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Comparison of the effects of inquiry-based cooperative learning and demonstrations in science education

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A COMPARISON OF THE EFFECTS OF INQUIRY-BASED COOPERATIVE LEARNING AND DEMONSTRATIONS IN SCIENCE EDUCATION

By

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A REPORT

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This report, “A Comparison of the Effects of Inquiry-based Cooperative Learning and Demonstrations in Science Education,” is hereby approved in partial fulfillment of the requirements for the Degree of MASTER OF SCIENCE IN APPLIED SCIENCE EDUCATION.

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Abstract

The reported research project involved studying how teaching science using demonstrations, inquiry-based cooperative learning groups, or a combination of the two methods affected sixth grade students' understanding of air pressure and density. Three different groups of students were each taught the two units using different teaching methods. Group one learned about the topics through both demonstrations and inquiry-based cooperative learning, whereas group two only viewed demonstrations, and group three only participated in inquiry-based learning in cooperative learning groups.

The study was designed to answer the following two questions:

1. Which teaching strategy works best for supporting student understanding of air pressure and density: demonstrations, inquiry-based labs in cooperative learning groups, or a combination of the two?
2. And what effect does the time spent engaging in a particular learning experience (demonstrations or labs) have on student learning?

Overall, the data did not provide sufficient evidence that one method of learning was more effective than the others. The results also suggested that spending more time on a unit does not necessarily equate to a better understanding of the concepts by the students. Implications for science instruction are discussed.

Table of Contents

List of Tables

Chapter 1

Introduction

Educators in the United States are constantly reminded by the media that as a country, we are falling behind the international education community. The PISA test scores, for example, rank the U.S. in the middle of other industrialized countries (Education Trust, 2010) Other reports, such as the international report card and TIMMS, have reported similar results (Graham, 2010).

Why is the U.S. system not working? It will depend on who you listen or talk to. There are many opinions about the problems and potential answers to them. For example, Boyer and Hamil (2008) attribute some of the major problems in education to teacher attrition, lack of parental involvement, and low student reading abilities. They report that forty-six percent of new teachers quit teaching after five years or less, that parents are only contacting teachers if there is a problem, and eight million students cannot read at the basic level.

According to Brady (2010), the government and mainstream media push reform by portraying schools as mediocre, blaming teachers and students, saying that more standardized tests and standards are needed. In fact, Brady is predicting that all the new education laws and reforms will fail. He feels that there are 22 actual underlying problems that need to be dealt with. Some of these are that education "directs random information at learners at a rate far beyond even the most capable learner's ability to cope", "is so inefficient it leaves little time for apprenticeships, internships, co-ops, projects, and other links to real world and adulthood", "is keyed to students' ages rather

than their aptitudes, interests, and abilities", and "penalizes rather than capitalizes on individual differences" (p. 3).

Personally, I do not know if there is only one answer, or whether we can even say for sure that the current system is "broken". It seems that a lot of the data contradict each other. For example, Nihalani, Wilson, Thomas, and Robinson (2010) state that "Heterogeneously grouping students may be detrimental to overall team achievement if there is a great discrepancy between high-performing individuals and the rest of the team members" (p. 523). On the other hand, Millis (2002) suggests that a key ingredient in picking successful groups is making sure that the groups are heterogeneous.

Top ranking countries, such as Japan and Finland, take different approaches to their education system and both seem to be working if international test scores are used as the benchmarks. In Japan, the teaching style is mostly teacher- and book-centered, with emphasis on rote memorization (Zhenhui, 2001). In Finland, reforms in the early 90s pushed for more student-centered learning and the national curriculum started emphasizing cooperative learning (Sahlberg, 2004). The question this raises, then, is which methods or combination of methods might be adopted in the United States? Again, there are no clear answers, but what is certain is that the perception that our students are falling behind will lead to changes in the school curriculum and educational laws.

Currently our national and state governments are looking at various education reforms. In my nine years of teaching I have already seen many changes in the science curriculum as a result of mandates such as the Michigan Grade Level Content Expectations (Michigan Department of Education, 2006) and the No Child Left Behind law (U.S. Department of Education, 2002). I cannot predict what changes will come my

way in the future, but what ever they are, it is my job as an educator to implement them. It has also become clear that changes need to take place in the classroom if we want to improve our student's academic achievement. I have come to find that I need to be continually doing informal action research in my classroom to figure out what works best for each individual student. I also have realized that every year my students change, which means I need continually find ways to change my practices to give my current students the best opportunity to achieve the highest level of success possible.

My Challenges in Teaching Science

In my classroom at Washington Middle School, I am continuously challenged to teach in ways that will allow all of my students to meet Michigan's state standards for 6^{th} grade science (MDE, 2006). This is not easy. If I teach too quickly, the bottom 20% will fall behind. If I teach too slowly, the top 20% will get bored. I also have to deal with full inclusion in my classroom, which means I often have some students at a 9^{th} grade reading level, while others are at 1^{st} grade reading level (Machiela, 2010).

One major factor that affects my instruction is the Michigan Grade Level Content Standards (GLCEs) (MDE, 2006) that are assessed by the State of Michigan with the Michigan Education Assessment Program (MEAP) test. The overall school results are used to assign a grade to each school in the state; both the MEAP results and the school grade are published in local papers and on a state website. The school administration, as well as the state government, push for high grades to show that schools are doing a good job teaching children. The attention paid to these grades creates added pressure for teachers.

While developing my curriculum and teaching strategies, I also need to keep in mind that Calumet currently has a child population with 24.4 % of its children below the poverty level, whereas the state as a whole has 20.2 % (U.S. Census Bureau, 2010). This creates numerous problems, such as how much time I can expect students to work on science outside of the classroom, since many students in poverty do not have the resources such as computers at home. Also, many of the students' parents do not have higher than a high school degree, which means students may not be getting help from their parents on confusing topics.

Another issue I need to keep in mind is time. My classes are between 48 and 54 minutes long. If I use 51 minutes as my average, I will see my students for 153 hours per year, if they are present for all 180 days that school is in session. Each student averages 9.5 absences per year (Niebuhr, 2010). We have MEAP testing, which takes up six days, students attend an outdoor education camp that takes up five days, and students also miss class for pep assemblies, snow days, and other activities that take away from the classroom. This means that I am missing another 23 hours of class time, on average, per year. I now have 130 hours to teach my students 49 Grade Level Content Expectations in science per year (MDE, 2006). Thus, time is the major obstacle I encounter. If I had more contact time with students, I could pull the lower achieving students aside for one-on-one help; I would not have such a problem finishing the curriculum, while making sure my students have every possible opportunity to succeed. The students coming from low-income homes would have more time at school to do their work, along with access to the technology and other resources they may not have at home.

These issues—time, state expectations, students' lives, and reading levels—push me to constantly change and try new techniques that may or may not have a positive impact on my students. Teaching for nine year has allowed me to make many qualitative observations that have influenced my thinking about what is best for my students. However, I have never actually used quantitative data, other than tests, to determine whether the strategies that I truly believe are positively affecting learning actually do so. As far as the tests are concerned, I take a class average. If that average is around 70%, I move on to the next set of content expectations.

My Instruction

My own observations have led me to believe that my students are more aware of the connections between scientific concepts when I demonstrate these concepts as part of instruction. I still do not always know, however, if students are necessarily learning all the skills they need in order to be successful in science. For example, students have a lot of difficulty understanding air pressure. They can remember what air consists of and how much pressure it is exerting on an area, but have difficulty applying air pressure concepts to real word situations. If I ask them to explain why clouds form, many students really do not have the ability to use their knowledge of air pressure and low pressure systems to explain cloud formation. I realize this may be due to 6^{th} grade students' cognitive levels, but if I use a lot of demonstrations, it seems that the students are better equipped to apply prior knowledge to new ideas.

I have found that laboratory experiences are also a great way to teach students the skills they need to succeed in science. My students use cooperative learning groups and inquiry-based learning while conducting a lab; working in groups and engaging in inquiry

are important skills they need to be successful in science. After teaching a concept, I will have students get into groups of two or three. Sometimes I choose the groups, and sometimes they choose the groups. I then have the students work on a problem that will allow them to use prior knowledge to understand a new concept. The idea is to get the students to learn how to work together while learning with and from each other.

In my opinion, I think it is best to prepare students to meet each state standard by first providing them some background knowledge on the subject with notes and lecture, followed by some demonstrations to catch their interests. I follow this up with a lab that allows them to learn through inquiry. Although this style of teaching seems to work for me, I have difficulty addressing all of the state standards during a school year. Currently, I look at the standards at the beginning of the year and split up my time to cover all of the GLCEs during the year. The issue I run into is this: I end up quickly teaching nine weeks of information in three weeks at the end of the year. I clearly need to find a way to address this issue. Thus, the question arose of whether I could use either a demonstration or cooperative learning groups to teach a concept, and not do both.

Research Questions

The difficulties I have described led to this study about the difference in student learning due to demonstration style instruction versus having students complete laboratory experiments in cooperative learning groups. Through the study, my goal was to find a more efficient way of teaching my students by better understanding the effects of these two different methods of instruction. Specifically, I aimed to determine whether my students demonstrated a better level of learning by only engaging in labs, only viewing demonstrations or by engaging in a combination of the two. If it were known that

the level of learning was similar among these three methods, it would allow me to set up my curriculum in a way that the students would either view demonstrations or participate in an inquiry-based lab, but not both, when addressing each learning objective. This would save my students and me a lot of time, allowing me to spend more instructional time on a wider range of science topics.

Specifically, this study addressed the following research questions:

- Which teaching strategy works best for supporting student understanding of air pressure and density: demonstrations, inquiry-based labs in cooperative learning groups, or a combination of the two?
- What effect does the time spent engaging in a particular learning experience (demonstrations or labs) have on student learning?

Chapter 2

Literature Review

Science Benchmarks and Curriculum

Currently, the sixth grade curriculum in Michigan is based on the state's Grade Level Content Expectations (GLCEs). In science, there are forty-nine concepts to cover. They include twenty expectations about science processes. Of these processes, eleven are based on inquiry and nine are based on reflection and social implications. Of the other twenty-nine standards, six are from physical science, ten from life science, and thirteen from earth science (MDE, 2006).

The United States' education system might benefit by adopting a national science curriculum (Achieve, 2010). This would mean more changes to the school science curriculum. The National Research Council, the American Association for the Advancement of Science, the National Science Teachers Association, Achieve, and others are working together to push for adopting national science standards that are based on international benchmarks (Achieve, 2010). The National Standards currently consist of eight content strands which are: (a) unifying concepts and processes in science, (b) science as inquiry, (c) physical science, (d) life science, (e) earth and space science, (f) science and technology, (g) science in personal and social perspectives, and (h) history and nature of science (National Science Education Standards, 1998). These standards also include six teacher strands which are: (a) teachers plan an inquiry-based science program; (b) teachers guide and facilitate learning; (c) teachers engage in ongoing assessment; (d) teachers design and manage learning environments that provide time,

space, and resources needed for learning science; (e) teachers develop science learners that reflect on inquiry learning and social environments; and (f) teachers continue developing the schools science program. If these standards were adopted, all students in the United States would be taught similar material, which means that students would receive the same science education regardless of which school they attend. In addition, the standards would push teachers to adapt their instruction to include inquiry as a major mode of instruction.

Middle School Student Learning

There is an established relationship between learning styles, teaching styles, and student achievement. Even though this research has been done, this does not mean that it has led to improvements in student learning. One of the main reasons that improvements are not being made is because the research is not making it into the classroom. Instead of using research to make decisions about what works best for students, teachers often teach in a way that they themselves learn best (Holt, Vore, Denny, Smith, & Capps, 2007).

In middle school, there are three main types of learners on which teachers need to concentrate. The first are auditory learners who do best by listening, especially during lectures. Then there are visual learners who learn best by seeing drawings, pictures, concept maps, outlines, and diagrams. Finally, some students are kinesthetic learners. These students learn best through movement and touch (Gault, n.d.). Teaching at the middle school level can be difficult if a teacher cannot adapt to different teaching and learning styles. The reason for this is that students between the age of ten and fourteen are going through many changes, and each individual changes at a different rate. Thus,

middle school students will range anywhere from a concrete operational learner to a formal operational thinker (Fantauzzo, n.d.)

According to Gault (n.d.), research has found that the traditional teaching methods favor visual learners, yet fifth and sixth graders tend to not prefer visual learning. Rather, fifth and sixth graders tend to prefer learning that has quiet noise levels, dim lights, high structure, informal design, and authority figures around. They also like working with peers, being motivated by teachers, and tend to have kinesthetic learning styles (Holt, Vore, Denny, Smith, and Capps, 2007).

Middle school is also a time when students are starting to find themselves. Because they are defining their identity in society, peers become very important to them. This means that teachers should use cooperative learning, peer tutoring, and cross-age grouping in their lessons (Fantauzzo, n.d.). Students need structure along with an authority figure to learn content, but students learn who they are from their peers. They are also much more comfortable speaking up in small groups (Holt, Vore, Denny, Smith, and Capps, 2007).

Activity- and Inquiry-Based Learning

Activity-based learning is a teaching method that engages students in the learning process. It is a student-centered process where students do activities that require them to reflect, evaluate, analyze, synthesize, and communicate (Smith & Cardaciotto, 2011). Activity-based learning differs from lecture style instruction in that lecture style is an efficient way to transfer knowledge from the teacher to the student, focused mainly on learning through listening (Schwerdt & Wuppermann, 2010), whereas students are actively engaged during activity-based learning.

Inquiry-based learning can be used as a specific type of activity-based learning. According to Haury (1993) "inquiry involves activity and skill, but the focus is on the active search for knowledge or understanding to satisfy a curiosity" (p. 1). Inquiry-based learning is a very important component of science education, in that it allows students to make better connections to the world around them (Kyle, 1980). Rutherford (1964) agrees that inquiry is an important part of science, and defines it as learning in which students need to be, "inquisitive, curious, ask questions, and try finding answers for themselves" (p. 81). Rutherford's definition of inquiry fits into Smith and Cardaciotto's (2011) definition of active learning. Both learning through inquiry and activity-based learning require students to actively seek knowledge for themselves. Inquiry does not necessarily have to be activity-based, but the laboratories used in a school science class are often structured as guided inquiry, where the students learn about new science content by doing an activity instead of through listening to a lecture (Haury, 1993).

Smith and Cardaciotto (2011) have found activity-based learning to be more effective than demonstration and lecture style learning. Their work, along with that of Fogleman and McNeill (2011), suggests that students who generate information themselves are more likely to remember it, and will also be more engaged and positive towards learning.

Fogleman and McNeill (2011) conducted a study of teachers' adaptations to an inquiry-oriented curriculum. They studied 19 teachers who were given a unit plan to teach to their students. The teachers were able to adapt the unit in any way they thought best. The point of the study was to find how curriculum adaptations affected student learning. They found that there was a wide range of learning gains from one teacher to

another. Their study showed that the time spent on the unit, teacher comfort level, teacher report of student understanding, and the level of unit completion did not significantly influence student learning. They did find, however, that there was a significant impact on a students' learning when the teacher had experience teaching the unit and when the students did an activity on their own instead of watching the activity done as a demonstration. In fact, these researchers found that 33% of student gains could be explained by a teacher's experience and the activity structure of the unit. Their study was not able to conclude that the other variables were not important or that other influences do not have a effect on a student's learning, but only that activity-based learning and teacher experience are important when it comes to a student's learning.

Inquiry is a process that is required for success in science and has been a major goal of science education since the 1950's (DeBoer, 1991). In 1960, many science teachers agreed that engaging students in inquiry was an effective teaching method, but research showed that many teachers were not implementing it well (Rutherford, 1964). Rutherford felt that teachers needed to be trained on how to use this model of instruction effectively. Today, many science teachers still feel that inquiry is an important part of science education even though many teachers still do not use it for a variety of reasons (Hardin, 2009), These reasons include that: (a) teachers feel they may lose control of learning; (b) teachers need extra training in implementing inquiry-based learning; and (c) teachers feel that because they are required to cover many concepts, they do not have time to implement inquiry-based learning in their classrooms.

Cooperative Learning

Cooperative learning is an instructional method in which a small group of students work together to achieve a shared goal. Cooperative learning, combined with lecture, has been shown to help students become more positive about and active in their learning (Nihalani, Wilson, Thomas, & Robinson, 2010). In order for students to learn effectively through cooperative learning groups, teachers need to break the notion that students are in competition with each other, but instead, need each other in order to find success. With cooperative learning groups, each member needs to have a task that is essential to the group, individuals need to be responsible for their own learning, and both students and teachers need to monitor the group behavior. Organizing successful cooperative learning groups' means keeping the group size small, selecting heterogeneous groups, and keeping groups together long enough to develop good teamwork skills (Millis, 2002).

The advantages of cooperative learning groups are that students develop higher level of self-esteem, are more motivated, learn respect, learn to work with others, and reach higher achievements if the group is structured correctly (Tejada, n.d.). Research has shown that the biggest advantage of cooperative learning groups is that individuals can learn from each other and develop alternative solutions to problems (Huang, 2000). Each individual in a group can learn and understand better when members of a group collectively seek and provide explanations.

Research has also documented that working in small groups can aid student learning when a teacher performs demonstrations using new technologies such as computer animations, simulations, and interactive multimedia (Huang, 2000). As students

watch a simulation on the computer or a video, the student groups can replicate the tasks being demonstrated. In this situation, the teacher would monitor the groups, but it is the group members who help each other make sense of what was observed.

Although research has found that cooperative learning can benefit students, group dynamics can potentially cause problems. If a team has a member that is a significantly higher performer than the rest of the group, the entire group may not do as well as if a group has all similar performers in it (Nihalani, Wilson, Thomas, & Robinson, 2010). Other disadvantages are that student performance may suffer if group members do not develop a good relationship: a high achiever in a group may be the only one who learns, low achievers may not focus or help, or a high achiever may feel like he or she does all the work (Tejada, n.d.).

Sahlberg's (2004) study of cooperative learning groups in Finland has led him to the conclusion that cooperative learning groups are a very effective way to teach, but, as with inquiry-based learning, long-term teaching programs are needed to ensure teachers can truly use the cooperative learning approach effectively.

Demonstrations and Laboratories

Demonstration style learning is the process of demonstrating a skill or process—either by the teacher or a computer aided device—and then coaching or guiding students in developing their knowledge of what they have observed (Stein, Steeves, and Mitsuhashi, 2001). McKee, Williamson, and Ruebush (2007) define it as a teacher showing and discussing a lab instead of having the students do the lab themselves. Demonstrations have many positive effects when done correctly, including that they

allow the teacher to show enthusiasm, spark students' interest, initiate scientific inquiry, and display scientific phenomena in the classroom (Swanson, 1999).

The recommended way to conduct a demonstration is to have students first predict the outcome of a demonstration with a partner, the class, or individually. The class then engages with the demonstration by observing the teacher, a group, or other students conduct the experiment. The students then reflect on the outcome by thinking about why they held their original belief and then confirming whether it is correct. Students then compare their thoughts with other in the class, and often finish with a write-up about what they learned (Merritts, Walter, & MacKay, n.d.).

Even though research has shown that a demonstration may not be as effective as activity-based learning, it has still been found to benefit students (McKee, Williamson, and Ruebush, 2007). With budget cuts, time restraints, and lack of resources, teachers will see class sizes increase, have fewer resources to implement good cooperative learning activities, and have less time to work with individual students or groups (Jimerson, 2006). This may force teachers to use lecture and demonstration style learning as a way of keeping students interested in science, while still completing the curriculum.

On the other hand, demonstrations take a long time to prepare, practice, and clean up. Some feel that it takes away from lecture and lab time, and too often, students are left amazed but do not connect the demonstration to the learning objective (Swanson, 1999). Thus, Swanson feels that a demonstration should not ever replace a laboratory investigation unless money, time, and resources are limited.

With the advance of technology, the future of education may entail using more demonstration style learning through computer simulations. Research has found that

educational games and simulations resulted in positive gains in knowledge, skill, and attitudes of students (Squire & Patterson, 2010). In fact, the U.S. military is now using simulations and computer aided instruction to educate individuals while they are serving their country (Military, n.d.).

Laboratory experiences are an opportunity for students to become active learners while learning through inquiry and also give students the opportunity to work in real-world situations. During labs, students learn how to use scientific tools, make observations, collect data, draw conclusions, and build models and theories (Singer, Hilton, and Schweingruber, 2005). Basey, Sackett, and Robinson (2008) have suggested that there are two ways to conduct a laboratory. The first way is a hands-on observation lab where the students observe data being collected in a lab that helps with term recognition and visual association. The other is an inquiry-based lab where students design their own experiment to find the answer to a problem. This style helps to develop reasoning skills and an understanding of the science process.

Hands-on labs have been shown to increase students' excitement in a science class. Research has found that students enjoy and learn more in science classes when labs are part of the learning experience. Students gain more when they are given a problem and are allowed the opportunity to discover a general principal on their own (Basey, Sackett, & Robinson, 2008).

In general, research suggests that students learn better when engaged in active learning in a cooperative learning group than when observing whole class demonstration style teaching or listening to traditional style lecturing (Taraban, Box, Myers, Pollard, & Bowen, 2007). McKee, Williamson and Ruebush (2007) agree that labs are better suited

to support student learning; they suggest that students develop a conceptual understanding through demonstration, but do not gain the higher order cognitive skills that are gained by performing inquiry-based labs. While combinations of lecture/demonstration and lecture/laboratory both have a positive effect on students, lecture/laboratory may have a larger positive effect on learning (McKee, Williamson, & Ruebush, 2007).

Density

Density is a difficult unit to teach in middle school because students have trouble understanding that matter has mass and that volume is how much space the mass takes up. To complicate the issue, students also have trouble with the idea that the volume and mass of a substance may change, but the density does not. Mathematically, students also struggle to understand proportions, fractions, ratios, relationships, and linear functions. Finally, a lot of teachers use labs to teach density, and students have trouble with basic lab skills such as measuring mass and volume. If the teacher does not address the errors made by each individual group during a laboratory investigation, misconceptions about density may be formed (Balfe, 2001).

A study of 1002 sixth and seventh graders allowed researchers to pinpoint ten common misconceptions about density among middle school students (Yin, Tomita, and Shavelson, 2008). The ten misconceptions students commonly hold about density are:

1. Big/heavy things sink, small/light things float.
2. Hollow things float; things with air in them float.
3. Things with holes sink.
4. Flat things float.

5. The sharp edge of an object makes it sink.

6. Vertical things sink; horizontal things float.

7. Hard things sink; soft things float.

8. Floating fillers help heavy things float.

9. A large amount of water makes things float.

10. Sticky liquid makes things float.

To deal with these misconceptions, it is suggested that teachers should teach new concepts in a way that students understand, build on students' correct conceptions to develop new ones, use model-based reasoning, use examples that challenge multiple assumptions, make students aware of their misconceptions, teach students what learning is, help students "self-repair" the misconception, and finally, have students support their new knowledge by engaging them in a thought-provoking discussion. Things that are suggested that teachers avoid are to rely on only lecture, labs, demonstrations, or reading, but rather, to make sure to incorporate as many teaching styles as possible (Lucariello, n.d.).

When teaching a unit on density, the teacher should first consider the student objectives. Good objectives for a density units should include developing an understanding that density is a relationship between mass and volume, understanding that whether an object sinks or floats depends on the material that is used, and understanding that density is a property of matter regardless of the phase of matter. The teacher then needs to consider possible misconceptions, including those identified in the literature, and address them when designing their lesson (Patterson, Kennedy, and Miller, n.d.)

Air Pressure

A common misconception among sixth graders is that gas does not have mass. This misconception may come from a student's perception of balloons. If you put helium in a balloon it floats up, and even if simply you blow in the balloon, it seems lighter (Henriques, 2000). This misconception may be corrected if students better understood density. So a student's misconceptions and difficulty of air pressure may be intertwined with the difficulties associated with understanding density.

According to Henriques (2000), there are eight more misconceptions that may cause student difficulties when learning about air pressure. The misconceptions follow:

1. Humid air is heavier than dry air; students think the moisture added to the air adds more weight.
2. Hot air weighs less than cold air; students often confuse weight with density because it is said that hot air rises.
3. Air changes composition from place to place; students have trouble understanding air is a mixture of gases.
4. Air only exerts pressure when moving, gasses flow like a liquid, gasses only exert force in one direction, and pressure is not the same in all directions are common misconceptions about the force of air. These misconceptions may come from the students' inability to feel the force being exerted on them.
5. Students do not consider a gas to be matter because they do not think that it has mass or takes up space. They also think that when a gas expands, more gas fills in the spaces. This comes from a student's inability to see or feel gas molecules.

6. The atmosphere is made up of only air; students are not able to see the other micro particles mixed in with the air, so they assume there is nothing else in the atmosphere.
7. Students believe that blowing on something always makes it move away: they do not realize that they are creating a low pressure area by speeding up the air molecules, which then causes air to move towards the low pressure area.
8. When reading weather maps, students thinks the H stands for hot air and the L stands for cold air.

In order to help students understand air pressure, a teacher needs to address these misconceptions. They can do so by following the same procedure as Lucariello (n.d.) suggested and was discussed in the density section.

Summary

In summary, sixth graders need for many different learning styles to be taken into account, along with a flexible teacher who can act as a motivator and has an air of authority (Holt, Vore, Denny, Smith, and Capps, 2007) in order for learning to take place. A teacher needs to realize that experience with a lesson will lead to more success. The teacher needs to constantly be doing active research in the class in order to find out what is best for each individual student, as the students will range widely in capabilities due to different levels of development (Fantauzzo, n.d.).

It may take time for the teacher to gain the experience and develop a teaching style. Once they do, they need to take into consideration that time on a certain concept, and students' ability level are not as important as making sure students are being active learners. They also need to realize that demonstrations can improve learning, interest, and

class participation, but may not be as successful as engaging students in cooperative learning groups in which they are working on an inquiry-based project (Fogleman, McNeill, 2011).

Chapter 3

Methodology

The study involved teaching units on air pressure and density while using different instructional methods, and then analyzing the effects of the type of instruction used. The researcher/instructor was teaching five sections of sixth grade science, and conducted the study in his second, third, and fourth hour classes. For both units, the second hour class was the comparison group, the third hour class was the demonstration group, and the fourth hour class participated in inquiry-based lab experiences in cooperative learning groups.

Participants

There were 55 total students who participated in at least one part of the study. This number dropped slightly throughout the study due to excessive absences by some students, and one student moved before the study ended. Thus, complete data was collected from a total of 49 students.

All of the students in the study were either eleven or twelve years old and were enrolled in a sixth grade science class taught by the researcher. Prior to the study, all of the students were informed of their rights as human subjects, and both they and their parents signed informed consent forms (MTU IRB protocol M0633; see Appendix A for IRB approval form and participant consent letters). For reporting purposes, each student in the study was assigned a number, starting at one and ending at the total number of students in their respective class. Special education help was given to students in need, following the students' Individual Education Plans (IEP). None of the IEPs required

shortened versions of the assignments or tests, and thus, all students participated in all of the required classroom activities.

Tables 1 and 2 summarize student participation in the air pressure unit. As seen in Table 1, the number of students who participated in each group ranged from 17 to 20. The gender distribution of students was not consistent among the groups due to the way students were assigned to the classes by school officials. Table 2 summarizes student absences, as well as whether or not students received special education assistance. Absence rates were similar among the groups, as was the number of students receiving assistance.

Table 1

Students Participating in Air Pressure Unit by Class

Group	**Total # of Students in the Class**	**# of Students who Participated in the Study**	**# of Boys**	**# of Girls**
2nd hour Control	20	17	14	3
3rd hour Demonstration	22	18	4	14
4th hour Cooperative Learning Groups	23	20	12	8

Table 2

Air Pressure Unit Participant Summary by Individual

2nd hour Participants			3rd hour Participants			4th hour Participants		
Student #	**Days absent**	**Special help**	**Student #**	**Days absent**	**Special help**	**Student #**	**Days absent**	**Special help**
1	None	No	1	None	No	1	None	No
2	None	No	2	Day 4	Yes	2	None	No
3	None	No	3	None	No	3	None	No
4	None	Yes	4	None	No	4	None	No
5	None	No	5	None	No	5	None	No
6	None	No	6	None	No	6	None	No
7	None	No	7	None	No	7	None	Yes
8	None	Yes	8	None	No	8	None	No
9	Day 4	Yes	9	None	No	9	Day 3, 4	No
10	None	No	10	Day 4	No	10	None	No
11	Day 4	No	11	None	No	11	Day 2, 3	No
12	None	No	12	None	No	12	Day 3, 4	Yes
13	Day 5	Yes	13	None	No	13	None	No
14	None	No	14	Day 5	Yes	14	None	No
15	None	No	15	None	No	15	None	No
16	None	No	16	None	No	16	None	No
17	Day 3	No	17	None	Yes	17	Day 1	Yes
			18	None	No	18	None	No
						19	None	No
						20	None	No

Tables 3 and 4 summarize student participation in the density unit. Table 3 shows that the total number of students was similar in each class, but the number of boys and girls in each class varied widely. Table 4 shows which students were absent and whether

they received extra assistance. Again, there were similar absence and assistance rates among the groups. One can also note that more students were dropped from the study in fourth hour than in the other classes; this was because the students were given outside help on the test, which the instructor was only informed of afterwards.

Table 3

Students Participating in Density Unit by Class

Group	Total # of Students in the Class	# of Students who Participated in the Study	# of Boys	# of Girls
2nd hour Control	20	16	13	3
3rd hour Demonstration	20	17	4	13
4th hour Cooperative Learning Groups	23	16	10	6

Procedures

During the air pressure unit, all three groups were given six days to complete the instructional activities. Time was held constant during the air pressure unit in order to make sure the amount of time spent with a concept did not affect the results of the study. After this unit, it was decided that holding time constant may have affected the study in that the shorter labs and demonstrations for the control group may have influenced their effectiveness. Thus, it could not be determined if demonstrations or labs by themselves were more or less effective than doing them together.

Table 4

Density Unit Participant Summary by Individual

2nd hour Participants			3rd hour Participants			4th hour Participants		
Student #	**Days absent**	**Special help**	**Student #**	**Days absent**	**Special help**	**Student #**	**Days absent**	**Special help**
1	None	No	1	None	No	1	None	No
2	None	No	2	Drop	Drop	2	Day 4	No
3	None	No	3	Day 4	No	3	None	No
4	None	Yes	4	None	No	4	Day 2, 3	No
5	None	No	5	None	No	5	None	No
6	None	No	6	Day 3	No	6	None	No
7	Day 5	No	7	None	No	7	Drop	Drop
8	None	Yes	8	None	No	8	None	No
9	None	Yes	9	Day 1	No	9	None	No
10	None	No	10	None	No	10	Day 5	No
11	Day 4	No	11	None	No	11	Drop	Drop
12	None	No	12	None	No	12	Drop	Drop
13	Drop	Drop	13	None	No	13	None	No
14	None	No	14	None	Yes	14	None	No
15	None	No	15	None	No	15	Day 3, 5	No
16	Day 1,8	No	16	None	No	16	None	No
17	None	No	17	None	Yes	17	Drop	Drop
			18	None	No	18	None	No
						19	Day 4, 5	No
						20	None	No

During the density unit, the time devoted to completing demonstrations and labs was not kept constant among the groups, but rather, more time was devoted to instructional activities as necessary. Making this change allowed for the investigation of whether time spent on a concept had an effect on student learning. This change resulted in a difference of the number of days spent on the unit: the second hour comparison group finished in nine days, the third hour demonstration group in six days, and fourth hour cooperative learning lab group in eight days.

Air Pressure Unit Overview

The air pressure unit took six days for each group to complete. An overview of the instruction is given in Table 5. The specific instructional activities in which each group was engaged are elaborated in the following sections.

Air Pressure Unit: Control Group, Second Hour

The second hour comparison group class was taught using the same instructional methods that the instructor used to teach the air pressure unit in the past. The unit began with a lecture, followed by demonstrations and class discussions, and finally ended with a lab. For this unit of the study, the time spent on some activities was shortened and some demonstrations, or parts thereof, were left out in order to keep the instructional time constant among all three groups. The details of the activities for each day of the unit are described in the following sections.

Table 5

Air Pressure Unit Plan

Day	Time	Comparison (Second Hour)	Demonstration (Third Hour)	Inquiry-based Labs (Fourth Hour)
1	48 min.	Pre-test Air Pressure Lecture	Pre-test Air Pressure Lecture	Pre-test Air Pressure Lecture
2	92 min.	Air Pressure Lecture "Bar" Demo "Inverted Cup" Demo "Suction Cup" Demo	Air Pressure Lecture "Iron Ore Pellet" Demo "Bar" Demo "Inverted Cup" Demo	Air Pressure Lecture "Find the Mass of Air in a Balloon" Lab
3	48 min.	"Cloud Machine" Lab	"Suction Cup" Demo "Why Don't you Feel Air" Demo Started "Cloud Machine" Demo	"Cloud Machine" Lab
4	48 min.	"Pressure and Temperature" Lab	"Cloud Machine," "Pressure and Temperature," and "Weighing Air" Demos	"Pressure and Temperature" Lab
5	48 min.	"Weighing Air" Lab	Finished Lab Demonstrations	"Weighing Air" Lab
6	48 min.	Post test	Post test	Post test

Day 1. The first day of the unit was a 48-minute class session. The class began with a pre-test (Appendix B). The pre-test contained eight questions, which all of the students completed in thirty minutes. The test was not timed. Once the test was completed, lecture notes were given (Appendix C). The lecture started with a classroom demonstration on finding the mass of air. The demonstration began with a survey asking the students "What would happen to a balloon's mass if it were blown up?" When

answering the survey anonymously, the majority of the students thought the balloon would get lighter.

After discussing the students' thoughts, the mass of an empty balloon was found using a triple beam balance. The balloon was then blown up and the mass was found again. After some discussion about what was observed, the class ended.

Day 2. The second day of the unit was 92 minutes long. The class began by finishing the lecture about air pressure (Appendix C), which included the properties of air and definitions. After the definitions, the weight of air was discussed and finally, the lecture concluded with the definition of two types of barometers. While discussing the property of density in the lecture, a homemade model made of BBs (Appendix D) was used to help students visualize what different densities of air molecules might look like. The BB model consisted of three fixed volume containers with different amounts of BBs in each. The lecture ended with a demonstration of an aneroid barometer, which consisted of handing it around the room and allowing students to blow into it.

After the lecture, three additional demonstrations were done by the teacher:

1. The weight of air pressure with a bar: This consisted of a steel bar that was one inch, by one inch, by fifty-two inches, and weighed fifteen pounds (Appendix E). Each student lifted the bar so that they could feel what one square inch of air pressure felt like. A calculation to determine how much pressure was being exerted on the top of a table was done next. The total force caused students to ask "Why does it not break?" This erupted into a class discussion where students were eventually able to agree that the air is pushing in all directions.

2. Inverted water in a cup: The inverted cup (Appendix F) was a demonstration of how air pressure can be used to hold water into an inverted cup. A cup was filled three-quarters full with water, then a student volunteer was asked to stand under the cup while the demonstrator inverted the cup of water with only a piece of cardboard on the open end over the student's head. The cardboard was released so that the class thought the student volunteer was going to get wet. When the cardboard stayed in place, the students were amazed and a classroom discussion about this phenomenon began. The students were finally able to conclude that the air pressure pushing up on the cardboard was stronger than the weight of the water pushing down.

3. Suction cups: The suction cup demonstration included two hand-held suction cups. The suction cups were put together, and students tried pulling them apart. Some students were able to pull them apart with a lot of effort, and some could not get them apart no matter how hard they tried. Finally, the cups were separated by the demonstrator with one finger by simply lifting one edge. When the cups fell apart, all the students wanted to try again. From here, students were able to figure out that if they let air in between the two cups, the air pressure would separate the cups.

After the demonstrations, the students were given a worksheet (Appendix G) to complete for the next day of class. The worksheet consisted of eight fill-in-the-blank questions about air pressure at different points of a mountain. These were followed by three short answer questions about air pressure, and seven matching questions related to air pressure vocabulary words.

Days 3 through 5. On day 3, the class period was 48 minutes long and the students were given three labs to work on. The students were able to select their own group members. The three labs were: “Weighing Air” (Appendix H), “Pressure and Temperature” (Appendix I), and “Cloud Machine” (Appendix J) (all three labs from Padilla, Miaoulis, Cyr, & Simons, 2000). The students were given no instructions other than safety precautions, location of materials, and strict directions to read each lab in its entirety first. Days 4 and 5 were both 48-minute classes during which the students worked on their labs. All groups were required to complete the lab by the end of the hour on Day 5.

During the “Weighing Air” lab, the students used a pressure pump to fill a two liter bottle. They were required to record the mass of the bottle every 25 pumps, with a total of 225 pumps of air entering the bottle. They ended this lab by answering questions that pertained to the mass of air.

Following the “Weighing Air” lab was the “Pressure and Temperature” lab, which focused on what happened to the temperature of air as the pressure was increased or decreased. The students inserted a thermometer into the bottle, so they were able to record the temperature as they added air. After 100 pumps, they released the pressure pumper and recorded the resulting temperature. Finally, they answered questions about the relationship between air pressure, volume, and temperature.

The students finished the laboratory experience by making a cloud inside of the two liter pop bottle. This was done by adding water and smoke to the bottle and increasing the air pressure of the bottle during the “Cloud Machine” lab. The students

answered questions about how air pressure affects temperature and the state of matter of water.

Day 6. The students were given the post-test (Appendix B), which was the exact same test that students had taken at the beginning of the unit; students were not given advance notice of the test. The students were given the entire hour to finish the test, but most students completed it in the first thirty minutes of class. The second hour air pressure unit lasted six class sessions and included a total of five hours and thirty-one minutes of instruction.

Air Pressure Unit: Demonstration Group, Third Hour

The third hour class, the demonstration group, participated in lecture and observed whole class demonstrations, followed by classroom discussions. This group did not participate in any labs or cooperative learning groups during the unit.

Day 1. This was a 48-minute class period that followed the same procedures as second hour's day one. This involved taking the same pre-test, and ended with the same demonstration of finding the mass of air in a balloon.

Day 2. This was a 90-minute class. The air pressure lecture was given, following the same procedures as second hour. The one exception was that while discussing the density property of air, a demonstration was given on how to find the density of iron pellets. This was done using a triple beam balance to find the mass of the pellets and then using a graduated cylinder to find the volume of the pellets through water displacement. This iron pellet demonstration was intended to give students a better understanding of density and the density of air. Day two finished with the "weight of air pressure with a bar" and "inverted water in a cup," demonstrations that were described previously.

Day 3. This class period lasted 48 minute and started with a quick summary of day two. This was facilitated by asking, “Why don’t we feel the air?” After a class discussion, students were asked to wave their hands really fast, and then describe what they were feeling; this prompted more class discussion. Finally, the discussion was concluded by having three student volunteers come to the front of the room and stand in a line. The student in the middle was pushed by the peers on either side of him/her from both the left and right with equal force. This was used to demonstrate and help explain how air pressure is pushing in all directions.

The lesson continued with the “suction cup” demonstration, which followed the same procedure as explained in the second hour section. This demonstration ended as the class time ran out, and the students were given the same worksheet that the second hour class received for homework.

Days 4 and 5. The “Cloud Machine,” “Pressure and Temperature,” and “Weighing Air” labs were demonstrated by the teacher during two class sessions. The students were required to complete the same lab write-up as the second hour class. The difference was that each individual student filled in data on the lab sheets during the demonstrations and then answered the questions during the class discussions. The discussions always immediately followed the data collection and started with the two questions: “What did you observe?” and “Why did it happen?” After some discussion, the class had time to answer the questions on the lab write-up individually.

Day 6. The students were given the post-test. They had the entire hour to complete it and did not have a prior warning that they would be given the post-test. The

majority of the class finished the test in 30 minutes. This unit took a total of six classroom sessions and included a total of five hours and thirty minutes of instruction.

Air Pressure Unit: Cooperative Learning Lab Group, Fourth Hour

The fourth hour class—the laboratory-based cooperative learning group—was given a lecture and a participated in inquiry-based laboratories in order to learn about air pressure. They did not see any of the demonstrations given in the other two classes.

Day 1. This class session was 48 minutes long. The students took the pre-test, which lasted forty minutes. This did not leave any time for lecture, but there was just enough time to discuss the procedure for finding the mass of air.

Day 2. This class was a 90-minute session. The class started with the "Finding the Mass of Air" lab that was briefly introduced on day one. This lab was very similar to the balloon demonstration that was done in the second hour class. The students were put into groups by the instructor. Each group received a triple beam balance and three balloons. The students found the mass of each balloon, and then blew air into each one to make three different sized balloons. They then found the mass of each balloon again and put the data into a table that showed the mass before and after the balloon was inflated. The students wrote up an analysis of the results, along with a conclusion about what they found. After the lab was completed, the air pressure lecture given; the information was presented in the same way as in the other two classes.

Days 3, 4, and 5. The students were given the "Cloud Machine," "Pressure and Temperature," and "Weighing Air" labs. They completed each following the same procedure as the second hour class. This group needed an extra day to work on the lab

and discuss results among their groups. They were able to pick their own groups and each group had three students, with one group having four.

Day 6. The fourth hour class completed the unit with a post-test that was the same as the pre-test and was again given without advance notice. The entire unit took six days and lasted five hours and thirty minutes.

Density Unit Overview

The density unit took between six and nine days for each group to complete. An overview of the instruction is given in Table 6. The specific instructional activities in which each group was engaged are elaborated in the following sections.

Density Unit: Control Group, Second Hour

Second hour control group was taught about density through lecture, notes, demonstrations and labs. The unit took nine class sessions, which amounted to seven hours and twelve minutes of class time.

Day 1. The students were given a pre-test (Appendix K) that lasted a half hour, and the teacher then began a lecture (Appendix L). The pre-test consisted of eight questions related to mathematical relationships about density, properties of density, and how density can be related to real world situations. The planned lecture consisted of defining and giving examples of mass, volume, and density, but only the volume portion was completed on Day 1. This included the definition of volume, explaining units of volume, and then completing several mathematics problems related to volume. The entire class lasted 48 minutes.

Table 6

Density Unit Plan

Day	Time	Comparison (Second Hour)	Demonstration (Third Hour)	Inquiry-based Labs (Fourth Hour)
1	48 min.	Pre-test Density Lecture	Pre-test Density Lecture	Pre-test Density Lecture
2	48 min.	Density Lecture	Density Lecture	Density Lecture
3	48 min.	Simulation On Density "Density Column" Demo	Simulation On Density	Introduction to Density Lab
4	48 min.	"Density of a Cube" Demo	"Density Column" Demo "Density of a Cube" Demo	Density Lab
5	48 min.	"Clay Density" Demo "Density of a Penny" Demo	"Density of a Cube" Demo "Clay Density" Demo	Density Lab
6	48 min.	Density Lab	Post Test	Density Lab
7	48 min.	Density Lab		Density Lab
8	48 min.	Density Lab		Post Test
9	48 min.	Post Test		

Day 2. On the second day of the unit, the teacher gave the rest of the lecture, which took most of the hour. This involved defining mass and density, while completing mathematical problems related to each. The class was 48 minutes long.

After the lecture was complete, the students were given homework (Appendix M), which they had five minutes to work on in class and ask any questions. The homework entailed writing a short paragraph, in which they described the relationship among matter,

mass, volume, density, and their properties. After this, they had to fill in a table, in which they found the density of five crowns that looked exactly the same, but were made of different materials. The homework concluded with six short-answer real-world problems about the crowns.

Day 3. This class was a 48 minute class period. At the beginning of the hour, the students worked for several minutes on two mathematical problems related to density. The problems were placed on the Smart board so the students started working on them as soon as they entered the classroom. Once the students completed the problems, they were discussed as a class. The homework was then discussed and collected. This was followed with an interactive, online simulation about density (PhET, 2011). The simulation compared the mass, volume, and density of many different types of blocks.

At the start of the PhET simulation, a virtual pine block was placed on the side of a virtual bucket of water. The students were asked if they thought the block would sink or float. All of the questions were answered with a show of hands, where the students had their head down so they would not know how others in the class were answering. The virtual pine block was dropped into the water to see if it would sink or float. The block stayed afloat. After this, the volume of the virtual block was greatly increased and the students were again asked if they thought if it would sink or float. This procedure was repeated with different masses of the virtual pine block, and then replicated again as the block was switched to ice, aluminum, and steel.

After the students started understanding that changing the volume and mass of a certain material would not change the density, the simulation was switched to unknown virtual materials with the same mass, but different volumes. The students again used a

show of hands to predict which virtual blocks would float, and which would sink. Most of the class thought the larger objects would sink and the smaller would float. They were surprised when the blocks were dropped in the water and the larger volume virtual blocks stayed afloat, while the smaller volume virtual block sunk. Finally, the simulation was switched to unknown blocks with the same volume, but different masses, and the same procedure was replicated. A discussion followed about how the visible size of the object did not determine if the object would sink or float, but rather, whether an object would float was determined by both mass and volume.

With the last 15 minutes of class, a density column was built by placing white glucose syrup, brown Karo syrup, blue dye colored water, yellow corn oil, white mineral oil, and green ethyl alcohol into a graduated cylinder (Appendices N and O). Thus, the density column consisted of six different liquids with different densities and colors. Once the density column was built, students placed a variety of liquids into the column to observe where they would end up in relation to one another. While the activity was progressing, a continuous class discussion was taking place about what was being observed and why.

Day 4. Again, class began with two computationally-based density questions that students completed individually. After the results were discussed, a demonstration of the density of copper, aluminum, and pine was done using a one cubic inch block of each material. The class calculated the volume of each block in cubic centimeters, and the instructor found the mass of each, while demonstrating each step in the mathematical process. After that, the density of each cube was calculated. Finally, the class was asked what the value of the density would be if one of the cubes was gold. With the class

watching and giving search advice, the instructor used the Smart board to find the density and price of gold online. The calculation for the mass of gold was demonstrated by the instructor. After finding out what the mass of the block would be, the cost of the block was calculated. The students were in class for 48 minutes.

Day 5. For the third straight day, the class began with two more mathematical problems about density. After a class discussion of the results, the instructor demonstrated how to find the density of irregularly shaped objects. Clay was used as the material to form three different irregular shapes. A demonstration of how to use a graduated cylinder and water displacement was done by the instructor to find the volume of each sample. The density of each sample was confirmed by the students after the instructor found the mass of each object. Some of the students still believed that the densities would be different. After the densities came out the same, it was discussed as a class why this was the case. The class ended with the teacher demonstrating how to find the density of a penny. Once the penny's density was found, it was compared to an online density table to determine the possible composition of the penny. This class lasted 48 minutes.

Days 6, 7, and 8. All three class periods were 48 minutes long. The students chose their own groups, with three students per group. They were given a density lab (Appendix P) to complete (Hopkins, J., et al., 1993). The only instruction they were given related to lab safety, information on the materials and equipment, and strict instructions to read the entire lab before they started. During the lab, a teacher's aid and the instructor walked around the room, answering group questions as they came up.

The students continued to work on the lab on day seven and used the entire day eight to complete and hand in the required report. The lab involved finding the density of ten different cubes with the same shape and volume. The cubes were made of aluminum, steel, brass, copper, oak, acrylic, nylon, polyvinyl chloride, pine, and poplar. Once the students found each density, they continued to find the density of the same material, clay, with different shapes and sizes. Finally, they answered mathematical and real world density questions that related to the lab.

Day 9. The unit was completed with a post-test (Appendix K). The post-test was exactly the same as the pre-test and the students used the entire class period, which was 48 minutes long, to finish. Most of the students finished in 30 minutes.

Density Unit: Demonstration Group, Third Hour

The density unit for the demonstration group lasted six class periods for a total of four hours and forty-eight minutes of instruction. The class learned from lecture, notes, and whole class demonstrations. The first five class periods followed the same procedure as the second hour class. On the sixth day, this group took the post-test instead of going on to the laboratory component of the unit. The post-test was the same as the pre-test completed at the beginning of the unit.

Density Unit: Cooperative Learning Lab Group, Fourth Hour

The cooperative learning lab group took eight days to complete the unit. This was a total of six hours and twenty-four minutes of instruction. This group learned about density through lecture and inquiry-based labs.

Day 1. The class was given the pre-test, which took thirty minutes to complete. They then learned about defining volume through the same lecture as the other classes.

Day 2. This class followed the same procedure as the other classes while finishing the density lecture and starting on the homework.

Days 3 through 8. At the start of day 3, the students completed a problem involving a mathematics-related density problem. After the results were discussed as a class, a demonstration on how to use a graduated cylinder to find density was done by the instructor.

Once the demonstration was complete, the students chose their own work groups of three to complete the same lab as second hour class. Lab safety, material and equipment usage, and the importance of reading the entire lab before they started were discussed by the instructor. The students had time to read the lab, but did not get a chance to start working on day three. They began the lab on day four and continued working on the fifth, six, and seventh day of the unit. As the lab was in process, a teacher's aid and the instructor walked around to the groups, giving help as needed. Compared to second hour, this class asked more questions, and needed more help with the equipment. They finished the unit on day eight with a post-test that mirrored the pre-test.

Data Collection

The data for the study consisted of a pre-test, post-test, laboratory reports, and homework assignments for each unit. Each data source is described in the following.

Pre- and Post-Unit Tests

All three groups were given the same pre-test for each of the two units; this was completed during class. Students were instructed to do their best and if they did not know the answer, to write down what they did know. They were only allowed a pencil during the test. The same post-test was also taken by each group for both units, and was the

identical to the pre-test. Each student used only a pencil during the post-test. Calculators, notes, or other aids were not allowed.

During the air pressure unit, the pre- and post-tests consisted of eight short answer questions that were designed to see what the students learned about the properties of air, characteristics of air pressure, instruments used to measure air pressure, units of air pressure, and how to apply concepts of air pressure to real life (Appendix B). A rubric was used to score the pre- and post-tests (Appendix Q).

The density pre- and post-tests also consisted of eight questions that checked the students' understanding of mathematical relationships about density, properties of density, and how density can be related to real world situations (Appendix K). A rubric was used to score the tests (Appendix R).

Air Pressure Unit Assignments and Labs

Homework (Appendix G) was administered and collected to reinforce what was learned during the lecture, while also allowing the instructor to evaluate students' understanding. This was done through an analysis of the individual homework scores before any demonstrations or labs were completed. An in-depth statistical analysis was not preformed during instruction, but rather, a quick check for understanding was done by simply comparing the students' answers to an answer key. If the overall mean was above 70%, it was determined that the students were ready to move on to the next part of the unit. The homework assessed student understanding of definitions and main ideas related to air pressure that were discussed in the notes.

The second and fourth hour classes completed the lab write-ups in groups, as they did the inquiry-based activities. The lab (Appendix H, I, and J) data was evaluated to help

understand what the students comprehended during the labs and demonstrations. The labs were assessed by looking at individual students' grades, as well as how they scored on individual questions. The student's individual questions were compared to an answer key. If the group scored high on the lab overall, or on an individual question, it was assumed that they understood the lab objectives—that students will understand the properties and relationships of air that deal with temperature, mass, density, volume, and pressure. The lab scores alone do not allow for an assessment of individuals, but do indicate what the group understood as a whole.

Although, the third hour class did not complete the lab activities, they did complete the same lab write-up as the other two groups. The third hour class filled in the lab write-up individually while the instructor demonstrated each lab.

Density Unit Assignments and Labs

All three groups were given a homework assignment (Appendix M) that was used to show what was comprehended from the lecture. The homework consisted vocabulary, main ideas, and real world problems related to density. The homework was collected the day after the lecture and each question was scored right or wrong according to the key. The overall scores were used to do a quick "check-for-understanding" of the ideas in the lecture.

A lab worksheet was given to the second and fourth hour classes to complete during the investigation, which consisted of data collection tables, graphs, and questions that could be used to evaluate what the students were learning during the lab (Appendix P). The lab was designed with the following learning objectives:

1. Students will be able to define mass, volume, and density.

2. Students will understand how to compute the density of an object when the mass and volume are given.

3. Students will be able to apply density concepts to real world situations?

The labs responses were scored according to how close they were to the correct answer, as well as how close the collected data was to what the actual data should have been. The actual data was that which the instructor had collected when doing the same lab. A scoring key was used for grading the labs. These scores were used to check the groups' understanding of density concepts and relationships.

Data Analysis

The pre-test and the post-test scores were the main data sources used to determine whether student understanding increased during each unit. These test scores were used to compare student understanding both within and among the groups. First, a paired t-test using the pre- and post-test scores was used to see whether there was a statistically significant difference from the pre-test to the post-test within each individual group of students. A 5% significance level was used to determine statistical significance. If the t-score was less than 0.05, it was determined that there was a statistically significant difference in the data. The means of the pre- and post-test scores were then used to decide if the increase was positive. If there was a positive difference in means from the pre-test to the post-test, it was determined that the student's comprehension of density or air pressure had increased during the unit.

After checking for significant differences within each student group for both units, the instructor also checked for significant differences between pairs of groups to determine whether there were differences in understanding among them. The researcher

did an unpaired t-test for the second and third hour classes, the second and fourth hour classes, and the third and fourth hour classes for both the pre- and post-test scores. Again, 0.05 was used for the significance level when determining if there was a significant difference between each pair of groups. If the t-score on either test resulted in a value less than 0.05, it was determined if there was a statistically significant difference between the groups on that particular test. If this was the case, the data was examined more closely to determine whether the difference could be explained.

The mean and standard deviation were calculated for each student group for all of the homework and lab data that was collected. During the unit, the mean and standard deviation of the homework and labs were used to make sure students were at an appropriate level of understanding before the instructor proceeded to the next lesson in the unit. The instructor also used the individual scores of each participant on the homework and labs to see if students were improving or not throughout the unit. The mean and standard deviation allowed the instructor to get a quick picture of individuals' overall performance in comparison to the group, as well as the group's performance.

As with the pre- and post-test data, the means of the homework and lab scores were compared among the groups to determine whether there were statistically significant differences among them. This was done to determine if one group was performing at a different level than the other groups as the unit was being taught. If it was found that one group was performing lower or higher than another on the labs or homework, the data was scrutinized to determine whether there was an explanation for the different levels of performances or whether the results indicated differences in outcomes of the instructional methods.

In summary, the data collected during the study was analyzed to see if there was a difference in the students' learning when different instructional methods were used. Knowing this would allow the instructor to understand what methods worked best to support students' learning. The results will help the instructor choose instructional methods that best support learning and to decide how much time is needed when developing new curriculum or repeating the unit on air pressure and density.

Chapter 4

Data and Results

During the teaching of the air pressure and density units, data was collected to understand the effects of three different teaching methods. The main goal of the research was to find if students learn more effectively through demonstrations, cooperative learning through inquiry, or both. The secondary question addressed in the research was: What effect does the time spent engaging in a particular learning experience have on the students' learning? The results discussed below focus on determining whether there was a significant statistical difference in student learning between the teaching methods and how differences in instructional time may have affected the results.

Air Pressure Unit

Within Class Pre- and Post-Test Comparisons

Table 7 shows a comparison of the pre-test and post-test scores for the individual groups in the study. The t-score was used to see if there was a significant statistical difference in the scores between the pre-test and post-test, whereas the mean was used to find how much each class improved overall.

From the table, one can see that the t-tests indicated a significant statistical difference between the pre- and post-test scores for each individual class. The second hour classes' scores improved 45%, the third hour class improved 43%, and the fourth hour class improved 36% from the pre-test to the post-test. The data suggests that the students benefited from all three types of instruction—demonstrations, cooperative learning laboratories, and both methods used together. Although the data indicates that

the students showed improvements in learning, it does not clearly show which method of teaching had a larger impact.

Table 7

Air Pressure Pre-Test to Post-Test Comparisons

Class	**T-score**	**Pre-test mean**	**Post-test mean**
2nd hour (Control)	$p < 0.001$	8%	53%
3rd hour (Demonstration)	$p < 0.001$	7%	50%
4th hour (Cooperative Learning Groups)	$p < 0.001$	6%	42%

Between Class Pre- and Post-Test Comparisons

Table 8 shows the t-score comparison between each pair of classes on both the pre-test and post-test. The data shows that there was not a significant statistical difference on either the post-test or pre-test data for any pair of classes. This data does not show with confidence that teaching using one of the methods of instruction—only demonstration, only laboratories in cooperative learning groups, or both—positively affects the students' understanding of air pressure better than the others.

The pre-test t-scores show that there was a larger difference between the second and fourth hour students' understanding of air pressure entering the unit, but not enough to say with certainty that one group had an advantage over the other. Recall that Table 7

Table 8

Air Pressure Unit T-Score Comparison Between Different Groups

Comparison	Post-Test t-score	Pre-Test t-score
2nd and 3rd hour	0.611	0.578
2nd and 4th hour	0.096	0.263
3rd and 4th hour	0.213	0.511

showed that there was only a two percent difference between the mean scores from the lowest scoring group to the highest scoring group on the air pressure pre-test.

Homework and Lab Reports

Table 9 gives a summary of how each class performed on the homework and laboratory reports during the unit. The air pressure homework and lab data do not give a clear indication of any major differences in students' learning during the unit. The table shows that the second and third hour classes had very similar outcomes on the homework and labs, while the fourth hour class performed lower than both the second and third hour classes on both the labs and homework. This might be explained by looking at the standard deviation, which indicates that there was a wider range in scores for the fourth hour class. Two students in this class did not complete any of the homework, and one student only completed half of it. If the two students who did not hand in the homework were removed from the data, the mean homework score would be 86%, which is consistent with the mean for the other classes. With the labs, one group in the fourth hour class did not include any labels on their graphs, which caused their score to be lowered by 10 points, in turn pulling the class average down from 84% to 82%.

Table 9

Comparison of Homework and Lab Grades During the Air Pressure Unit

Assignment	Hour	Mean	Standard Deviation
Homework	2	83 %	15%
	3	86%	16%
	4	77%	30%
Lab	2	90%	6%
	3	92%	5%
	4	82%	10%

Summary

When comparing the post-test scores, Table 8 showed no significant difference among the groups, but it did show a larger difference among the second and fourth hour classes. This difference may be explained in several ways:

1. From Table 7, one can see that the students in the second hour class performed two percent better on the pre-test than their fourth hour counterparts. This may have lead to a better understanding of air pressure for the second hour class since they had a better understanding at the beginning of the unit.
2. Teaching using a combination of demonstrations and cooperative learning labs may have a slightly more positive affect on students' learning than simply teaching air pressure through only cooperative learning labs or demonstrations.
3. The students who did not complete the homework may not have reinforced their learning from the notes, which in turn caused the entire class average to slightly drop on the post-test.

4. Or finally, a combination of all three may have slightly affected the overall performance of fourth hour on the test.

Overall, the data does not clearly indicate that one method of teaching was better than another when it comes to teaching with demonstrations or cooperative learning inquiry-based labs. The data also showed that combining the two methods did not appear to significantly affect the learning of students.

Density Unit

Within Class Pre- and Post-Test Comparisons

Table 10 shows a comparison of the pre-test and post-test results for the individual groups in the study for the density unit. The t-score was used to determine whether there was a significant statistical difference in the data between the pre-test and post-test, whereas the mean was used to determine how much the each class improved overall.

Table 10

Density Pre-Test to Post-Test Comparisons

Class	**Pre-test to Post-test t-score**	**Pre-test Mean**	**Post-test Mean**
2nd hour (Control)	$p < 0.001$	8%	70%
3rd hour (Demonstration)	$p < 0.001$	18%	69%
4th hour (Cooperative Learning Group)	$p < 0.001$	20%	67%

From the table, one can see that the t-scores indicate a significant statistical difference between the pre- and post-test scores for each class. The second hour class improved 62%, the third hour class improved 51%, and the fourth hour class improved 47% from the pre-test to the post-test. Thus, the data indicates that all of the students benefited from the type of instruction they received, either demonstration style learning, cooperative learning labs, or both methods used together. Even though the data does not show a significant statistical difference between classes and the post-test means scores in range only 3% among the classes, the data do indicate that the second hour class had the greatest improvement from the pre-test to the post-test.

Between Class Pre- and Post-Test Comparisons

Table 11 shows the t-score comparisons between each pair of classes on the pre-test and post-test. The table shows that there was not a significant statistical difference between any two classes on the post-test. It does, however, show a significant statistical difference between the second and fourth hour classes on the pre-test. The other comparisons for the pre-test do not show a significant statistical difference.

Table 11

Density Unit T-Score Comparison Between Different Groups

Comparison	**Post-Test t-score**	**Pre-Test t-score**	**Pre-to Post-test Gain t-score**
2^{nd} and 3^{rd} hour	0.863	0.096	0.077
2^{nd} and 4^{th} hour	0.536	0.011	0.010
3^{rd} and 4^{th} hour	0.652	0.816	0.493

Table 11 also shows that the difference in gains student made from the pre-test to the post-test were statistically significant between the second and fourth hour classes. The

second hour class made a 62% gain from the pre- to post-test, while the fourth hour class made a 47% gain. The other comparisons of the pre-to post-test gains did not show a significant statistical difference, although the difference between the second and third hour classes was fairly substantial at 11% (62% gain for the second hour class; 51% gain for the third hour class).

Although this comparison suggests that the difference in time spent on the density unit may have affected student learning, there are other factors to consider. According to Table 10, scores for students in the second hour class were, on average, 10% lower than the third hour class and 12% lower than the fourth hour class on the pre-test. Additional analysis of the data indicates that there may be several reasons for this difference.

1. The third hour class had one student score a 96% on the pre-test; this was 58% higher than the next closest score, which means that the class average was slightly increased. With this student's score removed from the data, the class average would drop from 18% to a 13%.
2. The fourth hour class had four students' data removed from the density unit study because their data was compromised. These students did not originally score very high on the pre-test. If their pre-tests were included, the overall class average would drop from 20% to 17%.
3. The second hour class was composed of mostly males, whereas the third hour class was mostly females, and the fourth hour class was a mixed group. Gender in the sixth grade may be a factor in how serious students take a pre-test that does not count towards their grade.

4. A combination of all three factors may account for the discrepancy in the density pre-test scores.

These reasons may explain the difference in the pre- to post-test gains between the second and fourth hour classes. While it may be the case that time spent on the unit accounts for some of the noted difference, the question arises as to why, then, there was not a statistically significant difference between the other pairs of classes. The second hour class had three extra days of instruction on density than the third hour class, and the fourth hour class had two extra days than the third hour class. Further investigation has lead the researcher to believe that time was not the primary factor, but rather, an anomaly in the pre-test data for the second hour class primarily accounted for the difference. When looking at individual student scores from throughout the year, there was no apparent reason that the second hour class began the density unit with less prior knowledge than the other classes. Also, other teachers who work with this group agree that the individuals taking the pre-test would not put a lot of effort into something that does not affect their overall grade.

Homework and Lab Reports

Table 12 gives a summary of how each class performed on the homework and laboratory reports that were completed during the unit. The density homework and lab results do not give a clear indication of any major differences in students' learning during the unit. The table shows that the second and third hour classes had very similar outcomes on the homework, but the fourth hour class did score 9% higher, on average, than the third hour class and 16% higher than the second hour class. There was no indication in the data as to why this may have happened. There was not a lab for the third

hour class and both the second and fourth hour class scores were very comparable with a 92% and 94% average, respectively. Thus, the labs do not give any indication that one style of teaching allowed students to learn the material better than the others.

Table 12

Comparison of Homework and Lab Grades During the Density Unit

Assignment	Hour	Mean	Standard Deviation
Homework	2	72%	18%
	3	79%	21%
	4	88%	26%
Lab	2	92%	8%
	3	No Lab	No Lab
	4	94%	5%

Summary

When comparing the post-test scores, Table 11 showed no significant difference among the groups. Table 10 showed that there was only a three percentage-point difference between the highest and lowest mean scores on this assessment. Thus, the post-test data indicates that demonstrations, cooperative learning lab groups, or a combination of both do not have different overall effects on students' learning.

When taking into consideration the pre-test data and the post-test data, it may indicate that the students improved the most in second hour with a combination of demonstrations and cooperative learning groups, and improved the least with only cooperative learning groups. As previously discussed, however, there may be confounding variables affecting the pre-test scores, which leaves no clear indication that one style of learning was better than the others.

Chapter 5

Conclusion

The purpose of this study was to determine which teaching strategy was most effective for helping student understand air pressure and density: demonstrations, inquiry-based learning in cooperative learning groups, or a combination of the two. In addition, the study focused on understanding whether the amount of time devoted to each type of instruction affected student learning.

In both units, the data showed that there was not a statistically significant difference in student learning between using demonstrations, inquiry-based learning in cooperative learning groups, or both combined. Even though the data did not show a significant difference, while using both demonstrations and cooperative learning groups in the air pressure unit, the students improved 45% from the pre-test to the post-test. The students who only viewed demonstrations improved 43%, whereas the students who worked in cooperative learning lab groups improved 36%. Similar results were seen during the density unit, in which students who learned through both methods of teaching improved 62%, while the students who had learned with demonstrations saw a 51% increase, and the cooperative learning lab group improved 47% percent. This suggests that although data for both units was not conclusive that one method of teaching was better than another, using a combination of the two methods may offer a slight advantage.

Time may have affected the results, however, since the group that learned through both teaching methods had more time working with the density concept than the other two groups. Recall that during the air pressure unit, one of the three teaching methods

was used in each class, but the class time for the students did not change from one class to another. During this unit, labs and demonstrations were shortened or lengthened in order to make sure that each class spent the exact same amount of time learning about air pressure. During the density unit, however, the same demonstrations and labs were used, but the time spent on the unit in each class was not kept constant. In other words, no activities were shortened by the instructor to keep the classes on track with one another.

By not holding time constant, the unit was nine days long in the second hour class, six days in the third hour class, and eight days in the fourth hour class. The post-test data showed, however, that there was still not a statistically significant difference between the classes on this assessment. This suggests that it was not the length of time spent on a particular instructional method that affected the student's level of understanding. The class that spent the most time on the unit, however, did show the largest overall gain from pre- to post-test.

The extra time spent on the density unit may have helped the second hour class achieve 11% and 15% larger pre- to post-test gains than the third and fourth hour groups, respectively, but other factors may have also come into play. For example, the second hour class was made up of mostly male participants. Qualitative observations by the instructor indicated that the males in this class tended to not try as hard when a grade on an assignment did not count toward their course grade. Recall that although the second hour class scored lower than the other classes on the pre-test, their post-test scores were almost identical to the other classes. Thus, the lack of effort on the non-graded pre-test and the fact that the post-test counted toward their overall class average may explain the difference in the data.

This classroom research suggests that the three teaching styles and time spent on the topics were statistically insignificant in terms of how they supported student learning. The results suggest that it does not affect the students' learning greatly if they are taught with only demonstration, only inquiry-based cooperative learning groups, or both. Recall that Fogelman and McNeill (2011) found that the time spent teaching a unit does not affect student learning as much as unobserved teacher characteristics, a result that may be supported by the results of this work. They did, however, find that an inquiry-based activity does positively affect the students learning; this was also found to be the case in this study as all three instructional methods resulted in significant gains in understanding. Schwerdt and Wuppermann (2010) found that demonstrations can be just as effective as inquiry-based activities in cooperative learning groups. This study also found that demonstrations have the same effect on students' learning as inquiry-based activities in a cooperative learning group. Thus, the results of this study generally confirm previous findings that students' learning improves through using demonstrations and through participating in inquiry-based learning, and that time spent on a unit does not have a significant effect.

Implications for the Classroom

Eighty-four percent of eighth graders in Washington Middle School tested as proficient in science on the 2010 MEAP assessment (Michigan Department of Education, 2010). Of the eighteen students who did not pass the test, three tested using a special form of the test for learning disabled students, four had not attended Washington Middle School in the sixth grade, and two failed both semesters of science class when they were in the sixth grade. The other nine received high enough grades in sixth grade science to

anticipate that they would test as proficient on the MEAP by the eighth grade (Michigan Department of Education, 2010). An analysis of these nine students showed, however, that they consistently missed five questions related to the sixth grade science curriculum. These five questions were related to several state standards that were not adequately taught due time constraints. Thus, these standards need more attention, which they will not get unless other units can be shortened.

This research suggests that many of the current units in the sixth grade curriculum could be shortened without significantly affecting student learning. If units are shortened, then the inadequately taught standards can be addressed in a way that will increase student learning. It is very important, however, to make sure that students still are exposed to both inquiry-based learning through cooperative learning groups as well as demonstrations. Although demonstrations allow the students to see proper techniques with lab equipment as well as gain interest in concepts that they may not otherwise put a lot of effort into, performing labs engages students in inquiry. Learning to inquire about science allows students to gain very important lab skills and learn to use tools to work in different social situations, as well as develop the ability to question and think about the natural world around them. In addition, 11 of the 49 sixth grade science standards are related to inquiry, so it is important that this is part of the science curriculum. In sum, the findings of this report simply suggest that a teacher does not have to use both inquiry-based cooperative learning and demonstrations together, but rather, might use only one of the tools during each unit. A teacher needs to remember, however, that both are very important teaching tools.

Limitations and Further Research

Further research might be done to understand how variables such as time, gender, cooperative learning group dynamics, and a teacher's experience with teaching the unit affect student learning.

The current study had three student groups where one was predominantly male, one predominantly female, and one more evenly mixed. This class composition could have affected the data. This study was not designed with the intent to study gender issues in the classroom, but after the research was completed, it seemed that student gender might have affected the results. Since there were only three girls in the second hour class and four boys in the third hour class, there was not enough data to analyze if gender affected the overall study. A further study of the effects of gender in science classes might show whether males learn differently than females and thus, whether different teaching methods might be more effective for each group, or if group dynamics differ for a mixed gender group compared to a same gender group.

During the air pressure lesson time was held constant, and there was not a significant difference in the student learning. However, when time was not held constant during the density unit, a slight difference was noted. This may be due to the instructor's experience with the lesson. Recall that Fogleman and McNeill (2011) showed that the more experience a teacher has with a lesson, the more the students' learning is positively affected. The significant difference between the second and fourth hour classes may be due to the fact that in the fourth hour class, the lesson was being taught for the second time. Also, the fourth hour class was taught the same lessons several days later, so something may have affected the delivery of the lessons. A further study would need to

be done in order to determine if there is an effect on students' learning if the same lesson is taught multiple times.

Finally, the way lab groups are selected may make a difference. In this study, the students picked their own groups. More research would need to be done to see how group dynamics affect the students learning when different teaching methods are being used.

Summary

In conclusion, the data in this study did not show that one method of teaching—demonstrations, inquiry-based learning in cooperative learning groups, or a combination of the two—had a greater effect on a sixth grade students learning. Rather, the data indicated that there was no statistically significant difference between student learning as a result of the different teaching methods. There was also evidence that more time spent on a unit does not guarantee better results in terms of student learning. This conclusion can lead to changes in the way a teacher builds unit plans.

A teacher can use the results from the study to build a unit plan that involves inquiry-based lessons with cooperative learning groups or using demonstrations. Unit plans might be shortened to save time on the unit by only incorporating one style of teaching, which might leave time to incorporate at least one of these teaching methods into the instruction of every concept that is required in the curriculum. If time is saved on some units, a teacher can ensure that they meet all of the required learning objectives during a science course and also spend more one-on-one time with struggling students who may not have the ability to get help outside of the classroom.

References

Achieve. (2010). *International science benchmarking report*. United States: Achieve.

Balfe, C. (2001). 8th grade: Density and buoyancy: Density concepts and misconcepts. *8th grade Physical Science Curriculum*. Retrieved April 5, 2011, from http://tlc.ousd.k12.ca.us/~acody/densitymisc.html

Basey, J., Sackett, L., & Robinson, N. (2008). Optimal science lab design: Impacts of various components of lab design on students' attitudes toward lab. *International Journal for the Scholarship of Teaching and Learning*, *2*(1), 1-15.

Boyer, A., & Hamil, B. (2008). Problems facing American education. *National Forum Journals*, *2*(1), 9.

Brady, M. (2010). Education reform: 22 problems, and a proposal. *Ecology of Education: Exploring the Landscapes of Learning, One Voice at a Time*. Retrieved April 12, 2011, from http://ecologyofeducation.net/wsite/?p=2436

DeBoer, G. (1991). *A history of ideas in science education*. New York: Teachers College Press.

Education Trust. (2010). Ed Trust analysis of 2009 PISA results: United States is average in performance, but leads the world in inequity. *Education Trust*. Retrieved January 20, 2011, from http://www.edtrust.org/print/2125

Fantauzzo, M. (n.d.). The complexities of the middle school student. *Frontier Homepage*. Retrieved April 2, 2011, from http://www.frontiernet.net/~mikef/portfolio/adol.htm

Fogleman, J., & McNeill, K. L. (2011). Comparing teachers' adaptations of an inquiry-oriented curriculum unit with student learning. *Journal of Research in Science*

Teaching, *48*(2), 149-169.

Gault, A. M. (n.d.). Do you know your middle schooler's learning style?. *Scholastic, Helping Children Around the World to Read and Learn* . Retrieved March 22, 2011, from http://www.scholastic.com/familymatters/parentguides/middleschool/quiz_learningstyles/index.htm

Graham, E. (2010). International test scores: U.S. not in top 10. *CBN.com - The Christian Broadcasting Network*. Retrieved April 25, 2011, from http://www.cbn.com/cbnnews/world/2010/December/International-Test-Scores-US-Not-in-Top-10-/

Hardin, C. (2009). Effectiveness and accountibility of the inquiry-based methodology in middle school science. *E.R.I.C.*, *1*, 1-45. Retrieved May 21, 2011, from the Education Resource Information Center database.

Haury, D. (1993). Teaching science through inquiry. *ERIC Clearinghouse for science mathematics and environmental education, Columbus OH*. Retrieved May 16, 2011, from http://www.uhu.es/gaia-inm/invest_escolar/httpdocs/biblioteca_pdf/14_HAURY%5B1%5D.1993%20TEACHING%20SCIENCE%20THROUGH%20INQUIRY.pdf

Henriques, L. (2000). Misconceptions about weather . *California State University, Long Beach*. Retrieved February 7, 2011, from http://www.csulb.edu/~lhenriqu/NARST2000.htm

Holt, C. R., De Vore, J. B., Denny, G. S., Smith, R. M., & Capps, M. (2007). Learning

preferences of 5th and 6th grade students in Northwest Arkansas. *International Journal of Arts and Science*, *2*, 29-33.

Hopkins, J., Johnson, S., LaHart, D., McLaughlin, C., Warner, M., & Wright, J. (1993). *Matter*. Englewood Cliffs, NJ: Prentice Hall.

Huang, C. (2000). The effects of cooperative learning and model demonstration strategies on motor skill performance during video instruction. *Proceedings of the National Science Council, Republic of China*, *10*(2), 255-268.

Jimerson, L. (2006). *The hobbit effect: Why small works in public schools*. Arlington, VA: The Rural School and Community Trust.

Kyle, W. (1980). The distinction between inquiry and scientific inquiry and why high school students should be cognizant of the distinction. *Journal of Research in Science Teaching*, *17*, 123-130.

Lucariello, J. (n.d.). How do I get my students over their alternative conceptions (misconceptions) for learning. *American Psychological Association (APA)*. Retrieved April 5, 2011, from http://www.apa.org/education/k12/misconceptions.aspx#

Machiela, A. (2010). Intervention grouping report, Washington Middle School. *SRI*, *1.38*(1), 2-4. Retrieved September 24, 2010, from the Scholastic Inc database.

McKee, E., Williamson, V., & Ruebush, L. (2007). Effects of a demonstration laboratory on student learning. *Journal of Science Education and Technology*, *16*(10), 395-400.

Merritts, D., Walter, R., & MacKay, B. (n.d.). Interactive lecture demonstrations. *State*

Education Resource Center. Retrieved May 16, 2011, from http://serc.carleton.edu/introgeo/demonstrations/

Michigan Department of Education (2010). *Michigan Educational Assessment Results for Washington Middle School*,

Michigan Department of Education (2006). *State of Michigan Grade Level Content Expectations, Grade 6*. Retrieved May 18, 2011, from http://www.michigan.gov/mde/0,1607,7-140-28753_33232---,00.html

Military.com (n.d.). The online option. *Military.com Education*. Retrieved May 17, 2011, from http://www.military.com/education/content/finding-a-school/the-online-option.html

Millis, B. (2002). Enhancing learning-and more!-through cooperative learning. *IDEA Paper*, *38*, 6.

National Science Education Standards. (1998). *The National Academies Press*. Retrieved January 21, 2011, from http://www.nap.edu/openbook.php?record_id=4962&page=R1

Niebuhr, M. (2010). Michigan percent attendance report-2010. *Washington Middle School*. Retrieved December 13, 2010, from the Skyward database.

Nihalani, P., Wilson, H., Thomas, G., & Robinson, D. (2010). What determines high-and low-performing groups? *Journal of Advanced Academics*, *21*(3), 500-529.

Padilla, M. J., Miaoulis, I., Cyr, M., & Simons, B. B. (2000). *Weather and climate*. Needham, Mass.: Prentice Hall.

Patterson, C., Kennedy, T., & Miller, T. (n.d.). Lesson plans on density for middle school

teachers. *Manifest density*. Retrieved April 11, 2011, from http://www.unr.edu/educ/raggiocenter/pdf/TIES-balloon-module.pdf

PhET. (2011). Density: Density, mass, volume. *PhET: Free online physics, chemistry, biology, earth science and math simulations*. Retrieved April 23, 2011, from http://phet.colorado.edu/en/simulation/density

Rutherford, J. (1964). The role of inquiry in science teaching. *Journal of Research in Science Teaching*, *2*, 80-84.

Sahlberg, D. P. (2004). Cooperative learning in Finland. *IASCE Newsletter*, *23*(1), 6.

Schwerdt, G., & Wuppermann, A. (2010). Programs on education policy and governance working papers series. *Harvard Kennedy School*. Retrieved March 29, 2011, from http://hks.harvard.edu/pepg/

Singer, S., Hilton, M., & Schweingruber, H. (2005). America's lab report. *National Academies Press*, *1*. Retrieved May 16, 2011, from www.nap.edu

Smith, V., & Cardaciotto, L. (2011). Is active learning like broccoli? student perceptions of active learning in large lecture classes. *Journal of the Scholarship of teaching and learning*, *11*(1), 53-61.

Squire, K., & Patterson, N. (2010). *Games and simulations in informal science education*. Madison: Wisconsin Center For Education Research.

Stein, J., Steeves, L., & Mitsuhashi, C. (2001). Teaching styles categories. *Teaching styles*. Retrieved January 19, 2011, from http://members.shaw.ca/mdde615/tchstycats.htm

Swanson, E. (1999). Chemical demonstrations in the classroom. *Nothing Here*. Retrieved

April 15, 2011, from http://bradley.bradley.edu/~campbell/elishapaper.htm

Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. (2007). Effect of active-learning experiences on achievement, attitudes, and behaviors in high school biology. *Journal of Research in Science Teaching*, *44*(7), 960-979.

Tejada, C. (n.d.). Define and describe cooperative learning. *Cooperative learning*. Retrieved April 14, 2011, from http://condor.admin.ccny.cuny.edu/~eg9306/candy%20research.htm

U. S. Census Bureau. (2010). Estimates for Michigan school districts, 2009. *U S Census Bureau*. Retrieved February 16, 2011, from http://www.census.gov/cgi-bin/saipe/saipe.cgi

U. S. Department of Education. (2002). Executive summary of the No Child Left Behind Act of 2001. *ed.gov*. Retrieved May 16, 2011, from www2.ed.gov/nclb/overview/intro/execsumm.html

Yin, Y., Tomita, M., & Shavelson, R. (2008). Diagnosing and dealing with student misconceptions: Floating and sinking. *Science Scope*, *1*, 34-39.

Zhenhui, R. (2001). Matching teaching styles with learning styles in East Asian contexts. *TESL Journal*, *7*. Retrieved April 25, 2011, from http://iteslj.org/Techniques/Zhenhui-TeachingStyles.html

Appendix A

Human Subjects Forms

Michigan Technological University

Office of Research Integrity and Compliance

302 Lakeshore Center
1400 Townsend Drive
Houghton, MI 49931
906.487.2902

MEMO

TO: Dr. Shari Stockero, CLS

CC: John Asiala, CLS

FROM: Joanne Polzien, Director Research Integrity and Compliance Joanne Polzien

DATE: August 26, 2010

SUBJECT: Approval M0633

Your application to use human subjects in research or classroom situations has been reviewed with the following determination:

Protocol #: M0633
Protocol Title: "The Effects of Group Learning and Demonstration in Science Instruction"
Approved Dates: August 25, 2010 through August 24, 2011

Approvals are granted for up to a one year period. You will need to request a continuation for each year of the project six weeks prior to the end date indicated above for each year of the project. The Office of Research Integrity and Compliance will make every effort to send the Principal Investigator annual reminders. However, the Principal Investigator is responsible for submitting annual Continuation Forms in advance of the expiration date for the project. It is very important that these expiration dates are not missed. Failure to submit annual review materials on time will result in the termination of this protocol.

This approval applies only for this project, and only under the conditions and procedures described in the application; if any changes are made in the protocol or conditions set forth in the application, the principal investigator must obtain a separate approval before these changes take place. The approved project will be subject to surveillance procedures requiring periodic review. This review will consist of consulting with the principal investigator and examining the appropriate project records.

Individual identification of human subjects in any publication is an invasion of privacy. Before beginning a project involving human subjects, and only if required, the principal investigator must obtain a properly executed informed consent from each subject and/or the person legally responsible for the subject. **If a consent form has been reviewed and approved it has been attached with an official date stamp on it. Only copies of the official date stamped informed consent is to be distributed to participants relating to this project. If any changes or modifications are needed regarding this form, you must first submit the revised document for review and approval prior to use.** The principal investigator must retain informed consent forms on file for at least three years after the end of the project. If a project involves a high level of risk, copies of the signed informed consent forms must be filed with the Human Subjects Committee; if this is the case, you will be notified.

This document is on file in the Office of Research Integrity and Compliance. If you have any questions, please contact me at 487-2902 or jpolzien@mtu.edu.

09/07/2010

Dear Parent or Guardian:

I am a graduate student in the Applied Science Education program at Michigan Technological University. I am conducting a research project on *The Effects of Group Learning and Demonstration in Science Instruction*. I request permission for your child to participate.

The study consists of your child taking two pre-test and post-tests and allowing me to use their classroom work for my research. I may also record some classroom discussions in order to document the questions that are asked during instruction. All of your child's work will remain anonymous; pseudonyms will be assigned to protect students' identities. The project will be explained in terms that your child can understand, and your child will participate only if he or she is willing to do so. Only my advisor, Shari Stockero, and I will have access to information from your child. At the conclusion of the study, children's responses will be reported as group results only.

Participation in this study is voluntary. Your decision whether or not to allow your child to participate will not affect the services normally provided to your child by Washington Middle School. The student's grade will not be affected in anyway if they choose not to participate in the study. The student will still be required to participate in the normal classroom routines, but their work will not be used as research data. Even if you give your permission for your child to participate, your child is free to refuse to participate. If your child agrees to participate, he or she is free to end participation at any time. You and your child are not waiving any legal claims, rights, or remedies because of your child's participation in this research study.

Any information that is obtained in connection with this study and that can be identified with your child will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by storing the information in a locked file cabinet, assigning pseudonyms and reporting only group results.

Should you have any questions or desire further information, please call me or email me at 337-0311 or jasiala@clkschools.org. You can also contact my advisor, Shari Stockero, at stockero@mtu.edu or 487-1126. Please complete and return the second page of this letter with your child; you may keep the first page for your records.

If you have any questions about your rights as a research subject, you may contact the Michigan Technological University Institutional Review Board (IRB) by mail at 1400 Townsend Drive, Houghton, MI 49931, by phone at (908) 487-2902, or by e-mail at jpolzien@mtu.edu.

Sincerely,

John Asiala

DATE OF IRB APPROVAL: 08-25-10
IRB NUMBER: M0633
PROJECT EXPIRATION DATE: 08-24-11

Initial_____ Page 1 of 2

Parent Consent

Please indicate whether or not you wish to allow your child to participate in this project by checking one of the statements below. Then, sign your name and have your child return the permission slip to me. Keep the first page for your records.

_____ I grant permission for my child to participate in John Asiala's study on the effects of group learning and demonstration in a science classroom.

_____ I *do not* grant permission for my child to participate in John Asiala's study on the effects of group learning and demonstration in a science classroom.

Signature of Parent/Guardian	Printed Parent/Guardian Name
Printed Name of Child	Date

DATE OF IRB APPROVAL: 08-25-10
IRB NUMBER: M0633
PROJECT EXPIRATION DATE: 08-24-11

Initial_____ Page 2 of 2

Appendix B

Air Pressure Pre- and Post-Test

Air Pressure Test

Pre-test____________ or Post-test_____________

1. Name and describe the properties of air.

2. What is the average weight of air per square inch pushing down on a person? Why doesn't it crush you?

3. What are the two types of instruments used to measure air pressure? Explain how they work.

4. As air pressure increases, what will the temperature do? Why?

5. What are two units meteorologists use when measuring air pressure?

6. Where is air pressure the greatest at the top or bottom of a mountain? Why?

7. Why is the air at the top of a mountain hard to breathe? (Hint: Think about the percentage of oxygen in the air…)

8. What would happen to a balloon if you started carrying it several miles down into a mine?

Appendix C

Air Pressure Lecture Notes

1-3 Air Pressure

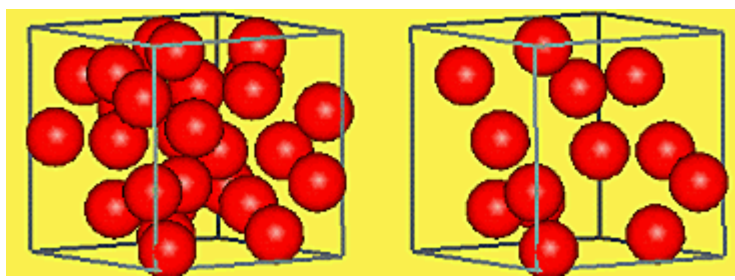
Does air have mass? How can we prove it does or doesn't?

I. **Properties of air:** Air has….

a. **Mass**: Air consists of atoms and molecules, which means it has mass.

b. **Density**: density shows how compact an object is.

Formula for density: D=m/v…..density equals mass divide by volume



Each box has the same volume, and each red ball has the same amount of mass. Which box has more mass? Why?

Example: If an object has a mass of 10g, and a volume of 20ml, what is its density? What does the number you come up with mean?

c. **Pressure**: A force pushing on an area. The more dense the air, the more pressure it exerts.

High air pressure------------→ High Density
Low air pressure------------→ Low Density

II. **Air pressure**: The weight of a column of air pushing down on an area.

a. The average weight of air pushing on you in all directions is approximately 15 pounds per square inch.

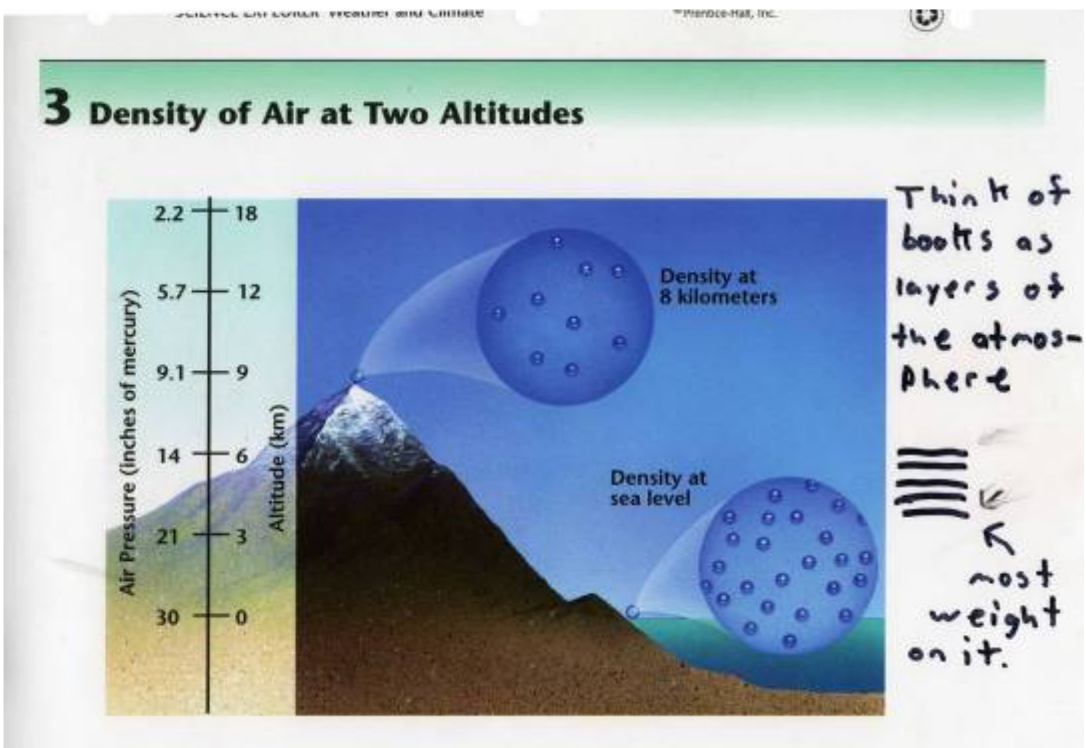
Note: How much weight is air exerting on your hand? Why doesn't the air crush you?

III. **Barometers:** An instrument that is used to measure changes in air pressure.

a. **Mercury barometer**: a thin tube with mercury in it but no air. The height of the mercury is usually 76 centimeters which is approximately 30 inches or 1014 millibars at sea level.

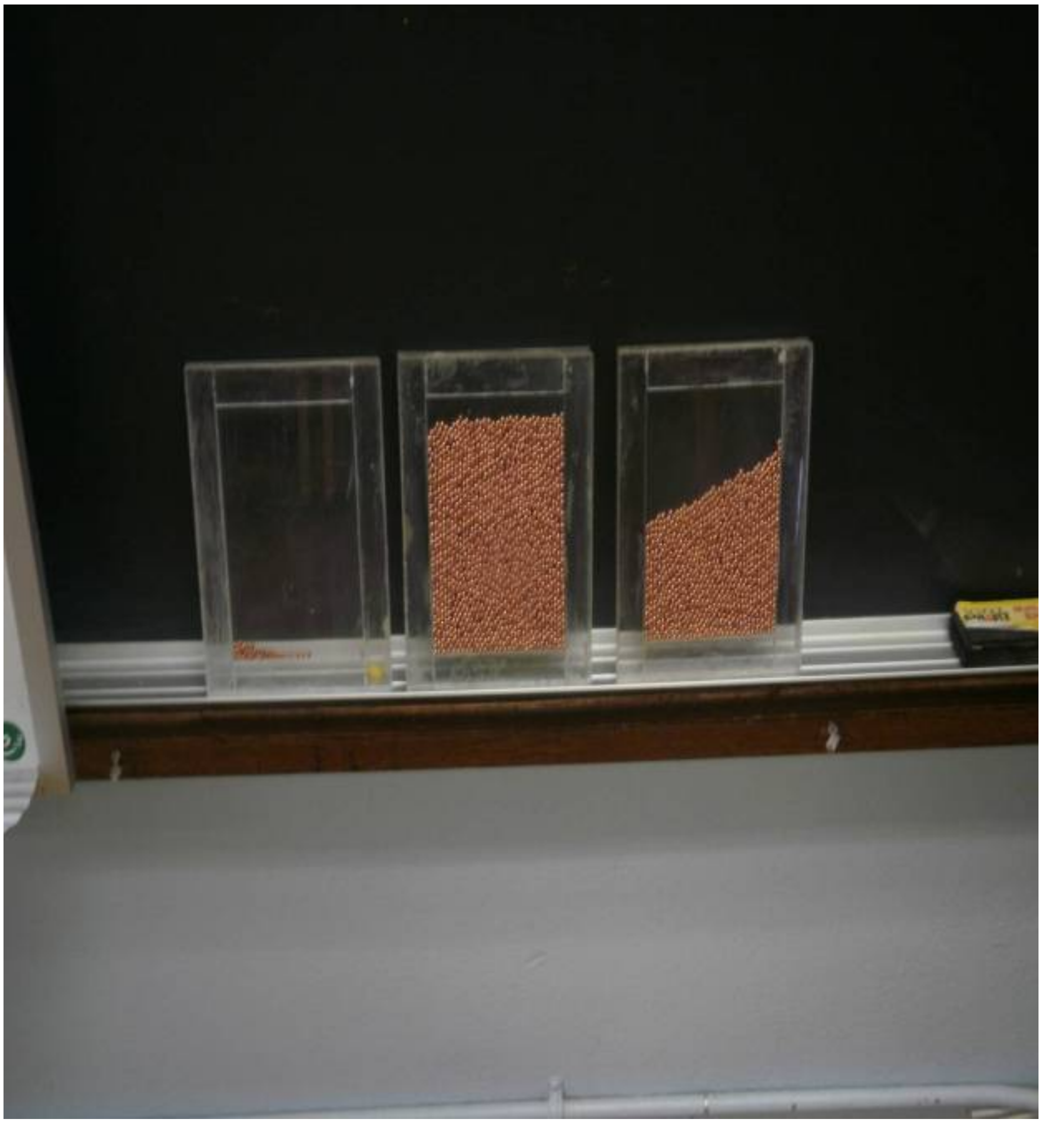
*A drop on the barometer means lower air pressure, and a possible storm.
*A rise on the barometer means higher air pressure, and fair weather.

b. **Aneroid barometer**: Most common, uses springs instead of liquid.



Appendix D

Photos of BB Model of Air Density



Appendix E

Photo of 15 Pound Bar Demonstration

Appendix F

Photo of Inverted Water in a Cup Demonstration

Appendix G

Air Pressure Homework Assignment

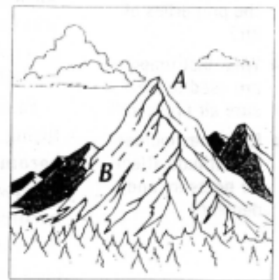
Name Date Class

SECTION 1-3 **REVIEW AND REINFORCE**

Air Pressure

◆ Understanding Main Ideas

Study the figure below, and then complete the following statements.



1. Altitude is greater at point ______________.

2. Air pressure is greater at point ______________.

3. Density of the air is greater at point ______________.

4. A cubic meter of air has less mass at point ______________.

5. The percentage of oxygen in the air at point A is ______________ percent.

Answer the following questions on a separate sheet of paper.

6. State three properties of air.

7. Why doesn't air pressure crush people or things?

8. What two units are used to measure air pressure?

◆ Building Vocabulary

Match each term with its definition by writing the letter of the correct definition on the line beside the term.

______________ **9.** air pressure

______________ **10.** altitude

______________ **11.** aneroid barometer

______________ **12.** barometer

______________ **13.** density

______________ **14.** mercury barometer

______________ **15.** pressure

a. the amount of mass in a given volume of a substance

b. the force pressing on an area or surface

c. the result of the weight of a column of air pushing down on an area

d. any instrument that measures changes in air pressure

e. instrument that measures changes in air pressure using a liquid

f. the distance above sea level

g. instrument that measures changes in air pressure without using a liquid

Appendix H

Weighing Air Lab

Name: ____________________

Weighing Air

1. Attach a Pressure Pumper to a two liter pop bottle.
2. Measure the mass of the bottle to at least the nearest 0.1 gram. Record the mass in the table below.
3. Pump the Pressure Pumper 25 times.
4. Repeat step 2.
5. Pump the Pressure Pumper another 25 times.
6. Repeat step 2.
7. Repeat this process until you have 225 total pumps, recording the mass of the bottle each time.
8. Release the pressure by slowly removing the Pressure Pumper and find the mass a final time.
9. Calculate the mass gained (or lost) during each step.

Pumps	Mass (g)	Mass gained
0		
25		
50		
75		
100		
125		
150		
175		
200		
225		
Release		

Pressure Pumper Activities

Contributed by Stu Schultz
Physics Pharm Consulting Services
Detroit, Michigan

Appendix I

Pressure and Temperature Lab

Name: ____________________

Pressure and Temperature

1. Put a temperature strip (58-88 °F) in a clean dry 20 oz. pop bottle.
2. Record the temperature in the bottle: ____________________
3. Put the Pressure Pumper on top of the bottle.
4. Pump the Pressure Pumper 100 times. What is happening to the pressure in the bottle?
5. Record the temperature in the bottle: ____________________
6. What happened to the temperature in the bottle?
7. While watching the temperature strip, unscrew the Pressure Pumper. What happens to the temperature as the pressure is released?
8. State the relationship between the pressure of a gas and its temperature.
9. A student got a large balloon at the store. She walked home with the balloon on a very cold day. What do you think happened to the balloon as she walked? Explain your reasoning.

Pressure Pumper Activities

Contributed by Stu Schultz
Physics Pharm Consulting Services
Detroit, Michigan

Extension Activity:

1. Repeat steps 1-4 from the previous activity. Record the unpressurized and pressurized temperatures.

   Unpressurized temperature: ____________________

   Pressurized temperature: ____________________

2. Let the pressurized bottle sit until it returns to the unpressurized temperature. What is happening to the heat energy that was in the bottle?

3. When the bottle has returned to the previous temperature, release the pressure. Record the new temperature. __________________

Theory:

This is the principle behind refrigeration. A gas is compressed. It heats up, and that heat energy is released into the environment (out of the air conditioning unit, or out of the back of the refrigerator). The cooled, compressed gas is allowed to decompress, and it cools to an even lower temperature. The expanding gas absorbs heat from the area being refrigerated. As demonstrated here, air works for this process, but it cannot carry much heat at a time. Special refrigerant gases are used in air conditioners because they are more efficient in moving heat through this process.

If you ever let air out of your car tires, feel the air that is escaping. It feels cold!

4. If you left the door open on the refrigerator, would the whole room get cooler? Explain.

Contributed by Stu Schult
Physics Pharm Consulting Service
Detroit, Michiga

Appendix J

Cloud Machine Lab

Name: ____________________

Cloud Machine

1. Add a little water to a 20-oz. pop bottle.
2. Light a match and blow it out. Hold it inside the mouth of the bottle and let some of the smoke go in the bottle.
3. Put the Pressure Pumper on top of the bottle.
4. Pump the Pressure Pumper 100 times. What is happening to the pressure inside the bottle?

5. Release the pressure by slowly unscrewing the Pressure Pumper. Carefully watch the air inside the bottle. What happens?

Theory:

As you increased the pressure in the bottle, you also increased the temperature. When the pressure was released, the temperature decreased. The water vapor in the air in the bottle, when cooled suddenly, condensed into water droplets. These water droplets could be seen as a cloud.

The smoke in the bottle acts as a condensation point, something for the water molecules to stick to. Small particles such as those in smoke are called aerosols. An aerosol is about 1000 times larger than a water molecule. A water droplet (like in a cloud or fog) is 20 times larger than an aerosol and a raindrop is composed of about 100 droplets.

Questions:

1. What happens to water vapor as it cools?
2. What is the purpose of the smoke?
3. Why does fog form more often in the early morning than any other time?

Pressure Pumper Activities

Contributed by Stu Schultz
Physics Pharm Consulting Services
Detroit, Michigan

Theory:

Air is composed of atoms and molecules. The atoms and molecules have mass and occupy space. Therefore, air is matter. Why can't we see it if it has mass and takes up space? The atoms and molecules are very small, and have a lot of space between them. (The molecules in your desk, on the other hand, are much closer together.) Why can't we feel the mass when we hold air in our hands? The mass of the atoms and molecules in air is very small. You have to collect a lot of atoms and molecules in one place to detect their mass. This activity used the Pressure Pumper to force a lot of air into a small container. The change in the mass of the container represents the mass of air that you pumped in.

Questions:

1. Why can't you see air?

2. Why can't you feel the mass of air in your hand?

3. How many grams of air did you add to the bottle?

4. If it took 225 pumps to add that many grams of air, what is the mass of air in 1 pump?

5. Name an object, if you can, that has a mass approximately that size.

Contributed by Stu Schultz
Physics Pharm Consulting Services
Detroit, Michigan

Appendix K

Density Pre- and Post-Test

1. **What are the mathematical relationship between mass, density, and volume?**

2. **Define in your own words:**
   a. **mass:**

   b. **volume:**

   c. **density:**

3a. If an object has a mass of 20 g and a volume of 5 ml, what is its density? (Use correct units)

b. Will the object float on water, why?

4a. If an object has a mass of 25 g and a volume of 50 ml, what is its density?

b. Will the object float on water, why?

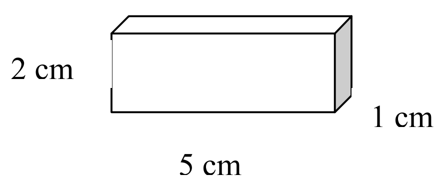
Short Answers:

5. If you put Helium in a balloon, the balloon will float above your head. Why?

6. A person who cannot float in a freshwater lake can float easily in the Great Salt Lake in Utah. Explain this?

7. What is the difference between a gas, solid, and liquid? (Use density and molecules in your explanation.)

8. The density of aluminum is 2.7 g/ml. What would the mass be of the following aluminum block?



Appendix L

Density Lecture Notes

1-3 Density

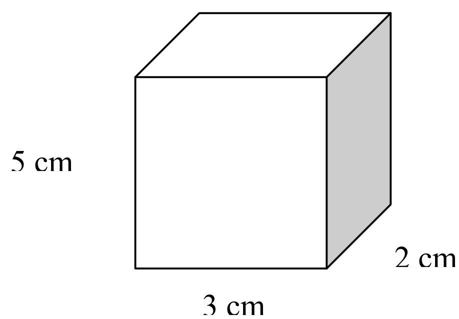
I: Volume: The amount of space an object takes up.

a. Metric system for volume: We will use Liter (L), milliliter (ml), or cubic centimeter (cm^3)

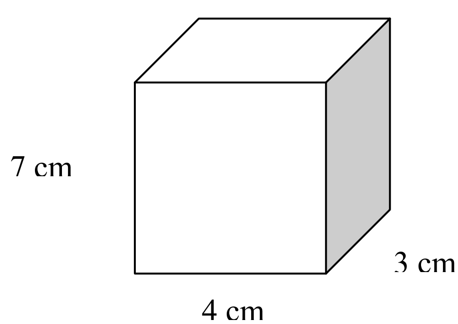
1. Liter: half a two liter bottle of pop.
2. ml=cm^3: Used for measuring medicine

Note: V = L x W x H (for regular shaped objects)
L=length W=width H=Height V=volume

Question: Find the Volume of the below figure in ml and cm.



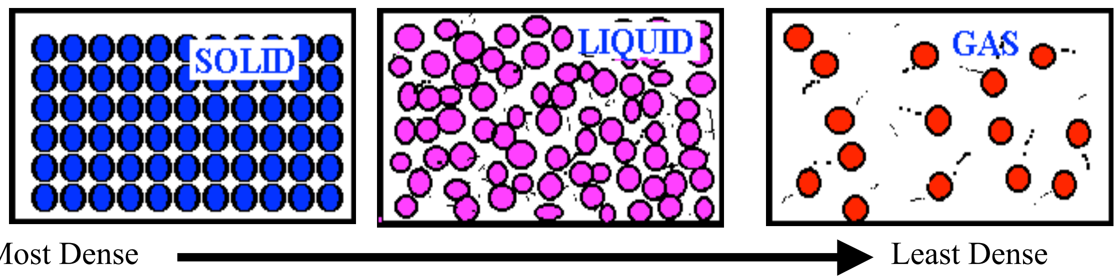
Question: Find the Volume of the below figure in ml and cm.



Question: How would we find the volume of an irregular shaped figure such as a jagged rock?

***Remember:** Mass is the amount of matter in an object and is measured in grams (g), Kilograms (kg), or milligrams (mg).

II. Density: The measure of the amount of mass per given volume: D = m / v (in g/ml)
One can think of density as how compact an object is. (Show BB model)



Note: Density can be used to determine what a substance is.

Densities of some common Substances	
Substance	**Density (g/cm^3)**
Helium	.000167
Air	.0013
Gasoline	.7
Wood (oak)	.85
Water (ice)	.92
Water (liquid)	1.0
Aluminum	2.7
Steel	7.8
Silver	10.5
Lead	11.3
Mercury	13.5
Gold	19.3

Question: What is the density of an object that has a mass of 8 g and a volume of 4 ml? Will the object sink or float on water?

Question: What is the density of an object that has a mass of 3g and a volume of 12 ml? Will the object sink or float on water?

Question: What is the density of an object that has a volume of 20 ml and a mass of 156 g? What is the object made of?

Question: What is the Volume of liquid water that has a mass of 1 liter?

Appendix M

Density Homework Assignment

Name ______________ Class ______ Date ______

SECTION **1-3** **Volume and Density** *(pages 20–2*

KEY CONCEPTS

▲ Matter is anything that has mass and volume.

▲ Density is the mass per unit volume of an object.

Vocabulary Skills: Using Definitions

Write a short paragraph in which you explain how the following terms are related.

matter mass volume density property

____

____

____

____

The Case of the Missing Crown: Exploring the Main Ideas

Imagine that you are living in Europe in the Middle Ages. You have been summoned by the king of your land to help in a very important matter. Someone has stolen the king's solid gold crown. The king has issued a proclamation offering a reward of 500 gold coins for the safe return of his crown. The problem is that the king has received hundreds of crowns—and they all look exactly like the missing crown! Your job as a brilliant scientist is to find out which crown is the real one. The chart below shows some data that you have collected on one batch of crowns. Study the data, then answer the questions.

Crown #	Volume (cm^3)	Mass (g)	
1	180	1890	
2	180	486	
3	180	1404	
4	180	3474	
5	180	2034	

1. What property of each crown can you determine from this data? Why is this property valuable?

2. In the spaces provided to the right of the data, calculate the property that you named in question 1.

3. Based on your calculations, do you think that any of these crowns could be the real one? Why or why not?

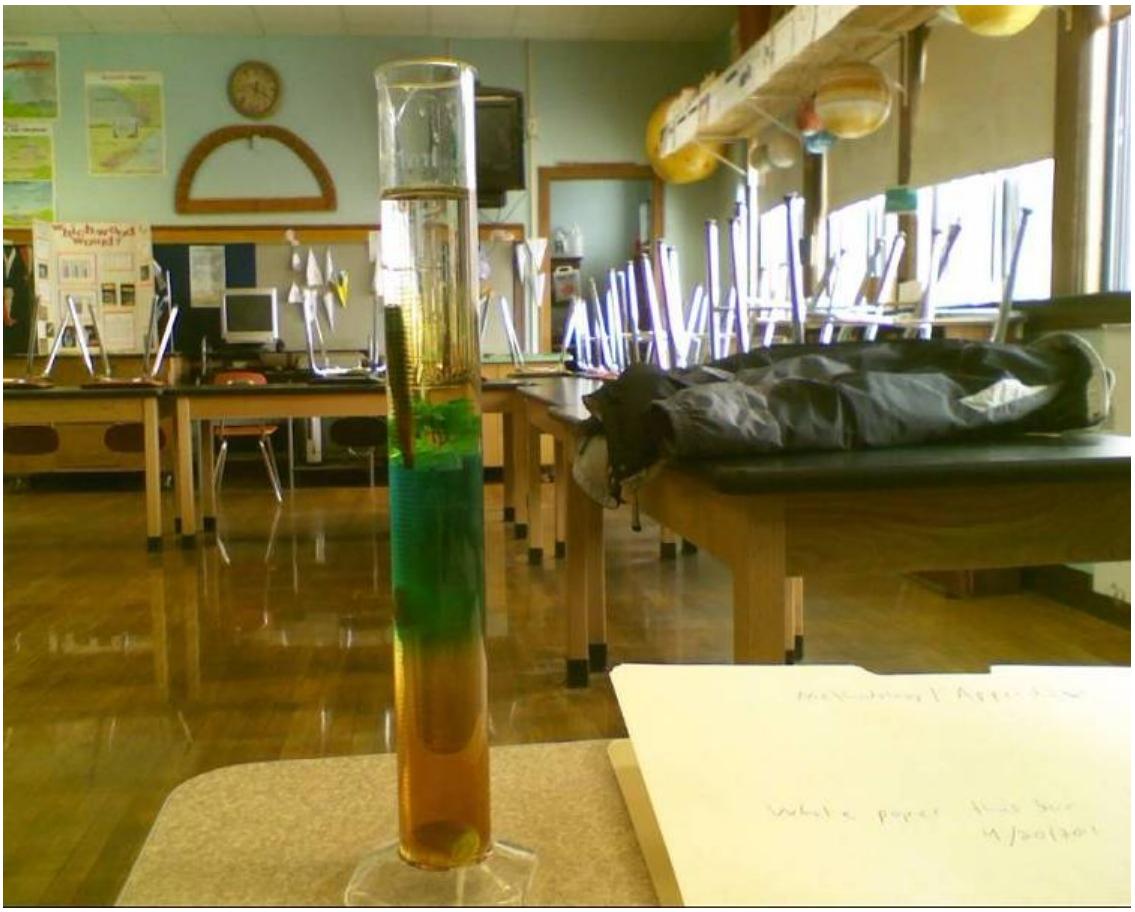
4. Which of these crowns do you think are fakes? Why?

5. Can you guess what the fake crowns are made of? On what did you base your guess?

6. How do you think the fake crowns were made to look like the real crown?

Appendix N

Photo of a Density Column



Note: The density column picture shown here was taken three weeks after it was built so some of the materials are starting to mix.

Appendix O

Density Column Demonstration

Density Column

Material:

1-graduated cylinder
2-glucose syrup (white)
3-Karol syrup (Brown)
4-blue dye mixed with water (blue)
5-corn oil (yellow)
6-mineral oil (white)
7-ethyl alcohol (green)
8-random objects

Procedure:
Build a density column that can be use to determine density of objects.

Question #1: Why do we get a separation of colors in the density column?

Question #2: What can we do to determine what has a larger density between a cork and a wood pencil?

Question #3: Explain density in your own words.

Appendix P

Density Lab

Problems:

How can density of an object be determined?

Materials:

-triple beam balance
-metric ruler
-graduated cylinder
-density cubes of different materials
-modeling clay

Procedure:

Part A. Density of cubes.

Note**:** Density equals mass divided by volume. D=m/v where mass is measured in grams and volume is measured in milliliters.

Note: 1ml = 1cubic cm ***** to find the volume of a rectangular solid, multiply the length by width by height.

1. Use the balance to mass each of the 10 cubes provided. Make sure you measure as exact as possible.

2. Find the volume in cubic cm of each block. You need to be very precise when measuring. Each block should be the same size, but you need to make sure.

3. Calculate the density of each cube and record your results below.

Type of material	Mass (g)	Volume (ml)	Density (g/ml)
Copper			
Brass			
Steel			
Aluminum			
Acrylic			
Oak			
Nylon			
Pine			
Poplar			
PVC			

Name ______________________ Class ______________ Date __________

Critical Thinking and Application

1. Could the water displacement method be used to determine the volume of a rectangular solid as well as an irregular solid? ______________ Explain. ______________

____

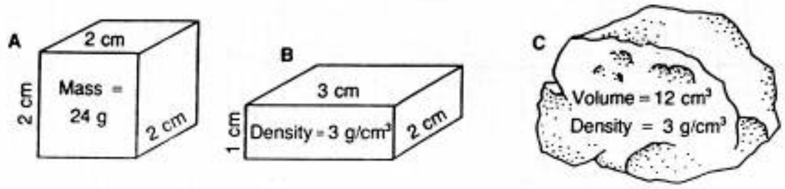
____

2. If an object with a density of $5 g/cm^3$ is cut into two equal pieces, what is the density of each piece?

____

3. The diagrams below represent three samples of the same substance, each having a different size and shape. Arrange the letters of the samples to show the order by volume from largest to smallest. ______________________________

What is the density of A? B? C?



4. Explain how the results of this laboratory investigation show that differences in size and shape do not affect the density of a given substance.

____

____

____

5. Why is density such an important physical property?

____

____

____

____

____

pg 4

Going Further

1. The density of water is 1 g/cm^3. An object will float in water if its density is less than 1 g/cm^3. If its density is greater than 1 g/cm^3, the object will sink. Given the following substances and their densities, determine whether each substance will float or sink in water.

aluminum	2.7 g/cm^3	___	gold	19.3 g/cm^3	___	chlorine	3.2 g/cm^3	___
arsenic	5.7 g/cm^3	___	neon	0.89 g/cm^3	___	uranium	19.0 g/cm^3	___
helium	0.18 g/cm^3	___	lithium	0.53 g/cm^3	___	potassium	0.86 g/cm^3	___

2. Substance X has a volume of 50 cm^3 and a mass of 160 g. Will substance X float or sink?

____

Substance Y has a volume of 140 cm^3 and a mass of 112 g. Will substance Y float or sink?

____

Final Question: Explain density in your own words. (make it detailed, No formula

pg 5

Appendix Q

Air Pressure Pre- and Post-Test Rubric

Question	Description of Points	Points
1	**1 point** for naming each property, and **1 point** for describing each property. Mass: made up of atoms and molecules. Density: shows how compact, or D=m/v. Pressure: a force pushing on an area.	6 points
2	**1 point** for part one and **1 point** for part 2… a. approximately 15 pounds per square inch b**.** Because air is pushing in all directions	2 points
3	**1 point** for the name of each and **1 point** for each correct description. a. Aneroid barometer: Uses springs b. Mercury barometer: Uses mercury	4 points
4	**1 point** for saying the temperature will increase.	1 points
5	**1point** for each up to 2. a. inches b. centimeters c. millibars	2 points
6	**1 point** for saying at the bottom of the mountain. **1 point** for saying that the lower altitude you are at, the more air molecules pushing down, which means an increases air pressure.	2 points
7	The air pressure at the top of a mountain is hard to breathe because there is a lower air pressure at a higher elevation. (**1 point**) The lower the air pressure, the less air molecules there are. (**1 point**) Oxygen makes up 21 % of the air, but 21% of a smaller number of air molecules means less oxygen atoms to breath in. (**1 point**)	3 points
8	**1 pt**.: The air pressure will increase on the outside of the balloon. **1pt**: The balloon will decrease in size. 1pt: Because as you drop in elevation the air pressure increases which means the air on the outside is pushing in harder than the air on the inside is pushing out.	3 points
	Total points:	23 points

Appendix R

Density Pre- and Post-Test Rubric

Question	Answer	Points
1	**D=m/v**...1pt for left side and 1 point of right side of the equation	2 pts
2	**Mass**: The amount of matter in an object. 1pt **Volume**: The amount of space an object takes up. 1pt **Density**: How compact an object is. 1 pt (accept many other definition including D=m/v)	3 pts
3	a. 4 g/ml 2pts (partial credit for showing work) b. sink because it is more dense than water 2pts	4 pts
4	5 g/ml 2pts (partial credit for showing work) oats because it is less dense than water. 2 pts	4 pts
5	Helium is less dense than air.	2 pts
6	The salt water is **denser** than freshwater.	2 pts
7	The molecules in a **gas** are not bonded together and a gas is the least dense of the 3. 2 points The molecules in a **liquid** have a weak bond, and the density is usually between the density of a gas and solid. 2 points The molecules in a **solid** have a strong bond, and the density is usually the densest. 2 points	6 pts
8	2.7=m/10…27 grams 3 point (points will be awarded for showing correct work)	3 pts
	Total Points	**26 points**