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COMPARISON OF HIGH SCHOOL PHYSICS STUDENTS' ACHIEVEMENT IN A TRADITIONAL CLASSROOM TO STUDENTS IN A DISCOVERY BASED CLASSROOM

presented by

Jeffery John Chorny

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COMPARISON OF HIGH SCHOOL PHYSICS STUDENTS' ACHIEVEMENT IN A TRADITIONAL CLASSROOM TO STUDENTS IN A DISCOVERY BASED CLASSROOM

By

Jeffery John Chorny

A THESIS

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ABSTRACT

COMPARISON OF HIGH SCHOOL PHYSICS STUDENTS' ACHIEVEMENT IN A TRADITIONAL CLASSROOM TO STUDENTS IN A DISCOVERY BASED CLASSROOM

By

Jeffery John Chorny

The purpose of this study is to compare student achievement in a high school physics unit on pressure using two different teaching methods. The control group was taught in a traditional teaching environment where students heard teacher lecture, saw teacher demonstrations, and were assigned physics problems from the textbook in an effort to learn the content. The test group received very little direct teacher instruction. Rather, students worked in small groups and were given investigative activities to construct their knowledge of the objectives. The test group recorded their learning in research lab books and the teacher acted solely as a facilitator. Both groups were expected to master the same objectives and were given identical tests and quizzes. When comparing assessments, this study did not reveal extreme differences between the groups, but some key points can be noted when the data is analyzed. When assessments were analyzed more thoroughly, the test group showed a little more thorough understanding of the concepts and were able to apply these concepts in new situations.

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To my wife who had
the patience and
proofreading skills
to assist me with this.
I would not have been able to
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INTRODUCTION

STATEMENT OF PROBLEM AND RATIONALE FOR STUDY

I have been teaching physics for five years and have attended several hours of workshops and seminars on how we as educators should be using inquiry based learning. I wanted to know if there is a difference in student comprehension when comparing cooperative discovery based learning to traditional teaching methods. I decided to test this notion in an introductory physics course on pressure. Before the study, my classroom was set up as an interactive lecture. I used demonstrations and laboratories to enhance the objectives. I involved my students in lectures and/or demonstrations. I used real life scenarios because I believed that if one can make the concept relevant, students remember it.

I wanted to know if the technique of cooperative discovery based learning is indeed effective. The questions I asked myself were: Should school districts make drastic changes from traditional to discovery learning? What kind of changes should be made? How will this affect the students comprehension? In a comparative study which group, traditional or inquiry based, will actually learn and apply the objectives? Is cooperative learning an effective technique for learning? Because I wanted these questions answered, I developed and executed a study of inquiry based learning.

Inquiry based learning requires active students and their use of higher order thinking skills. Michigan Essential Goals and Objectives for Science Education, as well as my local district's goals, stress higher order thinking skills. Students in the inquiry based test group not only had to comprehend the objectives, but also plan, judge, examine, construct, set up and argue their learning with group members. Students in the test group had to analyze, evaluate, and synthesize the new information and apply this knowledge to real life situations. Students in the control group simply were taught the objective on the knowledge and comprehensive levels of understanding.

I chose to base this study on the unit on pressure because it involves some exciting labs and demonstrations and typically students have several misconceptions on this topic. Therefore, I thought a quality comparison could be made between the control and test group. In the test group, students explore their misconceptions using hands-on activities. The best discovery is when a student figures out his or her own misconception and makes the correction. In my previous experience, I found that many times students go back to their original misconception despite intensive instruction. My goal was for students to discover their misconceptions about pressure, make the corrections in their scientific knowledge, and retain this information.

To construct the test group activities many materials were used and adapted. The physics textbook <u>Study guide for Giancoli's Physics</u> by Joseph Boyle was the source for the objectives in the study. Students in the control group strictly used the textbook <u>Physics</u> by Douglas C. Giancoli. Students in the test group did activities designed by the researcher who based them on the sources <u>Strengthening Your Teaching of Physical Science Concepts</u> by Al Guenther and <u>Hands-on Physics Activities with Real-Life Applications</u> by James Cunningham and Norman Herr. Several activity ideas were derived from the these textbooks.

In designing the investigations for the comparative study, several hours were spent researching , designing, and testing the activities using Michigan State University's facilities. Several hands on activities were gathered and modified. These include:

Can Crusher	Balloon in a Vacuum
Marshmallow in a Vacuum	Siphons
Measuring Densities	Pressure Versus Depth
Bernoulli's Principle	Garbage Bag

See Appendix B and D for full description of activities

Additional work developing questions for assessment and evaluation was also done at Michigan State during the summer of 1997. These activities will be explained in more detail in the Implementation section.

LITERATURE REVIEW

Based on my experience, business and industry seem to condemn public schools for producing students lacking required skills. They need students who can think on their own yet can work with others effectively in a group. The discovery learning approach of teaching is possibly a step toward meeting their needs. Discovery learning is an example of a constructivist approach to learning. Constructivism is a learn-by-doing approach. "The theory is that the knowledge we acquire on our own is easier to remember than the knowledge we get from others" (Friedman, 1997). Constructivism has its roots in the humanistic philosophy of education which centers on human interests and values (Slavin,1988). In constructivism, the teacher guides students on their educational journey. This type of pedagogy used in this study, is a cooperative discovery approach (Miller,1990). The famous Swiss psychologist Jean Piaget was the leader of the constructivist movement: He said, "The basic idea of constructivism is that knowledge must be constructed by the learner; it cannot be supplied by the teacher" (Holzer,1997).

Many other historical philosophers had an impact on education that support the discovery approach to teaching. For example, Jean Jacques Rousseau believed in student centered curriculum, which ultimately results in deepened student understanding (Lawrence, 1970). John Dewey also called for more active student involvement in learning. He supported problem or thematic based learning where the content was not selected by adults alone (Travers and Rebore, 1987). Later, Jerome Bruner echoed Dewey's thoughts and further said that subject matter could be changed to fit the child's individual needs by making the activities open ended. Bruner wrote that students should be scientists in their own inquiry (1966).

The discovery learning approach involves the following process:

-Problem posing (an hypothesis is not true or false; more of an open ended question)
-Generating observations
-Confirming/Disconfirming Hypothesis
-Reaffirming Hypotheses
-Explaining or proving a Hypothesis
(Bishay, 1998)

The above steps were the bases of the format that I used to develop lessons/investigations for the test group as will be discussed in the Implementation section.

Current research reported in Caine and Caine on how the human brain operates supports the use of discovery based learning in classrooms. The brain can detect patterns and make approximations, remember, self-correct and learn from experience. Many studies show that multiple complex and concrete experiences are essential for meaningful learning and teaching. The traditional model of education may be inappropriate because skills and attributes students need tend not to be addressed, and this model fails to take advantage of the brain's capacity to learn. To be successful learners and employees, students have to be problem solvers, decision makers, adept negotiators, and thinkers who are at home with open-endedness, flexibility and resourcefulness. "For any skill to be deeply mastered, students must have substantial opportunity to create their own meanings and organize skills in their brains in their own ways" (Caine and Caine, 1994).

Slywester writes that memory networks are not engaged unless the students are emotionally involved (1995). Much of what is taught in school tends to be perceived by students as random obscure facts. Our task as educators is to help students to find relationships between the somewhat random, often "trivial" facts of everyday and school life and help them create memory networks that solidify those relationships. The best school vehicle for building these relationships is through conversations, debates, role playing, simulations, songs, games, films, and novels (Sylwester, 1995). This research on how the brain learns, remembers and forgets supports the use of cooperative discovery as a mode of learning, because in this approach students engage in conversation, debates, and are emotionally involved in their learning.

In reviewing this approach to learning and teaching, I needed to determine if we were just trying something new for the sake of change. I sought out and evaluated sources that contradicted the support of cooperative discovery learning. Geiker (1997), a practicing physicist, defended the lecture/demonstration technique of teaching. He believes that students have too many misconceptions in physics. If a teacher does not confront the student's misconception through lecture, it will never be corrected (Geilker, 1997). Another article (Birk, 1996) states that the key to lecture seems to be interactive, where the teacher still does most of the talking, but engages students with questioning and storytelling. Birk states that this method is particularly effective in teaching abstract subjects like higher math or physics. Birk restates that teachers still talk 70% of class time and students listen. She thinks there are trade-offs between lecture style and discovery learning: "Group learning does foster certain skills, but what does group learning not teach? And are those skills important?" (Birk, 1996).

Businesses say they want employees who can work well in cooperative teams. Education has long heralded the positive benefits of cooperative learning, but there are mixed opinions about whether cooperative learning is useful and productive in the work place. For example, Bryant, a writer from the New York Times states: "Cooperative learning and working sounds great but it's often misused or overhyped. Learning takes work, and cooperative learning takes the work right out of learning. Businesses talk about teamwork, but do not actually use it in their job in any meaningful way. Some say that teamwork is a feel-good approach that gets in the way of actually accomplishing something" (Bryant, 1998).

Discovery learning has not taken a strong hold in education for many reasons. One reason is that the processes and outcomes of inquiry learning are not well documented and understood. Also, do students really learn more effectively through discovery learning than didactic teaching? Lastly, there is no clear consensus on the goals for discovery learning (Cohen, 1988). Critics worry that children take longer to 'construct' their own meaning and may come to incorrect conclusions without more guidance (Friedman, 1997). The basic question is: Is discovery based learning worth the extra time compared to more traditional approaches? Several studies suggest that it is. For example, of 67 studies pertaining to discovery learning verses traditional learning, 61% showed greater achievement in a discovery based class. 37% showed no difference in achievement (Baris-Sanders, 1997).

In every source reviewed, the main goal of discovery based learning was to have students develop higher order thinking skills. This was one of the main reasons I wanted to take the extra time to test a cooperative discovery learning approach. I think that students will gain the necessary skills to be successful in the real world from this approach. I am, however, skeptical about the extra time needed to teach using this approach. Is it most efficient in learning physics content and correcting students' misconceptions?

DEMOGRAPHICS

The school in which this study took place was a suburban high school with a student body of approximately 960 students. Of the 960, about 90% are Caucasian. The remaining 10% were a variety of Indian, Afro-American, and Asian. Most of the students came from a middle to upper class background. Of the 91 students in the control and test group, 37 were juniors and the 54 were seniors. Most students did not need this physics class, but took it because it looks good on a transcript or they were looking for one more science credit. Of the 91, there were 36 female and 55 male students.

All of the students in the study plan on attending college and ultimately receiving a bachelor's degree. The majority of students have not chosen their careers. There are approximately four students who plan to pursue engineering. The rest plan on going into fields related to medicine, or are undecided.

The Physics course is an elective class and few of the students were highly motivated to learn the subject. By my estimate, there were approximately 26 students throughout the test and control group who were actually interested in physics. The remaining students did show an interest in different concepts throughout the year. This indifferent attitude makes teaching this course challenging. The course is not required for graduation from high school, but is important for students going to college in science or engineering.

There were five physics class sessions involved in the study, each approximately 55 minutes. All of the students had completed algebra with a grade of B or better. Many students were taking pre-calculus or calculus. Most students were hard working, serious students, and discipline was not a problem. Although most were not intrinsically interested in learning physics, they were very grade conscious. In my view, this provided for an ideal climate to test the academically inclined students in order to conclude what teaching strategy works best.

Following is the break down of my schedule and which classes were control group and test group for each day:

Lecture/Demonstration Control Group

Hours	Number of students
1st hour - 8:00 to 9:05	19
2nd hour - 9:10 to 10:00	13
3rd hour - 10:05 to 10:55	Conference Period
4th hour - 11:00 to 11:55	24

Discovery Test Group

5th hour - 12:35 to 1:30	13
6th hour - 1:35 to 2:30	22

IMPLEMENTATION OF UNIT

The control group did not experience an extreme change in their learning environment compared to that of my previous classes during the study. This group was taught under the traditional philosophy that the teacher was the sole dispenser of knowledge. Teacher led discussions, demonstrations, and "cook book" type labs done by students were the primary teaching methods. In a traditional classroom such as this, the teacher states the objective, gives the information, leads students through some lab activities, and the students regurgitate information back on a test or quiz.

The second group was my test group. They saw a drastic change in the learning environment. Students in the test group were required to meet the same objectives, but were encouraged to construct their own understanding through hands-on investigations while working in small groups. Students were sometimes given only the problem and some materials and were instructed to create their own lab experiment to learn the objective. Students had access to computers, textbooks, and laboratory facility. The teacher acted as a facilitator. Other times the students were given guided investigations and additional information on the topic and then tested this concept in small groups. Each student was required to record in a research book the purpose, procedure, data of their test, and evaluate each discovery. Following this, students were given questions pertaining to real life scenarios where they had to apply this newly acquired knowledge.

The unit was taught right after the first semester exams and took 4.5 weeks to complete. The students previously had completed a four month study of mechanics. There were 56 students in the control group and 35 students in the test group. The test group was split up into working groups of two or three. Every group had an "academic" person as well as a more creative and "hands-on" type person based on performance in the first semester. Before implementing the unit, a pre-test (Appendix C1) was administered to all students to inform the researcher what areas needed work and to provide as a basis for data analysis.

Following are the five topics and the corresponding objectives taught in this unit. A brief outline of what was done by the control group and test group is included with each objective. Lastly, a brief overview of what took place during the lesson and students' behavior are documented.

Students Under Pressure

1. Density - $\rho = M/V$

Objective: Distinguish between density, weight density, and specific gravity. Given an object's mass and volume, calculate the object's density, weight density and specific gravity.

Control Group: Students were given a lecture on density. All terms were defined and examples were given. There were comparisons of different densities and how they are important in science. The teacher completed a few sample problems on the board and then students were assigned problems from the textbook. The laboratory was a textbook lab (Robinson, 1992) on finding density of regular and irregular objects (Appendix A1).

Test Group: Students were given handouts on the objectives and the investigation they were to do (Appendix B1). Each group was to learn this objective using textbooks, computers, and the teacher as resources. This group had to discuss, research, analyze the objective, and then apply this to their lab investigation. The investigation was to find the density of regular or irregular solid objects. They needed to devise a plan to solve this problem. The students had to use a complete scientific format in their research books.

Overview: The students in the control group did not have many questions. They completed the problems and lab as was done in the past. The test group wanted all of the answers from the teacher. The students had to rely on each other to develop the activity and learn the objective. When using the computers as a resource, the students were extremely frustrated because the Internet was running slowly and there were six people per computer. In future, computers will be used on a limited basis.

2. Pressure - P = F/A

Objective: Define pressure, air pressure and calculate the pressure that an object of known weight exerts on a surface of known area, and then express the magnitude of the pressure in psi, lb/ft^2, N/m^2 or Pascal's (Pa).

Control Group: The teacher defined terms and discussed sample problems. As a group students calculated how much pressure they apply to the floor. There were two demonstrations on air pressure: 1. A person was placed in a garbage bag with their head sticking out of the bag and the air was removed;

2. By heating a can with a little water at the bottom and tipping it upside down into cool water, you will see a can get crushed. (Appendix D1 and D2).

Test Group: The test group was given information about pressure and air pressure in the form of handouts. The terms were defined to make sure they understood them. They were also given four investigations to test and evaluate. The four investigations were: 1. Calculating pressure of someone's foot on the floor and making comparison to air pressure; 2. Collapsing a can; 3. Breaking wood slats using paper, air pressure and a hammer; 4. Students climbed into a garbage bag with their head sticking out of the bag and used a vacuum cleaner to remove the air out of the bag (Appendix B2).

Overview: I believe that the test group started to enjoy their freedom of learning. The students were actually applying some physics to real life situations. This was exciting for the teacher and students. The test group was seeing a connection from the objective to the actual investigation. The problem with the investigations was time. The control group finished this objective in a day but the test group needed two to three days.

After teaching the first three objectives, the teacher presented three demonstrations to both groups: 1. Behavior of a marshmallow in a vacuum jar; 2. Behavior of a balloon in a vacuum jar; 3. Boiling water at room temperature. The control group just saw the demonstration; then we discussed it as a group. The test group had to explain what happened in each case in their research lab books (Appendix D4, D5, and D6).

3. Fluid Pressure - $P = \rho gh$

Objective: Calculate the pressure acting at a depth below the surface of a liquid with known density. Distinguish between absolute pressure and gauge pressure, and solve problems involving each type of pressure.

Control Group: They had a lecture on how depth affects pressure. All terms were defined and sample problems were done using the equation above. The teacher demonstrated a newly developed apparatus. This apparatus is described in Appendix D. The water filled tube demonstrates how a balloon contracts at different depths. The teacher set up the tube where students could pull a balloon down to different depths and measure the volume change (Appendix D3).

Test Group: The test group was given information regarding fluid pressure. The students had to define all relevant terms and then apply them to real life situations. The students were given four investigations to test and evaluate: 1. Using the new apparatus the students actually measured the volume change of a balloon as it was pulled down deeper into the tube; 2. Make a siphon and explain how it works and its uses; 3. The students made a carpenter's level to show how water seeks its own level; 4. The students used a two liter bottle to show how depth effects pressure. In every investigation, the students were to use the scientific approach and write in their research lab books. (Appendix B3)

Overview: The control group, in my observation, feels as if they are dragging their feet. They would like to move on to another topic. The test group needs more time to investigate. The lab gets wet just about every day. Some students in this group wonder if they are actually learning the objectives. The test group is very concerned about their grade.

4. Archimedes's Principle - Buoyancy Force ($F_B = m_l g$)

Objective: State Archimedes's principle and use this principle to solve and apply to related buoyancy problems.

Control Group: This group was presented with a definition on Archimedes's principle. There were discussions on how this applies in everyday life. Sample problems were done on the board and students were assigned problems out of the textbook. There was one "cook book" style lab from a lab text (Robinson, 1992) to demonstrate Archimedes's principle (Appendix A2).

Test Group: They were given background information on buoyancy and told to define each term and make sure they understood these terms. The students were given three investigations: 1. To make a boat out of aluminum foil. This was to demonstrate that water has to be displaced before things can float; 2. This investigation was to go one step further by calculating the buoyancy force of different objects; 3. To make a fresh egg float and explain why it did. Each investigation required observations, procedures, and evaluations (Appendix B4).

Overview: Investigations related to Archimedes's principle did not go well for either group. The boats they made did not float. I had to change the lab slightly to make it more meaningful. The biggest difficulty in teaching this concept was for them to think on their own. The students wanted the teacher to give them the answer on how they should measure how much water was displaced.

5. Bernoulli's Principle - (no equations)

Objective: Be able to state Bernoulli's principle and apply it to everyday life.

Control Group: I as the teacher defined the terms and conducted two demonstrations. In one demonstration, two pieces of paper are pushed together when you blow air between them (Appendix D7). The other demonstration was drawing water up into a straw by blowing air over the top of the straw. The subsequent demonstrations led to a discussion on how airplanes fly. The students had some concept questions they had to apply pertaining to this principle.

Test Group: The students were given handouts on Bernoulli's principle. They were required to go through the material as a group and investigate the pressure changes related to fluid motion. The students had access to computers, textbooks, and the teacher. The students then had three investigations that they were to write up completely in their lab books: 1. Two ping pong balls get pushed together by blowing air between them; 2. Make a manometer by drawing water up into a straw and measuring the height; 3. Make a piece of paper go up by blowing over the top of it. These investigations really did not take long and required few calculations. The students simply recorded their observations (Appendix B5).

Overview: From the assessments and my observation, the control group did not understand the demonstrations. They did not really understand the objective. The test group again ran out of time to complete the required investigations. I had to cut them short. The investigation in the test group went very well. Based on the assessments and my observations, these students actually understood Bernoulli's principle and could apply it to a real life situation.

EVALUATION

The pretest (Appendix C1) given at the beginning of the unit consisted of 24 real life questions pertaining to all of the objectives. This was used as a gauge of what the students already knew about pressure. It was also a basis for comparison of the data collected between the control and test group. Each question on the pretest was graded on a three point scale: one point for the correct answer; one point for the correct explanation, and the last point was a judgment call on my part. The results of the pretest show that the test group had more background knowledge about the unit. The *t-test* shows that the calculated number is greater than the critical number. This indicates that there is a definite difference between the two groups normal distribution curve (Table 1).

Table1: Statistics from the Pretest.

	Control Group	Test Group
Number of Students	56	35
Average on Test	34.66%	41.23%
Standard Deviation	11.96%	12.23%
	T - Test	
Calculated Score		Critical Score
2.483		2.021

The quiz (Appendix C2) was given after the first objective was taught. The questions were generated from previous problems and labs. All questions had equal value and partial credit was given for stating the right equation or process. This was determined by me. There were two laboratory questions where the students had to measure and calculate different densities. My observation of the lab portion of the quiz was that the test group completed the task much more quickly. The results of the quiz do not show significant differences in the average or the *t-test* (Table 2).

Table 2: Statistics from the Quiz.

	Control Group	Test Group
Number of Students	56	35
Average on Test	85.07%	88.37%
Standard Deviation	10.34%	12.76%
	T - Test	
Calculated Score		Critical Score
1.27		2.021

The concept test (Appendix C1), consisting of the same questions as the pretest, was administered at the end of the unit. The same three point grading scale discussed earlier was used to evaluate this test. The results of the concept test do not show significant differences in the average or the *t-test*. In fact, both groups are at the same level at the end of the unit (Table 3).

Table 3: Statistics from the Concept Test.

	Control Group	Test Group
Number of Students	56	35
Average on Test	72.27%	77.17%
Standard Deviation	11.31%	10.98%
	T - Test	
Calculated Score		Critical Score
2.022		2.021

The problem test (Appendix C3) had 8 questions that required the students to apply an equation to a problem. All questions were problems that both groups completed in class. The students could not have prior knowledge of the equations so I did not give a pretest on this. Every question was of equal value and there was partial credit given for students using the right process. This was a judgment call on my part. The results of the problem test do not show a drastic change in the average but the *t-test* does show that the students in the test group as a whole had a better understanding of the problems.

Table 4: Statistics from the Problem Test.

	Control Group	Test Group
Number of Students	56	35
Average on Test	76.20%	80.74%
Standard Deviation	10.91%	8.61%
	T - Test	
Calculated Score		Critical Score
2.396		2.021

The post test (Appendix C4) was given three months after the unit was completed. The students were not aware that they would be given this test. The questions were generated from the problem test and pretest. I took what I thought were important questions related to each objective. Each question was worth 3 points and the same scoring was used as in the pretest. The result show that the students in the test group did have a higher average. The *t-test* also indicates that the normal distribution curve was not overlapping. This shows that more of the students in the test group had a better understanding of the unit after three months (Table 5).

Table 5: Statistics from the Post Test.

	Control Group	Test Group
Number of Students	56	35
Average on Test	52.50%	59.94%
Standard Deviation	14.85%	12.82%
	T - Test	
Calculated Score		Critical Score
2.501		2.021

When comparing the pretest data (Table 1) between the control group and test group, no striking differences are found. In the pretest, there was a 7% difference in the average score, with the test group scoring higher. The test group continued to score higher on all assessments throughout the teaching of the unit. On the quiz, the test group scored 3.3% higher at 88.37% (Table 2). On the concept test, the test group scored 5.1% higher at 77.17% (Table 3). On the problem test they scored 4.54% higher at 80.74% (Table 4). This indicates that overall the test group did slightly better than the control group in all areas. However, one must note that the test group had scored higher on the pretest.

One important difference noticed in the scores is the standard deviation. Comparing all the standard deviations on all four tables, one can see that the test group's standard deviation went down compared to that of the pretest. There were definite changes in Table 3 and Table 4. The test group had a lower standard deviation by 1 or 2 percentage points. This is not very significant but the improvement suggests that the cooperative learning groups put everyone closer to the average. I can attribute the drop to students working in cooperative groups on the investigations.

After completing the unit on pressure, I administered a post test. Once again the test group scored better, 7.44 % higher, with an average of 59.94% (Table 5). The test group also had a lower standard deviation by 2 points at 12.82. This suggested that the test group retained more, and after three months, could perform better on this test than the control group. It would be interesting to test these same students one year later to see what the test scores would indicate.

The averages and standard deviation of the assessments do show some interesting data. In the *t-test* score, I see slightly different results. The *t-test* shows the overlapping of the normal distribution curve. The critical score is from a table. If the calculated score is above the critical score, I can conclude that there is a definite change between the two distribution curves from each group. The pretest, problem test and post test showed the strongest change. They are approximately 0.3 to 0.5 points above the critical score. Looking at Table 1, I note that the test group had much more prior knowledge and they did sustain this throughout the unit. The concept test, on the other hand, did not show a drastic change between groups. This suggests that the control and test groups were not all that different right after the unit. In comparing Table 1 and Table 5, the *t-test* indicates that the test group did retain the material and performed better as a group.

The data indicates that the test group performed better on the various assessment instruments. I also analyzed the data by topics. Each question on the tests could be broken into five topics correlated to the five objectives. The concept, post and problem test questions were sorted into these five topics. I went through each test and tallied each question that 15% or more of the students missed. Figure 1 (Concept Test) shows that the test group knew the topics as well as or better than the control group. Data for Figure 2 (Problem Test) was derived the same way, and again the test group did not miss as many of the topics. In the post test, the test group continued to score better (Figure 3). This suggests more of the students in the test group had a deeper understanding of the concepts because they had more time to analyze, think for themselves, devise a hypothesis and test.

The successful investigations correlate with the data in the Figures. Density, pressure, fluid pressure, and Bernoulli's principle were the investigations for which students showed improvement for the test group. When learning these four topics, the test group had time to analyze the investigations. The cooperative learning groups were a benefit in this type of learning. The concepts were reinforced with the investigations as well as the cooperative learning groups. By my observation, the students saw a connection between the concept and real life situations. The area of study that did not show a change between the test and control group was Archimedes's principle. This objective was the most difficult for all of the students and the data reflects this.

Figure 1: Student's missed questions by topics in the Concept Test.

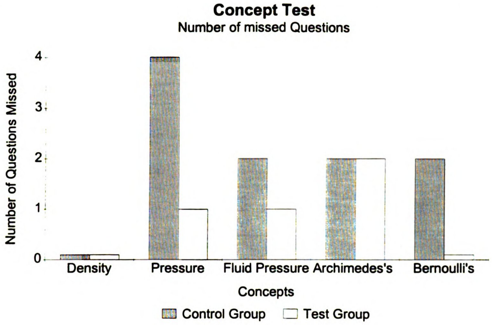


Figure2: Student's missed problems by topics in the Problem Test.

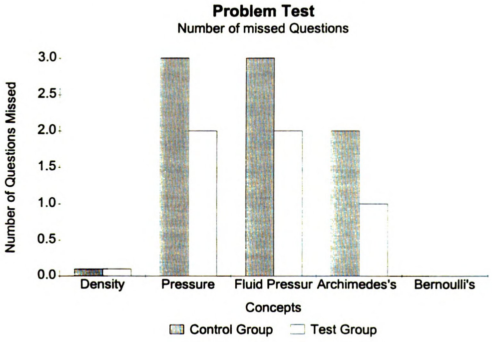
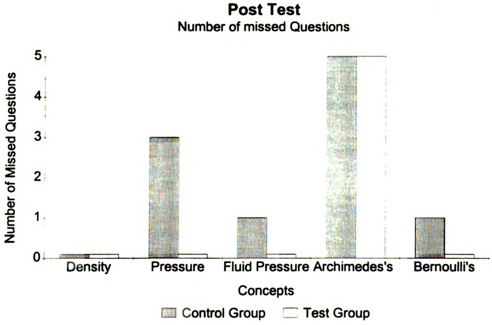


Figure 3: Student's missed questions by topics in the Post Test.



The students in the test group were very excited and interested about the new discovery approach to learning. This excitement did taper off near the end of the fourth week. According to the survey that I conducted informally, most students in the test group enjoyed the hands-on approach (Table 6). The majority of the students did not enjoy writing every day in their lab books. This is typical of most students. Some students did enjoy the freedom to learn the objective as a group and others did not. Most students wanted the teacher to lecture to them. Typically, these were students who were very conscientious and very concerned about an "A" grade. The two or three students that did not like the discovery approach did not do well. All students learn differently, so several teaching techniques should be used. By looking at some of the students' comments, one can see that some students did not like being forced into higher order of thinking. Below are some typical responses from the test group:

"Are we learning anything?"

"When can you go back to lecture?"

"This is the way classrooms should be run."

"I dread going to your class everyday."

"I love playing in the water everyday."

"I wish we could just investigate and not write in our lab books."

"Do we have to go back to lecture?"

Table 6: Students' Opinions.

Question Asked	**Yes**	**No**
Liked the Investigations	33	2
Liked the writing	4	31
Liked the independence	8	27
Lecture back again	27	8

CONCLUSION

Organizing and executing the discovery approach to teaching was a difficult task to accomplish. The lessons, based on investigations, were very time consuming to create, set up and monitor. It was also difficult to act as a facilitator, especially for students who begged for answers. That said, the hands-on approach and higher order thinking skills used in learning the concepts went well. The time constraint for the test group was the biggest drawback. The control group would have taken about two and a half weeks to work through the objectives, but the test group required much more time. Questions for an instructor are: Do I have the time to cover all required concepts using a discovery approach? What is most important for the students to learn, content or process? I believe a combination of discovery based learning and traditional based lecture is the best form of teaching physics. I agree with critics who say discovery learning takes too long for students to construct meaning and that incorrect conclusions may be made without more guidance. Therefore, I believe that interactive lecture, several hands-on discovery lab experiments, and the use of cooperative groups is the most efficient way to teach physics. Every student learns differently, so using the above combination of approaches should help more students understand. I believe that when a student comes to the correct conclusion on his or her own that the student's understanding is much deeper. However, students do not always make these connections on their own. I believe the use of investigative hands-on laboratories helps students to learn, retain, and apply the concepts better, and I intend to change my labs to be more investigative. I think using cooperative groups is an effective teaching technique and I intend to use this more often in my class. The use of computers as a resource is not feasible until our school's computer system is changed to handle a larger number of students. I will be using this new unit in all my classes next year because I believe that the control group missed out on some very important concepts on pressure. They also missed out on learning valuable skills such as working with others in a group and higher order thinking. The answer to the question, "Should school districts change from traditional to discovery learning?", is in my opinion, not exclusively. Both approaches have benefits, and a teacher should pick and choose what aspects are most effective for students for a given topic.

APPENDICES

Name ______________________ Period __________ Date __________

Chapter 19: Liquids

Displacement and Density

45 Eureka!

Purpose

To explore the displacement method of finding volumes of irregularly shaped objects and to compare their masses with their volumes.

Required Equipment/Supplies

two 35-mm film canisters (prepared by the teacher): one which is filled with lead shot, and the other with a bolt just large enough to cause the canister to sink when placed in water
triple-beam balance
string
graduated cylinder
water
masking tape
5 steel bolts of different size
irregularly shaped piece of scrap iron
1000-mL beaker

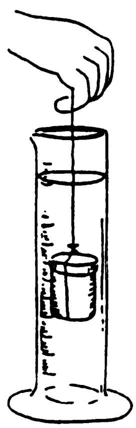


Fig. A

Discussion

The volume of a block is easy to compute. Simply measure its length, width, and height. Then multiply length times width times height. But how would you go about computing the volume of an irregularly shaped object such as a bolt or rock? One way is by the displacement method. Submerge the object in water, and measure the volume of water displaced, or moved elsewhere. This volume is also the volume of the object. Go two steps further and (1) measure the mass of the object; (2) divide the mass by the volume. The result is an important property of the object—its density.

PART A

Procedure

Find the mass of each canister

Step 1: Your teacher has prepared two film canisters for you. Each canister should have a piece of string attached to it. Use a triple-beam balance to find the mass of each one.

mass of lighter canister = ______________

mass of heavier canister = ______________

Observe rise in water level

Step 2: Place a strip of masking tape vertically at the water level of a graduated cylinder about 2/3 full of water. Mark the water level on the tape. Submerge the lighter canister in the water, as shown in Figure A. Observe the rise in water level. Mark the new water level on the tape. Remove the canister.

Predict rise in water level

Step 3: Predict what you think the rise in the water level for the heavier canister will be when it is submerged. Do you think it will be less than, the same as, or greater than the rise in water level for the lighter canister?

prediction; ____________________

Observe rise in water level

Step 4: Test your prediction by submerging the heavier canister. Write down your findings.

findings: ____________________

Analysis

1. How do the amounts of water displaced by each canister compare?

Since the rise in water level is the same for each canister, they must each displace the same amount of water.

2. Does the amount of water displaced by a submerged canister depend on the mass of the canister? On the volume of the canister?

The amount of water displaced by a submerged canister depends on its volume but not on its mass.

PART B

Procedure

Measure mass and volume of bolts

Step 5: Measure the mass and volume of 5 different sized bolts using the displacement method. Record your data in Data Table A.

Data Table A

BOLT NUMBER	MASS (g)	VOLUME (mL)	------- (g/mL or g/cm³)
1			
2			
3			
4			
5			

Compute ratio of mass to volume

Step 6: For each bolt divide its mass by its volume, and enter the results in the last column of Data Table A.

Name ______________________ Period ____________ Date ____________

Analysis

3. How do the ratios of mass to volume compare for each of the bolts?

All the bolts should have about the same ratio of mass to volume.

4. Would you expect the ratio of mass to volume to be the same for bolts of different metals?

Bolts of different metals would have different ratios of mass to volume.

5. What name is given to the ratio of mass to volume? (Fill this name in at the top of the last column in Data Table A.)

The ratio of mass to volume is the density.

PART C

Going Further

Pretend that you are living in ancient Greece during the time of Archimedes. The king has commissioned a new gold crown to be made of pure gold. The king is worried that the goldsmith may have cheated him by replacing some of the gold with less precious metals. You are asked to devise a way to tell, without damaging the crown, whether the king was cheated or not.

Unfortunately, your school cannot supply you with an actual gold crown for this activity. A less valuable piece of scrap iron will simulate the crown.

Write down your procedure and any measurements you make.

APPENDIX A2

Name ______________________ Period __________ Date __________

Chapter 19: Liquids **Archimedes' Principle and Flotation**

46 Sink or Swim

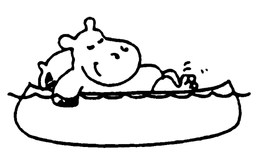
Purpose

To introduce Archimedes' principle and the principle of flotation.

Required Equipment/Supplies

spring scale	water
triple-beam balance	masking tape
string	chunk of wood
rock or hook mass	modeling clay
600-mL beaker	toy boat
500-mL graduated cylinder	50-g mass
clear container	2 100-g masses

Discussion



An object submerged in water takes up space and pushes water out of the way. The water is said to be displaced. Interestingly enough, the water that is pushed out of the way in effect pushes back on the submerged object. For example, if the object pushes a volume of water with a weight of 10 N out of its way, then the water reacts by pushing back on the object with a force of 10 N. We say that the object is buoyed upward with a force of 10 N. In this experiment you will investigate what determines whether an object sinks or floats in water.

Procedure

Weigh an object in air and submerged in water

Step 1: Use a spring scale to determine the weight of an object (rock or hook mass) first in air and then under water. The difference in weights is the buoyant force. Record the weights and the buoyant force.

weight of object in air = __________

apparent weight of object in water = __________

buoyant force on object = __________

Measure the water displaced

Step 2: Devise an experimental set-up to find the volume of water displaced by the object. Record the volume of water displaced. Compute the mass and weight of this water. (Remember, 1 mL of water has a mass of 1 g and a weight of 0.01 N.)

volume of water displaced = __________

mass of water displaced = __________

weight of water displaced = __________

1. How does the buoyant force on the submerged object compare to the weight of the water displaced?

The buoyant force should equal the weight of the water displaced.

Float a piece of wood

Step 3: Find the mass of a piece of wood with a triple-beam balance, and record the mass in Data Table A.

NOTE: To keep the calculations simple, from here on in this experiment you will measure and determine masses, without finding the equivalent weights. Keep in mind, however, that an object floats because of a buoyant force. This force is due to the weight of the water displaced.

Measure the volume of water displaced when the wood floats. Record the volume and mass of water displaced in Data Table A.

Data Table A

OBJECT	MASS (g)	VOLUME OF WATER DISPLACED (mL)	MASS OF WATER DISPLACED (g)
WOOD			
WOOD AND 50-g MASS			
CLAY BALL			
FLOATING CLAY			

2. What is the relation between the buoyant force on any floating object and the weight of the object?

The buoyant force on any floating object equals the weight of the object. (If it were less, the object would sink; if it were more, the object would rise higher.)

3. How does the mass of the floating wood compare to the mass of water displaced?

The mass of the floating object should equal the mass of water displaced.

4. How does the buoyant force on the wood compare to the weight of water displaced?

The buoyant force on the wood, equal to the weight of the wood, also equals the weight of water displaced, since the masses are equal.

Name ______________________ Period __________ Date __________

Float wood plus 50-g mass

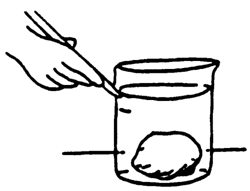
Step 4: Add a 50-g mass to the wood so that the wood displaces more water but still floats. Measure the volume of water displaced and calculate its mass, recording them in Data Table A.

5. How does the combined buoyant force on the wood and the 50-g mass compare to the weight of water displaced?

The combined buoyant force, equal to the combined weight, also equals the weight of water displaced, since the masses are equal.

Measure displacement of clay

Step 5: Find the mass of a ball of modeling clay. Measure the volume of water it displaces as it sinks to the bottom. Calculate the mass of water displaced, and record all volumes and masses in Data Table A.



6. How does the mass of water displaced by the clay compare to the mass of the clay?

The mass of water displaced is less than the mass of the clay.

7. Is the buoyant force on the submerged clay greater than, equal to, or less than its weight in air? Explain.

The buoyant force on the submerged clay is less than its weight in air. Otherwise, the clay could not remain submerged.

Mold the clay so that it floats

For more observable results use dense masses such as lead weights.

Step 6: Retrieve the clay from the bottom, and mold it into a shape that allows it to float. Sketch or describe this shape.

Measure the volume of water displaced by the floating clay. Calculate the mass of the water, and record in Data Table A.

8. Does the clay displace more, less, or the same amount of water when it floats as it did when it sank?

The clay displaces more water when it floats.

9. Is the buoyant force on the floating clay greater than, equal to, or less than its weight in air?

The buoyant force on the floating clay equals its weight in air.

10. What can you conclude about the weight of water displaced by a floating object compared to the weight in air of the object?

The weight of water displaced by any floating object equals the weight in air of the object.

Predict new water level in canal lock

Step 7: Suppose you are on a ship in a canal lock. If you throw a ton of bricks overboard into the canal lock, will the water level in the canal lock go up, down, or stay the same? Write down your answer *before* you proceed to Step 8.

prediction for water level in canal lock: ____________________

Step 8: Float a toy boat loaded with "cargo" (such as one or two 100-g masses) in a container filled with water deeper than the height of the masses. Mark and label the water levels on masking tape placed on the container and on the sides of the boat. Remove the masses from the boat and put them in the water. Mark and label the new water levels.

11. What happens to the water level on the side of the boat when you place the cargo in the water?

The water level on the boat goes down, and the boat rides higher in the water.

12. If a large freighter is riding high in the water, is it carrying a relatively light or heavy load of cargo?

A freighter riding high is carrying a relatively light cargo.

13. What happens to the water level in the container when you place the cargo in the water? Explain why it happens.

It drops, since the cargo displaces less water when it sinks compared to when it is floating.

14. What will happen to the water level in the canal lock when the bricks are thrown overboard?

The water level in the canal lock will drop.

APPENDIX B1

Investigations of Density.

1. Distinguish between density which is mass per unit volume, weight density which is weight per unit volume and specific gravity which is the ratio of the density of an object to a known density. When given an object's mass and volume, calculate the object's density, weight density and specific gravity.

$\rho = m / V$

a. Calculate known density with known mass and volume.
b. Calculate specific gravity and make comparison to density.
c. Figure out density of a cylinder or block vs. an irregular shaped solid.

Assignment from physics textbook: Page 302 - 304 Q:1,9,11,12 P: 1 - 6

Laboratory: 1. Given two 35 mm canisters, triple beam balance, string, graduated cylinder, water, bolts, scrap piece of iron and masking tape. Calculate the densities of the bolts, piece of iron and the two canisters filled with different amounts of material. 2. Find the density of a block of wood. 3. Compare / Contrast the density of the bolts in your conclusion

Questions: How do the amounts of water displaced by each canister compare? Does the amount of water displaced by a submerged canister depend on the mass of the canister? On the volume of the canister?

Every lab should contain the following: Use ink!

Title:
Purpose:
Procedure: Write in paragraph or number form. Diagrams are expectable.
Data/Calculations: The more detailed the better grade. Significant Digits and precision of the instruments are very important. Graph if possible.

Conclusion/Evaluation: Answer the questions. Summarize the lab. Possible Errors. Did you learn anything? Changes you should have made to the lab.

APPENDIX B2

Investigations of Air Pressure.

Concepts to investigate: Definition of pressure, pressure equation, implosions, atmospheric pressure.

Materials: Balance, meter stick, graph paper, soft drink can, beaker tongs, large beaker or bucket, packing tape, newspaper, notebook paper, thin wooded slat, hammer and vacuum cleaner.

Principles and Procedures:

Part 1: How great is atmospheric pressure? Atmospheric pressure at sea level is 101.3 kPa [14.7 lb/in^2] . Is this a large pressure or a small pressure? Measure the area of the bottom of your foot. Measure your weight and calculate the pressure you exert on the floor. Do this same calculation for several other objects in the room. Make a table of the mass, weight, area, pressure in Pascal's, and pressure in lb/in^2. Make sure you have the pressure of at least four different things. Show all work and calculations. Develop a plan before getting started with this activity. Show all developments in your lab manual.

Part 2: The collapsing can. To demonstrate the strength of air pressure. You need to put a little water at the bottom of a can and boil it. After boiling for several minutes take the can and put it upside down in a tank of cold water. Record all observations and explain why this would happened.

Part 3: Put a thin slat of wood such as a paint stirrer on a table so approximately 20 cm hangs over the edge. Place two sheets of notebook paper on the slat and press against the table until the paper is as flat as possible. Strike the overhanging portion of the slat with a hammer. Repeat this procedure using two pieces of unfolded newspaper and record the area. Calculate the force exerted upon the paper using the pressure equation. Did the wood break? Record all observations in your lab book.

Part 4: Put yourself in a garbage bag. Stand so your head sticks out and suck the air out of the bag using the vacuum cleaner hose. The hose should be in with the person. If it is a quality garbage bag, every student can experience the affects of air pressure on our bodies.

APPENDIX B2 (cont.)

Questions.

1. On the basis of your calculations in part 1, what is the magnitude of atmospheric pressure at sea level compared to the pressure you exert on two feet?

2. Under what conditions does the can collapse in Part 2? Explain.

3. Using a diagram of your ears explain why your ears pop when you travel up and down the mountains.

4. Is it possible to lose your hearing in an airplane if the plane does not become pressurized? Explain.

5. Why may it be painful to travel into the mountains if you have a head cold?

6. Is the air pressure on the sheet of notebook and newspaper the same? Explain. Is the force upon them the same? Explain.

7. Did the wood break when placed under the notebook paper? When placed under the newspaper? Explain.

8. Why do large ships require large sails if air pressure is independent of surface area?

APPENDIX B3

Investigations on Fluid Pressure.

Concepts to investigate: Fluid pressure, pressure differential, siphons, water levels, pressure, water pressure and depth, pressure and fluid flow.

Materials: Two liter soft drink container, tape, pencil, ruler, pliers, nail, burner, large pan, tube, beakers.

Principles and Procedures:

Part 1: Measure the volume of a balloon by measuring the radius. Pull the balloon down with a string. Appendix D3 has further details. Using the graduated cylinder at the top measure the volume change. Record data in your lab books.

Part 2: Make a siphon using a tube and beakers. Make sure tube is filled with water and place tube in both beakers. Raise and lower the beakers. Write down any observations. Using a 5 m length of tube, determine if water will siphon between beakers if the barrier between them is 2 m high. Try connecting several beakers in a row with the tubes. What happens? Record all observations.

Part 3: Carpenter's level: Using a piece of tube about 10 m long, fill the tube with water so there is about 50 cm of empty tube on each end. Take one end of the tube to one side of the classroom. Carry the other end with a meter stick to the opposite end and measure from the floor how high the water level is in the tube. Determine if the floor is level. Try this again with other parts of the floor. Make sure both meter sticks are perpendicular to the ground. Record the heights measured at each end. Are the heights always the same?

Part 4: Pressure versus depth: Place three holes into a two liter bottle, using a heated nail. Make sure the holes are at different levels and not in line with each other perpendicularly. Fill the two liter bottle with water making sure the holes are covered using the pencil or tape. Record the depth of each hole. Calculate the pressure at each level using the equation $P = \rho gh$ where the density of water is 1000 kg/m^3. Measure the length of water stream when the straw or tape is removed. Record all calculations and data in a table.

Questions.

1. Under what conditions, other than entry of air into the tube, will water stop flowing in the siphon?

2. Using water pressure explain how the water level works in part 3.

3. Explain how a siphon works.

4. Does your data support the equation in part 4? Explain.

5. Describe what would happen to a strong flexible volleyball if you released it from a submarine at the bottom of the ocean.

6. The Marinas Trench is the deepest known portion of the Earth's surface, with a maximum depth of 11,034 m. Using the pressure equation determine the pressure at this depth. How many times greater is the pressure at this depth than at the surface?

7. What happened to the volume of the balloon as the balloon went to different depths. Explain.

8. Did the balloon lose any air? Explain.

9. In part 1, what if the tube was filled with a different solution?

APPENDIX B4

Investigations on Archimedes's Principle.

Concepts to investigate: Archimedes's principle, displacement, determining buoyant force, buoyancy of different materials, Newton's third law, weight, and density.

Materials: Aluminum foil, caulking, beaker, spring balance, graduated cylinder, metal and wooden weights of equal mass, metal object, salt, and eggs.

Principles and Procedures:

Part 1: Bend a flat piece of aluminum foil so that it will float. Make sure the boat will displace its weight. Using your constructed measuring device for displacement, watch what happens to the displacement of water as you submerge the boat. Make a comparison to the displacement as more is loaded on the boat until it sinks. Measure the displacement of water in each case. Record your data in a table for the displaced water. You will have to devise a plan to measure displacement of water because the boat will not fit into a graduated cylinder.

Part 2: Using the weights, a piece of metal, and a block of wood measure, calculate, and record the weight of each in air, and in water. Measure the difference in weight and the weight of the displaced water. Record all of this in a data table.

Part 3: Place a fresh egg in a beaker full of water. Record any observations. Slowly stir salt into the beaker and record any and all observations.

Questions:

1. Using Archimedes's principle, explain why your boat will sink if placed on its side.

2. Explain how concrete boats are able to float.

3. The density of lead is 11.3 times the density of water. How would you modify the design of your boat to make it float.

4. What is the buoyant force on the metal and wood objects in this activity? Explain.

5. What was the weight of the wood when resting in the water? Explain.

6. Would an object weigh more or less if there were no atmosphere on Earth?

7. If a block of metal and a block of wood of identical mass were submerged, would the buoyant force on both be the same? Why or why not?

8. An average sized adult human has a volume of 68,000 cm^3. If air weighs 1 Newton per cubic meter, what is the buoyant force of the atmosphere on such an individual?

9. What should be added to raise or lower the egg? Explain.

10. Why did the egg rise when salt was added to the system?

11. Will a ship ride higher in an ocean or a lake?

12. Will more or less of an iceberg be submerged if it is floating in fresh water? Explain.

13. Petroleum geologists and engineers often flood oil wells with salt water to increase production. Why?

APPENDIX B5

Investigations of Bernoulli's Principle.

Concepts to investigate: Bernoulli's principle, manometer, atomizers, pressure differential, lift and flight.

Materials: Table tennis balls, thread, tape, paper, straw, food coloring, pencil, paper, tape, straight pin, funnel, and tubing.

Principles and Procedures:

Part 1: Air stream between two objects: Using a straw, blow air between two ping pong balls hung about 10 cm apart. Bend two ends of a piece of paper. Stand the piece of paper on the edges. Blow under the piece of paper and see what happens. Record all observations. Can you explain why this happens?

Part 2: Measuring pressure with a straw - manometer: Using two straws, place one straw in a colored water solution. Blow air through the straw over the other straw and make observations. Measure the height the colored water rises. Record air pressure when blowing air above the straw. 10 centimeters is about 10 mbar. Make comparisons to the actual air pressure which is 1013 mbar. By shortening the straw, you can create an atomizer which is used in a lot of garden sprayers, perfumes and spray fertilizers. Make observations.

Part 3: Airfoil: Wings, rudders, and propeller blades are examples of airfoils, surfaces used to control the speed and direction of aircraft. Tape a piece of paper to a pencil. Put pencil against lip and blow air over paper. Record all observations. Try blowing at different speeds.

Questions.

1. Given two straws, how can you separate the two table tennis balls without blowing them apart? Explain.

2. The table tennis balls in part 1 appeared as though they were attracted to each other. Explain why this is incorrect.

3. The reduction in fluid pressure is proportional to the square of the speed of the fluid. On the basis of this relationship, how much higher would water move in a straw if the velocity of the air across the top doubled?

4. Could you develop an anemometer which is a device that measures wind speed using Bernoulli's principle? Explain.

5. Hurricanes and tornadoes may cause houses to explode. Explain.

6. Why is it dangerous to stand near a fast moving train? Explain.

7. Ships that pass close to each other run the risk of a sideways collision. Explain.

8. What is the relationship between the speed of air across the paper and the amount of lift in part 3?

9. Some race cars have elevated inverted wing-like structures known as spoilers. What effect may such spoilers have on a race car's performance?

APPENDIX C1

Explain your answers. (3 points each)

1. As an ice cube in a glass of water melts, does the level of the water in the glass rise, fall, or stay the same?
2. Why are bottles of intravenous fluid hung so high over the hospital bed?
3. Why are high altitude directions given on food packages?
4. What is the advantage of a pressure cooker?
5. Why do spears, arrows, needles, etc. have pointed tips?
6. You are standing on a scale when all of the air is suddenly sucked out of the room. Bravely, you look at the reading on the scale before you run out of the room in search of breath. Was the reading with the air removed higher, lower or the same as that before the air was removed?
7. You are sitting in a boat in a quiet pool. You pick up a rock from the bottom of the boat and drop it into the water. Does the water level in the pool go up, go down, or stay the same?
8. Why do champagne bottles have wire cages on them while other wine bottles do not?
9. Why do women wearing high heels have more trouble than their heavier male counterparts when walking across soft ground?
10. Would you rather be stepped on by a 1000 lb. elephant with a one square foot or a 120 lb. female wearing high heals with one square centimeter?
11. Why do bicycle tires need to be pumped up to higher pressure than automobile tires when they don't need to support as much weight?
12. Why do your ears "pop" when you travel in an airplane or drive in the mountains?
13. Many community water towers have the shape shown in the diagram. Doesn't this shape represent an unstable situation, since the center of mass is so high and the support area so small? Wouldn't it be easier and safer to just build a cylindrical tower with vertical sides? Why do water towers have this strange shape?
14. Farm silos have bands around them to provide sturdiness to the walls. Why are the bands closer together near the bottom of the silo than at the top?
15. Scuba divers need to be wary of the "Bends". What are the "Bends"?
16. Atmospheric pressure is 14.7 lb/in^2. If you multiply this by the surface area of your body in inches, you obtain a huge force. Why aren't we all crushed?
17. Take a look at a non-retractable ball point pen. Somewhere on the barrel you are very likely to find a small hole. Why do they do this?
18. If you are caught in quicksand, what is the best way to escape?
19. Why do golf balls have dimples?
20. Why are airport runways longer in Denver than in San Francisco?
21. Why are scuba divers instructed to exhale while ascending to the surface?
22. If a helium balloon is released into the air, it rises upward until it finds an equilibrium position and comes to rest. A sinking submarine, on the other hand, simply sinks to the bottom, without ever finding an equilibrium position in the water. Why?
23. If you have ever been snorkeling, you may recall that snorkels are only a fraction of a meter in length. Why isn't it possible to buy a longer snorkel, so that you can dive deeper?
24. Why are tennis balls stored in pressurized cans?

APPENDIX C2

Show all work! 5 points each

1. Which has a the greater density -- 1 kg of water or 10 kg of water? Explain your answer.

2. When finding the volume of the two 35mm canister in the lab, how did they compare?

3. If one material has a lighter density than another, does this mean the molecules of the first must be heavier than those of the second? Explain.

4. Will an empty balloon have precisely the same apparent weight on a scale as one that is filled with air? Explain.

5. Find the density of a piece of wood. Show all work for full credit.

6. Given an irregular shaped object find its density.

APPENDIX C3

1. What is the total force and the absolute pressure on the bottom of a swimming pool 22.0m by 12.0 m whose uniform depth is 3.5 m? What will be the pressure against the side of the pool near the bottom?

2. A king orders a gold crown having a mass of 0.5 kg. When it arrives from the metal-smith, the volume of the crown is found to be 185 cm^3. Is the crown made of gold?

3. A 50 kg woman balances on one heel of a pair of high heel shoes. If the heel is circular with radius 0.5 cm, what pressure does she exert on the floor? Compare this to the pressure exerted by a 1500 kg elephant standing on one foot (area = 800 cm^2).

4. A car sinks to the bottom of a 15 m deep pool of water. A door on the car measures 1 m by 0.6 m. (a) If the inside of the car is at atmospheric pressure, what force most one exert on the door in order to open it? (b) What procedure might one use to escape from the submerged vehicle?

5. Calculate the buoyant force on a solid object made of copper and having a volume of 0.5m^3 if it is submerged in water. What is the result if the object is made of steel?

6. A steel cube 3 cm on a side floats in a pool of mercury. What volume of the cube is above the level of the mercury surface?

7. A man decides to make some measurements on a bar of gold before buying it at a cut rate price. He finds the that the bar weighs 2000 N in air and 1600 N when submerged in water. Is the bar made of gold?

8. What is the approximate difference in air pressure between the top and the bottom of the World Trade Center buildings in New York City? They are 450 m tall and are located at sea level. Express as a fraction of atmospheric pressure at sea level. What would be the approximate force on an eardrum of area 0.5 cm^2 if your ears did not pop?

APPENDIX C4

Explain your answers. (3 points each)

1. As an ice cube in a glass of water melts, does the level of the water in the glass rise, fall, or stay the same?

2. Why are bottles of intravenous fluid hung so high over the hospital bed?

3. Why do spears, arrows, needles, etc. have pointed tips?

4. You are standing on a scale when all of the air is suddenly sucked out of the room. Bravely, you look at the reading on the scale before you run out of the room in search of breath. Was the reading with the air removed higher, lower or the same as that before the air was removed?

5. You are sitting in a boat in a quiet pool. You pick up a rock from the bottom of the boat and drop it into the water. Does the water level in the pool go up, go down, or stay the same?

6. Farm silos have bands around them to provide sturdiness to the walls. Why are the bands closer together near the bottom of the silo than at the top?

7. Atmospheric pressure is 14.7 lb/in^2. If you multiply this by the surface area of your body in inches, you obtain a huge force. Why aren't we all crushed?

8. If you are caught in quicksand, what is the best way to escape?

9. Why are airport runways longer in Denver than in San Francisco?

10. A king orders a gold crown having a mass of 0.5 kg. When it arrives from the metalsmith, the volume of the crown is found to be 185 cm^3. Is the crown made of gold?

11. A car sinks to the bottom of a 15 m deep pool of water. A door on the car measures 1 m by 0.6 m. (a) If the inside of the car is at atmospheric pressure, what force most one exert on the door in order to open it? (b) What procedure might one use to escape from the submerged vehicle?

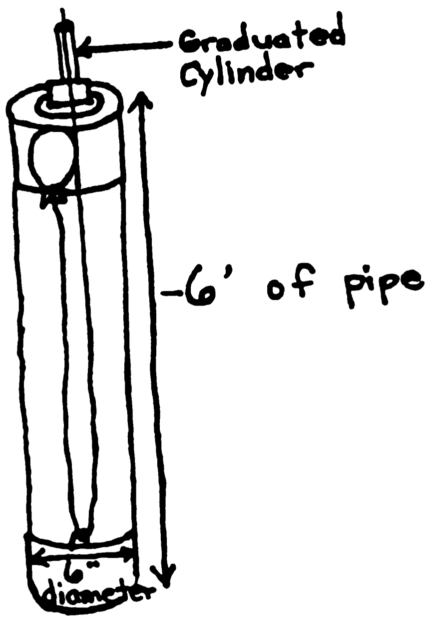
12. Calculate the buoyant force on a solid object made of copper and having a volume of $0.5m^3$ if it is submerged in water. What is the result if the object is made of steel?

APPENDIX D

Demonstration One: Materials: Garbage bag, and vacuum cleaner. Have someone climb into a garbage bag with just their head sticking out. Place the hose of the vacuum cleaner in the bag with them. Turn on the vacuum. The student will experience 14.7 lb/in^2 of pressure.

Demonstration Two: Materials: empty pop can, burner, tongs, and bucket. Heat some water in a pop can. Make sure there is barely enough water to cover the bottom of the can. Make sure the water is at a good boil and then place the can upside down in a pool of cold water. The can will crush because of the decreased pressure inside of the can. Decreased pressure inside and normal pressure outside.

Demonstration Three: Materials: String, onion bag, balloon, 6' of PVC that is 6" in diameter, end cap for 6" PVC, coupling and female threaded hub for 6" PVC, threaded hub for 6" PVC a plastic graduated cylinder, and an metal eye hook. The eye hook is placed in the end cap at the center. The end cap is placed on the 6' piece of pipe. The other end gets the female coupling. See Diagram Below. Make sure you put the string through the eye hook to be able to pull the balloon down the tube. The graduated cylinder needs the end cut off and a hole should be drilled in the top of the threaded end cap. Place the graduated cylinder in the hole. This had to be a tight fit and place putty around the graduated cylinder. Put string through the graduated cylinder and place balloon in the onion bag. Fill the tube full of water and seal off the threaded end. Pull the string up and down to remove any air bubbles and then you should be ready to go. The volume change can be measured with graduated cylinder.



APPENDIX D (cont.)

Demonstration Four: Materials: Vacuum pump, marshmallow and sealed container. Place the marshmallow in the sealed container and suck out the air using the vacuum pump. Let it run for a few minutes, making all observations. Then turn off vacuum pump and release the pressure. Watch what happens. The marshmallow shrinks smaller than original size.

Demonstration Five: Do the same thing in demonstration four but use a balloon instead. Ask the question did the balloon actually gain air?

Demonstration Six: Place warm water in the same sealed vacuum pump jar. Turn the vacuum pump on and watch what happens. The water will begin to boil. Have students explain this phenomena. Make sure students can feel the water before and after.

Demonstration Seven: Blow air between two pieces of paper and the pieces of paper will get pushed together because of the decrease of pressure in the middle.

BIBLIOGRAPHY

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Baris-Sanders, Marcia. "Cooperative Education: Lessons from Japan." Phi Delta Kappan. April 97, Vol. 78 Issue 8.

Beihler, Robert. Snowman, Jack. Psychology Applied to Teaching. (6th ed.). Boston: Houghton Mifflin. 1990. p 268

Birk, Lisa. "What's So Bad About the Lecture?" The Harvard Education Letter.12. Nov./Dec. 1996. pp. 58-61.

Bishay, Miran. Lewis, Matthew. McArthur, David. "The Macrostructure and Microstructure of Inquiry Activities: Evidence from Students using a Microworld for Mathematical Discovery." Edinburgh Paper. (Online) Available. http://www.rand.org/hot/mcarthur/Papers/edin.html. June, 1998.

Boyle, Joseph J. Study Guide for Giancoli's Physics 3rd edition. Englewoood Cliffs, NJ. Prentice-Hall. 1991

Bruner, Jerome. Toward a Theory of Instruction. New York: Norton. 1966. p 72.

Bryant, Adam. "All for One, One for All and Every Man for Himself." New York Times. February 22,1998. Section 4 p. 1.

Caine, Geoffrey and Caine, Renate. Making Connections: Teaching and the Human Brain. Addison-Wesley. pp. 3-7, 13-17.

Cohen, D.K. "Educational Technology and School Organization." Technology in Education: Looking toward 2020. Hillsdale, NJ. Earlbaum. 1988 (pp.231-264).

Cunningham, James. Herr, Norman. Hands - On Physics Activities. The center for Applied Research in Education. 1994. pp. 136 - 145 pp. 188 - 192, 234 - 255.

Friedman, Dorain. "Pet Teacher Phrases." U.S. News and World Report. Sept. 8, 1997, Vol. 123 Issue 9, pp. 68-69.

BIBLIOGRAPHY (cont.)

Geilker, Charles. "Guest Comment: In defense of the lecture-demonstration method of teaching physics." American Journal of Physics. Feb. 1997. Vol. 65, Issue 2. p. 107.

Giancoli, Douglas. Physics: Principles With Applications, Fifth Edition. Upper Saddle River, NJ: Prentice Hall. 1998.

Guenther, Al. Strengthening Your teaching of Physical Science Concepts. Bureau of Education and Research. 1997. pp. 28, 29, 61, 62.

Holzer, Siegfried M. "From Constructivism........to Active Learning." Center for Technology and Communication, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061 (Internet - May 1997).

Lawrence, E. The Origins and Growth of Modern Education. Baltimore, MD: Penguin Books. 1970.

Miller, John and Seller, Wayne. Perspectives in Practice. Toronto: Copp Clark Pittman, 1990

Robinson, Paul. Conceptual Physics Laboratory Manual Menlo Park, CA. Addison-Wesley. 1992 pp. 151-158

Slavin, Robert. Educational Psychology: Theory into Practice. Englewood Cliffs, NJ: Prentice Hall. 1988. p. 36.

Sylwester, Robert. A Celebration of Neurons: An Educator's Guide to the Human Brain. Alexandria, Virginia: Association for Supervision and curriculum Development. 1995. pp. 102-103.

Travers, Paul. Rebore, Ronald. Foundations of Education: Becoming a Teacher Englewood Cliffs, NJ: Prentice-Hall. 1987. pp. 53-56, 59, 85.