecules move farther apart, but they stay the same shape". Before the unit, Student C understood that the molecules move apart and changed shape when melting occurred. However, after the unit, Student C said "the chocolate bar has the same number of molecules before and after (melting), and they are the same shape. The molecules themselves don't change, they only move farther apart." After the unit was over, Student D said "there are the same number of molecules after melting, and they stay the same shape".

The students were asked to explain the difference between chemical and physical changes. Tables 6 and 7 show the students' responses. Two of the four students illustrated their ideas, as shown in Figure 4.

Table 6: Chemical vs. Physical Change - Before the Unit

	Chemical	Physical
Student A	"You change the actual substance. You totally change what's in it. The molecules fight during a chemical reaction. Whichever molecules has the most (most abundant) wins, so that's what you get at the end."	"They (molecules) change form. The shape of the molecues changes. They probably change size and what's in them."
Student B	"You get a different substance, and it can't be put back together." "The molecules change into something else. They could get smaller or bigger."	"The matter itself doesn't change. Most of the time you can put it back together. The molecules stay the same."
Student C	"The chemicals separate and turn into different things. The molecules would look different."	"Only the appearance changes."
Student D	Irreversible. "When you burn wood to get ash, you can't take ash and make wood again."	"Changes the physical appearance, but you always get the same product again and again."

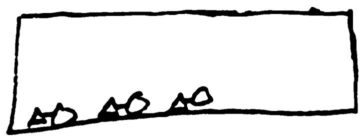
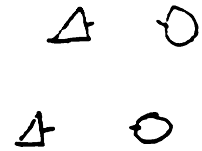
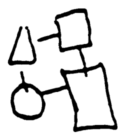
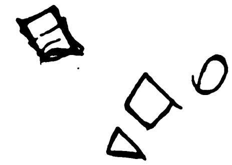
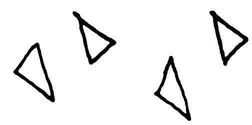
Student C further explained her understanding of chemical change by discussing a rusting nail. She said the molecules change color, from silver to red or brown. Student D used ice melting as an example for physical change. He said that when the ice melts, the molecules "must change shape to make up for the extra space."

Table 7: Chemical vs. Physical Change - After the Unit

	Chemical	Physical
Student A	See explanation below.	"The shape of the (chocolate) bar changes, but its still chocolate. The same chemicals are in the chocolate, but the molecules are changing."
Student B	See figure 4.	See figure 3.
Student C	See figure 4.	See figure 3.
Student D	"Changing properties, two new things." See figure 4.	"No breaking bonds." See figure 3.

During the post-unit interview, Student A referred back to the chocolate question. She said "to make a chemical change, I would add vanilla to the melting chocolate. Then it would taste different because it's chocolate and vanilla. They form something new, not quite chocolate, not quite vanilla. Adding salt to water is also a chemical change because it tastes different." In class I pointed out that the properties of individual atoms are not the same as the properties of the molecule formed when those atoms chemically combine. Student A seems to understand that a change in properties, such as taste, can indicate a change in bonding on the molecular level. However, she is incorrectly applying that fragment of knowledge to her example. She clearly does not understand the molecular distinction between chemical and physical changes. She also seems to think that anytime you put two things together a chemical change will occur and you will get something new.

Figure 4: Chemical Change

	Before	After
Student B		
Student C		
Student D		

The sketches in figure 4 show that Students B, C, and D clearly understand what happens during a chemical change on a molecular level. Each student chose to illustrate a decomposition reaction in which chemical bonds between atoms are broken. All students correctly show atoms that are the same shape both before and after the change. For example, Student B drew triangles and circles. The shapes represent two different atoms, such as sodium and chlorine. This student, like the others, recognized that the same atoms are present both before and after a chemical change, and that none of the atoms involved change shape during the change. All students also correctly show one bonding pattern before the change and a different one after the change. For example, Student B shows a triangle and a circle connected by a line before the chemical change. The line represents a chemical bond. After the change occurred, the student has shown that the bond has broken and the atoms are no longer connected to form a molecule. Student D conveys the same understanding, however he drew the atoms touching each other instead of connected with a line to represent bonding.

In addition to the pre- and post-unit interviews, I also evaluated the students informally. I listened closely to their comments during class activities and read their journal entries. Many different students commented throughout the unit that they enjoyed going to lab and moving around during class. I heard "this class goes by so fast" and "you really seem to care about whether or not we understand this stuff" often. Students not enrolled in Chemistry stopped by just to see what we were doing, especially when we did the hotdog and penny labs.

DISCUSSION AND CONCLUSIONS

When I began my unit on Matter, I had two goals. First, I wanted my students to be able to distinguish, compare and find relationships between heterogeneous mixtures, homogeneous mixtures, compounds and elements. Second, I wanted the students to apply their critical thinking skills and knowledge in hands-on, minds-on activities with the hope that they would experience conceptual change about matter.

Methods and content:

I believe the class discussion on what matter is was successful with respect to my second goal. Even though only two of my test students remembered that matter is composed of atoms, the entire class was involved in the discussion. This was definitely a minds-on, motivating experience for these students. Part of the constructivist model includes giving students an opportunity to test their hypotheses. While we proved to some students, including test students B and D, that gases have mass, I have not been able to find a good way for students to see that matter also is made up of atoms. I believe the lack of a reasonable experiment explains why the other two test students did not remember that all matter is made up of atoms.

Before the unit began, test students A and C clearly could not distinguish between homogeneous mixtures and compounds. The data on student D is inconclusive because he did not classify any homogeneous mixtures or compounds as matter in the first test. On the molecular scale, homogeneous mixtures are composed of two or more substances that are not bonded to each other. Compounds are made up of two or more substances that are bonded to each other, creating one entirely new substance with its own properties. On the macroscale, mixtures can be separated physically, but compounds can only be separated chemically. The problem is that to the students, these are just words without much meaning, or inaccurate meanings.

The students performed the hotdog and analgesics labs, both examples of physical separations. They did not create anything new. But how would they know that? In the hotdog lab, it sure looked like they had made new things when they saw the fat, water and filler layers. Alone, the labs were ineffective. However, I spent a great deal of time with each lab group discussing the behavior of the particles during the procedures. I essentially told them that the atoms were not changing the way they were chemically bonded, therefore making the hotdogs and analgesics homogeneous mixtures. They did not come to that understanding on their own, which tells me that the connection between what the students see with their eyes and what is happening on a molecular level is too abstract for students to grasp. For this concept, the constructivist model did not work. The students simply do not have enough experiences to which they can connect such an abstract concept.

The students also performed the open-ended Gold Pennies experiment. This was successful in terms of applying knowledge, critical thinking, and active learning. However, it did not address the problem of distinguishing between homogeneous mixtures and pure substances.

When I interviewed the test students after the unit ended, all four students had a difficult time categorizing the cards during the notecard activity. Each student quickly grouped some cards and then pondered what to do with the rest. They began to put cards in certain piles, and then changed their minds. When asked why those particular cards were difficult to group, the students offered a variety of conflicting statements. For example, Student B originally classified air as a pure substance because he thought carbon dioxide, oxygen and nitrogen were all bonded to each other to form one big compound. When asked why carbon dioxide had two parts to its name, he replied that the molecule contained carbon and oxygen. When asked to describe oxygen and nitrogen, he said they were individual atoms floating around in the air. I then asked him to distinguish between "floating around" in the air and being a part of air. He remembered our discussion about separating air into its components and realized that since that process was a physical change, the components of air must not be chemically bonded to each other. Therefore, air must be a mixture, so he moved the card to the mixture pile. In the end, he was able to correctly classify the substances and explain the distinction between the four types of matter.

After a similar struggle, Student A realized that copper and silver are "all itself" and therefore pure substances, but she classified the compounds water and carbon dioxide with the mixtures. She believed that since water and carbon dioxide each contain more than one thing (atoms), they must be mixtures. The concept that those atoms were chemically bonded to make a compound that is also "all itself" was missing. Student C was also missing the concept that when atoms are chemically bonded, they make something entirely new that is considered a single entity. Student D remembered fragments of information from the unit, but did not put them all together until the interview.

Because the students found articulating their ideas so difficult during the interviews, and because I found myself explaining the bonding and separation concepts directly to the students during class, I do not feel the new hotdog, analgesic and gold penny labs encouraged true conceptual change. I found myself acting as the primary source of knowledge instead of the coach, which contradicts the rationale behind the constructivist model of teaching.

As stated earlier, having students sketch pictures of the molecules in a chocolate bar before and after it melts worked well as an assessment tool. The students were actively engaged in the activity during class, and wanted to know if their pictures were correct. After the unit ended, two of the four test students showed a drastic improvement in their conceptual pictures of what happens to atoms during the melting process, while one understood the concept before the unit began. In addition, the four test students referred to their melting chocolate pictures when asked to describe a physical change.

As stated in the Implementation section of this paper, I assigned a group activity in which students had to sketch molecular pictures of chemical and physical changes on a transparency. Doing this as a group activity was a modification made to a similar individual poster activity done the prior year. By allowing the students to work together, I was adding the peer discussion aspect of the constructivist model to my teaching. However, so few students understood the distinction between chemical and physical changes on the molecular level that many of the groups could not even begin the assignment, even with teacher coaching. What happens to atoms during chemical and physical changes is a highly abstract concept. Students cannot actually see the atoms, so they cannot possibly have prior understandings about these processes on the molecular level. Therefore, using the constructivist model exclusively cannot work for this topic. Lecture, including visual modeling, must be the approach used first to provide the basic rules governing chemical and physical change. Then it should be reasonable to expect students to apply the basic rules as they explain phenomena observed in the laboratory. Since I did the demonstrations and sent the students into the lab without lecturing, as is consistent with the constructivist model, my students were unable to meet my unreasonable expectations when asked to illustrate their understanding of chemical and physical changes on the transparencies.

During the post-unit interview, Student A offered the most inaccurate descriptions of chemical and physical changes. She seems to have learned that something stays the same in a physical change, but she does not make a distinction between "chemicals" and "molecules". Her example of chemical change actually is a physical change. Before the unit she said that you get something new in a chemical change, and during the unit she incorporated the idea that the properties change. However, her molecular picture of chemical and physical changes are still inaccurate. She seems to have learned fragments of information and incorporated them into her original misconception.

Students B, C, and D had the correct (or nearly correct) macroscopic pictures of chemical and physical changes. From their pictures and comments it appears that they added more detail to their cognitive understanding.

Evaluation techniques

To evaluate the effectiveness of the Matter unit, I interviewed a cross section of students before and after the unit using the same questions. I also used student feedback during class discussions, labs, paired activities, and journal entries.

To more thoroughly evaluate whether or not the incorporation of the constructivist method of teaching was an improvement, I could compare the Matter unit student test scores for each year studied. If the new approach worked better than the old lecture-style method at helping students correct their misconceptions, I should see higher unit test grades across the board in the test year (1997-8) compared to previous years (1995-6 and 1996-7). However, I do not believe such a comparison would be scientifically valid because there are too many variables, any one of which could have affected the overall unit test grades.

First, our school converted to the block schedule in the middle of my study. In the first year (1995-6) each student took seven classes that lasted the entire year. Based on student questionaires distributed and analyzed by the school, the students found it difficult to stay organized and focus on any one class in particular when the school was on the seven period day. They also said they had a hard time keeping up with the volume of homework assigned daily by seven different teachers. Based on teacher surveys conducted by the school, teachers found the quality of student work to be low on the seven period day and the students were only mentally engaged in learning for approximately 30 of the 45 minutes allotted for one class period. The same questionaires addressed student and teacher attitudes and accomplishments after switching to the block schedule (1996-7). The overwhelming majority of students and teachers agreed that it was easier to stay focused on each subject, the students produced higher quality work on a regular basis, and the amount of time students remained engaged during a class period increased to approximately 75 of the 90 minutes. The increase of time and ability to focus could easily account for a rise in student test scores independent of my change in teaching styles.

Having more time in each class period also forced me to teach more material in greater depth every day. This means that my unit test in 1996-7 was drastically different from the test given in 1995-6. I again revised the Matter unit test to include more open-ended questions for the 1997-8 Chemistry classes to accomodate my different teaching style. There is no way to determine whether a change in scores was due to the implementation of a different teaching approach or a change in the content of the test.

Another way to more thoroughly evaluate whether or not the incorporation of the constructivist method of teaching was an improvement would be to compare the Matter unit student test scores in the test year (1997-8) with other unit test scores from the same students. However, doing so would also be invalid for several reasons. First, Chemistry is the first college-preparatory class the students take in the high school science curriculum. Therefore, the expectations in that course are much more demanding than the ones the students are used to in other courses. Often, typically above average students need to take one or two unit tests in Chemistry before they learn to perform at the expected level. Therefore, any increase in test scores could be attributed to an improved understanding of expectations, not a change in teaching methods.

Second, as a teacher, I continually try to improve my methods to help students understand chemistry. Once I saw that students were more excited and engaged in their own learning when I used the constructivist approach, I incorporated similar minds-on activities in subsequent units. Since I did not use the lecture method exclusively in these units, I cannot draw a valid conclusion about whether or not a change in unit test scores could be attributed to the use of the constructivist model.

Third, each unit contains content of varying difficulty and abstraction. Some content, such as the study of atomic structure, is more abstract than others, like the trends of the periodic table. As a result, one would expect to see a fluctuation of unit test scores that should reflect the level of difficulty students experience as they try to understand the concepts.

Finally, external factors affect students' abilities to concentrate on topics covered in class. For example, students tend to perform at a higher level in the winter than in the spring when it's warm outside. They also have trouble concentrating during Homecoming week when there are many student-centered social events. These external factors could be reflected in unit test scores, which makes a comparison of the scores on one unit test to those of another test invalid.

In light of the substantial number of variables that occurred during the time I evaluated the effectiveness of incorporating the constructivist model into my teaching, I believe choosing a cross section of students to interview before and after the unit was the best method for gathering scientifically valid data. Choosing only four students presented a statistical problem; however conducting and analyzing interviews takes a tremendous amount of time. I spent thirty to forty-five minutes questioning each student both before and after the Matter unit, approximately six hours transcribing the interview tapes, and an additional two days analyzing student responses. Based on student feedback during the unit, such as journal responses, quiz answers and informal comments, I do not believe I would have obtained any significantly different data had I invested the time to involve more students in the interview process.

Overall evaluation and conclusion

The incorporation of activities that require mental engagement was effective in helping students stay motivated during the unit. They seemed to enjoy the unit more, and asked more content-related questions compared to prior years in which I used the lecture approach. The journal questions and open-ended laboratory activities were particularly useful for this purpose.

The recipe-type experiments, while good for exercising common lab procedures, were not useful in helping students distinguish between the four types of matter, particularly the difference between homogeneous mixtures and compounds. This problem is clearly evidenced in the interviews. The chemical and physical changes transparency activity was also not successful. In all cases, I had to resort to lecture to explain and connect concepts. This was very disappointing because my students and I have been struggling with these topics for so long.

To truly follow the constructivist model, the teacher must include activities that provide opportunities for students to change their own conceptions about the world. I do not believe the hotdog, anaglesic and gold penny labs I added met this criterion. Students could not see what was happening to the atoms. Instead of the students developing their own knowledge, I had to directly explain that the atoms were being physically separated during the experiments. To experience conceptual change, a student must witness an event that cannot be adequately explained by his current understandings. The student then experiences dissonance, which provides motivation for modifying or completely reorganizing his own understandings. While the students were actively involved and asked good questions, the labs did not provide enough (if any) dissonance for conceptual change. The labs also did not give students any more insight into the difference between homogeneous mixtures and compounds than they had before performing the experiments. To make these activities more valuable, I could have the students sketch molecular pictures of what they think happened to the atoms during the experiment. I could then ask coaching questions in a class discussion about any pictures that reflect miconceptions. By adding these components to the labs, I should be able to help the students see where their thinking does not make sense, thereby motivating them to explore the correct explanation for the results they see in lab.

I am starting to believe that not all concepts can be understood through the constructivist approach. At the end of the post-interviews, I asked the students for suggestions to make the unit more clear. With respect to the transparency activity, each student told me I should sketch the molecules in chemical and physical changes at the start of that subtopic, then ask the students to do the same with different examples. They were asking me to model the correct thinking first, then ask the students to use those basic principles to illustrate similar phenomena. At first, it seemed the students were asking me to give them the answers instead of having them think for themselves. I thought they were just being lazy. According to the constructivist model, students should be constructing their own knowledge when given appropriate opportunities and teacher coaching. To do what the students suggested seemed to contradict the constructivist model. However, upon further consideration and evaluation of the entire unit, I now believe the students were correct. By not giving the students any fundamental information, I was asking them to do an impossible task - illustrate knowledge they did not have. Since students cannot directly experience what happens to atoms during chemical and physical changes, this concept is simply too abstract for students to understand without knowledge of basic principles.

I believe teachers need to use a combination of lecture and constructivist approaches to teaching to be effective in the classroom. Teachers need to realize there are some topics, like matter classification and chemical and physical changes, that they must address directly because they are simply to abstract for students to understand on their own. Teachers must then provide opportunities for students to apply their knowledge in the laboratory or other group and individual activities.

Future plans:

This unit remains a work in progress. I will continue to search for meaningful activities to help students understand matter classification and chemical and physical changes. In the meantime, I will continue to use the hands-on, minds-on activities, such as journal questions and discussions, because they keep the students interested. I will also continue to incorporate similar activities in my other units as necessary, keeping in mind that there is a place for both constructivism and lecture in good teaching.

APPENDICES

APPENDIX A

APPENDIX A

DEMONSTRATION: PROPERTIES

I take volunteers to participate in the following demonstrations.

1. Heat conductivity
   A student puts a ball of wax on each end of a five-pronged stick. The prongs are connected to a center ring, which is connected to a wooden handle. Each prong is a different metal. The student holds the ring over the flame of a Bunsen burner and we see that the wax melts and falls off at different times for each ring.

2. Magnetism
   Several objects are provided, such as coins, paper clips, aluminum foil, etc. The students guess which ones will be magnetic. A volunteer holds the magnet above each object to see if it is magnetic.

3. Surface tension
   Students try to float paper clips on one full glass each of water and rubbing alcohol. We have been able to float up to eight on water, but none will float on alcohol.

4. Malleability
   Different samples of metal sheets are passed around for the students to try to bend. Some bend easily, some do not.

5. Solubility
   Students have beakers with equal amounts of water. The class predicts how many teaspoons of corn starch and salt will dissolve in each glass. The students see that the corn starch does not dissolve well, but several teaspoons of salt dissolve in the same volume of water.

6. Boiling point
   Students record the temperature of a liquid every two minutes as it heats slowly on a hotplate. One beaker contains 100 mL of water, one contains 100 mL of alcohol, and one beaker contains 50 mL of water. Students see that the alcohol boils at a lower temperature than water, and water boils at the same temperature no matter what sample size you use.

7. Flammability
   A small amount of water and a small amount of alcohol are poured in different places on a lab bench. A match is thrown into each puddle. The match in water goes out, but the alcohol burns.

APPENDIX B

APPENDIX B

DENSITY - EXTENSIVE OR INTENSIVE?

<u>Part 1</u> Writing the experiment.

Students are told they will be given no more than 100 mL of sample liquid. Each lab group gets a different sample. Baby oil, distilled water, rubbing alcohol, salt water, and nail polish work well. Each group is to write a protocol that will prove whether density is an intensive or extensive property. Their procedure should include instructions that will result in at least four data points to plot on a graph. The students are given 30 minutes to write an objective, list of materials, hypothesis, step by step procedure, and data tables with headings in preparation for the experiment.

<u>Part 2</u> Exchanging protocols.

Each group must justify why their protocol will lead to a conclusion about the classification of density as an intensive or extensive property. When all protocols have been approved, I collect them, shuffle them, and distribute them to different groups.

<u>Part 3</u> Performing the experiment.

Each group is given 20 minutes to carry out the protocol written by a different group in the class. During the experiment, they are to make notes regarding how easy the procedure is to follow.

<u>Part 4</u> Processing.

The following day each group calculates the density of their liquid for at least four different volumes, as instructed in the procedure. They record their data on the board, and graph their data as well as the other groups' data on the same paper using colored pencils. We use the data on the board to discuss sources of error that would affect the outcome of the density calculations. We also discuss the relationship between a straight-line graph and intensive properties. We review how to calculate slope and predict how the samples will arrange themselves if we put them all in a test tube. The students test their hypotheses in lab. At the end of the exercise, the students receive a group grade based on their data and conclusions and how easy their own procedure was to follow.

APPENDIX C

APPENDIX C

DEMONSTRATION: FLOATING BUBBLES

The purpose of this demonstration is to show that gases, like solids and liquids, have density.

<u>Part 1</u>
Line the bottom of a medium size fish tank with foil. Cover the foil with baking soda. Kneel so your mouth is just above the top edge of the tank and blow bubbles over the top of the tank, parallel to the table. Students will notice that the bubbles fall to the bottom of the tank and pop.

<u>Part 2</u>
Pour about 500 mL of vinegar over the baking soda and repeat the bubbles. Students will notice that the bubbles appear to float in the center of the tank and do not pop.

I got this demonstration from a friend and fellow chemistry teacher, Barbara Obinger.

APPENDIX D

APPENDIX D

ROTATION LAB

Name of material	Symbol or Formula	Observations	HM	S	E	C	Why?
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							

HM = heterogeneous mixture
S = solution (homogeneous mixture)
E = element
C = compound

APPENDIX E

APPENDIX E

Is Grape Kool-Aid® a Mixture or Pure Substance?

BACKGROUND: Molecules of different dyes have different structures. If a dye molecule has a structure like the solvent, it will be pulled by the solvent as the solvent moves by.

In this lab, grape Kool-Aid® is prepared with water and passed through a column. As the Kool-Aid® enters the column, it sticks to the packing material. You will then pass water and different percentages of alcohol solution through the column and collect the fractions in separate test tubes. The dye molecules that are most like water molecules will come out first, and the ones most like alcohol will come out last.

HYPOTHESIS: If each test tube contains a different color dye at the end of the experiment, then

----

MATERIALS

Sep Pak with syringe	4 small test tubes
70% alcohol	grape Kool-Aid® solution
23% alcohol	waste beaker
11.5% alcohol	

PROCEDURE:

1. Label the test tubes: #1, #2, #3. Make a data table to record your observations during the procedure. Include a place to record what you see in each test tube at the end of the experiment.

2. Pour 1 mL of water into the column. Pull out the plunger and attach the syringe. Push on the plunger until most of the water moves through the column, and empty the column into the waste beaker.

3. Add 1 mL of grape Kool-Aid® to the column. Force the Kool-Aid® solution into the column using the plunger. When the Kool-Aid® meniscus is at the top of the column, stop. As you are pushing, watch what happens to the Kool-Aid®. Record your observations in the data table.

4. Repeat step 3 using 1 mL of water and collect the liquid in the test tube marked #1. Record your observations.

5. Repeat step 3 using 1 mL of 11.5% alcohol and collect the fraction in test tube #2. Record your observations.

6. Repeat step 3 using 1 mL of 23% alcohol and collect the fraction in test tube #3. Record your observations.

7. Clean the column by repeating step 3 using 1 mL of 70% alcohol and collect liquid in the waste beaker. Then, wash the column with water and empty into the waste beaker.

RESULTS:

CONCLUSIONS:

1. Is grape Kool-Aid® a mixture or a pure substance? What proof do you have?

   ----

2. Can you put the components back together? Yes No

3. Is separating the dyes in Kool-Aid® a physical change or a chemical change? How do you know?

   ----

4. Could this process be used on a colorless solution? Why or why not?

APPENDIX F

APPENDIX F

SEPARATION USING PAPER CHROMATOGRAPHY

BACKGROUND INFORMATION

Chromatographic separation is based on the fact that substances dissolve differently in various solvents. In paper chromatography, substances that are more soluble and less strongly adsorbed to the paper move quickly (usually smaller molecules), while substances that are less soluble and more strongly adsorbed to the paper move slower (usually larger molecules). As the mixture moves up the paper with the solvent, it separates into distinct bands based on solubility in that particular solvent. As the dyes separate, they form bands of color on the filter paper. The thicker the band, the more molecules of that dye are present.

PURPOSE: To classify different inks as mixtures or pure substances, and to determine the relative amount of each dye in the inks.

SAFETY: ethanol and acetone are flammable

MATERIALS

100mL graduated cylinder
3 strips of filter paper
several ink markers
water
acetone
ethanol

PROCEDURE

1. Using pencil, make a horizontal line 1 cm from the short edge of each strip of chromatography paper. Then, write "acetone" on one, "ethanol" on another, and "water" on the last piece of paper.

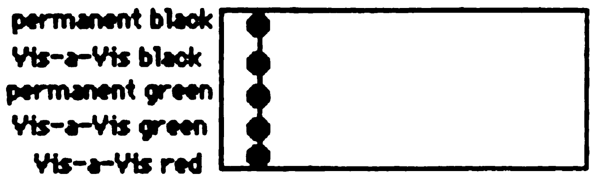
2. Using the inks below, make dots on each strip of chromatography paper in the order shown on the picture below. This is called "spotting" the paper. Smaller, more concentrated dots that are far apart from each other work best.

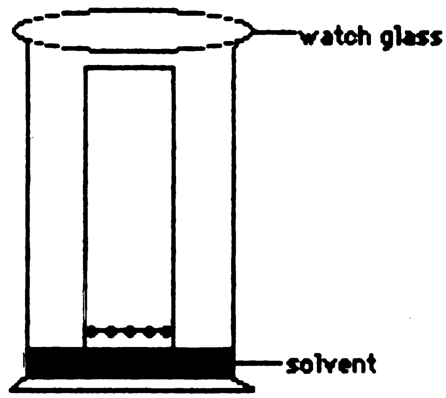
3. Put approximately 8-10 mL of acetone in the graduated cylinder, being careful NOT to splash on the sides.

4. Put the chromatography paper strip marked "acetone" into the graduated cylinder as shown below. MAKE SURE THE SOLVENT LINE IS UNDER THE DOTS! Put a watch glass on top of the graduated cylinder.

5. When the solvent is approximately 3 cm from the top of the paper, remove the paper strip and set it aside to dry. Once the paper is dry, sketch what you see in the RESULTS section using colored pencils. BE SPECIFIC!

6. Dump the acetone into the sink and rinse the graduated cylinder with ethanol 3 times. Then, repeat steps 3-5 using ethanol. Repeat again using water. Remember to rinse the graduated cylinder!





RESULTS

acetone | ethanol | water

CONCLUSIONS

1. Describe what you saw happening to the ink as the solvent moved to the edge of your paper.

2. Suppose band A is thicker than band B. What does this tell you about the amount of ink forming each band?

----

3. Sometimes an ink will separate into certain colors in one solvent, but other colors in another solvent. Where are the missing colors, and why?

----

4. Suppose at the end of a separation you have blue near the top of the paper and yellow closer to the center.

   Which molecule is bigger: blue or yellow? ____________________

5. Is chromatography a chemical or physical change? ______________

   What evidence do you have to support your answer? ____________

----

6. Does a color change always indicate a chemical change? ___________

7. Which inks are mixtures? How do you know? _________________

----

8. Which inks are pure substances? How do you know? ____________

APPENDIX G

APPENDIX G

LAB - PERFUME

Part 1.

Put approximately one-quarter pound lard in a round-bottom flask and heat in a water bath until melted. Meanwhile, grate the peel of a citrus fruit into a bowl. Anything with a strong smell will work, including oranges, lemons, chocolate, cinnamon, garlic, and dill. Add the scent to the melted lard and boil for one hour. Remove from heat and let sit overnight.

Part 2.

Melt the lard/scent mixture in a hot water bath. Add approximately 35 mL of ethyl alcohol, loosely stopper, and swirl for five minutes.

Part 3.

Put flask back in water bath and attach a distillation tube and a vial. The alcohol will boil and condense, taking the scent with it.

APPENDIX H

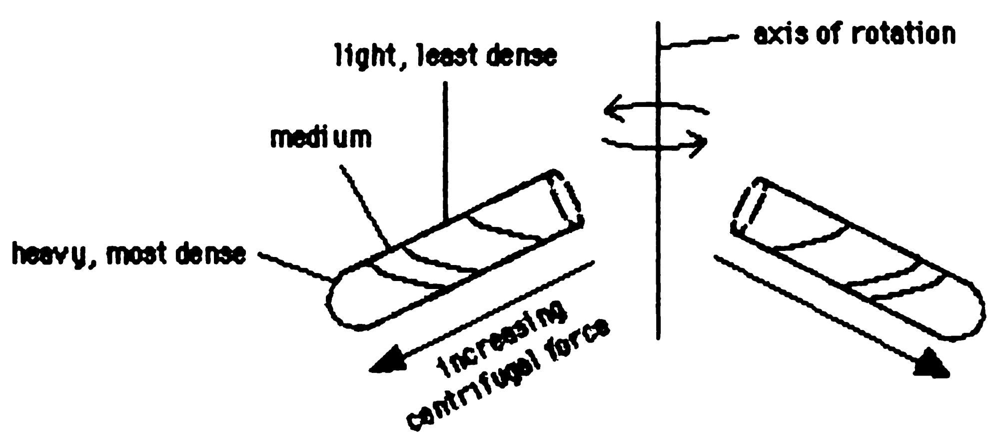
How much fat is in a hotdog?

Problem

You are working as a food analyst in the Science and Technology Division of the United States Department of Agriculture Food Safety Inspection Service (USDAFSIS). You're supervisor has recently sent you a memo indicating that a small group of health club members in Boston have reason to believe that Eckrich is printing incorrect nutritional information on its hotdog packages. They believe that the hotdogs labelled "Fat-free" really contain fat, and that the regular hotdogs contain much more fat than the label indicates. At the end of the memo, your supervisor has asked a few questions to help you stay focused. According to standard complaint regulations, the USDAFSIS must respond to the heath club members within 10 days of receiving the complaint. Your supervisor has asked that you complete the necessary analyses to determine whether or not Eckrich is misrepresenting its hotdogs, answer the questions, and return all information to her no later than 5 days from today.

Background

A mixture of particles of different sizes suspended in solution can be separated using a centrifuge. A centrifuge is a machine that spins samples around a central axis at a high rate of speed, accelerating the force of gravity acting on the particles. If the particles are heavier or more dense than the medium they are suspended in, they will move to the bottom of the container. If the particles are lighter or less dense than the medium, they will float to the top.



Centrifuges have a wide variety of applications. Hematologists use centrifuges to separate serum in blood from the solid parts (red and white blood cells and platelets) so they can run pregnancy, mono, and drug tests. The Environmental Protection Agency uses centrifuges to get the sediment out of water and sewage samples so they can examine it for contamination. Botanists use centrifuges for separating plant cell parts to determine enzyme activity in particular organelles. Since the centrifuge stresses the force of gravity, very large centrifuges are used to simulate the effect of gravity on other planets. You, too, have worked with centrifugal force if you have ever run a clothes washer. During the spin cycle, centrifugal force pulls the water away from the clothes and out of the drum.

Since centrifuges separate particles based on mass or density, they can also be used to separate different types of lipids. Lipids, also called fats and oils, are greasy, oily compounds that do not dissolve in water. Most lipids contain fatty acids, or long hydrocarbon chains that have -COOH groups on one end.

One kind of lipid that contains fatty acid chains is the saturated fats, such as butter and lard. They are called "saturated" fats because they only contain single C-C bonds. Most of them are mammal fat. Because the fatty acid chains are saturated, they are flat. This property allows them to layer on top of each other, forming a solid. The saturated fats are the most dangerous to humans because they can form layers on the inner walls of blood vessels, restricting blood flow around the body.

Another kind of lipid that contains fatty acid chains is the unsaturated fats, such as corn, peanut, and fish oils. They are called "unsaturated" fats because they contain one or more double bonds. They are liquid at room temperature because the double bonds create kinks that disrupt layering between hydrocarbon chains.

saturated fatty acid chain

unsaturated fatty acid chain

Objectives

To separate a hotdog into its parts based on density using a centrifuge
To calculate the percent unsaturated fat in a regular hotdog and compare it to the amount stated on the package.
To qualitatively determine whether or not an Eckrich Fat-free hotdog contains fat

Materials

one regular hotdog and one fat-free hotdog
distilled water
table salt, NaCl
2 test tubes that fit in your centrifuge
1 small test tube
1 micropipette with suction bulb
100 mL beaker
250 mL Erlenmeyer flask
2 blenders with lids
brown paper or towels
balance
thermometer
hot plate or other heat source

Procedure

1. Label one blender *Regular* and the other blender *Fat-free*. Put your class period and group number on two brown towels. Label one of them *Regular* and a second one *Fat-free*. Label one medium test tube *#1*, the second medium test tube *#2*, and the small test tube *#3*. Find the mass of each test tube.

2. Make a 2% salt solution by adding 3 grams of NaCl to 150 mL distilled water in the flask. Heat on a hot plate until the solution is approximately 80 °C.

3. Use a paper towel to dry one regular hotdog and one fat-free hotdog. Determine the mass of each one, and put them into the correct blenders.

4. Put the 100 mL beaker on the balance and tare it. Then pour enough hot salt water into the beaker to equal the mass of the Regular hotdog. Quickly pour the solution into the Regular blender. Return the flask to the hot plate, and continue heating on low.

5. Put the lid on the blender and mix at high speed for 4-5 minutes.

6. Fill test tube #1 approximately 3/4 full of Regular hotdog slurry. Put the tube into the centrifuge and record your slot number. The tubes should be positioned so they are balanced in the centrifuge. If there is an odd number of tubes, fill a tube 3/4 full of tap water and place it in the slot opposite the unpaired tube. Centrifuge for 10 minutes.

7. While the Regular hotdog tubes are spinning, repeat steps 4 and 5 for the Fat-free hotdog.

8. When the centrifuge comes to a complete stop, remove your Regular test tube (#1) and insert your Fat-free test tube (#2). Spin the Fat-free test tubes for 10 minutes.

9. Sketch a picture of what you see in test tube #1. Label the picture with a short description, including color and texture.

10. Use a micropipette to transfer the top layer to test tube #3. Transfer as much as you can without picking up any particles from the next layer.

11. When the centrifuge stops, remove your Fat-free test tube and insert your Regular test tube. Spin the Regular test tubes for another 10 minutes.

12. Repeat step 9, using test tube #2.

13. On your brown paper or towel labelled *Fat-free,* make a column for each layer you see in test tube #2 and put a title on each column that identifies that layer. Using your micropipette, suction a small amount of the bottom layer out of test tube #2 and smear it onto the brown paper in the correct column. Repeat for each layer in test tube #2. When you are finished, use a pencil to draw a line around the perimeter of each smear.

14. When the centrifuge stops, transfer the top layer to test tube #3 as you did in step 10. After you have transferred as much of the top layer as possible, find the mass of test tube #3 containing the top layer.

15. Repeat step 13 for test tubes 1 and 3. Leave the brown towels on the desk overnight to dry.

16. The next day, hold the brown towels up to the light and look for any transluscent areas. Make a data table and record whether or not you see any transluscent areas for each column.

<u>Clean-up</u>

Dump as much of the contents of the test tubes as possible into the trash. Then wash the test tubes, blenders, lids, and micropipettes with soap and water.

Data

Picture: Regular hotdog

Picture: Fat-free hotdog

Regular Hotdog

Mass of hotdog	
Mass of salt water added	
Mass of test tube 1	
Mass of test tube 1 + sample (salt water + hotdog)	
Mass of sample (salt water + hot dog)	
Mass of test tube 3	
Mass of test tube 3 + layer	
Mass of layer	

Fat-Free Hotdog

Mass of hotdog	
Mass of salt water added	
Mass of test tube 2	
Mass of test tube 2 + sample (salt water + hotdog)	
Mass of sample (salt water + hotdog)	

Brown towel test:

Regular hotdog

Fat-free hotdog

Analysis

1. Calculate the actual percentage of unsaturated fat in the regular hotdog.
   a) % hotdog in stock slurry = $\frac{\text{mass of hotdog in stock slurry}}{\text{mass of salt water in stock slurry} + \text{mass of hotdog in stock slurry}} \times 100$

   b) Mass of hotdog in sample = (mass of hotdog+salt water in test tube #1) x % hotdog in stock slurry

   c) % unsat. fat in sample = $\frac{\text{mass of fat in test tube \#3}}{\text{mass of hotdog in sample}} \times 100$

2. Calculate the percentage of unsaturated fat in the regular hotdog according to the package.
   a) % unsat. fat = $\frac{\text{total fat - saturated fat}}{\text{mass of one hotdog}} \times 100$

Discussion/Conclusions

1. Which of the layers contained fat, and how do you know?
2. Was the top layer of the Regular hotdog made up of saturated or unsaturated fat? What physical properties fats helps you distinguish them?
3. After centrifuging the regular hotdog, two layers form that appear to be the same. Are they made of the same "stuff"? Support your hypothesis. How could you test your hypothesis?
4. Based on your analysis, is Eckrich misrepresenting its hotdogs? Support your answer.
5. List several sources of error, and how these errors may have affected your final percentage of unsaturated fat in the sample.
6. What is a possible extension of this experiment?

APPENDIX I

APPENDIX I

Sample Permission Slip

August 25, 1997

Dear Parents:

I am currently attempting to obtain a Masters degree in Biological Science with an emphasis in Chemistry. Last summer I spent five weeks on the campus of Michigan State University doing research to find better assessment techniques and create laboratory activities to use in my Chemistry class. At this point, I am ready to gather data with which to write my thesis.

The topic of my studies is classification of matter. I chose this topic because it is assessed on the High School Proficiency Test, it is referenced in several of the Montrose High School Science Curriculum objectives, and it is a topic I already cover in class. My thesis will focus on how well the new teaching techniques help students change their misconceptions about matter.

The data I need will come from student work, such as test scores, journal entries, answers to questions posed in student interviews both before and after the unit, essay answers, etc. The purpose of all questions will be to probe for student understanding of matter classification concepts.

I am asking your permission to anonymously use your student's work as data in my thesis. As you consider my request, please understand that your child's name will be removed from all work, and your child's grade will not be affected regardless of whether or not he/she agrees to let me use the work. Please also understand that I would be using these new techniques independent of my thesis study because I believe they are the most effective methods available at this time.

After you have made your decision, please fill out the permission slip below and return it to me by Friday, August 29. If you have any questions, please feel free to contact me at 810-639-6131, ext. 2010 between 1:00 and 2:25 p.m.

Sincerely,

Sue Donley, Chemistry Teacher

I, ______________________________, grant Sue Donley permission to anonymously use the work of ______________________________, in the Matter unit as data for her Masters Thesis.

______________________________ ______________________

Parent/Guardian signature Date

APPENDIX J

APPENDIX J

Pre- and Post-Interview Questions

1. What is matter?

2. Take ten labelled notecards and put them into three piles: "matter", "not matter", and "not sure". Explain why you put the cards in each pile. (The cards were labelled: air, blueberry muffin, carbon dioxide, copper, energy, pop, salt water, silver, 2% milk, water.)

3. Using only the cards previously classified as "matter", put the cards into two piles: "mixtures" and "pure substances". Explain what the cards in each pile have in common.

4. Sketch before and after pictures to show what happens to the molecules in a chocolate bar as it melts. (Are the molecules changing?)

5. What is the difference between chemical and physical changes?

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