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A COMPARISON OF STUDENT PERCEIVED CONTROL AND RETENTION WITH VARIED METHODOLOGIES IN A HIGH SCHOOL CHEMISTRY CLASSROOM

By

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ABSTRACT

A COMPARISON OF STUDENT PERCEIVED CONTROL AND RETENTION WITH VARIED METHODOLOGIES IN A HIGH SCHOOL CHEMISTRY CLASSROOM

By

Brian Dennis Pohl

In this study a comparison is made of five basic teaching methods used in a high school chemistry classroom: reading, notes with lecture, demonstrations, traditional step-by-step labs, and student designed labs. The goal was to determine the retention of inquiry-based methods such as student-designed labs and to a lesser extent, traditional labs and demonstrations. Students were asked to answer a series of questions immediately before and after each activity and then again at the end of the semester. Students were also asked to rate each activity on how much control they felt they had in the activity and how effective they think it is in teaching the concept. These responses were then compared to questions that measured retention at different points in time. Comparisons made were:

I. What activity type has the best initial gains?

II. What activity type has the best retention?

III. What correlation is there between student-perceived ownership and retention?

IV. What correlation is there between how well a student actually did and how well they perceived that they did?

V. Is there a correlation between how much control students feel they have and their own perceived mastery of the concept?

Final results showed a statistical correlation between the amount of control a student reported and retention.

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Thank you so much to my family for their support during the last three years of this program. Summers without breaks and weekends shared with class have been the rule of thumb. Thank you also to my mentor teacher who always sees the best in people and encourages them to attain what she sees within them. This project has been going for a year and they all have been there for me every step of the way to encourage me along.

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INTRODUCTION

I. Rationale for Study

Over the past few years I have been dealing with the collision of traditional teaching methods and inquiry-based teaching strategies in my high school introductory chemistry class. As we are pushed by administration and university staff to make our classes entirely inquiry-based, I question this approach's effectiveness. Oftentimes when using inquiry-based methods alone, my students seem more confused after an activity than before if I let them have total control in designing and implementing an activity. Inquiry activities are ones that build off students' natural inquisitiveness to solve problems and investigate. These methods allow the students to design methods to solve problems through investigations (NRC, 2000).

While having students that feel in control of an activity is valuable, a balance with teacher control is also needed for student success (Eshel and Kohavi, 2003). Control over learning situations alone does not seem to be a reliable indicator of student success. In teacher-directed activities such as lectures, readings, demonstrations, and traditional labs the students report feeling comfortable in class surveys. However, the value of students listening, watching, and copying notes also leaves questions of effectiveness. Such methods are the backbone of classes from universities on down with the idea of teachers filling empty vessels (Wyckoff, 2001). There is little student control with these activities. Will their perceived learning suffer?

Prior to this study, I asked my chemistry class what methods they felt aided their learning the most. This informal question led to an almost unanimous voice from the class in answering "demos". There is no doubt that a demonstration can be a lasting memory as teachers have given anecdotes of students coming up to them 30-40 years later and still remembering a demonstration (Bent, 1980). I doubt that any of my students will come up to me in 30 years and comment on my wonderful entropy lecture. Will this perceived mastery reflect itself in retention and in the students' reported control for different types of teaching methods?

Even though the students enjoy demonstrations, I also wanted to see if their enjoyment and perceived learning could be reflected in pre and post scores. Demonstrations can be taught as either traditional or inquiry activities but for this study I performed the demonstrations as more traditional activities.

I developed a study on the comparison between how much control a student perceived that they had in an activity's development to both their reported mastery of the concept and their actual short and long term retention. In this study I expected to determine if there is a difference in the students' minds in actual control of an activity and how well they did. My hypothesis was that the inquiry activities may have a higher initial increase in scores, but in the long term each type of activity will lead to similar retention. The reason I say this is because each type of activity is not taught in a vacuum. In reality, my chemistry class engaged in a learning cycle involving many types of activities for each topic including inquiry and traditional methodologies. I expected that the perception of students' control to be linked with their perceived mastery of the concept but not to be linked to long-term retention.

In designing this experiment, stress was given to developing an order of events where each activity that I designed or borrowed would not contribute very much to influencing the next activity's scores in short pre and post activity questions used to determine improvement and retention. The reading, demonstration, traditional lab, student-designed labs, and lecture topics were chosen as smaller units or chunks that could be introduced independently without necessarily building upon the previous activities' information. However, this does not exclude the same topics from being revisited in a different type of activity later on in the unit.

To engage in this type of comprehensive study, many of the activities that were performed, which spanned the entire year, were generated and collected during the previous summer (2004) at Michigan State University. The inquiry labs were unique, adapted and/or designed and tested during this period. Some focused only on having student control being a small part of the activity, while others were designed to have almost entire student control. If there is a correlation between control and perceived mastery and retention then it is my expectation that these comparisons of scores will show it with a direct relationship being present with student perception of control and long term retention questions.

II. Theoretical Framework

I looked at a number of different types of activities and tried to correlate a relationship between the control that the students felt that they had and retention of learning. Each teaching method has significant literature on its relative merits in the classroom (Matthews,1996 & Lewis, 2005). Each method has its supporters and detractors with plenty of research to back up both. Teaching seems to be as much an art of adapting to the class that is in front of you as it is a science with set methods and tools that will work for every student. Based on my reading and classroom experience, for each teaching method I assessed in this study, my expectation would be that reading will offer the least control to the students, and then lecture, demonstrations, traditional labs, and student-designed labs in that order.

Each of these five methods of teaching was examined four times during the second semester. Student responses were collected for pre activity test scores and then post activity test scores to look for immediate improvement. At this time students reported on how much control of the activity they felt they had and how much they felt that activity helped them master the concept. They were asked again for their perceptions of control and mastery for the activity and were given additional concept questions to check for retention at two later points in the semester.

Reading from any textbook can be challenging but a chemistry book that tries to encompass all of the burgeoning chemical knowledge can be even more daunting (Gold, 1988) and contributes to the subject routinely being put on the list of "killer courses" (Rowe, 1983). There are few students who are able to read science not as a novel but as the information that it is. An excerpt about Newton shows this way of learning:

> "Took Descartes's Geometry in hand, tho he had been told it would be very difficult, read some ten pages in it, then stopt, began again, went a little farther than the first time, stopt again, went back again to the beginning, read on till by degrees he made himself master of the whole, to that degree that he understood Descartes's Geometry better than he had done Euclid." (Huber, 2004)

Students that attempt to read a textbook like a novel will quickly tire and stop processing the information if they continue reading in that manner. Students may read Harry Potter in a weekend but they should not read their chemistry book in the same time frame or mind set.

There are methods that show students how to take ownership of the reading material, but most students are unaware of these methods and if taught them will stop when it stops being required (Phanstiel, 1990). My students were not instructed in how to read the assignments but merely told to read them for information. For retention and control I expected there to be little improvement and low retention. Reading alone has been shown to not be effective in correcting misconceptions, so I would expect there to be low improvement from pre to post scores (Kendeou, 2005).

Lecturing to a class is thought to be the most common classroom activity and walking through my own school I would tend to agree. The typical scenario is of the students walking into the room, taking their seats, opening their notebooks and proceeding to spend the next fifty-five minutes copying down every syllable that comes off the teacher's tongue and every symbol that he/she scratches on the board. This method offers the benefits of being able to pass large amounts of information from the lector (lektor in Greek means expert) to the class and has been the method of choice since oral history (Cronin-Jones, 2003).

Many would wish this method of teaching banished from the classroom as some studies have shown that students missing lecture has no effect on their performance on the final exam (Wyckoff, 2001). This study was done with medical students so its applicability to the high school student should be questioned. Another example of lectures falling short deals with the frustration of, arguably, the best science lecturer of our time, Richard Feynman. His highly engaging and popular lectures have become legend but also failed to raise his students' scores. (Feynman, 1965)

One of the conclusions of the TIMSS (Trends In Mathematics and Science Study) report (1998) was that, "Teaching by lecture rather than interactive engagement may be among the significant factors limiting the quality of science education in this nation". Lectures will remain in the class though for the same reason they started: getting information from the 'expert' to the students in an efficient manner. Student's interest in the subject may make all the difference if that information gets into their knowledge base (Weld, 2002). I expect that my analysis will show moderate improvement at the initial level and retention levels with low reported control levels by the students.

Demonstrations can be a key component of a lecture program. At best they can engage students in critical thinking and problem solving skills that they can use in further experimentation (Freedman, 2000). At worst they can be a small distraction with little thought or learning attached to it with unnecessary risk. In my classroom they are used in every possible aspect of the class from inquiry activities, introduction, reinforcement, explanation of the unexpected, etc. These activities can be used to draw in students that otherwise may be lost in a straight lecture format (Trimarchi, 2002).

Even though the students predicted that demonstrations would be their best method of learning I expected it to be not the most effective on its own. I expected mid initial improvement with decent retention compared to the others even with their claiming of more control.

Traditional labs are the 'cookie cutter' labs that give the students steps and walk them through an investigation. Some have the students merely observe without much in the way of prediction or explanation while others can challenge the students to complete the steps and then explain their results. It can be argued that such a lab does little to teach the students concepts if they are not making predictions or analyzing data for themselves (Rudd, Greenbowe, and Hand, 2001). My own personal experience with such cookie cutter labs would agree with Johanna Mazlo et al (2002) when they noted that students' primary concern in such a lab is simply to 'get through it'.

In my initial years of teaching I was baffled that students seemed to have no idea what they just did in the lab as they were simply going through the steps with little thought. This observation is apparently not mine alone as some universities are removing their science lab requirement for non-science majors (Hawkes, 2004). The Hawkes article goes beyond just 'cookie cutter labs' and argues to remove all labs from the curriculum for non-science majors. Regardless of whether a lab is traditional or inquiry-based it has been shown that in isolation the learning benefit is small. The topic must be visited again in different forms to truly give meaning to the student (Sonochik-Marine, 2003). With traditional lab activities I would predict the students to feel they had more control and higher than normal growth and retention.

With inquiry-based labs I would predict the best initial improvement and if implemented in isolation (without a full learning cycle) may have higher retention scores than the other methods as well. Inquiry labs are activities in which the students take control of activities to a greater or lesser degree. These methods have been promoted since John Dewey first suggested getting out of the lecture based class format around the turn of the twentieth century. The activities that I prepared and presented gave as much control in the design, implementation, and interpretation to the students as possible within safety limits. Effectively being able to predict, design, and interpret labs such as these is a key component of producing the chemists of the next generation (Kerr and Rundquist, 2005).

A problem with such open activities, unless carefully monitored by the instructor, is that it accentuates a problem that is in every lab: some students dominating the process. With student-designed labs the designated 'smart kids' can put their ideas forward, and without much in the way of discussion, they are accepted. Lower achieving and quieter students can fall behind in understanding the concept. (King, 1993)

Any activity that can elicit critical thinking (labs, demos, lectures, etc.) will benefit the students as long as they are engaged in the process and they have control over their learning (Jacob, 2004). In this study I tried to teach all of these methods as I would normally during the course of my class. Reading is assigned without guidelines as to 'how' to read it, lectures are open to questions with a slide presentation and discussion with examples, demonstrations are used for multiple purposes, and labs are both traditional at times and very student controlled at others. Only the student-designed labs are considered inquiry for this study in regards to the pre and post activity assessment of control, mastery, and retention described earlier.

III. Scientific Background

The order of topics covered in this study roughly followed the basic outline of Holt, Rinehart, and Winston's Modern Chemistry and contains unit and chapter references going back to this work. The main focus after introduction of how to do an inquiry-based lab in the first semester took place during the Atomic Theory and Bonding unit (Unit 6) with parts of Reactions and Stoichiometry interspersed throughout (Unit 7). The time scale for this entire study was about twelve weeks covering four chapters within the units mentioned previously. Being as guilty as the majority of American chemistry instructors in trying to cram as much into a year as possible, this is one set of topics that I definitely try to extend and try to ensure that my students have a very deep knowledge of these concepts (Gold, 1988).

In teaching about the *atomic models* and *bond types* I have two main goals that I wish for my students to achieve. The first is an understanding that the atom and most of chemistry can be imagined if you picture atoms going to where they are most attracted and least repelled (corresponding to lowest potential energy given the current conditions). This helps in not only predicting if a reaction will occur but also will open up questions about the atomic model. One such question involves *why* the electrons do not simply all collide into the nucleus and why there are gaps in the 'rings' of Bohr's model. Picturing the particles in their attractions and repulsions allows the students to explain bond types, atomic structure, molecular structure, etc. I believe that once students are to this point, harder though it may be initially, chemistry becomes a simpler subject. The attractions/repulsions are followed by shielding effects and rotational energy to explain the trends in reactivity with the periodic table to give a more complete description of why atoms behave the way that they do.

The second main goal that I have during this unit is to show a much more detailed sequence of people and experiments that led to the atomic model. At each new development/experiment my class stops and imagines how this would change our current working model of how the atom looks and behaves. Beginning with an in-class debate between Aristotle and Democritus about the nature of matter and ending with Heisenberg and Schroedinger, we look at each development and how that can more accurately fit our world observations.

Walking through over two thousand years of science takes up a large chunk of class time but for the remainder of the year the students have a model in their mind of how atoms behave and why they behave as they do. Before we get to Rutherford's gold foil experiment's conclusion, we hypothesize about what we would predict would happen in this experiment given the old model with which we were still working. When our in-class model shows different results then our model shifts and we analyze how this changes our model and can we justify the change to our scientific peers.

The development of the atomic model took thousands of years to get from Aristotle's vision of the four classic elements combining to make matter to the current model, which is far more detailed than needed in a high school classroom. The development was sequential with each development allowing the next development to happen though a series of repeatable experiments and logical arguments. If this model is understood then it can be used to predict and explain chemical bonds and reactions that the student can repeat and observe in the world around them.

IV. Demographics

I teach in a class C rural school roughly 20 miles from Lansing, MI. The community is agricultural with strong ties and many of the families having been in the area for over a hundred years. The school is a focal point of community interest and we enjoy strong family support and involvement. The high school has 272 students but a total of 412 students are in the 6-12 building. Of those 272 students 16 (5.8%) qualify for special education and 23 (8.5%) qualify for free or reduced lunches. Our students funnel into the high school from the public elementary (~25%) and two different parochial elementary schools (~75%) in neighboring communities. Each of these schools ends at a different time (5^{th}, 6^{th}, and 8^{th} grades respectively) so all three groups are not together until the freshmen year each with a different collection of background knowledge and experiences.

The introductory chemistry class in this study consists of 23 students with six males and seventeen females. This is a low year for chemistry numbers as it is offered opposite of anatomy and physiology. The school has two sections of chemistry on alternating years when AP biology is offered. Averaged out, about 50% of all juniors take chemistry and about 60% take a higher science. The low number of males attempting the higher sciences has become problematic in recent years and is also reflected in our change of profile of the top ten students. All 23 students returned consent forms and are represented in the data for the study.

The chemistry class is an elective class and consists entirely of juniors following the majority of other schools in offering the Biology-Chemistry-Physics sequence (Sheppard and Robbins, 2005). With community expectations high this is not exclusively only the highest achieving students as many families push students to take chemistry when otherwise they may not have chosen to do so. As with any other class, some students were very interested in the subject, while others had difficulty staying awake during anything other than explosions.

IMPLEMENTATION

I. Building the Skills: first semester

This study took place in an introductory chemistry class for a general population junior chemistry class during the second semester. Prior to this was a time period during first semester where emphasis was put on building the students' ability to design and run a student-designed lab so that the data garnered in the second semester window would be valid. The first semester was spent introducing macrochemistry and physical traits of matter. The students became familiar with the laboratory, math, and behavior of matter as particles.

While some say that true inquiry-based activities should be student controlled in the analysis but not necessarily in the data collection (Monteyne and Cracolice, 2004), in this comparison of student control vs. performance I wanted as much control by the students as possible. They were given a challenge and basic tools then allowed to design their own activities and evaluate their own data. Each group started with a common topic and a common challenge but was free to design a method to meet this challenge.

During this initial trial period, lab design and results were anything but consistent between groups. This degree of control over their activities was not something that the students have often experienced. As an informal observation, there was definitely a difference among the ways that students' problem solving skills developed. Some were able to manipulate and adapt tools to solve some problems, but many simply waited to be shown what to do without initiative/ability to proceed.

One of these activities was an extension of an activity that they had all done with me in an earlier class in trying to discover how much of the atmosphere was oxygen (Appendix H-1). This experiment reliably shows a 20% reduction in volume of air afterwards corresponding to 20% oxygen.

In this activity I asked students to determine if this same method can be used to determine how much oxygen the human body removes from the air that is breathed in. Some groups immediately started setting up their experiments and adapting their source of oxygen from the air to balloons inflated by their own lungs before and after activities. One group tried to hold their breath to exhaustion thinking that the longer they held it, the less oxygen would be present. Other groups spent the majority of their time figuring out how to get a balloon of air into a test tube without contamination.

Another skill building design during the first semester was a methodology lab where I gave them unknown samples of phenol red, calcium chloride, sodium bicarbonate, and water. They were to determine what particular combination or chemical was responsible for different physical phenomena they observed (endothermic, exothermic, gas evolution, and color change). I gave them droppers and baggies and they were to work from there. This seemingly straightforward activity was the first student-controlled activity for the year. Beyond lab skills, the amazing observation was their lack of ability to analyze their own results. This seemingly simple activity led to very little agreement between the groups as to what combination was responsible for the different phenomena. My initial expectation was to conduct this study during the first semester, but having student-controlled activities that would provide reliable data was not possible until their lab skills were better.

Throughout the first semester the class performed a series of similar experiments related to each chapter that were designed during the previous summer. These were used to build the students' confidence and skill in developing a properly designed lab that can lead to a conclusion that they can defend. After struggling through activities on densities of sucrose solutions, separation of mixtures, and others, my efforts were finally rewarded by second quarter with phase behavior. When the students were asked to design a barometer and to calculate (and build) the world's largest possible straw, the groups came through remarkably well. Within a couple of days the room was lined with well-designed barometers that were predicting the weather. What seemed like miles of straws were ready to bring out to the bleachers to drink from two liter bottles of soda. They were designing experiments and reporting data well enough to officially begin this study in the second semester.

II. Methodology

As this study was not restricted to a single unit, but addressed activity types over several units, the format did not follow a sequential timetable of one event following another in a step-by-step activity list. However, there was a sequence of events that built upon each other. Each time the students followed the sequence of formally observed activities for the four chapters that were included in this study, their familiarity with the process should have risen. Their average performance over these four chapters with each of the five teaching methods should lead to a telling picture of how student perceived control relates to retention.

Figure 1 shows how the order of events in this study occurred for each of the four chapters and each of the five teaching methods looked at in this study. This pattern cycled a total of 20 times and the data recorded for each cycle is recorded in Appendix I.

Figure 1. Flowchart for sequence of events for each of the teaching methods studied.

Prior to activity, two questions given with one question requiring explanation to gauge students base knowledge of concept.
↓
Activity performed (reading, demonstration, lecture, traditional lab, or student-designed lab) to teach the concept.
↓
Immediately after, two different post-questions are given with one question requiring explanation to gauge immediate improvement.
↓
At same time, students asked about perception of control and mastery from activity
↓
About two weeks later, post questions again given to determine mid-term retention
↓
About two months later, students asked post questions to determine long term retention
↓
At same time students are asked to report *overall perceptions* of control and mastery by activity type

The unit where this study occurred pertained primarily to atomic theory and bond formation in reactions and focused on student retention and reported control by activity type. This study could have taken place during any series of units. The original time frame was to have been four months prior to this particular unit, but it quickly became apparent that the students needed time to develop their lab design skills before a worthwhile investigation could begin as described in the first part of this section (see previous section). This new period was chosen as a second choice due to the large amount of time that could be utilized to record short, mid, and long-term retention of information and skills that were gathered in these different activities.

Over this long period of time mid and long term retention data were only taken on the first two cycles of engaging in the five different teaching methods (Figure 1) so that there was an adequate amount of time between the activity and the final data collection. If the third and fourth cycle were analyzed the mid and long term retention data could not have been collected as insufficient time would have passed. The third and fourth cycles were used to compare their perception of control and perceived mastery. Pre and post scores for these cycles will also be compared to ascertain initial improvement.

Each of the four chapters (cycles) had five topics chosen that were fairly independent of each other, so that one activity did not necessarily have to build from another. These topics were then assigned to one of the learning activities that were going to be examined in this study: reading, lecture/notes, demonstrations, traditional labs, and student-designed labs. Prior to each chapter, students were given a packet with a set of two pre and post questions for each activity (Appendix E-2). In addition at the bottom of these questionnaires were two questions: 'How much control did you feel that you had in this activity?' and 'How well do you feel this activity helped you to master this concept?' They were to respond to these questions from zero to four, where zero would indicate no control or benefit and four would be total control or mastery (Appendix D-7).

Before each activity students were to answer two multiple-choice questions each assigned one point. One of the multiple choice questions was to be expanded upon with a 'because..' where the student was to demonstrate why they thought that answer was true. This short response was also worth two points so that each pre and post set of questions was to also be assigned a value of zero to four where zero would indicate no knowledge of the topic and four would be a complete and well detailed answer (Appendix B-8). Responses before and after instruction will be statistically analyzed using paired students t tests for a comparison and improvement ($p=0.05$ threshold).

For the first two chapters following the chapter tests the same post questions from all five activity types were again administered to check for retention of improvement based on the activity (Appendices F-1 and F-2). These were compared to the same questions administered immediately after the activity to check for retention over this time period (Figure 1). If there is a statistical difference ($p=0.05$ threshold) then retention was not strong. For these two chapters, students completed a final set of questions after the exam (Appendix F-3). After their final set they were asked for an overall impression of how much control they had on that type of activity in general and how much they felt that type of activity led to their mastery of concepts.

III. Outline of Activities

Rotating through the cycle of five different teaching methods analyzed in this study corresponded to five chapters from Holt's Modern Chemistry textbook that is used in the general chemistry class. All five teaching methods: readings, lectures, demonstrations, student-designed labs, and traditional labs were utilized in each cycle.

Chapter 3: Atoms: The Building Blocks of Matter

1. Reading: Travels with C (Appendix E-1)
2. Lecture: Development of the Atomic Model (Appendix A-1)
3. Demonstration: JJ Thomas' Cathode Ray Tube (Appendix B-1)

4. Traditional Lab: Penny Isotope Lab (Appendix C-1)
5. Student-designed Lab: Discovering Definite and Multiple Proportions (Appendix D-1)

Chapter 4: Arrangement of Electrons in Atoms
1. Reading: The Noble Decade (Appendix E-1)
2. Lecture: The Quantum Model (Appendix A-2)
3. Demonstration: The Photoelectric Effect (Appendix B-2)
4. Traditional Lab: Identifying Element Spectra (Appendix C-2)
5. Student-designed Lab: Testing Sunscreen (Appendix D-2)

Chapter 5: The Periodic Law
1. Reading: Scandal Over Elements 116 and 118 (Appendix E-1)
2. Lecture: The Shielding Effect (Appendix A-3)
3. Demonstration: Periodic Trends (Appendix B-3)
4. Traditional Lab: Reactivity of the Halides Lab (Appendix C-3)
5. Student-designed Lab: Marshmallow Electrons (Appendix D-3)

Chapter 6: Chemical Bonding
1. Reading: Ultrasonic Toxic Waste Destroyer (Appendix E-1)
2. Lecture: Valence Shell Electron Pair Repulsion Theory (Appendix A-4)
3. Demonstration: Predicting Bond Types (Appendix B-4)
4. Traditional Lab: Activity Series Lab w/ Copper & Silver (Appendix C-4)
5. Student-designed Lab: Project Twinkie 2015 (Appendix D-4)

All pre and post questions may be found in the appendix as previously discussed ((A-E)-(5-8)).

IV. Observations of Activities

A. Comments and Reflections for Reading Activities

The reading activities (Appendix E-1) leave the type of memories in my head that they probably do in the students' minds as well. Other than casual mention of 'neat' and 'cool' from the students, nothing much in the way of memorable events happened with this section. The exception may be the reading activity for chapter five dealing with Victor Nimov's false claims of discovering elements 116 and 118 at Berkley. The students were to prepare different sections of the reading as 'press releases'. Each group then described their section for the rest of the class and the scandal unfolded. The discussion that followed (after students completed the pre and post questions) showed that the students had never thought that there could be such controversy at the upper levels of academia. Some of them would admit to fudging their own data but are used to accepting information from texts and magazines as truth without questioning. This was a great activity leading them to question what they hear.

B. Comments and Reflections for the Lecture Activities

The lecture activities (Appendix A) were chosen to augment some of the more detailed and complex topics that were taught. One of the benefits of lecturing that few other methods can match is conveying detailed information for the first time to a large group of students. The first two chapters' lectures were an outline of the people and experiments that led to the development of the modern atomic model. These chapters, although very important in understanding chemistry, got old to the students. After each experiment we stopped and tried to imagine what change that would have for our atomic model. One student in particular got so frustrated with this stream of people and experiments (about 10 by the end) that she was in tears trying to keep them all straight. Most students, however, ended with a working picture of the atomic model that let them explain the later differences in behavior between one element and another.

The material in the following two chapters led to more interactive lectures with the students taking an active role after the post activity questions so that our initial change in scores could be based on the lecture alone. Their 'active role' was in modeling what they learned in lecture. Both of these later lecture applications got the students on to of their feet trying to model, using their own bodies, what they think they understood.

Modeling the shielding effect had the students acting as protons and electrons forming a walking Bohr model for an atom and a student was a roving reporter asking the different electrons how much attractions they felt and why they were in the position that they were. The VSEPR (Valence Shell Electron Pair Repulsion theory) modeling had the students stacking chairs and desks on top of each other to try to create the shapes that they imagined different number of repulsive areas around a central atom would form. This activity was one of the best understood of the entire year as it is one of those aspects of chemistry that seems to makes sense if you can make a model of it. (Appendix A)

C. Comments and Reflections for the Demonstration Activities

The first demonstration on cathode rays was high in student involvement, as they were asked to bring in cathode ray tubes from old television sets (Appendix B-1). Whenever they are told something is going to be destroyed, their interest is piqued. Once the televisions were in the class we used electricity to cause a stream of electrons that should be detected by a phosphorous detector (the screen). We verified that a charge was being formed on the screen (static shock) and that this charge was negative as well. To model if the cathode ray had mass we attempted to place a pinwheel inside of the tube (knowing that this would not work ahead of time). When the vacuum was broken to put a pinwheel inside, the students heard the air rush in and then we postulated and discussed why the television would no longer work without vacuum in place. This was one of the more interactive demonstrations of the year even if they were very disappointed with the very mild destruction of the television.

Demonstrating the photoelectric effect (Appendix B-2) was, I thought, one of the more clever ideas I had developed that fell absolutely flat for most of the class. Most of the class has photovoltaic calculators without battery backup so this was the tool that I was going to use. First the class was reasonably able to explain a model from Flinn Scientific that shows how a glow in the dark strip only glows behind some differently colored filters and not others. In discussion prior to the activity, the students were able to explain that the different frequencies of light have different energies that could or could not meet the threshold energy of the paper. When I dimmed the classroom lights and asked the students to explain what happened on their calculator screens, or at the same light levels, had different students place different colored filters over their solar panels, the activity seemed to fall apart. They were not able to explain, as a whole, why some calculators could work in dim light but not in bright light with a filter over the panel.

Demonstrating periodic trends (Appendix B-3) showed the biggest discrepancy between how well they thought they did and how well they actually did on any activity in this study. In this demonstration I chose five elements (Ca, Li, K, Na, Cs) from the first and second columns of the periodic table. The students were to observe their properties and then use this knowledge about reactivity trends in the table to determine the proper order that they would be found in the table. These elements were observed for physical properties, mixed with water and checked with an indicator to see if they formed an acidic or basic solution. After recording their observations I got *every* possible combination of orders in two columns that were possible. The correct answer did receive the most votes but the class proposed *every possible order*.

In another demonstration using student volunteers we played 'The Element Dating Game' where one atom tries to form a perfect binary compound with another atom (Appendix B-4). They chose the bond types (ionic, polar, single covalent, etc) and we tried to make a combination that would work. The other students, as the audience, voted if this would be a long term success. This activity is a lot of fun and the students remember it for a long time. It was one that I started doing my first year teaching and students still talk to me about it. It seems to be effective for those students that can describe an atom already but there are always some students that do not know the answer when the atomette asks if they are a strong or weak attractor for valence electrons.

D. Comments and Reflections for the Traditional Lab Activities

The traditional lab activities that I did for this unit corresponded with the Mazlo study (2002) in that the students' main goal was to simply finish the activity (Appendix C). They mixed chemicals and performed calculations but when questioned about the activity they seemed to learn very little from it. One apparent reason for this has to do with time. Students who are running behind are concerned with getting done on time and getting cleaned up so that they do not miss their next class. They do not necessarily understand what they are doing.

The first traditional lab involved isotopes using pre and post 1982 pennies that switched to a copper-coated zinc penny from a solid copper penny (Appendix C-1).

This lab was supposed to relate the abstract world of atomic isotopes to macroscopic items that they could manipulate and count. This change in composition caused a very real change in the mass of the penny that can be used as a model for a sample of an element with two naturally occurring isotopes. Weighing samples each type of penny gives a reliable average mass for each "isotope" that can be used with a simple formula to determine the percent composition of a sample of mixed pennies.

That simple formula took over this activity. Some students got so locked into that formula that the entire activity stopped having anything to do with isotopes at all but became a math problem. The math was little trouble for most of the students. However, this did not necessarily transfer to their understanding how you can tell the composition of element samples using the same methods.

The following traditional lab topic involved looking at spectral lines using photospectrometers and emission tubes (Appendix C-2). The goal of this activity was trying to have students connect the theory of photon emission with observable phenomenon. We had already discussed the photoelectric effect and how energy was needed to promote electrons to an excited state, from which they could fall to give off a photon of equivalent energy. I asked them to sketch what they saw for numerous elements and then we would use this data to try to explain what gaps were larger than others and to identify unknown elements.

Our photospectrometers are not graduated so the students had to estimate what frequency they were observing based on how far apart the lines were and what color they were observing. This led some students to become very confused because they did not know *exactly* how to draw the lines. This activity was one that showed good theoretical knowledge that was difficult to transfer to an everyday observation of the effect. Identifying mercury lights as containing mercury or, through discussion, determining how astronomers might 'discover' gold in distant stars were difficult applications for the students.

The following topic had them in the lab working with different solutions of the halide elements and how they would react with different other solutions (Appendix C-3). This lab activity should have shown the reactivity trends throughout the family and how they were similar in many instances but had different traits (iodine starch test for one). Sloppy lab technique threw off a few of the groups' data as contamination between their wells gave false readings. Overall, this lab did a good job of showing periodic trends in a family for those that were looking for it, but was merely observations of color changing solution for those students that were not.

The final traditional lab topic involved the displacement of silver by copper in a nitrate solution. This lab is commonly used in high school chemistry courses (Appendix C-4) to model activity series for elements. I used it as a stoichiometry activity to balance the reaction and compare the results of the lab against predicted masses using the balanced formulas and ratios. This activity also introduced the class to the word 'decant' as a few groups did not decant their final solutions with silver crystals and set our class back a couple of days while we waited for their solutions to evaporate so they could get their final masses.

This lab was straight forward "cookie-cutter" with one exception: there was not a prepared data table. With the many masses they had to record, was tricky for groups to see what they were supposed to be doing with what numbers, much less what chemistry those numbers were supposed to be describing.

Final mass measurements were suspiciously accurate for some groups with almost one hundred percent yields and very odd for others with four hundred percent yields or twenty percent yields. Overall, this lab was a typical chemistry lab where students mixed chemicals, and produced precipitations and color changes. The students were not thoughtful with getting their numbers and what to do with their numbers taking center stage.

E. Comments and Reflections for the Student-Designed Activities

The student-designed lab activities were hit-or-miss on success as some of the kids could run with these while others got bogged down with problems. This appeared to be strongly tied to how comfortable they were with the basic concepts. The first designed lab was on definite and multiple proportions (Appendix D-1). My goal was simple with this activity as I was only wanting them to understand what these two theories meant. From the beginning to the end of the year this idea tripped up many students. This was a topic set that was not only close in name but also in meaning. This confusion was compounded by it being 'merely covered' and not used as a foundation for Dalton's atomic model as it should have been.

I gave the students only a set of balances and masses with bolts and nuts. They were to use the equipment to convince other groups that the bolts and nuts could only be combined in whole number ratios, trying to convince them that matter must be in these units and not divisible (atomic). During this first student-designed lab analyzed for this study I purposefully stepped out of the lab (there were no safety concerns) into another classroom with which I share the lab. When I returned about ten minutes later, five to ten hands shot up and asking for my help. After restating what these two laws were, I left them to work until they presented their findings. This activity either did not lend much in the way of originality or the groups quickly compared data from ones that 'got it' because most of their presentations were the same.

The next student-designed lab topic was to test the absorption of ultra violet (UV) rays by different items under different conditions (Appendix D-2). This lab was meant to be an extension of the traditional lab activity on the photoelectric effect where the groups would explain the photon absorption instead of emission. Each group was to have a different item to test. The common factor was that they were all to use the same type of UV detecting card that changed color to different intensities depending on the amount of UV to which it is exposed. One group compared the different cost of sunglasses to how well they blocked the UV, another studied different sun protection factors (SPF) over the same time, another how waterproof different brands of sunscreen were, another to determine whether waterproof sunscreens were more or less effective to equivalent normal SPF values. In a late winter cold spell, one group was outside for hours comparing the water effect on their suntan lotion as they did not want to have more than one test going on in the kiddy pool at the same time!

These presentations were due one week after the challenge was given and all the groups were done with no class time allowed to work on it. I expected that this would be the most effective activity at teaching a concept and while the groups were very good at doing the comparison, few included the theory of how the UV is absorbed in their reports.

Flinging marshmallow in slings to mimic the different valence shells was the next student-designed lab (Appendix D-3). The class was already familiar with the idea of electrons being attracted to the nucleus was tied to shielding effect and proximity to the nucleus so my goal with this was to show that there were other factors that could explain reactivity. I introduced them to how the sling could model the electron spinning and then gave them the challenge of how to compare the alkali metals' valence shell in terms of energy of the electron and how hard different electrons would be for the atom to hold in. This was one of the most entertaining days to observe, as the students were in our new gym flinging stale marshmallows as far as they could.

The concept that they should have developed was that the farther the marshmallow flew when released from the sling, the more energy it had. In principle they would all be master slingers but many of the groups' data were completely unusable as they were releasing all of their marshmallows at different angles and with different speeds. This lack of consistency turned a quantitative lab into a qualitative discussion after some groups were still on their first or second element. Other groups did have sling prodigies in them and were able to complete the required tosses in record time and sat waiting for the other groups for the balance of the hour.

The final student-designed lab was my personal favorite and was inspired by the popular legend of Twinkies and cockroaches being the only two things that could survive a nuclear war (Appendix D-4). This was a straight-forward lab where I wanted the students to demonstrate a mastery of kinetics and how they can manipulate reaction rates. In studying reaction rates I asked them to prepare a Twinkie that they would preserve to eat for their tenth class reunion.

The students knew that the two ways to control a reaction rate was to either control atoms' attraction for each other, which was very hard, or control the rate at which the particles could meet, which was much easier. We discussed six different methods that this could be done and they were required to use at least four different methods to preserve their Twinkie for the ages. They were to bring in either the Twinkie itself or a picture of it in its preserved state. Motivated students would realize that combined with what the manufacturer already did for them they could simply freeze it and get their fourth method (the wrapper limits the concentration of reactants, the Twinkie is not being stirred, has a reasonably low volume to surface area, and has enough preservatives in it to inhibit most reactions).

In one of the more humorous stories of the year a student brought in a Twinkie that she had purchased the evening before in the local party store off the shelf. It was already five years expired so we opened it and those of the class that would try some enjoyed some slightly stale but otherwise perfectly edible Twinkie. This joined the Twinkie that one student preserved in a mason jar full of oil to put on my desk for future classes to wonder about and ask.

RESULTS

I. Summary of Data

Each of the five methods of teaching was utilized over a four-chapter window that occurred during second semester dealing mainly with atomic theory and behavior. My expectation was that there would be an increase in pre and post activity scores for all methods immediately following an activity and that retention would be similar for all activities as a learning cycle was completed for each topic. I predicted that the students' recorded perception of mastery and control for each activity would not be related to actual retention but would that students' perception of mastery would be linked to their perception of control. All scores on the pre/post activity questions as well as the student reported control and perceived mastery questionnaires are based on a zero to four point value. All data are used for mid and long term retention for students that had both scores recorded. Immediate post activity data was not used if both the pre and post scores were a four as no improvement could be reflected in this score (Appendix I).

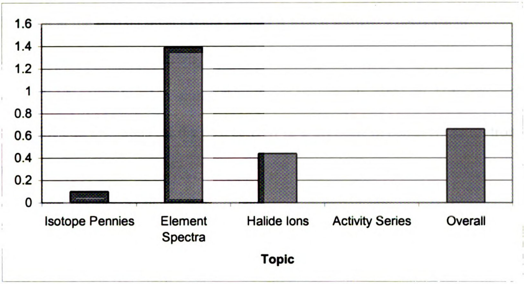
A. Immediate Pre and Post Activity Score Results

All rubrics for all activity evaluations are in the appendices (A-F) along with all raw data (Appendix H).

a) Traditional Lab Scores

The traditional lab activities and the total of all traditional labs all showed a statistical increase at the $p=0.05$ level using the student t test except for the isotope lab topic from chapter 3 (Figure 2). The topic on activity series from chapter 6 data are not included due to the students not being instructed to do the pre questions prior to the assignment.

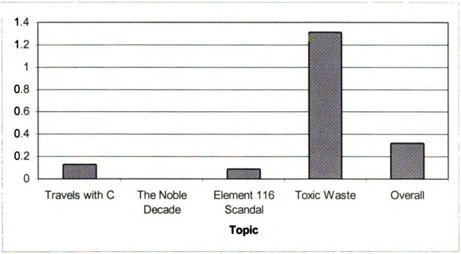
Figure 2. Average change in pre and post scores of compiled traditional lab scores.



b) Reading Scores

Figure 3 shows in the reading scores only the chapter 6 topic on toxic waste and the average showed a statistical difference between pre and post scores at the p=0.05 level to indicate improvement. The chapter 4 topic on the noble gases indicates zero improvement as the averaged score for the class and not as a missed score.

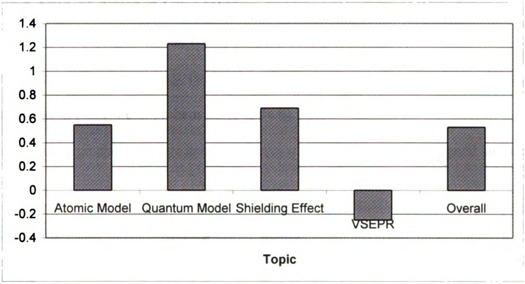
Figure 3. Average change in pre and post scores of compiled reading scores.



c) Lecture Scores

All immediate pre and post lecture differences (Figure 4) were statistically different at the p=0.05 level except chapter 6 which showed a decrease in comprehension after the activity. The chapter 6 reading activity on VSEPR modeling showed a decrease trend in scores, though not statistically different, indicating either more difficult questions for the post activity or a decrease in comprehension from the activity.

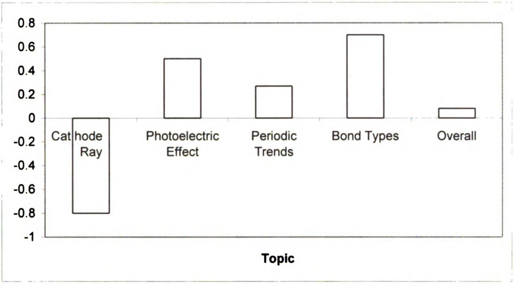
Figure 4. Average change in pre and post scores of compiled lecture scores.



d) Demonstration Scores

With the demonstrations only the chapter 4 topic with photoelectric effect showed a statistical increase in student scores after the activity. Topics for chapters 5, 6, and the average all are not statistically different and the topic for chapter 3 on cathode ray showed a statistical decrease in scores. (Figure 5)

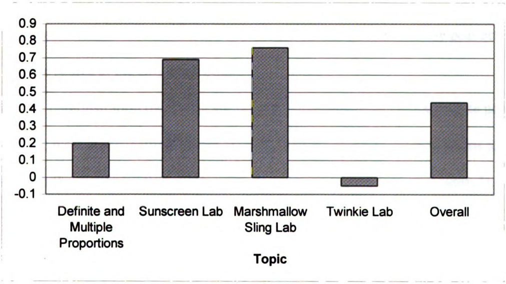
Figure 5. Average change in pre and post scores of compiled demonstration scores.



e. Student-designed Lab Scores

Topics for chapters 3 and 6 on cathode rays and bond types do not have a statistical difference at the p=0.05 level. The Twinkie Lab shows a non statistical decrease in student comprehension (Figure 6).

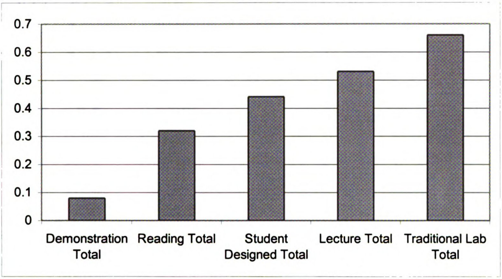
Figure 6. Average change in pre and post scores of compiled student-designed lab scores.



f. Summary of Pre and Post Score Difference for Activity Type

Taking only the average scores compiled from Figures 2-6 the overall comparison can be seen from the methods (Figure 7). Only the demonstration total is not a statistically significant improvement at the p=0.05 level.

Figure 7. Comparisons of Average Pre and Post Score Improvement by Method



B. Comparisons of Mid and Long Term Retentions

Figure 8 shows mid term retention for the topics from chapters three and four. Retention was determined if there was no statistical difference between the post activity score and the scores at the two week point.

Only the demonstration data, with strong growth compared to the immediate post activity data, were statistically different at the p=0.05 level. This retention seems to contrast with the demonstrations having the lowest initial improvement (Figure 7). The more passive methods (reading and lecture) showed a decrease trend in mastery.

Figure 8. Comparisons of mid retention for all activity types.

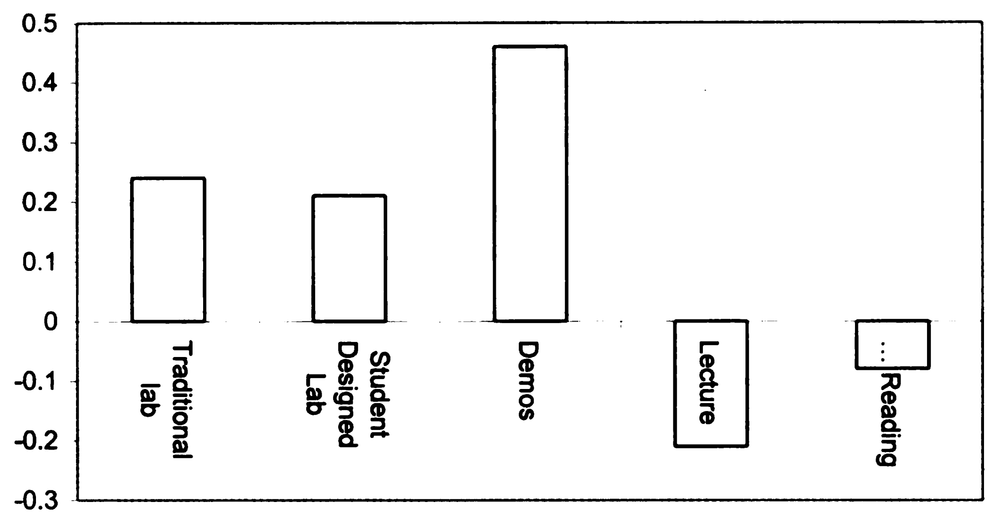
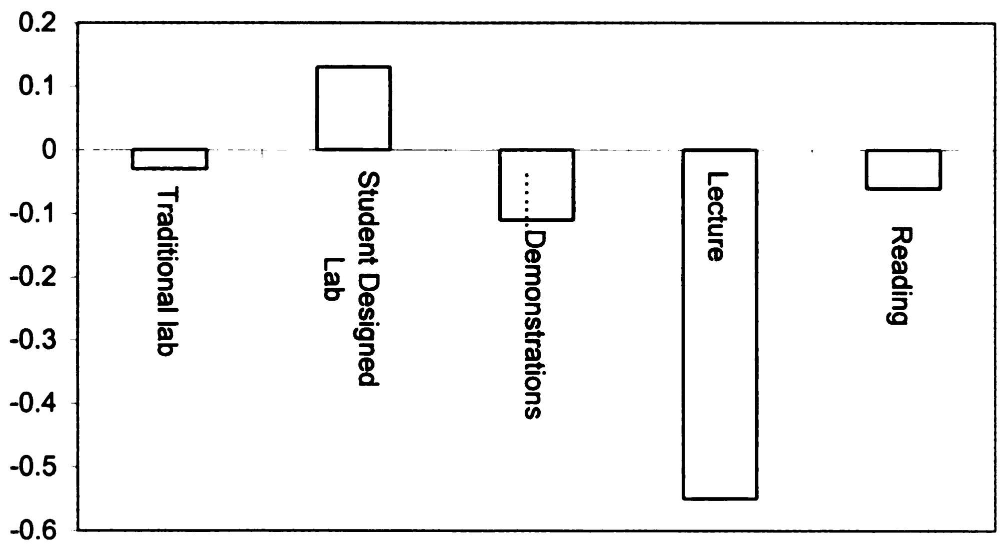


Figure 9 shows the long term retention, about two months after the initial activity. Only the lecture showed a statistical drop in retention at the p=0.05 value. The student-designed lab is the only method that held an improvement in scores over this longest time period.

Figure 9. Comparisons of long term retention for all activity types.



C. Student Reported Control and Mastery of Concepts

Figure 10 shows the averaged amount of control of their learning reported for each of the twenty different activities that were analyzed for this study.

Figure 10. Comparison of total average amount of reported control for activities.

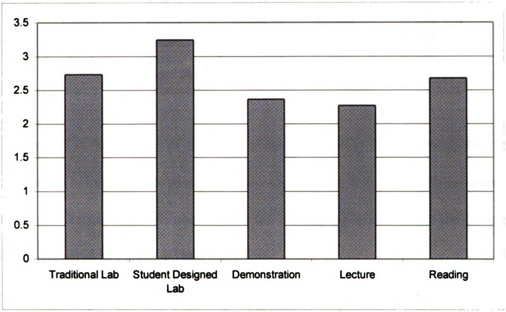


Figure 11 shows the amount of control of learning that the students reported that they had after the final exam. These scores show that their overall impression on the activity type in hindsight rather than looking at each activity as it occurs. The trend for the individual examples is roughly the same, with the exception of demonstrations. They remember having much less control over demonstrations than they reported when they occurred.

Figure 11. Comparison of overall perception of control by activity type.

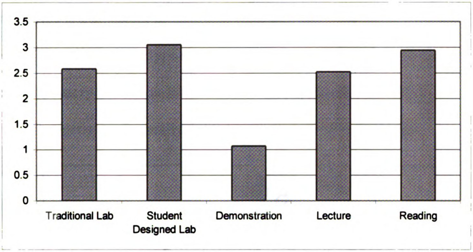


Figure 12 is the average of all of the students' reporting for how much they felt each activity helped them to master the concept of an activity. Student-designed lab is the lowest reported and demonstrations are the highest in contrast to the control of learning reported in Figure 10 and Figure 11.

Figure 12. Comparison of total average amount of reported mastery for activities.

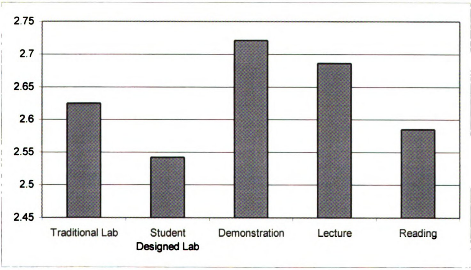
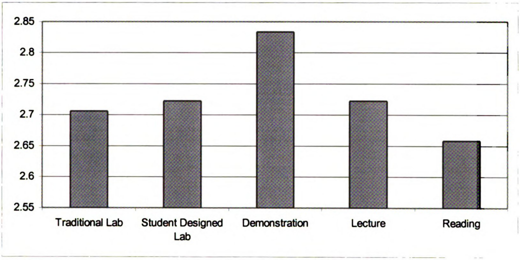


Figure 13 shows the amount of mastery that the students reported at the final exam. This is a hindsight reflection of how well each type of activity helped them master. The only activity type that had a noticeable change from the immediate reported mastery is student-designed labs which have risen over time.

Figure 13. Comparison of overall perception of mastery by activity type.



Figures 7-13 can be summarized in the following tables.

Table 1. Comparison of percentage improvements in pre/post scores by activity.

Activity	Traditional Lab	Student-designed Lab	Demos	Lecture	Reading
Percent Increase	17%	11%	2%*	13%	8%

* No statistical increase in pre and post scores

Table 2. Summary of retention data.

Method	Traditional Lab	Student-designed Lab	Demo	Lecture	Reading
Mid Term Retention	6%	5.3%	11.5%*	-5.3%	-2%
Long Term Retention	-.5%	3.8%	-2.75%	-14%*	-1.25%

* Show a statistical change so loss of retention if negative and retention if positive

Table 3. Summary of perceived control levels for activity types.

Method	Traditional Lab	Student-designed Lab	Demo	Lecture	Reading
Average of each activity	2.7	3.2	2.4	2.3	2.6
Overall Impression	2.6	3.1	1.1	2.5	2.9

Table 4. Summary of retention and reported mastery levels.

Method	Traditional Lab	Student-designed Lab	Demo	Lecture	Reading
Initial % increase in pre	17%	11%	2%	13%	8%
Long Term Retention	-.5%	3.8%	-2.75%	-14%	-1.25%
Average mastery reported for each activity	2.63	2.54	2.73	2.68	2.58
Overall impression of mastery by activity type	2.71	2.72	2.83	2.72	2.66

Table 5. Summary of reported mastery and control levels.

Method	Traditional Lab	Student-designed Lab	Demo	Lecture	Reading
Average of reported control for each activity	2.7	3.2	2.4	2.3	2.6
Overall impression of control by activity type	2.6	3.1	1.1	2.5	2.9
Average mastery reported for each activity	2.63	2.54	2.73	2.68	2.58
Overall impression of mastery by activity type	2.71	2.72	2.83	2.72	2.66

DISCUSSION

I. What activity type has the best initial gains?

My initial prediction was that the inquiry-based activities would have a higher initial improvement between pre and post activity scores over the more passive activity types. Figures 2-7 show that this was not case. Table 1 summarizes these data and shows, surprisingly, that the lecture had a higher initial increase in post activity scores than did the designed labs. Traditional labs showed the highest overall improvement, even with one of the individual labs of this type having a static growth level. The lecture scores were higher across the board, except with the topic of VSEPR geometry that actually showed a decrease in comprehension.

The most surprising finding to me was that the lowest improvement came not from reading but from demonstrations. The small overall growth with only one demonstration activity having statistically significant improvement showed that as many students were going down or flat in their comprehension as were improving. One interpretation is that much of the class put away their learning for 'the show' and were not actually thinking about what they were observing. Even with an average improvement of 12.5% (Appendix I-2) in scores associated with the photoelectric effect demonstration with solar calculators, there still was not an overall statistically significant difference. This suggests that many students also went down to counter the ones going up in retention. Prior to the study the class indicated demonstrations was their best learning activity. In fact, the data suggest that this activity is the least helpful. My conclusion is that I have to redo how I use demonstrations to turn them into problem solving activities with the students explaining and predicting rather than watching. I believe that they originally answered by indicating which type of activity they enjoyed the most rather than what activity was most helpful in their learning.

My initial supposition that student-designed labs would show the best initial gains was not validated by the data (Figure 7). The reason for this, judging from students' responses and my personal observations during the student-designed labs, was that success was linked to their understanding of the basic concepts prior to their investigation. As described earlier, their confusion in the initial activity on the laws of multiple and definite compositions can be seen in the improvement scores for this activity (Figure 5). The next two topics with student-design activities had very strong improvements, but I cannot explain why the Twinkie lab fell flat when this was an activity which the students seemed to both enjoy and understand. Looking at the scores does show that this activity started with the highest initial scores of any activity but that does not explain the initial drop in scores rather than at least a plateau.

II. What activity type has the best short and long term retention?

Retention was examined at two different points in the study. The mid term retention was the equivalent of when a test would usually be at about two to three weeks past the activity. The long term retention was observed about two months after the activity after the final exam for the year. My initial idea was that learning retention would plateau for all teaching methods as more activities were done with most of the concepts. The students should all have similar experiences for each concept regardless of what teaching method laid the groundwork. This hypothesis was not supported. Only lecture activities had a statistical change from initial post scores with a strong drop of about 14% (Figure 10) over the long term period. The rest of the activities were statistically the same at the p=0.05 level even though the averages may have gone up or down.

Scores for long term retention (Table 2) had the most surprising result for me. I did not expect my data to agree with what the literature suggests in stating that departing from the lecture to more student-designed inquiry activities pays off in long term student retention (Lewis and Lewis, 2005). The initial confusion students had with designing labs described earlier led me to question their overall effectiveness.

At the mid retention level (Figure 7 & Table 2) the activity-based methods (demonstrations, traditional labs, and student-designed labs) all had an increase in scores while the passive methods (reading and lecture) showed a drop in scores. The more active methods must have been a benefit as an example in their minds to explain the concepts that came later while the lecture and reading that were not followed by demonstrations, did not.

Lecture is the only method that showed a statistical change in retention and it was a strong average drop. Only student-designed labs showed an improvement in retention over the long term, with the remainder of the activity types showing a non-statistically significant decrease. The two aspects that I did not predict were the large decrease in reading scores (Figure 9) and the student-designed labs showing the only increase in retention scores over this period as discussed earlier. Overall all methods except lecture did show some retention over the long term.

III. What correlation is there between student-perceived ownership and retention?

My initial prediction was that there would not be a correlation between student-perceived control and retention. Retention scores related to Figures 8 & 9 are shown in Table 2.

As predicted, the students did record the most control over the student-designed lab activities, but surprisingly, reading was reported as second in a virtual tie with traditional labs. I thought that reading would have a low amount of control reported by students, however demonstrations were reported as the lowest amount of control that they felt they had. This is the point in the study where I had to look at my own data set three times before I could see it. When arranged from one to five, where one is the highest retention level and five the lowest, these rankings match up perfectly between long term retention and average amount of control reported by students for each activity. They align even with the students reporting high levels of control for reading and low levels of control for demonstrations. The differences between the levels are not great but this relationship does exist.

IV. What correlation is there between how well a student actually did and how well they perceived that they did?

I expected a direct relationship between how well students perceived they did on learning concepts and how well they actually did learn. The data summarizing retention and student reported mastery is shown in Table 4.

Demonstrations again showed the most interesting data. Students said that demonstrations were the most effective in teaching the information (Table 4) but the pre and post scores indicate demonstrations were the *least* effective teaching method

(Figure 7). This contradiction is hard to explain other than, once again, the students are confusing enjoyment with learning.

The student-designed lab data also showed a unique switch, in which the initial mastery was reported as low and the initial increase was only in the middle of the pack of scores. However, over time the retention rose to first place and the students' overall impression of mastery rose to second. These activities must have a shelf life where they have to sit in students' brains and ripen for a while to be appreciated.

V. Is there a correlation between how much control students feel they have and their own perceived mastery of the concept?

I did expect a correlation between how well students perceived they did and the amount of control that they reported having. The data are summarized in Table 5 and range from 0 to 4 where 0 is no mastery or control and 4 would be reported complete mastery or control..

The numbers for mastery reported are so close that it leaves the impression that the students were simply putting numbers down regardless of the activity type. If the small differences are ignored and ranked, no pattern between reported control and mastery is noticeable. One interesting aspect is the change in the student-designed lab information. The students reported having the most control for these activities but gave it their lowest amount of perceived mastery immediately following the activities. By the time of the final questioning, their impression had shifted to their ranking it second in overall effectiveness at learning the concept.

The exact opposite happened with the demonstration scores. The class reported low amounts of control but then followed by ranking them the most mastered in both the average mastery scores and overall impression of the activity type. These data indicate that there is an *inverse* relationship and that taking away control makes the students feel they have mastered it. This would be interesting to study, as with low control, students probably do not have question how much they actually learned from the activity.

VI. Overall Impressions

My closing impression for this study is that I have major changes to make in my teaching methodology. Almost every prediction that I made in this study was not supported by my analysis. Students reported demonstrations as the most beneficial type of activity and on inspection they turn out to be one of the least beneficial. The students enjoy demonstrations and so do I, but it is apparent that these must be made to be more inquiry-based activities where the students have more control. The cathode ray tube demonstration could be changed where the students try to recreate the experiment that JJ performed with his expectations rather than just being told that we were doing so (Appendix B-1).

The lecture activities had decent increases in initial pre/post scores but without further examples, were not helpful in terms of long term retention (Table 2). I have worked hard over the past years to develop engaging lectures but I find myself in the same position as Richard Feynman: test scores are not improved from lectures and demonstrations alone.

In balancing the different types of teaching methods, I will increase the total amount of control in learning that each student has. Varying teaching methods with consistent student control has been shown to increase learning in all types of learning styles (Matthews, 1996).

My final impression from this study is that student control of their learning does have an impact in long term retention and improved scores (see student-designed activities). The struggle and confusion in the beginning that I observed and that the students reported faded with time, and become lasting learning that they will take out of my class.

VII. For Further Study

This study left some unresolved questions for me as an investigator. After a year of effort I am examining aspects of my teaching that I could improve and expand upon. Some of the inconclusive statistics may be due to inconsistent question difficulties in pre and post questions for the activities. Maintaining consistent questions and topic depth across all of the activities may change the outcomes of this study.

As shown in the data set (Appendix I) not all of the students consistently reported or turned in their data for every activity. Not wishing to have scores for the class attached to this project had an adverse effect on some students turning in their data. Our school policy is also that students may opt out of one final exam if they have at least an A- average for the semester. Having the final data set after the final exam led to 5 of the students with the highest average for the class not reporting with their final data set on long term retention. A larger student pool may have minimized this effect.

Adding student control and inquiry aspects to any teaching method is possible. Doing this study again in the future, after I have optimized my classroom with as much inquiry and student control as possible, would provide an interesting comparison. Would active reading that gives students more control of their reading change their results? Would lectures that require their constant input and participation affect the outcome? These are questions for another study and another time for which this study has laid the ground work.

Appendix A-1: Chapter 3 Activity w/ notes and discussion on Development of the Atomic Model

Note: The slides have been omitted for clarity and may be obtained by contacting the author.

The first slide is just an introduction that we will be using a developing model that we will be changing as a class as we walk through the information. Old model→ new data/experiment → discussion of how this changes our model if at all → new model if appropriate.

This slide merely sets the stage for one of Newton's quotes.. "If I have seen farther than others it is merely because I have stood on the shoulder of giants". I wanted to show that this knowledge did not appear out of nowhere but it was a series of advancements that built upon each other.

Most books begin with Democritus because he was the 'father' of the atomic model. I wanted to set the stage for the fact that there is usually competition for ideas in science. What evidence did each have? What was more convincing? Whom would they believe?

Democritus I wanted to show was a typical man that could afford to think such things..wealthy with plenty of leisure time. His ideas were not based on facts so were not theories but just ideas. I also wanted to stress (again) that this was a passing of ideas from one person to the next. We discussed the modern view and what is still accepted and what is not from his model.

Alchemy is an often overlooked part of chemistry (ours doesn't even mention it in this context) but is very important. I wanted to challenge the students if you can get 'good' science when you don't even understand what it is that you are doing. Is it only science when someone later explains your results?

Henry Cavendish was presented as one of the Jack of all trades scientists that were common during this period. He made some great side stories (bashful to the utmost extreme and his experiments with measuring capacitance with pain, etc). What we focused on was how the realization that water could be formed from hydrogen (and oxygen) would affect our model (Aristotlean and Democritus').

Lavoisier was a great man to know about not only from his theft of others' works (scientists are just as human as anyone else) as his work with the law of conservation of mass.

Joseph Priestly is noted just as another example and more for redundancy and to show a larger picture of the model's development. I did not require the students to know his achievements.

John Dalton is the culmination of this part of our modeling. We are left without knowing about the nucleus or the electron shell but we do have an atomic model that can be firmly described and backed with evidence. How did this model come to be? Back up each statement with evidence from other experimenters.

Time allowing it is always good to show the experiments that these men were performing but as this section is only about the notes and not actually seeing it this will be discussion only.

Appendix A-2 Chapter 4 Notes w/ Discussion: The Quantum Model

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Note: The slides have been omitted for clarity and may be obtained by contacting the author.

This is not mentioned in the text at all so was a good starting point for this 'notes' section as it is the only possible place for them to get this information.

The main ideas I am trying to get across here are that all matter is really wave-like in nature so it should not be a big surprise that electrons are as well. And for them to think their way to the next level of what this means for the nature of the atom.

Although this section is in the text it is not anywhere to the same level. It is treated more as a 'take it or leave it' without having the students think through any of the ramifications for themselves.

This is a very familiar term to people but how many chemistry teachers truly understand its implications? I want the students to tell me what the principle is *before* the notes do.

This is just where the principle is just given but at the same time I want them to visually (in their minds' eyes) how a photon (particle light) would interact with an electron (wave particle).

We will likely also get up and model this as well at this point by having the students run around as the electrons, protons, neutrons, and photons. Maybe we will add some gluons in there as well as they know about the strong nuclear force already.

Although I will *definitely* not bring the actual equation up I will state what it did for the model of the atom. It used wave nature to correctly describe where particles would be (thus verifying de Broglie's theory again).

Max Planck's correction of Schrodinger's own equation's meaning will also be a good discussion point for them. These people are geniuses but not perfect!

The finish of this section will be with the atomic model that we have now (I will save molecular orbitals until we get to the reaction sections).

We will as a class wrap up everything that we have done and where it has all come from all the way from Democritus, Aristotle, et al.

Appendix A-3 Notes with Discussion for Chapter 5: The Shielding Effect

Note: The slides have been omitted for clarity and may be obtained by contacting the author.

The shielding effect is to me one of the most important reasons for the cause of periodic properties. My goal is after they have relearned this effect (from freshmen year) they will be able to predict the trend direction of the periodic properties across the table before they are told them (ionization energy, electron affinity, etc.) The book barely mentions this topic so all of the information that they have on it will be either 2 years old from freshmen year or just from this section of the notes.

With this slide I wanted to have them rethink that it is only the valence electron behavior that causes chemical activity and most of what we think of with properties of an element.

With this slide I wanted them to brainstorm what determines how strongly an element would attract its valence electrons. It goes back to what I have stressed all year as to what causes the majority of chemistry: negatives attract positives but are repelled by other negatives.

After they brainstormed what would cause a shielding effect it is time to look at the culprits. Of course, in class I used some reference like you want to get to the cookies but ogres are in your way. So is it worth it or not? The ogres are playing the part of the shielding core electrons.

I had them break out their old Bohr modeling skills (again from two years ago when I taught them as freshmen) and we predicted the shielding attraction for valence electrons going across the period. We then did the Bohr model and physically looked at the attractions/repulsions for each element to verify the trend. Finally, we looked at a property to explain it with the trend.

Doing the same thing down a row we noticed that they all had identical shielding attractions within the first group (and every other group). When I asked them if they all had the same attractions though they were very good about pointing out that distance would also play a role and correctly analyzed what that role would be.

Appendix A-4 Notes with Discussion for Chapter 6: VSEPR Theory

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Note: The slides have been omitted for clarity and may be obtained by contacting the author.

With this introduction slide I wanted to just simply have the students realize and picture that these molecules are taking up space in 3 dimensions and that they are there for the same reason as always: - repel – and attract +

In this slide I ask the kids to try to break down the VSEPR into what this is actually telling us. They get fairly quickly that it simply means that it is a theory that tries to explain how these electrons try to get away from each other. This makes general sense as we try to start to predict shapes based on how many areas are trying to repel.

With this slide they get their first taste of some of the odd names that these shapes have. We try to figure out how many areas are repelling to form each shape from the central atom.

This is a simple application that is an extension of what we just talked about. What would be the result of lone pairs on the central atom to the molecular shape? The one additional question here is do the lone pairs take up more or less space and why that would be true.

One last application/practice/discussion to predict both the orbital shape and the molecular shape

Appendix A-5 Pre and Post Questions for Chapter 3 Notes

Instructions: Please respond to the following questions before we take the notes. Be sure to mark your two selections as well as to briefly explain your logic to the one response. After the notes please conclude by answering the final two questions with your logic response.

Pre Questions:

1. Which best describes the development of the atomic model?
    a. The atomic model was developed in ancient times through scientific experimentation and reasoning.
    b. The atomic model was developed in the middle ages by the alchemists in their search for turning base metals into gold.
    c. During the Renaissance when people realized that they could find meaning in nature and began to actively pursue 'universal' truths.
    d. The atomic model is a recent development (last 200 years or so).

2. When Lord Cavendish fist combined hydrogen and oxygen to make water, what happened to the atomic model?
    a. The continuous view of matter was justified.
    b. The atomic nature was justified.
    c. Both were justified.
    d. Neither were justified.
    Because...

Post Activity Questions:

1. What time period showed the greatest advancements in the atomic model?
    a. Colonial Times (1700-1800 AD)
    b. The Rennaisance (~1500-1600 AD)
    c. Dark Ages (~400-1400 AD)
    d. Classical Greece (~500-300 BC)

2. When Lavoisier demonstrated the law of conservation of mass what did it do to the atomic model?
    a. The continuous view of matter was justified.
    b. The atomic nature was justified.
    c. Both were justified.
    d. Neither were justified.
    Because...

How much control do you feel you had in this activity? 0-4 ___
How well do you feel that you have mastered this concept? 0-4 ___
Pre: 1) d 2) b, things are combining that shows a basic unit (non continuous)
Post: 1) a 2) b, if mass is conserved after things break apart then the parts must all still be there but separated (non continuous)

Appendix A-6: Pre and Post Questions for Chapter 4 Notes Activity

Pre Questions:

1. Using fundamentally common sense there is an error with the Bohr model, what is it?
    a. The atom does not contain neutrons into account
    b. The atom is placed in 2-D space rather than 3-D
    c. Gravity would actually pull the electrons away from the nucleus toward more massive objects.
    d. His model ignores all the data from previous experiments
2. If you look around the room what do you imagine is not true at the small level of matter?
    a. Everything is vibrating because they are all really energy waves
    b. Although it looks solid everything is essentially just empty space
    c. Everything is really just a teeming mass of atoms held together with simple attractions
    d. Everything you see is fleeting as it will decay into hydrogen again one day

    Because....

Post Activity Questions

1. According to Louis de Broglie you cannot treat electrons like planets around the sun because...
    a. Electrons do not get affected by gravity
    b. That ignores their wave nature
    c. They are too small and too close to the nucleus for that to have effect
    d. There simply are too many electrons for a model like that to be feasible
2. The Heisenberg uncertainty principle states that...
    a. You cannot truly know anything about the electron
    b. You cannot know an electron's speed and location at the same time
    c. The orbit of the electrons follow specific paths around the nucleus
    d. You can never be truly certain about anything

    Because...

How much control did you feel that you had over this activity? 0-4 ______
How well did you think you learned this topic? 0-4 ____

Answers: Pre: b, d because...there are many acceptable ways to answer this.
Post: b, b because if you interfere with it using a photon the photon will affect its motion/position.

Appendix A-7 Pre and Post Questions for Chapter 5 Notes

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1. What element has a stronger hold on its valence electrons than the others in the list?
    a. Nitrogen b. Bismuth c. Arsenic d. Antimony

    Because....

2. What element has a stronger hold on its valence electrons than the others in the list?
    a. Sodium b. Aluminum c. Phosphorous d. Chlorine

    Because....

Post Questions:

3. What element has a stronger hold on its valence electrons than the others in the list?
    a. Oxygen b. selenium c. Tellurium d. Polonium

    Because....

4. What element has a stronger hold on its valence electrons than the others in the list?
    a. Lithium b. boron c. beryllium d. Neon

    Because....

---

1. **How much control did you feel that you had in this activity? 0-4 _____**
2. **How much do you feel you benefited in this concept from this activity? 0-4 __**

Answers: Pre: A,D explain shielding patterns
Post: A, D explain shielding patterns

Appendix A-8: Pre and Post Questions for Chapter 6 Notes Activity

Pre Questions:

1) Which sketch would accurately show a central atom with 2 terminal atoms and 2 lone pairs attached to it? (Circle it)

2) What determines the shape that a molecule will have?
   a. The number of valence electrons it has
   b. The number of atoms that it has
   c. The number of electron pairs and bonding pairs around an atom
   d. It is random.

Because....

Post Questions:

1) Which of the above shapes would accurately be described as tetrahedral with 4 bonded pairs from the central atom? Draw a line to it.

2. Which type of bonds would be most likely to rotate on the central atom?
   a. C-C b. C=C c. C (triple bond) C d. C (quadruple bond) C

Because...

Amount of control I felt I had in this activity? 0-4 ___
How well I felt this activity taught this concept? 0-4 ____

Answers: Pre: (bent),c because of repulsion of pairs
Post: (draw to tetrahedral), a because not locked in place

Appendix B-1 Chapter 3 Demonstration Activity: JJ's Cathode Ray Tube

Demo Activity Outline: JJ Thomson's Cathode Ray Tube for Chapter 3

Every classroom has a cathode ray tube in it w/ a phosphorous detector already in place, otherwise known as the television. This will occur after an introduction to the experiment and its findings so they should already know the results. We will evaluate his findings using our own device.

1) Can we generate a cathode ray using a voltage source?
2) Can we create a detector that will allow us to see this cathode ray?
3) Is the vacuum in the tube important to the transit of these cathode rays to our detector?
4) Can we manipulate ours to move a paddle wheel and demonstrate that it has mass?
5) Can we use our detector to detect the charge (+ or -) and the charge to mass ratio of the particle?

1. This is an easy one for the kids to see. Plug it in.
2. Also an easy one for the kids to see and discuss. A picture shows up. Discuss at this point that we don't know why the light appears just that it does (does this make the conclusion justified?)
3. We need a volunteer sacrificial television for this as the seal will need to be broken. Discuss the results and what this says about the cathode ray.
4. The answer to this one will be 'no' but the kids will see that only after we do number 3 but it will offer insight into what Thomson's lab had to do to gather his results.
5. Magnets will be used here to look for a difference in effect when the north and south magnetic poles are brought near a projected dot on the television screen. Magnets of varying strengths can be used to check the effect and discuss how this could give the charge to mass ratio (do not do the math)

Materials:

1) a classroom television
2) a computer or videotape that can project an image of a single dot onto the screen.
3) A sacrificial television that will be destroyed in step 3.
4) Magnet(s)
5) Ruler to measure the deflection.

Appendix B-2 Chapter 4 Demonstration Activity: The Photoelectric Effect

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Goal: That each student will see the dual nature of the photoelectric effect both as it relates in its classic nature as only light that passes the 'threshold frequency' will excite the electrons in the sample but also that those same atoms when excited will give off light of only a certain frequency as well (that we can detect with our naked eyes).

1. Introduce the challenge of how a solar panel works.
2. Ask for comments on when these solar calculators work and when they do not. They should easily get that they do not work in the dark or in the dimming light when the overhead is on.
3. Try to find the threshold on brightness and why this is.
4. Briefly outline how a solar panel works in terms of photons knocking electrons loose. I want them through this point of the discussion to get to the point that even in darker lights there are still electrons being knocked across but there are no longer sufficient numbers of these to generate enough voltage to run their calculators. Observations that lead to this? It can still calculate even when it does not show the display and that the display slowly fades out.
5. Now to the challenging part. Does the frequency of light matter? And if so why? Bring out the glow in the dark strip that is covered in different parts by different colored filter papers. Be sure that they understand how this works. Discuss plants and photosynthesis that they absorb the blues and not the greens. Relate story of a farmer who used green gels to only allow green light to his plants, what happened?
6. Try to rig up a similar method of testing the calculator where we will still have bright light but just different colors of that light to check for the solar calculator to work.
7. Discuss the results.
8. Try to come up with a working model of how this is.

9. Final check for understanding on this: Have students explain how an 'invisible' ink pen works in UV light and how they can cast their shadow that stays on glow in the dark paper. I usually rig a series of 9 sheets of glow in the dark paper on the overhead and have them do an Alfred Hithcock impression in front of the overhead to create a semi-permanent shadow.

Appendix B-3 Demonstration Activity for Chapter 5: Periodic Trends

This demo is modeled after 'All in the Family' from A Demo a Day II and 'Introducing the Periodic Table with Sodium' from A Demo A Day I. I will be asking them to get out index cards and to note the properties of various alkali and alkaline earth metals (w/o knowing this). They will know that there are two groups represented. Their task will be to try to use their shielding effect knowledge and properties of the elements to correctly place them together in the same families in the correct order.

a. Show them the elements and have them record what properties that they may on their cards for each element from observation alone.
b. Cut them with a butter knife to reveal the shiny interior and the quick corrosion. Again have them record the properties they observe.
c. Place the calcium, lithium, sodium, potassium, and magnesium into water and check for reactions that way.
d. Add a small amount of indicator to check for the pH or use pH paper to check for change.
e. Add the magnesium and calcium to hydrochloric acid (3M solution) and check for that reaction
f. Have them try to order and justify their ordering on paper (turn in)
g. Discuss the class results and look for a consensus to compare against the real table.

Appendix B-4 Chapter 6 Demonstration Activity: Predicting Bond Types

This demonstration went back to reflect on an activity that I did with these students their freshmen year. In that activity I had certain students take on the persona of an atom of a specific element. They had already done Bohr models and touched on ion formation and bond types. We played 'The Atomic Dating Game' where I ripped off the role of Chuck Woolery and had them ask each other questions like, "Atom number 3, I am looking for one electron to fill my valence shell. Would you be willing to give me one of yours or are they held too tight to your nucleus?"

We had a retro lesson for them as we brought this back with (hopefully) much better questions and more proper alignments to try to form a 'perfect bond'. This time we added polar bonds as well to the mix to try to determine if that added piece of information would have an affect on who they chose to bond with.

Appendix B-5: Pre and Post Questions for Chapter 3 Demo

Pre Activity Questions:

1. If an unknown moving particle is put into a positive magnetic field which of the following is true? If the particle's path bends…
   a. toward the magnet it is positively charged.
   b. away from the magnet it is positively charged.
   c. toward the magnet it is massive
   d. away from the magnet it is not very massive

2. If you discovered neutral atoms contain very low mass negatively charged objects, what else can you determine?
   a. Atoms must also contain high mass particles.
   b. Atoms must also contain positively charged particles.
   c. Atoms must also contain neutrally charged particles.
   d. None of the above can be determined.

   Because…

Post Activity Questions:

1. In a television set the electron gun is aimed with.
   a. Negative magnets attracting the electrons
   b. Positive magnets attracting the electrons
   c. Magnets have no effect on electrons
   d. Electrons have nothing to do with a television picture

2. A working model of the atom based only on the information available to JJ Thomson would be
   a. A solid sphere composed of light electrons and heavier protons.
   b. A solid indestructible sphere.
   c. An atom with a nucleus in the middle containing protons and a cloud of electrons around it.
   d. An atom with a nucleus in the middle containing protons and neutrons and a cloud of electrons around it.

   Because…

Amount of control that you feel you had in this activity? 0-4___
How well do you feel that this activity helped you to master the concept? 0-4 __
Answers

Pre: 1) b 2) a&b, because to cancel the – e you must have a + that also accounts for the mass of the atom
Post: 1) b, 2)a, all we know is that – and + exist but our model still holds as tiny indestructible spheres.

Appendix B-6: Pre and Post Questions for Chapter 4 Demo

Pre Questions:

1. A solar panel obviously produces electricity by light falling on it. This works..
    a. through the light's heat
    b. through the light's intensity (brightness)
    c. through the light's frequency (area of the electromagnetic spectrum)
    d. through the light' electric field.
    Because....

2. Many dorm rooms have 'invisible' ink on the walls (toothpaste or detergent) that look invisible in regular light but 'glow' under a black light. This is because..
    a. The ink's electrons are absorbing one frequency of light and giving off others.
    b. The black light is warming the detergent so much it glows.
    c. The black light is providing the energy for a chemical reaction to occur.
    d. The black light reflects off our eyes in a way that allows us to see the detergent.

Post Questions:

1. If you provide light to a photoelectric cell (solar panel) that is of very low frequency but very bright. What do you think will occur?
    a. No voltage will be produced
    b. Voltage will be produced.
    c. Voltage will occur if it is bright enough but only then.
    d. The photo cell will absorb the light and through photosynthesis create the electricity.
2. Dayglow shirts is a brand name for a type of fabric that is the extremely bright pinks, oranges, greens, and yellows that seem to be way too bright for the amount of light in the room. What is happening?
    a. They are not brighter than other things around them.
    b. They are brighter than other things around them.
    c. They are giving off more visible light than is falling on them.
    d. This is just the nature of that color.

Because....

How much control did you feel you had over this activity? 0-4 ______
How well did you think you learned this concept? 0-4 _______

Answers: Pre: c, because light of certain frequencies may excite electrons into jumping to the other side.

Post: a, c as they absorb some of the UV light they emit more light in the visible spectrum.

Appendix B-7: Pre and Post Questions for Chapter 5 Demo

Pre Questions:

1. What will happen to the reactivity of a metal as you go down a group?
    a. No change
    b. More reactive
    c. Less reactive
    d. There is no way that you can determine this

2. What will happen to the reactivity of a metal as you go across a period?

a. no change
b. more reactive
c. less reactive
d. there is no way that you can determine this.

Because....

Post Questions.

1. What element will be more likely to react with hydrochloric acid?
    a. Boron
    b. Aluminum
    c. Gallium
    d. Indium
2. What element would be more likely to react with an acid?
    1. lithium
    2. berlyium
    3. boron
    4. carbon

Because....

How much control did you feel that you had in this activity? ______
How much do you feel that this activity has helped you to master this concept? _

Answers: Pre: b, c shielding with metals
Post: d,1 shielding with metals

Appendix B-8: Pre and Post Questions for Chapter 6 Demo

Pre Questions:

1) What exactly is an example of a bond below?
    a. Under high pressure two atoms are locked in place
    b. Two atoms that are next to each other experience an electromagnetic attraction to each other's electrons and protons
    c. One atom becomes charged through the addition of electrons
    d. A molecule getting charged thorough the removal of electrons

2) What will determine the type of bond that a set of atoms will form?
    a. The size of the atom
    b. The location of the atom on the periodic table
    c. The comparative pull that it has for electrons vs. the other atom
    d. The conditions of pressure and temperature that it forms in.

    Because....

Post Activity

1) Which of the following is true?
    a. The different types of bonds are completely different in nature from one another.
    b. The different types of bonds are really the same exact thing occurring.

    Because....

2) In the following pairings which would most likely form a polar covalent bond?
    a. A manganese – iron combination
    b. A oxygen- oxygen combination
    c. A sulfur- hydrogen combination
    d. A fluorine – sodium combination

How much control did you feel in this activity? _________
How well do you feel this activity helped you to master this concept? _

Answers: Pre: b, c discuss difference in bonds
Post: b, difference in en discussion, c

Appendix C-1 Traditional Lab for Chapter 3: Isotope Pennies

Name: ________________

____

____

Date: __________

Chapter 3 Chemistry
Isotope Modeling Lab

Goal: Your goal in this activity is to successfully model the atomic world using pennies that are pre and post 1982. In 1982 the United States mint stopped using all copper pennies and began using a copper sheathed zinc coin. The new coin is identical in volume but lower in mass than the older coin. You will be given a pile of coins containing both new and old types with the goal of using indirect means only trying to discover the ratio of each type in your pile.

Step One

1. Gather a pile of pennies from the front of the room and an electronic balance to set up *to share* with your table mates.
2. Determine the average mass of both types of coins by sorting out a pile of 25 of each kind and determine the average mass of each.

	# of pennies in sample	Total mass of sample	Average mass per penny
Newer			
Older			

3. Verify that this result is indicative of each penny in a sample by randomly grabbing 5 pennies of each kind.

Older	Penny 1	Penny 2	Penny 3	Penny 4	Penny 5
Mass					
Average mass					
% deviation					

Newer	Penny 1	Penny 2	Penny 3	Penny 4	Penny 5
Mass					
Average mass					
% deviation					

4. Show work for finding one of the standard deviations.

5. Comment on the validity of using the average mass for the sample as a large group.

6. Count out a sample of 100 pennies at random and determine its total mass. (You may have to weigh these in parts and add up to total.)Repeat 2 more times. DO NOT MIX YOUR PENNIES FROM TRIAL TO TRIAL

	Mass
Trial 1	
Trial 2	
Trial 3	

7. Determine the ratio of each isotope in each of the three mixtures. $(massofold * (100 - x)) + (massofnew * x) = totalmass$ Where x is the number of new pennies in sample and because our sample is 100 pennies is also the % of the sample that is new pennies.

Show your work for one example.

	% of older pennies	% of newer pennies
Trial 1		
Trial 2		
Trial 3		

8. Verify your results with a hand count.

	% of older pennies	% of newer pennies
Trial 1		
Trial 2		
Trial 3		

Analysis

1. How accurate was the bulk method to a hand count?

2. What is an isotope?

3. Pros/Cons of our model to an actual sample of an element that contains isotopes.

Appendix C-2 Traditional Lab for Chapter 4: Identifying Elemental Spectra

Name: ________________
____
____
Date: __________

Chapter 3 Chemistry
Isotope Modeling Lab

Goal: Your goal in this activity is to successfully model the atomic world using pennies that are pre and post 1982. In 1982 the United States mint stopped using all copper pennies and began using a copper sheathed zinc coin. The new coin is identical in volume but lower in mass than the older coin. You will be given a pile of coins containing both new and old types with the goal of using indirect means only trying to discover the ratio of each type in your pile.

Step One

9. Gather a pile of pennies from the front of the room and an electronic balance to set up *to share* with your table mates.
10. Determine the average mass of both types of coins by sorting out a pile of 25 of each kind and determine the average mass of each.

	# of pennies in sample	Total mass of sample	Average mass per penny
Newer			
Older			

11. Verify that this result is indicative of each penny in a sample by randomly grabbing 5 pennies of each kind.

Older	Penny 1	Penny 2	Penny 3	Penny 4	Penny 5
Mass					
Average mass					
% deviation					

Newer	Penny 1	Penny 2	Penny 3	Penny 4	Penny 5
Mass					
Average mass					
% deviation					

12. Show work for finding one of the standard deviations.

13. Comment on the validity of using the average mass for the sample as a large group.

14. Count out a sample of 100 pennies at random and determine its total mass. (You may have to weigh these in parts and add up to total.)Repeat 2 more times. DO NOT MIX YOUR PENNIES FROM TRIAL TO TRIAL

	Mass
Trial 1	
Trial 2	
Trial 3	

15. Determine the ratio of each isotope in each of the three mixtures. $(massofold * (100 - x)) + (massofnew * x) = totalmass$ Where x is the number of new pennies in sample and because our sample is 100 pennies is also the % of the sample that is new pennies.

Show your work for one example.

	% of older pennies	% of newer pennies
Trial 1		
Trial 2		
Trial 3		

16. Verify your results with a hand count.

	% of older pennies	% of newer pennies
Trial 1		
Trial 2		
Trial 3		

Analysis

4. How accurate was the bulk method to a hand count?

5. What is an isotope?

6. Pros/Cons of our model to an actual sample of an element that contains isotopes.

Appendix C-3 Traditional Lab for Chapter 5: **Reactivity of the Halide Ions**

This resource was from Holt, Rinehart, and Winston's ancillary resources for Modern Chemistry. Experiment A-3 'Reactivity of Halide Ions' from the Lab Experiments workbook.

Davis, Raymond E., H. Clark Metcalfe, John E. Williams, and Joseph F. Castka. *Modern Chemistry*. Austin: Holt, Rinehart, and Winston, 1999.

Appendix C-4 Traditional Lab for Chapter 6: Activity Series with Cu and Ag (Courtesy of Sheldon Knoespel)

In this experiment you will measure out an exact amount of a silver nitrate solution. The solution was prepared by dissolving silver nitrate crystals in distilled water. You will then weigh a piece of copper wire, place it in the silver nitrate solution, and observe the resulting reaction between the solid copper and the dissolved silver nitrate. By weighing the copper wire before and after the reaction. you will be able to determine the amount of copper that reacted. You will also weigh the product formed by the reaction. As you can see, you will be performing both a qualitative and a quantitative investigation.

We will refer to the chemical substances by using the appropriate symbols. Copper metal is an elemental substance and so it is made of only one kind of atom. The symbol for copper is Cu and since we are using it in the solid form, the correct notation is $Cu_{(s)}$. Silver nitrate is a compound, which in this case is made up of three kinds of atoms. Its formula is $AgNO_3$, in which the Ag stands for silver and the group of atoms NO_3, which consists of one nitrogen atom and three oxygen atoms, is given the name "nitrate". Since the $AgNO_3$ is dissolved in water, we use the notation $AgNO_{3\,(aq)}$.

Purpose To observe the reaction between solid copper, $Cu_{(s)}$, and an aqueous solution of silver nitrate, $AgNO_{3\,(aq)}$. You will also determine if a quantitative relationship exists in the reaction.

Materials

- Copper wire #22 or #24, 30 cm
- Stirring rod, small (about 6 inches)
- Small test tube (13 x 100 mm)
- Graduated pipet, +/- 0.1 mL
- Pasteur pipet
- Fine wire, 10 cm
- 3.0 mL silver nitrate solution (1.00 mole AgNO3 per liter of solution)
- 50 mL beaker
- Wash bottle
- Distilled water
- Pipet filler
- Pasteur pipet bulb
- Analytical balance (or a balance good to 0.001g)
- Goggles

Procedure

Part I Reacting the $Cu_{(s)}$ with the $AgNO_{3\,(aq)}$

A. Label a clean, small test tube with your name or station number and class hour. Weigh your test tube on the analvtical balance and record its weight.

B. Obtain a piece of copper wire approximatelv 30 cm long. Form a coil by carefully wrapping the wire around a stirring rod, leaving about 8 cm for a

Stretch the coil a little so there is some space between the loops. (See Figure 1)

C. Weigh vour copper coil on the analvtical balance and record the weight.

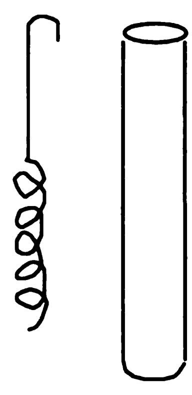


FIGURE 1

D. Using a graduated pipet, carefully place exactly 3.0 mL of the $AgNO_3$ solution into your test tube. Record the volume used for future reference.

CAUTION: Silver nitrate solution stains skin and clothing. Clean hands the day following this experiment indicates good laboratory technique!

E. Carefully slide your copper coil into the silver nitrate solution and observe any changes that take place for five to ten minutes. Observation should include occasional touching of the outside of the test tube as the reaction proceeds.

F. Move the copper coil up-and-down, shaking off the large crystals that have formed. This exposes some copper for further reaction with any unreacted $AgNO_{3\,(aq)}$. Allow the reaction, if any, to continue for several more minutes.

Part II Washing the Crystals

A. Shake the crystals off of the coil. Use a piece of thin wire to knock off any crystals which tend to adhere to the coil. Use distilled water for a final rinse as you remove the coil from the test tube. (See Figure 2) Set the coil aside to dry. Do not discard it!

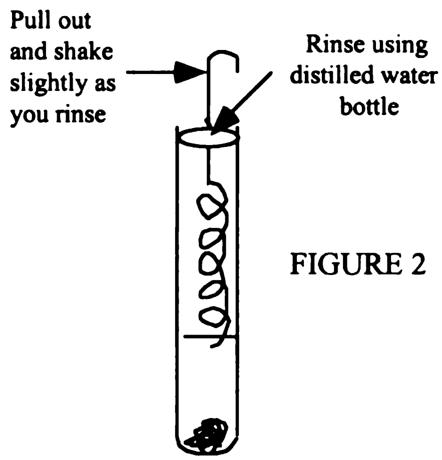


FIGURE 2

B. Let the crystals settle in the test tube. Using a pasteur pipette, carefully decant most of the solution from the crystals. (See Figure 3) (Try to avoid drawing up the crystals; you may leave a few drops of liquid covering the crystals.) Place the decanted liquid in a 50 mL beaker.

C. Add about 3 mL of distilled water to the test tube. Carefully and gently stir the crystals with the tip of the pasteur pipette. Gently break up any large clumps of crystals.

D. Let the crystals settle, then carefully decant the liquid as in step B. Place the liquid in the same beaker.

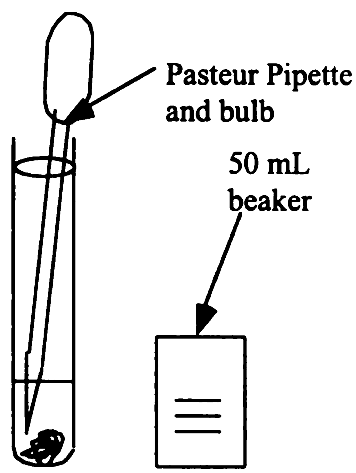
E. Repeat the rinsing and decanting procedure (steps C and D) two more times.

F. Repeat steps C through D with about 3 mL of ethyl alcohol or acetone (choice being made by your teacher).

G. The crystals in the test tube must be dried before weighing. Use the method suggested by your teacher.

H. Carefully inspect the decanted liquid and record your observations. Dispose of the liquid as instructed by your teacher.

FIGURE 3



I. Weigh your copper wire, which should be dry, on the analytical balance and record the weight. After weighing, place the copper wire in the copper waste container.

J. When the crystals are dry and cool, weigh the test tube and crystals on the analytical balance and record the weight. Dispose of the crystals as directed by your teacher or stopper the tube and store for the next experiment.

Suggested Summary of Results

Weight of empty test tube
Weight of Cu wire before reaction
Concentration of $AgNO_{3\,(aq)}$ solution
Volume of $AgNO_{3\,(aq)}$ solution used
Weight of Cu wire after reaction
Weight of Ag crystals and test tube

Additional Calculations

1. Calculate the number of moles of silver nitrate, $AgNO_3$, used. The silver nitrate solution contained 1.00 moles $AgNO_3$ per liter of solution.

2. Calculate **(a)** the weight of Cu that reacted, and **(b)** the weight of Ag crystals produced.

3. Calculate **(a)** the moles of Cu that reacted, and **(b)** the moles of Ag produced.

4. Calculate **(a)** the mole ratio of $AgNO_3$ reacted to Cu reacted, and **(b)** the mole ratio of Ag produced to Cu that reacted. Show your ratios first with the correct number of significant figures and then rounded off to the nearest whole number.

Summary of Results

Weight of Cu that reacted
Weight of Ag produced
Moles of Cu that reacted
Moles of $AgNO_3$ that reacted
Moles of Ag produced
Mole ratio $AgNO_3$ /Cu
Mole ratio Ag/Cu

Questions

1. What qualitative evidence do you have that a chemical reaction took place between the solid copper, Cu(s), and the dissolved silver nitrate, $AgNO_{3\,(aq)}$?

2. What quantitative evidence do you have that a chemical reaction took place between the solid copper, Cu(s), and the dissolved silver nitrate, $AgNO_{3\,(aq)}$?

3. Was the liquid remaining after the reaction pure water? Support your answer with evidence.

4. If you answered "no" to the previous question, what chemical substance(s) do you think was(were) dissolved in the liquid?

5. What do the symbols (s) and (aq) mean?

6. The equation for the reaction you observed is given below. Copy the equation and fill in the blanks using the simple mole ratios you determined.

$Cu_{(s)}$	+	$AgNO_{3\,(aq)}$	------->	$Ag_{(s)}$	+	$Cu(NO3)_{2\,(aq)}$
____moles		_____moles		____moles		Not determined

7. Starting with the "skeleton" equation given above, write a **balanced** equation for the reaction that you observed.

A Question to Speculate About (and answer!)

Is it a coincidence that the mole ratios found in the experiment are the same as the coefficients of the balanced equation? Share your reasoning for your answer.

Appendix C-5 Pre and Post Questions for Chapter 3 Traditional Lab

Pre Activity Questions

1. In a natural sample of a pure element there are *always* atoms of different isotopes present. How could you determine the ratio of each?
   a. The sample would have to be pulverized and a machine counts the atoms of each by mass.
   b. A mass spectrometer is used which can detect small mass differences of atoms.
   c. If the mass of each isotope is known then algebra can be used to find the composition ratio.
   d. Generally it is not possible to determine the % composition of a sample as atoms are too small to be counted.

2. In the Manhattan Project during WWII both sides were in a race to develop an atomic weapon. They both knew how to do it but needed to isolate enough of U-235 which is the smaller % component in a sample of uranium (U-238 is the majority). Why was this such a challenge?
   a. Isotopes react exactly the same chemically
   b. Isotopes share every property with each other
   c. U-235 forms stronger bonds so it is harder to separate
   d. The mass difference between these two isotopes is so small that they are extremely hard to separate.

   Because....

Post Activity Questions

1. The mass of each element on the periodic table is always these long and strange decimals (Example: Carbon is 12.011 amu/atom). Why is this?
   a. The mass of electrons is responsible for the small fraction of an amu at the end
   b. The relative % of each isotope throws off the average to a non whole number.
   c. The amu unit is not calibrated to give whole numbers measuring things like atoms
   d. Carbon is an exception and most atoms actually *do* have whole number values for their masses (U-235 for example)

2. A magician tries a neat trick of pulling out 'special' ice cubes that he guarantees are made of H_2O frozen solid and only frozen H_2O and that his water sample is equally pure. When the ice cubes are placed into the liquid *they sink!*
   a. This is impossible as water always is more dense than ice.
   b. This is possible as hydrogen and oxygen has isotopes.
   c. This is possible as the temperature of the water could be different.
   d. This is impossible as both hydrogen and oxygen are light gases.

Because...

How much control do you feel you had in this activity? 0-4 ___
How well do you feel this activity helped you to master this concept? 0-4 ___

Answers: 1) c, 2)d, definition of isotopes 1) b, 2) b, if heavier isotopes are used it may sink.

Appendix C-6 Pre and Post Questions for Chapter 4 Traditional Lab

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What is it that is in that sign? In this lab we are going to try to determine what gas truly is inside of a 'neon sign' and explain why they not only glow but glow the color that they do.

Pre Questions:

1. What will make a gas glow (like in a neon sign)?
    a. electricity heats up the gases until they are 'red hot'
    b. the gases randomly collide with each other and light is emitted if they are moving fast enough
    c. electricity is arcing through the gas
    d. electrons are being excited and emitting photons

2. What determines the color that a particular element emits when electricity is run through it?
    a. the number of valence electrons
    b. the number of atoms in the solution
    c. the voltage of the electricity
    d. the distance between the electron shells

    because...

Post Questions:

1. If you run electricity through some elements they do not appear to glow at all. Does this mean that the electrons are not being excited?

    a. yes b. no

    Because

    a. No, The electrons may just be giving off light that are outside of the range that we can see
    b. No, but excited electrons have nothing to do with light emission
    a. Yes, the voltage must not be being transmitted
    b. Yes, some elements have too strong a grip on their electrons to be excited
2. If you look at a spectrograph of an element you see the color that you see is a mixture of other colors. What do these lines mean?
    a. there is one line for each proton in the nucleus
    b. there is one line for each possible energy jump that an electron can do
    c. there is one line for each valence electron
    d. there is one line for each color that the eye can see

How much control did you feel that you had in this activity? 0-4 _________

How well did you feel that you learned this topic? 0-4 ____________

Answers: Pre: d, d, because the distance between the levels determines the amount of energy in the photon of light given off

Post: a, a, b

Appendix C-7 Pre and Post Questions for Chapter 5 Traditional Lab

Pre Questions:

1) As you go down the group of halides, what will happen to their reactivity?
   a) Increase
   b) Decrease
   c) Stay the same
   d) Will fluctuate

Because...

2) **Without looking at the periodic table, what will happen to the phase of the elemental halogens as you go down the periodic table?**
   a) They will all be gases
   b) They will all be solids
   c) They will go from solid to gas
   d) They will go from gas to solid

Post activity questions:

1) Within a family, knowing that they all have the same valence electron configuration, can you separate them?
   a. Yes with chemical means.
   b. Yes with physical means
   c. Yes with either physical or chemical means
   d. No

   Because...

2) Iodine is often used as an antiseptic before you get a shot. A reaction occurs where iodine can destroy the microbes that can cause infection. If you were out of iodine which would be the most likely outcome if you used a substitute if you wanted an at least equally effective one that would least likely damage your flesh?
   a. Fluorine b. chlorine c. bromine d. astatine

How much control did you feel that you had in this activity? 0-4 _____
How well do you feel you have mastered this concept? 0-4 _______

Answers: Pre: b (discuss reactivity and shielding),d
Post: b or c, depending on discussion

Appendix C-8 Pre and Post Questions for Chapter 6 Traditional Lab

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Pre:

1) Between the following atoms which would most likely be 'chosen' by a hydrogen atom to bond with
   a. Chlorine
   b. Bromine
   c. Telerium
   d. Polonium

   Because....

2) What would the mole ratio be for oxygen produced if it is displaced by fluorine (oxygen to fluorine)?
   a. 1: 1
   b. 1: 2
   c. 2: 1
   d. it depends how much fluorine is added

Post Questions:

1) If you were to place a silver necklace into a solution of copper nitrate, what would happen?
   a. The copper would displace the silver on the necklace
   b. The silver will displace the copper in the solution
   c. Nothing, no reaction
   d. An equilibrium will be reached that slowly dissolves the necklace

   Because....

2) Without seeing a periodic table what element would you predict would be on top of the activity series (most reactive) for the nonmetals:
   a. ________________________ for the metals _______________

How much control did you feel you had in this activity 0-4: ____
How well did you feel that this activity helped you to master this activity? 0-4 ___

Answers:

Pre: a (discuss activity series), b

Post: c (discuss activity series), fluorine, francium
(based on information available to them)

Appendix D-1 Student-designed Lab for Chapter 3: Definite and Multiple Proportions

Using your texts as a reference define the following.

Law of Multiple Proportions:

Law of Definite Proportions:

Law of Conservation of Mass:

At your lab station you will have a series of nuts, bolts, and washers of varying types. Using your balance as your only tool create models that will accurately show a chemical reaction that can be used by John Dalton to help justify his model. You are to show how an atomic model of nature can be justified with multiple and definite proportions.

Outline your method:

Sketch your models and record your data:

Final summary of argument. You are to create a statement based on your data that will help Dalton convince his contemporaries.

Appendix D-2 Student-designed Lab for Chapter 4: Testing Sunscreen

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Your group will have a two part challenge before you involving a possibly life saving concept. You are to pick a challenge from the list below and develop a way to test it. Your group will then bring your test, results, and reasoning to the rest of the class (combined with other groups that chose the same topic). If different groups are choosing the same category you should get together in the planning aspect so that you are all picking a different part of a larger design.

Topics:

1) What are the effects/effectiveness of UV protection of sunglasses?
2) What is the effectiveness of different SPF levels?
3) Is their a difference in sunblock effecectiveness for different kinds/intensities of light?
4) What is the effectiveness of sunblock against different environmental conditions (rain, sweat, wind, etc)?

Expectations:

Your groups will develop a problem that is more specific than what is outlined before following the lab report format that you have already received. In this you will explain how the UV beads work that all groups will be using as a detector for UV rays. When 5 out of the 10 beads that you will use have turned it is to be considered no longer effective.

Your group will have a visual method to demonstrate to the class the results of your findings. This should be educational for the entire class as well as finding the results for yourselves. Hypothesis and controls must be present and guiding throughout your trials.

Timeframe: you will have one week to present this information. We will have one day in class to pick your *personal* preference, combine into small and large groups, research and plan, another day to build your setups, and then one week from that point to present your findings whether that is within or past the test date for this chapter.

The Third Reason: Rotational motion

You are already well familiar with two reasons why electrons get easier to remove as you go down a column and to the left of a period. There is a third reason why it gets easier as well that we will explore in this investigation.

Q1: What are the two reasons that you already know?

- down a group:

- through a period:

Objective: You will construct a simple model of an electron using marshmallows and a hand sling. Releasing the marshmallow and seeing how far it went will give you an idea of how much 'rotational energy' it had. The more of this that it has the harder it is to hold that electron in its orbit.

Crtical Note: You must swing all the marshmallows at the same rate (RPM) so that the observation can be made without that as a variable. You only want the length of your sling (distance from the nucleus) to change.

The Challenge: Seven groups will construct slings that represent each of the seven alkali metals (1 valence electron). Your groups should all agree on the respective lengths for an 'energy level' before construction begins. Try your min and max to make sure that you can swing this. Also, groups must agree on the RPM that you will go for so that our data can be compared. You are to see if there is a correlation between how much energy there is in an electron and its position.

Requirements.

1. Outline your goal and your procedure
2. Sketch your sling and how you built it
3. Record your trials for all seven (trading slings as needed) with observations
4. Conclusion. How did the distance affect energy? Consistent or not?

Add the question that you answered on the top of this sheet to your write up.

Appendix D-4 Student-designed lab for Chapter 6: Project Twinkie 2015

Name: ______________________

Date: __________

Twinkie the Kid Rides Again

In this activity you are each going to prepare your dessert for your 10 year class reunion. We have been studying reactions and how to control the rate at which they occur. Your task is fairly simple in this case: You are to prepare a real Twinkie that you will bring into class for a 'show and tell' that is preserved well enough to eat 11 years from now at your 10 year class reunion. (I know that this will be 2016 but it doesn't have the same ring to it.)

Requirements: You are to use and explain at least 4 methods to slow down the reaction rate that will destroy your Twinkie. You may use methods that the company has already employed but you still must explain these. Explanations include at the molecular level how they slow down the reaction.

Your Twinkies should be in the class no later than one week from today. If there is no way to bring it in a photograph may suffice instead as long as I can clearly recognize your preserved pastry product.

In your write up I will also want a detailed explanation of what reaction you are trying to slow down is, what the reactants are, what the products would be, etc. Finally tell me if this reaction would be entropy or enthalpy (or both) driven.

Good luck and have fun!!

Appendix D-5 Pre and Post Questions for Chapter 3 Student-designed Lab

Pre Activity questions.

1. Which best illustrates the law of definite proportions?
   a. The amount of oxygen in the atmosphere is 19.32%
   b. If a sample of water has sugar added to it there will always be 3.4 g of sugar per 10 mL of water
   c. Any atom has 1 electron for each proton it contains
   d. Any sample of water in the world has 11.1% hydrogen and 88.9% oxygen by mass.

2. A person was working on the job site with nuts and bolts. The person is bored on his lunch break so started weighing various combinations of the two. If he found that one bolt with a single nut on it weighed 10 g and a bolt with two nuts weighed 12 g and with three bolts 14 g. What can he deduce?
   a. The mass of each using the law of multiple proportions.
   b. The mass of each using the law of definite proportions.
   c. The mass of each using the law of mass conservation
   d. He is only able to determine how much they weigh total.

Because...

Post Activity questions.

1. Which best illustrates the law of multiple proportions?
   a. If you double the amount of water in a sample you can dissolve twice as much sugar into it.
   b. An atmosphere's composition will have the same % composition on any planet that you visit
   c. Any compound containing the same elements within it will show whole number ratios when the masses are compared
   d. Any 2 compounds can combine in any multiple of ways

2. That same person was at Wendy's and was looking up the nutritional information of the single, double, and triple burgers. He found that a single was 9 weight watcher's points, a double was 15 points, and a triple was 21 points.
   a. The points of each using the law of multiple proportions.
   b. The points of each using the law of definite proportions.
   c. The points of each using the law of mass conservation
   d. He is only able to determine how many points they have total.

Because...

How much control did you feel you had in this activity? 0-4 ____
How well do you feel this activity helped in your mastering of this concept? ___

Answers: 1)d 2)a, algebra can solve 1) c 2)a, algebra can solve for unknown

Appendix D-6 Pre and Post Questions for Chapter 4 Student-designed Lab

What is the effect of sunscreen in defense of the skin?

Pre Questions:

1. What is it in sunlight that actually damages your skin?
   a. the heat cooking your skin one level at a time
   b. the UV exciting electrons that breaks bonds
   c. the IR adding too much heat to your DNA
   d. the skin just gets dehydrated from too much exposure

2. How does sun block actually protect the skin?
   a. it can absorb the UV rays
   b. it can act as a coolant on the skin
   c. it can reflect light off of your skin
   d. it can heal damage as it is done

   Because…

Post Questions:

1. The sun is essentially a giant ball of hydrogen that is slowly becoming helium and other elements. What indication do you have that these electrons are vibrating at frequencies different from those that are visible (Lyman and Balmer series)?
   a. The sunlight is visible
   b. The sunlight is bright
   c. The sunlight is capable of creating sunburns
   d. The sunlight is hot

2. If sunblock is actually 'blocking' the sunlight what would side effect would you notice?
   a. The sunblock will start to glow
   b. The sunblock will heat up
   c. The sunblock will degrade
   d. There would be no effect from absorbing this light.

   Because…

How much control did you feel you had in this experiment? 0-4 _______
How well did you feel this concept was learned by you? 0-4 _________

Answers: Pre: b,a because the UV band excites the sunblock's electrons so it absorbs these frequencies and they do not get to your skin.

Post: c, (a-c depending on answer) the energy being absorbed by the sunblock is being given off as warmth (or equivalent logic for other choices)

Appendix D-7 Pre and Post Questions for Chapter 5 Student-designed Lab

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Pre:

1) What electrons have the most energy?
   a. The closest electrons
   b. The farthest electrons from the nucleus
   c. Electrons that are in ground state
   d. Noble gas electrons

Because...

2) Picture a person on a merry-go-round. How hard is it to hold on as you move to the outside of the ride?
   a. It gets easier
   b. It gets harder
   c. There is no change
   d. This only depends on the rate that the ride is spinning.

Post Questions.

1) In the alkaline Earth metals which element would have the hardest time containing its electrons' inertia?
   a. Beryllium b. magnesium c. barium d. radium

2) Of all the noble gases there is a couple that have been found to be reactive under some conditions. Which do you think they are?
   a. Helium b. neon c. krypton d. xenon

Because....

How much control did you feel that you had in this activity? 0-4 _____
How much do you feel you benefited in this concept from this activity? 0-4 ____

Answers:

Pre: b (talk about centripetal force or potential energy), b
Post: d, d (then c)

Appendix D-8 Pre and Post Questions for Chapter 6 Student-designed Lab

We all know the legend of the Twinkie. That it never goes bad. That it will survive the coming nuclear apocalypse (see the Family Guy for details). The sad truth is though that this cake expires about two months after its baking. Your challenge will be to create the super twinkie that will last until your 10th class reunion. Enjoy.

Pre Questions

1. Which of the following would most likely preserve a Twinkie?
   a. heating it to a constant room temperature
   b. decreasing the pressure on the Twinkie
   c. Cutting the Twinkie into pieces
   d. Dehydrating the Twinkie

   Because...

2. A 'preservative' is a chemical that does what?
   a. Lowers temperature
   b. Decreases surface area
   c. Inhibits a reaction
   d. Catalyzes a reaction

Post Question

1. If you were to design a system to take smog out of your exhaust before it reacts with the atmosphere, which would not help?
   a. heat it up
   b. convolute the channels so it is agitated as it flows through
   c. add a catalyst
   d. decrease the pressure

Because...

2. Many health experts are concerned by the large number of preservatives our children (and adults) are consuming today. Why may this be a concern in the human body?
   a. They may speed up reactions that need to occur at a slower rate
   b. They may slow down reactions that need to occur at a slower rate
   c. They are high fat
   d. They are high in carbohydrates

Amount of control. ______ (0-4)
Amount of mastery due to this type of activity (0-4) _________

Answers: Pre Questions: B (explain), C
Post: D (explain), B

Chapter 3:

Levi, Primo. (1999). Travels with C. Modern Chemistry: 68-69.

A first person narrative from the carbon atom's point of view as it is continually rearranged in different compounds as it goes through time.

Chapter 4:

The Noble Decade. (1999). Modern Chemistry: 108-109

A look at William Ramsay in the 1890s and his discovery of many of the noble gases.

Chapter 5:

Wilson, Elizabeth. (22 July, 2002). Superheavy Furur. Chemical and Engineering News: 80:29, 12.

Yarris, Lynn. "New Superheavy Elements 116 and 118 Discovered at Berkley Lab". *Berkley Lab News Release.* 7 June 1999.

"Results of Element 118 Experiment Retracted". *Berkley Lab News Release.* 27 July 2001.

A series of press releases from Berkley Labs as they first introduce the discovery of the new elements, then the controversy, then the retraction of the discovery and the resultant scandal. Overall a look at how blindly can you accept the science that you read.

Chapter 6:

"Ultrasonic Toxic Waste Destroyer". *Modern Chemistry*, 1999: 166-167.

A look at current research and using the extreme conditions inside of collapsing bubbles to destroy very persistent molecules using sound wave generated bubbles. Changing the frequency of the sound can target different types of molecules to be destroyed.

Appendix E-2 Pre and Post Questions for Chapter 3 Reading Activity

Pre/Post Activity Questions for Chapter 3 Reading Activity

Instructions: Please respond to the following questions before reading the section ('Travels with C' on page 68). Be sure to mark your two selections as well as to briefly explain your logic to the one response. After reading the selection please conclude by answering the final two questions with your logic response.

Pre reading questions.

2. Atoms are:
    a. Continually being created and destroyed in natural processes
    b. Continually being broken down and reformed in natural processes
    c. Combining and breaking attractions without changing the atom itself
    d. Stable and indestructible and therefore do not change throughout time.

3. A scientist was observing a sample of limestone as it is being baked to form lime (a very important industrial chemical). The mass of the compound is dropping as it is being heated but there is no ash left to explain what happened to this mass. Propose a solution to the problem as you choose the law that best demonstrates your answer.
    a. The law of definite proportions because…
    b. The law of multiple proportions because…
    c. The law of conservation of mass because…
    d. Hess' law because…

Post reading Questions.

1. If an element is undergoing continual change from one compound to another what is best true of what is occurring?
    a. Energy is being provided to overcome old attractions so it can form new ones
    b. The atom is being destroyed and reformed as it shifts from one to another
    c. Atoms cannot change form (they are called atom, indivisibl)
    d. Atoms randomly change from one compound to another whenever they come into contact

2. A hawk is flying along and absorbed too much carbon dioxide into its blood streak and died. As it laid on the ground its mass began to drop as the days went on. Propose a solution to the problem as you choose the law that best demonstrates your answer.
    a. The law of definite proportions because…
    b. The law of multiple proportions because…
    c. The law of conservation of mass because…
    d. Hess' law because…

Appendix E-3: Pre and Post Questions for Chapter 4 Reading Activity

Read 'The Noble Decade' on pp 108-109 for this activity.

Pre Questions:

1. The periodic table is organized based on the periodic appearance of properties. So each column should demonstrate elements…
   a. with similar weights
   b. with similar chemical and physical properties
   c. with similar proton numbers
   d. with similar occurrence in nature

2. Which elements were the last to be discovered?
   a. light gases like hydrogen.
   b. The noble gases
   c. The royal metals
   d. Earth, Wind, and Fire

Because…

Post Questions:

1. There exists a family of elements that are unreactive with other elements to the point that they can be difficult to isolate and study. What observations led to these being found?
   a. the air had a higher mass than it should
   b. fire was being put out faster than it should
   c. there were too many protons in a sample of nitrogen
   d. helium was making the density of air lower than expected

2. If tomorrow another element was discovered that contained a heretofore undiscovered set of properties. What would be a response to this?
   a. Create another row for the periodic table.
   b. Create another column for the periodic table.
   c. Dismiss the possibility of the new element.
   d. Revise the atomic model

   Because…

How much control did you feel you had over this activity? 0-4 ________

How effective did you feel this activity was in your learning? 0-4 _________

Answers: Pre: b,b because they are unreactive so not easily detected.
Post: a, b because this new element must belong to a new family if it does not behave like any other element.

Appendix E-4: Pre and Post Questions for Chapter 5 Reading Activity

Pre Questions

2) Elements 116 and 118 are considered very heavy elements. Without looking at your periodic table or anything else, would these elements be easy or difficult to find and/or create?
   a. Easy
   b. Difficult
   c. No way of telling

Because...

3) In science all data can be accepted as truth because
   a. Scientists follow the scientific method
   b. There is always a back up where one person oversees others' work
   c. Both of the above
   d. You cannot always blindly trust anyone's work

Post Questions

1) Eventually, can you be reasonably sure that scientific postulates are correct?
   a. Yes
   b. No
   c. Undetermined

Because...

2) It is postulated that you will arrive at a 'island of stability' in the superheavy elements where they do not instantly blow apart. What is it that keeps those heavy elements so instable?
   a. Elements that big can no longer feel each other's electromagnetic attractions
   b. The strong nuclear force only works over a very short distance
   c. Larger elements simply weigh more and gravity pulls them apart
   d. Smaller elements keep smashing into them and cracking their neclei into smaller pieces.

How much control did you feel you had in this activity? 0-4 ____

How well do you feel that you mastered the concept? 0-4 _____

How much do you feel that this activity helped you understand the concept? 0-4

____

Appendix E-5: Pre and Post Questions for Chapter 6 Reading Activity

Pre Questions:

1) When a bubble forms in a solution and pops what do you predict will happen to the pressure and temperature inside of the bubble?
    a. T up, P up
    b. T down, P down
    c. T up, P down
    d. T down, P up

    Explain your response....

2) If you have a waste product from industry which is the most dangerous kind to deal with?
    a. Those that have extremely weak bonds and break down almost instantly
    b. Those that have extremely strong bonds and are attracted only to themselves for long periods of time.
    c. Those that have strong bonds within themselves but can also interact with other compounds

Post Questions

1) Incinerating can cause as much problems as it solves when you burn toxic waste. Why?
    a. The compounds that you burn simply evaporate into the air
    b. The law of conservation of mass states that mass cannot be destroyed so those reactive elements may reform other compounds in the atmosphere
    c. This is a lie spawned by tree-hugging hippies with too much time on their hands.
    d. The heat from the fires add to global warming

2) In a collapsing bubble what happens to the temperature/pressure inside of the bubble?
    a. T up, P up
    b. T down, P down
    c. T up, P down
    d. T down, P up

    Explain your response....

Appendix F-1 Mid Term Retention for Chapter 3

Chapter 3: Mid Retention Check for Chemistry

Reading:

1) If an element is undergoing continual change from one compound to another what is best true of what is occurring?

- a) Energy is being provided to overcome old attractions so it can form new ones
- b) The atom is being destroyed and reformed as it shifts from one to another
- c) Atoms cannot change form (they are called atom, indivisible)
- d) Atoms randomly change from one compound to another whenever they come into contact

2) A hawk is flying along and absorbed too much carbon dioxide into its blood stream and died. As it laid upon the ground its mass began to drop as the days went on. Propose a solution to the problem as you choose which law that best demonstrates your answer.

- a) The law of definite proportions because…
- b) The law of multiple proportions because..
- c) The law of conservation of mass because…
- d) Hess' law because…

Notes:

1) What time period showed the greatest advancements in the atomic model?

- a) Colonial Times (1700-1800)
- b) The Renaissance (~1500-1600)
- c) Dark Ages (~400-1400)
- d) Classical Greece (~500-300 BC)

2) When Lavoisier demonstrated the law of conservation of mass what did it do to the atomic model?

- a) The continuous view of matter was justified
- b) The atomic nature of matter was justified
- c) Both were justified
- d) Neither were justified

Because…

Demonstration:

1) In a television set the electron gun is aimed with

- a) Negative magnets attracting the electrons
- b) Positive magnets attracting the electrons
- c) Magnets do not affect electrons
- d) Electrons have nothing to do with the television picture

2) A working model of the atom based only on the information available to JJ Thomson would be

- a) A solid sphere composed of light electrons and heavier protons

b) A solid indestructible sphere
c) An atom with a nucleus in the middle containing protons and a cloud of electrons around it.
d) An atom with a nucleus in the middle containing protons and neutrons and a cloud of electrons around it.

Because...

Cookie Cutter Lab:

1) The mass of each element on the periodic table is always these long and strange decimals (Example: Carbon 12.011 amu/atom). Why is this?
   a) The mass of electrons is responsible for the small fraction of an amu at the end
   b) The relative % of each isotope throws off the average to non-whole numbers
   c) The amu is not calibrated to give whole numbers measuring things like atoms
   d) Carbon is an exception and most atoms actually do have whole number values (U-235 for example)

2) A magician tries a neat trick of pulling out 'special' ice cubes that he guarantees are made of H_2O and that his water sample is equally pure. When the ice cubes are placed into the liquid water they sink!
   a) This is impossible as water always is more dense than ice
   b) This is possible as hydrogen and oxygen have isotopes
   c) This is possible as the temperature of the water could be different
   d) This is impossible as both hydrogen and oxygen are light gases

Because...

Student-designed Labs:

1) Which best illustrates the law of multiple proportions?
   a) If you double the amount of water in a sample you can dissolve twice as much sugar into it.
   b) An atmosphere's composition will have the same % composition on any planet that you visit
   c) Any compound containing the same elements within it will show whole number ratios when the masses are compared
   d) Any 2 compounds can combine in any multiple of ways

2) That same person was at Wendy's and was looking up at the nutritional information of the single, double, and triple burgers. He found that a single was 9 weight watcher's points, a double was 15 points, and a triple was 21 points. He can determine..
   a) the points of each using the law of multiple proportions
   b) the points of each using the law of definite proportions
   c) the points of each using the law of conservation of mass
   d) he is only abe to determine how may points they have total

Because...

Appendix F-2 Mid Term Retention for Chapter 4

Chapter Four Chemistry
Mid Retention Master's Data

If you run electricity through some elements they do not appear to glow at all. Does this mean that the electrons are not being excited?
a)Yes
b) No
Because

a. No, The electrons may just be giving off light that are outside of the range that we can see
b. No, but excited electrons have nothing to do with light emission
c. Yes, the voltage must not be being transmitted
d. Yes, some elements have too strong a grip on their electrons to be excited

2. If you look at a spectrograph of an element you see the color that you see is a mixture of other colors. What do these lines mean?

e. there is one line for each proton in the nucleus
f. there is one line for each possible energy jump that an electron can do
g. there is one line for each valence electron
h. there is one line for each color that the eye can see

3. The sun is essentially a giant ball of hydrogen that is slowly becoming helium and other elements. What indication do you have that these electrons are vibrating at frequencies different from those that are visible (Lyman and Balmer series)?

e. The sunlight is visible
f. The sunlight is bright
g. The sunlight is capable of creating sunburns
h. The sunlight is hot

2. If sunblock is actually 'blocking' the sunlight what would side effect would you notice?

a. The sunblock will start to glow
b. The sunblock will heat up
c. The sunblock will degrade
d. There would be no effect from absorbing this light.

Because...

3. There exists a family of elements that are unreactive with other elements to the point that they can be difficult to isolate and study. What observations led to these being found?

a. the air had a higher mass than it should
b. fire was being put out faster than it should
c. there were too many protons in a sample of nitrogen
d. helium was making the density of air lower than expected

4. If tomorrow another element was discovered that contained a heretofore undiscovered set of properties. What would be a response to this?

a. Create another row for the periodic table.
b. Create another column for the periodic table.
c. Dismiss the possibility of the new element.

d. Revise the atomic model

Because…

3. If you provide light to a photoelectric cell (solar panel) that is of very low frequency but very bright. What do you think will occur?
   a. No voltage will be produced
   b. Voltage will be produced.
   c. Voltage will occur if it is bright enough but only then.
   d. The photo cell will absorb the light and through photosynthesis create the electricity.

4. Dayglow shirts is a brand name for a type of fabric that is the extremely bright pinks, oranges, greens, and yellows that seem to be way too bright for the amount of light in the room. What is happening?
   a. They are not brighter than other things around them.
   b. They are brighter than other things around them.
   c. They are giving off more visible light than is falling on them.
   d. This is just the nature of that color.

Because….

3. According to Louis de Broglie you cannot treat electrons like planets around the sun because…
   a. Electrons do not get affected by gravity
   b. That ignores their wave nature
   c. They are too small and too close to the nucleus for that to have effect
   d. There simply are too many electrons for a model like that to be feasible
4. The Heisenberg uncertainty principle states that…
   a. You cannot truly know anything about the electron
   b. You cannot know an electron's speed and location at the same time
   c. The orbit of the electrons follow specific paths around the nucleus
   d. You can never be truly certain about anything

Because…

Appendix F-3 Long Term Retention for Chapters 3 and 4

Reading Activities

3. If an element is undergoing continual change from one compound to another what is best true of what is occurring?
    a. Energy is being provided to overcome old attractions so it can form new ones
    b. The atom is being destroyed and reformed as it shifts from one to another
    c. Atoms cannot change form (they are called atom, indivisible)
    d. Atoms randomly change from one compound to another whenever they come into contact

4. A hawk is flying along and absorbed too much carbon dioxide into its blood streak and died. As it laid on the ground its mass began to drop as the days went on. Propose a solution to the problem as you choose the law that best demonstrates your answer.
    a. The law of definite proportions because...
    b. The law of multiple proportions because...
    c. The law of conservation of mass because...
    d. Hess' law because...

5. There exists a family of elements that are unreactive with other elements to the point that they can be difficult to isolate and study. What observations led to these being found?
    a. the air had a higher mass than it should
    b. fire was being put out faster than it should
    c. there were too many protons in a sample of nitrogen
    d. helium was making the density of air lower than expected

6. If tomorrow another element was discovered that contained a heretofore undiscovered set of properties. What would be a response to this?
    a. Create another row for the periodic table.
    b. Create another column for the periodic table.
    c. Dismiss the possibility of the new element.
    d. Revise the atomic model

    Because...

In general how much control did you feel you had in this type of activity? 0-4 __
In general, how well did you feel you benefited from this type of activity? 0-4 ___

Notes Activities

3. What time period showed the greatest advancements in the atomic model?
    a. Colonial Times (1700-1800 AD)
    b. The Rennaisance (~1500-1600 AD)

c. Dark Ages (~400-1400 AD)
d. Classical Greece (~500-300 BC)

4. When Lavoisier demonstrated the law of conservation of mass what did it do to the atomic model?
   a. The continuous view of matter was justified.
   b. The atomic nature was justified.
   c. Both were justified.
   d. Neither were justified.

   Because...

5. According to Louis de Broglie you cannot treat electrons like planets around the sun because...
   a. Electrons do not get affected by gravity
   b. That ignores their wave nature
   c. They are too small and too close to the nucleus for that to have effect
   d. There simply are too many electrons for a model like that to be feasible

6. The Heisenberg uncertainty principle states that...
   a. You cannot truly know anything about the electron
   b. You cannot know an electron's speed and location at the same time
   c. The orbit of the electrons follow specific paths around the nucleus
   d. You can never be truly certain about anything

   Because...

In general how much control did you feel you had in this type of activity? 0-4 __
In general, how well did you feel you benefited from this type of activity? 0-4 ___

Demo Activities

5. If you provide light to a photoelectric cell (solar panel) that is of very low frequency but very bright. What do you think will occur?
   a. No voltage will be produced
   b. Voltage will be produced.
   c. Voltage will occur if it is bright enough but only then.
   d. The photo cell will absorb the light and through photosynthesis create the electricity.

6. Dayglow shirts is a brand name for a type of fabric that is the extremely bright pinks, oranges, greens, and yellows that seem to be way too bright for the amount of light in the room. What is happening?
   a. They are not brighter than other things around them.
   b. They are brighter than other things around them.

c. They are giving off more visible light than is falling on them.
d. This is just the nature of that color.

Because....

3. In a television set the electron gun is aimed with.
    a. Negative magnets attracting the electrons
    b. Positive magnets attracting the electrons
    c. Magnets have no effect on electrons
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4. A working model of the atom based only on the information available to JJ Thomson would be
    a. A solid sphere composed of light electrons and heavier protons.
    b. A solid indestructible sphere.
    c. An atom with a nucleus in the middle containing protons and a cloud of electrons around it.
    d. An atom with a nucleus in the middle containing protons and neutrons and a cloud of electrons around it.

Because...

In general how much control did you feel you had in this type of activity? 0-4 __
In general, how well did you feel you benefited from this type of activity? 0-4 ___

Student-designed Activity

3. Which best illustrates the law of multiple proportions?
    a. If you double the amount of water in a sample you can dissolve twice as much sugar into it.
    b. An atmosphere's composition will have the same % composition on any planet that you visit
    c. Any compound containing the same elements within it will show whole number ratios when the masses are compared
    d. Any 2 compounds can combine in any multiple of ways

4. That same person was at Wendy's and was looking up the nutritional information of the single, double, and triple burgers. He found that a single was 9 weight watcher's points, a double was 15 points, and a triple was 21 points.
    a. The points of each using the law of multiple proportions.
    b. The points of each using the law of definite proportions.
    c. The points of each using the law of mass conservation
    d. He is only able to determine how many points they have total.

Because...

4. The sun is essentially a giant ball of hydrogen that is slowly becoming helium and other elements. What indication do you have that these electrons are vibrating at frequencies different from those that are visible (Lyman and Balmer series)?

i. The sunlight is visible
j. The sunlight is bright
k. The sunlight is capable of creating sunburns
l. The sunlight is hot

2. If sunblock is actually 'blocking' the sunlight what would side effect would you notice?

a. The sunblock will start to glow
b. The sunblock will heat up
c. The sunblock will degrade
d. There would be no effect from absorbing this light.

Because...

In general how much control did you feel you had in this type of activity? 0-4 __
In general, how well did you feel you benefited from this type of activity? 0-4 ___

Cookie Cutter Labs

3. The mass of each element on the periodic table is always these long and strange decimals (Example: Carbon is 12.011 amu/atom). Why is this?
    a. The mass of electrons is responsible for the small fraction of an amu at the end
    b. The relative % of each isotope throws off the average to a non whole number.
    c. The amu unit is not calibrated to give whole numbers measuring things like atoms
    d. Carbon is an exception and most atoms actually *do* have whole number values for their masses (U-235 for example)

4. A magician tries a neat trick of pulling out 'special' ice cubes that he guarantees are made of H_2O frozen solid and only frozen H_2O and that his water sample is equally pure. When the ice cubes are placed into the liquid *they sink!*
    a. This is impossible as water always is more dense than ice.
    b. This is possible as hydrogen and oxygen has isotopes.
    c. This is possible as the temperature of the water could be different.
    d. This is impossible as both hydrogen and oxygen are light gases.

Because...

3. If you run electricity through some elements they do not appear to glow at all. Does this mean that the electrons are not being excited?

a. No
b. Yes

Because

b. No, The electrons may just be giving off light that are outside of the range that we can see
b. No, but excited electrons have nothing to do with light emission
c. Yes, the voltage must not be being transmitted
d. Yes, some elements have too strong a grip on their electrons to be excited

4. If you look at a spectrograph of an element you see the color that you see is a mixture of other colors. What do these lines mean?
   a. there is one line for each proton in the nucleus
   b. there is one line for each possible energy jump that an electron can do
   c. there is one line for each valence electron
   d. there is one line for each color that the eye can see

In general how much control did you feel you had in this type of activity? 0-4 __
In general, how well did you feel you benefited from this type of activity? 0-4 ___

Appendix G- Student Consent Form

Research Participation Consent Form
Masters of Physical Science in Education

Dear Parents/Students,

I am so excited that you have chosen to take Chemistry at Pewamo-Westphalia for the 2004-2005 school year. My main focus for this upcoming year will involve a familiar theme for any of you that have had me before: I want the student to be able to visualize chemistry to a degree that they can explain what is happening and predict what will occur under new conditions. I will be implementing throughout the year a series of dedicated class and individual problems for students to analyze and solve. I will be analyzing these tasks as students progress throughout the year for improvement in modeling, predicting, designing, and analyzing skills.

This will also be the subject of my thesis at Michigan State University. Your student will be involved in this project as a member of this class. I am asking your permission (both student and parent) to use work done in this class in my study. Your participation in this is voluntary but will not affect your grade or workload in any way. All student work will remain as confidential as the law allows and at no time will the students' names be attached to their work or their photos.

Types of work that will be included in this project will be the pre and post lab/demonstration work, surveys, lab designs, and my personal observations so I can assess the knowledge and skills gained during the activity as well as the development of these skills through the year. Pictures will be taken of the class during these activities and I also ask for your permission to use images that may contain your student's picture in a presentation next summer where I will present the findings of this study. Again, this is strictly voluntary and will have no impact on your grade.

If you have any questions about this study you may contact myself through email at pohl@pw.k12.mi.us, or my advisor, Merle Heidemann at heidema2@msu.edu. You may also contact the University Committee on Research Involving Human Subjects (UCRIHS) if you have any questions regarding your rights as a study participant or if you are dissatisfied at any time, Peter Vasilenko, Ph.D. at ucrihs@msu.edu. You may also contact UCRIHS by phone (517) 355-2180, fax (517) 432-4503 or by regular mail at 202 Olds Hall, East Lansing, MI 48824. UCRIHS may be contacted anonymously if you prefer and a student may be removed from the data at any point in the project.

Thank you for your time and your cooperation,

Brian Pohl
Pewamo-Westphalia Schools

Please return this letter no later than 1 week from today.

I voluntarily agree to have ______________________ participate in this study.
(print student name)

______________________________ ______ ________
Parent/Guardian Signature Date Photo may be used (Y/N)

I voluntarily agree to participate in this study.

______________________________ ______ ________
Student Signature Date Photo may be used (Y/N)

Name: _______________

Date: __________

InQuiry Lab: How in shape are you?
Determining the Partial Pressure of Oxygen in the Atmosphere

Background: Your body powers itself by reacting glucose with oxygen in the process of respiration. If you hold your breath in your lungs (do not exhale) then you should be replacing the oxygen in that air sample with carbon dioxide. We are going to use this simple fact to try to determine what conclusions we can draw, including?

- Avogadro's law states that all gases occupy the same volume regardless of the type of gas that it is. The carbon dioxide will take up the exact same volume as the oxygen even though it has more mass per molecule.

- Dalton's law of partial pressure says that the percentage of the gas in a sample is the same percentage of the total pressure of the sample from that gas.

- The atmospheric pressure will equalize pressure with a barometer by raising and lowering the column until the atmospheric pressure outside is equal to the pressure inside of the column plus the weight of the fluid.

Purpose: You will use this very simple experiment to: (** main goals)

1) Write and balance a reaction that is occurring inside of the test tube.
2) Determine the amount of iron needed to react completely with the oxygen that will be present in a normal sample of air filling the test tube.
3) Create a control system.
4) Analyze the results and the known laws to determine the % of oxygen in each sample of air. **
5) Draw a conclusion on whether this can indeed be used as a method of determining the fitness of an individual. **
6) In addition you will be asked to calculate the vapor pressure of water in the test tube.

Pre-lab work:

1) read this lab.
2) Calculate how many moles of oxygen should be present in your test tube (you will be handed this test tube today and will need to determine its volume) if it is ¾ full. Mark this line with a china marker.
3) Have a balanced reaction of the reaction of this oxygen with iron to create iron (III) oxide.
4) Calculate the mass of iron that will need to be in the test tube so there is no limiting reagent.
5) Explanation (in research section)

Procedure: This procedure is incomplete and will only detail how you will be able to get the iron into the test tube without compromising the sample.

1) Construct a ring stand with a test tube clamp so that the test tube may be held upside down and its open mouth submerged in a beaker of water so that no atmospheric air can get into it. This is how it will look when you are complete.
2) Blow a balloon up so that it is prestretched and easily inflated. Each person will have their own balloon.
3) Using a wide necked funnel pour the proper amount of iron filings that you calculated to remove the oxygen (put twice this amount in because some will be lost sticking to the inside of the balloon).
4) Remove the funnel and hold your breath as long as possible. Before you pass out use your exhale to fill the balloon (you do not need much air here) and pinch off the balloon. You should hopefully have a partially deoxygenated balloon in your hands.
5) After filling a sink with water deep enough for the task you will need to fill the test tube completely up with water and submerge it so that its mouth is pointed down and under the water. The water will stay in the test tube even if it is above the surface. (I wonder why that is?)
6) Put the nozzle of the balloon in the opening and slowly let out the air (not completely) until the water is pushed out (I wonder what that is, too.) Pinch off the balloon again.
7) A second set of hands will be needed know to put the balloon around the neck of the test tube while still under water.
8) Take the balloon out and pour the iron fillings into the test tube (some water will come with it). After getting as much iron in as possible, slowly tilt the test tube back inverted so that the water pours back into the balloon leaving the iron behind. Shake the test tube gently to spread the iron around the inside of the test tube.
9) Place back under water and remove the balloon. Slowly tilt the test tube so that just enough water enters the test tube to your china marker line from yesterday.
10) Finally put the beaker of water under the test tube and lift and remove it to your ring stand. Clip it in and adjust the height of the test tube so that the height of the water inside is the same as outside.
11) Wait overnight.

This will give you data to come to a conclusion from. Do not forget to quantify your data and use sig figs!

Unexpected results are bolded. Expectations would be that all initial scores would increase with a noticable amount and the mid and long-term retention would hold steady or decrease with no notable amount.

Notes	**n**	**p**	**t**	**Mean Pre**	**std. dev.**	**mean post**	**std. dev.**
Chapter 3 Pre vs Post	22	0.019	-2.53	1.45	1.14	2	1.15
Chapter 4 Pre vs Post	13	0	-4.79	1.92	0.862	3.15	0.689
Chapter 5 Pre vs Post	18	0.001	-3.91	2.69	0.793	3.38	0.719
Chapter 6 Pre vs. Post	12	**0.571**	0.583	**3**	1.04	**2.75**	1.06
All Pre vs Post	65	0	-3.77	2.15	1.09	2.68	1.08
Mid 3 vs Post 3	17	0.651	0.46	**2.18**	1.07	**2.06**	1.14
Mid 4 vs Post 4	10	0.322	1.05	**3**	1.41	**2.5**	0.972
Overall Mid	28	0.364	0.923	2.39	1.31	2.18	1.09
Final 3 vs Post 3	18	0.57	-0.579	**1.94**	1.11	**2.17**	1.47
Final 4 vs Post 4	18	**0.018**	2.61	2.94	1.11	2.17	1.47
Overall Final	36	**0.012**	2.66	2.44	1.21	1.89	1.28

Reading	**n**	**p**	**t**	**Mean Pre**	**std. dev.**	**mean post**	**std. dev.**
Chapter 3 Pre vs Post	23	**0.633**	-0.485	2.52	1.12	2.65	1.19
Chapter 4 Pre vs Post	12	**1**	0	2.42	0.793	2.42	1.08
Chapter 5 Pre vs Post	21	**0.693**	-0.4	2.48	0.873	2.57	0.978
Chapter 6 Pre vs. Post	13	0.002	-3.99	1.77	1.01	3.08	1.26
All Pre vs Post	69	0.04	-2.09	2.35	0.997	2.67	1.12
Mid 3 vs Post 3	18	0.185	-1.38	**2.83**	1.15	**3.22**	0.943
Mid 4 vs Post 4	9	**0.021**	2.87	3.33	1	2.44	1.24
Overall Mid	27	0.769	0.296	3.04	1.13	2.96	1.09
Final 3 vs Post 3	19	0.767	0.301	2.74	1.24	2.63	1.38
Final 4 vs Post 4	14	1	0	2.79	1.25	2.79	1.37
Overall Final	33	0.818	0.232	2.76	1.23	2.7	1.36

Demonstrations	**n**	**p**	**t**	**Mean Pre**	**std. dev.**	**mean post**	**std. dev.**
Chapter 3 Pre vs Post	20	0.004	3.24	**3.15**	0.875	**2.35**	0.745
Chapter 4 Pre vs Post	22	0.038	-2.22	1.55	0.912	2.05	1.09
Chapter 5 Pre vs Post	19	**0.205**	-1.32	2.47	0.905	2.74	0.933
Chapter 6 Pre vs. Post	10	**0.089**	-1.91	2.5	0.85	3.2	0.632
All Pre vs Post	71	**0.54**	-0.616	2.38	1.07	2.46	0.954
Mid 3 vs Post 3	18	**0.001**	-4.12	**2.39**	0.85	**3.06**	0.802
Mid 4 vs Post 4	8	0.351	-1	**2.25**	1.04	**2.75**	1.04
Overall Mid	26	**0.031**	-2.29	**2.42**	0.902	**2.88**	0.909
Final 3 vs Post 3	19	0.848	-0.195	**2.58**	0.838	**2.63**	1.12
Final 4 vs Post 4	17	0.236	1.23	1.94	0.899	1.65	1.06
Overall Final	36	0.545	0.612	2.28	0.914	2.17	1.18

Unexpected results are bolded. Expectations would be that all initial scores would increase with a noticable amount and the mid and long-term retention would hold steady or decrease with no notable amount.

Notes	**n**	**p**	**t**	**Mean Pre**	**std. dev.**	**mean post**	**std. dev.**
Chapter 3 Pre vs Post	22	0.019	-2.53	1.45	1.14	2	1.15
Chapter 4 Pre vs Post	13	0	-4.79	1.92	0.862	3.15	0.689
Chapter 5 Pre vs Post	18	0.001	-3.91	2.69	0.793	3.38	0.719
Chapter 6 Pre vs. Post	12	**0.571**	0.583	**3**	1.04	**2.75**	1.06
All Pre vs Post	65	0	-3.77	2.15	1.09	2.68	1.08
Mid 3 vs Post 3	17	0.651	0.46	**2.18**	1.07	**2.06**	1.14
Mid 4 vs Post 4	10	0.322	1.05	**3**	1.41	**2.5**	0.972
Overall Mid	28	0.364	0.923	2.39	1.31	2.18	1.09
Final 3 vs Post 3	18	0.57	-0.579	**1.94**	1.11	**2.17**	1.47
Final 4 vs Post 4	18	**0.018**	2.61	2.94	1.11	2.17	1.47
Overall Final	36	**0.012**	2.66	2.44	1.21	1.89	1.28

Reading	**n**	**p**	**t**	**Mean Pre**	**std. dev.**	**mean post**	**std. dev.**
Chapter 3 Pre vs Post	23	**0.633**	-0.485	2.52	1.12	2.65	1.19
Chapter 4 Pre vs Post	12	**1**	0	2.42	0.793	2.42	1.08
Chapter 5 Pre vs Post	21	**0.693**	-0.4	2.48	0.873	2.57	0.978
Chapter 6 Pre vs. Post	13	0.002	-3.99	1.77	1.01	3.08	1.26
All Pre vs Post	69	0.04	-2.09	2.35	0.997	2.67	1.12
Mid 3 vs Post 3	18	0.185	-1.38	**2.83**	1.15	**3.22**	0.943
Mid 4 vs Post 4	9	**0.021**	2.87	3.33	1	2.44	1.24
Overall Mid	27	0.769	0.296	3.04	1.13	2.96	1.09
Final 3 vs Post 3	19	0.767	0.301	2.74	1.24	2.63	1.38
Final 4 vs Post 4	14	1	0	2.79	1.25	2.79	1.37
Overall Final	33	0.818	0.232	2.76	1.23	2.7	1.36

Demonstrations	**n**	**p**	**t**	**Mean Pre**	**std. dev.**	**mean post**	**std. dev.**
Chapter 3 Pre vs Post	20	0.004	3.24	**3.15**	0.875	**2.35**	0.745
Chapter 4 Pre vs Post	22	0.038	-2.22	1.55	0.912	2.05	1.09
Chapter 5 Pre vs Post	19	**0.205**	-1.32	2.47	0.905	2.74	0.933
Chapter 6 Pre vs. Post	10	**0.089**	-1.91	2.5	0.85	3.2	0.632
All Pre vs Post	71	**0.54**	-0.616	2.38	1.07	2.46	0.954
Mid 3 vs Post 3	18	**0.001**	-4.12	**2.39**	0.85	**3.06**	0.802
Mid 4 vs Post 4	8	0.351	-1	**2.25**	1.04	**2.75**	1.04
Overall Mid	26	**0.031**	-2.29	**2.42**	0.902	**2.88**	0.909
Final 3 vs Post 3	19	0.848	-0.195	**2.58**	0.838	**2.63**	1.12
Final 4 vs Post 4	17	0.236	1.23	1.94	0.899	1.65	1.06
Overall Final	36	0.545	0.612	2.28	0.914	2.17	1.18

READING DATA

Student #	Pre Chap3	Post Chap 3	Pre Chap 4	Post Chap 4	Pre Chap 5	Post Chap 5	Pre Chap 6	Post Chap 6	Mid Chap 3	Mid Chap 4	Final 3	Final 4
1	4	3	4	4	3	4	2	3	4			
2	3	3	4	3	4	4	1	4	4		1	4
3	4	2			3	3					4	4
4	3	4	3	3	2	2	3	4	3		4	2
5	3	3	3	1	2	3			3		2	4
6	0	0	2	3	2	3			2	3	2	3
7	4	1	2	1	2	3	1	2		1	1	1
8	3	4	2		3	1	2	4	4	3	3	4
9	4	4	4	4			1	4	4	4	4	4
10	2	2			4	3			3		4	4
11	3	3	2	3	2	2	3	2	4	1		
12	3	3	2	3	4	3				1	4	4
13	2	1			2	2			2		1	1
14	1	4	3	1	3	3			4		0	1
15	2	2	4	4	4	3	3	4		3		
16	3	3	4	4	2	3	1	4	4	4	4	4
17	1	1	2	3	1	1						
18	4	3	3	4	2	3	2	3	4	3	3	4
19	2	3	4	4	3	4	3	4	4		2	3
20	1	1	4	4	2	1	0	0	3	2	1	0
21	2	4	1		3	1	2		1	2	2	3
22	2	3	2	3	2	4			3		4	3
23	2	4	1	1	1	2	1	2	2		4	2
Average	**2.52**	**2.652**	**2.8**	**2.944**	**2.545**	**2.636**	**1.786**	**3.077**	**3.222**	**2.455**	**2.632**	**2.895**

	Control for 3	Mastery for 3	Control for 4	Mastery for 4	Control for 5	Mastery for 5	Control for 6	Mastery for 6		Overall Control	Overall Mastery
1	3	3	3	4	3	3					
2			4	3	2	4				4	3
3					3	2				3	4
4			3	3	3	3				4	4
5			3	3	3	3				3	3
6			4	3	4	1				4	2
7			3	2	2	3				3	3
8					2	2				3	2
9	2	4	0	3						4	3
10	2	3			2	3				3	3
11			3	2	3	3					
12					3	2				3	3
13	1	2			2	2				2	2
14	2.5	2.5	2	2	1	2				1	1.5
15			4	2	2	2					
16	2	4	4	3	4	2				4	2
17	1	2	3	2	2	2					
18	3	2	3	3	3	2				3	3
19			4	2	3	2					
20	3		4	2	4	3				2	2
21					3	2				2	2
22			2	3	2	4				2	3
23			2	2	2	3				3	3
Average	**2.17**	**2.813**	**3**	**2.588**	**2.636**	**2.5**	**#####**	**#####**		**2.944**	**2.694**

STUDENT DESIGNED LAB DATA

Student #	Pre Chap3	Post Chap 3	Pre Chap 4	Post Chap 4	Pre Chap 5	Post Chap 5	Pre Chap 6	Post Chap 6	Mid Chap 3	Mid Chap 4	Final 3	Final 4
1	2	3	2	4	2	4	3	4	3			
2	1	4	3	4	2	4	3	3	3	4	3	3
3	2		4		2	3	2	2			1	4
4	4	1	2	1	4	3	3	4	3		3	3
5	3	1	1	2	2	3	3	1	3		2	2
6	0	2	0	1	2	4	3		2	3	1	2
7	3	4	3	2	2	3	2	3		3	2	3
8	2	3	2	2	3	3	3	2	1	2	2	2
9	4	4	1	4			3	3	3	4	3	4
10	1	2	1		3	4			3		4	4
11	4	1	3	2	2	2	3	2	4	4		
12	2	2	2		3	3				2	2	1
13	2	2	1	1	1	1	2	2	1		2	2
14	3	1	2	1	1	3	3	2	3		3	1
15	2	4	3	4	3	4	3			2		
16	2	3	1	3	4	4	1	4	3	3	3	2
17	1	2	1	2	1	2	3	3				
18	3	4	3	4	3	4	3	3	3	4	4	3
19	2	1	1		2	3	2	4	2		2	4
20	2	3	0	2	3	1	3	1	1	2	0	0
21	4		1	2	1	1	3	2	1	3	1	1
22	2	4	1	2	3	4	2	1	2		2	2
23	2	1	1	1	1	3	2	2	3		3	3
Avg.	2.304	2.476	1.696	2.316	2.273	3	2.619	2.526	2.444	3	2.263	2.421

	Control for 3	Mastery for 3	Control for 4	Mastery for 4	Control for 5	Mastery for 5	Control for 6	Mastery for 6		Overall Control	Overall Mastery
1	3	3	3	3	3	3	3	3			
2	4	1	4	3	4	4	4	2		4	3
3					3	3	3	2		3	4
4			3	3	4	3	4	4		3	3
5			2	2	2	2	2	2		3	3
6			4		4	2	4	1		3	3
7	3	3	4	3	4	3	3	4		3	3
8	3	2	3	2			3	3		3	2
9	3	1	4	3			3	1		4	2
10	3	2			4	3				3	3
11			3	3	3	3	3	3			
12					4	2					
13			2	2	3	3	3	2		2	2
14			3.75	2.5	3	1	4	3.5		2	2
15	4	2.5	4	3	4	3					
16	2	2	4	3	4	3	4	2		4	2
17	3	2	2	2	3	2	4	4			
18	3	2	1	2	3	3	3	3		3	2
19	4	1			2	1	3	2		3	3
20	2	3	4	4	4	3	3	3		2	2
21			3	3	3	2	4	4		3	3
22			4	3	4	3	4	3		4	3
23			2	2	3	2	2	2		3	4
Average	3.083	2.042	3.145	2.694	3.381	2.571	3.3	2.675		3.056	2.722

TRADITIONAL LAB DATA

Student #	Pre Chap3	Post Chap 3	Pre Chap 4	Post Chap 4	Pre Chap 5	Post Chap 5	Pre Chap 6	Post Chap 6	Mid Chap 3	Mid Chap 4	Final 3	Final 4
1	4		4	4	4	3		2	4			
2	3	4	3	4	1	3		3	4	4	4	4
3	4	4	3	4			4	4			4	4
4	3	4	3	4	3	3		1	3		2	4
5	3	4	2	2	1	2	1	2	4		3	4
6	2	4	2	4	1	2		1	3	4	2	3
7	4	2	1	3						4	4	4
8	2	2	1	4	3	3			3	4	2	4
9	3	4	4	3				4	4	4	4	3
10	0	0	4	4					4		4	4
11	3	4	2	4	3	3		3	4	4		
12	2	0	4	4	2	3				4	2	4
13	2	2	2	4	0	1			2		0	2
14	3	3			2	3	2	1	3		3	4
15	3	4	4	4	4	3				4		
16	3	4	3	4	3	3		2	4	4	4	3
17	2	0	1	4	1							
18	4	4	2	4	1	2		2	4	1	2	4
19	2	4	3	1	4	3		3	4		3	3
20	2	1	1	3	1	2			3	1	2	3
21	2	2	3	4	0	0		4	4	4	2	0
22	3	0	2	4	2	3		2	4		3	4
23	2	3	0	3	1	2	1	2	2		3	3
Average	2.652	2.682	2.455	3.591	1.947	2.444	2	2.4	3.5	3.5	2.789	3.368

Student #	Control for 3	Mastery for 3	Control for 4	Mastery for 4	Control for 5	Mastery for 5	Control for 6	Mastery for 6	Overall Control	Overall Mastery
1			4	3	2	3	2	2		
2	4	2	1	3	4	2	4	1	2	4
3			4	4			4	3	4	4
4			3	3	3	3	3	3	4	3
5	3	4	2	3	3	3	3	3	3	3
6			3	2	2	2	4	2	2	3
7	2	3	3	3			2	2	3	3
8			3	3	3	2				
9	3	3	1	3			0	3	0	3
10			3	3						
11			3	4	2	2	2	2		
12			3	3	2	3			2	1
13			3	2	2	2			2	1
14					2	2	2	2	3	2
15			2	3	3	3				
16	3	3	2	2	3	1	3	2	3	2
17			3	2	2	2				
18	3	3	3	2	3	2	3	2	2	2
19	3	4	4	4	4	2			4	3
20			4	3	4	3	3	2	3	3
21			3	3	2	2	3	3	2	2
22			2	4	2	3	2	2	2	4
23			2	2	3	4	2	2	3	3
Average	3	3.143	2.773	2.909	2.684	2.421	2.625	2.25	2.588	2.706

DEMONSTRATION DATA

Student #	Pre Chap3	Post Chap 3	Pre Chap 4	Post Chap 4	Pre Chap 5	Post Chap 5	Pre Chap 6	Post Chap 6	Mid Chap 3	Mid Chap 4	Final 3	Final 4
1	4	3	1	2	3	4	4	4	4			
2	3	3	3	2	3	4	3	3	4	4	4	2
3	3	3	2	4	3	3					3	2
4	2	3	3	2	4	4	4	3	3		3	3
5	3	3	1	1	2	2			4		2	2
6	1	2	1	2	1	2	2	3	3	3	1	1
7	4	3	1		3	4	3	3		3	3	2
8	4	3	1	2	2	2	4	4	3	2	3	1
9	4	4	3	3			3	3	4	4	4	4
10	2	2	1	2	3	3			2		3	4
11	4	2	3	2	4	3	2		3			
12	3	3	1	3	3	3				1	1	2
13	3	1	2	2	1	1			3		1	1
14	4	2	1	2	3	3			1		3	4
15	4	4	1	4	2	4	4	4		3		
16	4	3	1	1	3	3	4	4	2	3	2	2
17	3	1	1	0	1	1						
18	4	4	3	3	4	4	3	4	3		2	3
19	4	2	1	2	2	3	4	4	2		4	4
20	3	2	2	1	2	2	2	2	3		1	1
21	4	1	0	1	4	3	2	4	2	2	2	0
22	3	3	1	1	4	4	1	4	4		4	2
23	2	2	1	1	2	3	2	3	3		4	2
Average	**3.261**	**2.565**	**1.522**	**1.955**	**2.682**	**2.955**	**2.938**	**3.467**	**2.944**	**2.778**	**2.632**	**2.211**

	Control for 3	Mastery for 3	Control for 4	Mastery for 4	Control for 5	Mastery for 5	Control for 6	Mastery for 6		Overall Control	Overall Mastery
1			2	2	2	3	3	3			
2			0	2	1	4	0	2		0	4
3			3	4	4	3				3	3
4			3	2	4	3	3	3		3	3
5			2	2	3	3					
6			2.5	0.5	3	2	3	3		1	2
7					4		4	4		3	3
8			2	1	3	3	3	3		3	3
9	1	3	2	3			3	3		2	4
10			3	3	2	3				2	3
11			3	3	2	2					
12			2	3	4	3				2	2
13			1	1	2	2				2	2
14			2.5	2.5	3.5	4				3	2
15			2	3	3	3	1	3			
16	1	3	2	2	2	2	0	3		1	3
17			2	1	2	2					
18	0	3	1	2	3	4	3	3		2	2
19			0	1	2	3	3	3		4	3
20			3	2	4	3	4	3		2	2
21			2	3	3	4	2	3		3	3
22			3	3	2	3	2	4		2	4
23			3	3	3	3	3	3		3	3
Average	**0.667**	**3**	**2.091**	**2.227**	**2.795**	**2.952**	**2.467**	**3.067**		**2.278**	**2.833**

NOTES - LECTURE DATA

Student #	Pre Chap3	Post Chap 3	Pre Chap 4	Post Chap 4	Pre Chap 5	Post Chap 5	Pre Chap 6	Post Chap 6	Mid Chap 3	Mid Chap 4	Final 3	Final 4
1	1	4		4	3	3	3	4	3			
2	0	0	2	3	2	3	3	4	2	2	2	4
3	2	2		3	2						3	3
4	2	2	1	3	4	4	4	4	2		2	2
5	3	3	2	3	2	4			2		1	1
6	0	1		1	2	2	1	3	1	3	1	0
7	1	2		4	3	4	4	1		3	1	3
8	1	2	3	4	2	3	2	1	1	2	1	1
9	3	4		4			4	2	4	4	4	4
10	2	2		4	3	3			3		2	4
11	0	1	2	2	3	4	2	3	2			
12	0	0	3	3	2	3				1	1	1
13	1	0		2					1		1	1
14	0	1	2	4	3	3			1			
15	1	3	1	4	3	3	3	4		4		
16	3	3	1	3	3	3	4	4	4	2	3	2
17	1	0		2		2						
18	3	2	3	4	3	4	4	4	3		2	4
19	1	2	1	2	3	3	4	3	1		2	3
20	1	2		0	2	1	2	2	0	2	0	0
21	0	2		4	3	3	4	3	1	2	1	1
22	3	3	3	3	2				3		2	4
23	3	3	1	3	3	2	4	3	2		0	1
Average	**1.391**	**1.913**	**1.923**	**3**	**2.65**	**3**	**3.2**	**3**	**2**	**2.5**	**1.611**	**2.167**

	Control for 3	Mastery for 3	Control for 4	Mastery for 4	Control for 5	Mastery for 5	Control for 6	Mastery for 6	Overall Control	Overall Mastery
1	3	3	3	3	3	2	2	3		
2	2	3	0	2	2	3	0	3	3	4
3	2	3	3	3					3	4
4	3	3	3	3	4	4	3	3	3	3
5	3	3	3	3	2	2			2	3
6	3	3	0	0	3	3	2	2	3	1
7	4	3			3	4	3	2	3	4
8	3	3	3	3	3	3			3	2
9	1	3	1	2			0	1	2	3
10	2	3	1	3	1	2			3	3
11	2	2	3	3	4	4	3	3		
12					2	3			2	2
13	2	2	1	2					2	2
14			3	3.5	3	3.25				
15			1	3	2	4	2	2		
16	0	2	0	3	2	3	0	1	1	2
17	3	3	2	2	2	2				
18	2	1	3	3	3	4	0	1	2	3
19	4	4	4	4	3	1	3	3	4	3
20	3	3	0	2	3	3	3	2	2	2
21			2	2	3	3			2	2
22	3	3							3	3
23	3	3	2	2	3	4	3	3	2	3
Average	**2.526**	**2.789**	**1.9**	**2.575**	**2.684**	**3.013**	**1.846**	**2.231**	**2.5**	**2.722**

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