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THE EFFECTIVENESS OF PERSONAL RESPONSE SYSTEMS AT INCREASING THE ENGAGEMENT AND ACHIEVEMENT OF STUDENTS IN A SCIENCE CLASSROOM

By

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ABSTRACT

THE EFFECTIVENESS OF PERSONAL RESPONSE SYSTEMS AT INCREASING THE ENGAGEMENT AND ACHIEVEMENT OF STUDENTS IN A SCIENCE CLASSROOM

By

Renee L. Gilson

Student engagement and immediate assessment of learning is crucial for students to successfully master the rigorous chemistry curriculum set forth under the Michigan Merit Curriculum. It has been my observation that students who are actively engaged and involved in the classroom discussion achieve greater success than students who aren't. The use of iClickers to increase every student's engagement and achievement in a non college prep chemistry course was evaluated. Specifically, students were evaluated on pretests and posttests and their results compared using a paired t test in two sections of a unit in the ChemCom curriculum. During the first section students regularly used the iClickers and during the second section they did not use them at all.

Both student engagement and achievement improved with the use of the iClickers as reported on student surveys and compared through pre- and posttest data. Students expressed that they liked using the iClickers and that the immediate feedback helped them better understand their mistakes. Student performance increased on all compared questions and the results of a paired t test showed significant p values for six out of the eight questions compared.

DEDICATION

I dedicate this thesis to my family. Their many sacrifices, patience, and unfaltering support have given me the strength to persevere to the end.

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Problem/Hypothesis

A common view among teachers is that student participation and engagement in class is a key component to student achievement. However, it is very difficult to engage most, if not all students, in class especially during lectures and to a lesser extent during activities and labs. Invariably, a few students are very eager to offer up their opinions and others occasionally get called on by the teacher, but all-in-all some students could go through most classroom lectures with very little engagement or participation.

Therefore, we teachers often make assumptions about the knowledge of the general populous of classes by the participation of a few students. Further development of concepts is based on this limited data set. Unless daily class formative assessments, such as daily quizzes, raising of hands, or holding up cards are performed, it is very difficult to evaluate where most students are in the learning process.

Giving students the opportunity to become engaged in lecture and laboratory activities in a non-threatening manner should, in principle, increase student achievement. In addition, by consistently giving feedback and opportunities to discuss the feedback, it is predicted that students will be better able to construct knowledge that is meaningful and lasting for them.

I hypothesize that through the daily use of personal response systems, or clickers, all students will increase their engagement and achievement in class, but specifically the lowest achievers, those with a 69% or lower in the class, will make the largest gains in achievement. Based upon informal observation, they are the students who least engaged in classroom discussions or question and answer sessions. They have trouble starting problems without assistance and often get overwhelmed with trying to make sense of new content.

Theoretical Framework

The foundation for this project is built on three areas of research. The first area of research is constructivism. The theory of constructivism delineates how students learn new concepts and is a fundamental scaffold in understanding the value of feedback to student achievement. The second area of research is feedback, specifically whether feedback is formative, which is often classified as diagnostic, or summative, which most often is evaluative. The third area of research is on the use of personal response systems, or clickers, as a tool used to aid in formative assessment and ultimately better equip the student to construct new and lasting knowledge.

Gail Bush (2006) categorizes the learning theories of the 20th century as mostly two varieties, behaviorism and constructivism. For most of the 20th century, Bush asserts that behaviorism was pervasive in the classroom. This teacher-centered instructional model was based primarily on the work of B.F. Skinner. Underlying assumptions of behaviorism included the belief that all learners gain the same understanding and that all students can learn given appropriate environmental influences. In this model teachers lectured and students passively took in what they were saying. Students practiced what they were taught and then demonstrated their knowledge of the concepts on a summative test at the end of the unit. Therefore, only at the culmination of a unit, perhaps weeks in duration, teachers would determine whether students "got it" or not (Gardiner, 1996).

With the advent of cognitive theory or the idea that learning is an active process that involves organizing new information and linking it to prior knowledge, educators began to seriously evaluate how they taught (Abrahamson, 1999). This learning process became known as constructivism. Constructivism is a set of beliefs about knowing and learning. It is based on the idea that each learner uses his or her prior knowledge and past experiences and builds upon them to modify and formulate new knowledge (Dufresne, Gerace, Leonard, Mestre, and Wenk 1996).

Currently, many educators conceive of learners as “architects building their own knowledge structures” (Wang, Haertel, and Walberg, 1993). The view of the learner has changed from that of a passive recipient of knowledge to that of an active constructor of knowledge. This view incorporates the assumption that the learner is aware of the processes of cognition and can control and regulate them. This self-awareness, or metacognition (Flavell, 1976), significantly influences the course of learning (Anthony, 1996).

Unfortunately, students often have difficulty with metacognition. Realizing what they actually know and don’t know is a crucial step in constuctivism. Not being able to adequately process information makes it extremely challenging for them to formulate new knowledge and know where it belongs within their prior knowledge (Kyriacou and Marshall, 1989). When faced with a problem that involves multiple steps, they often cannot complete the task or frequently have difficulty even knowing where to start. According to Chickering and Ehrmann (1996), knowing what you do and don’t know is a critical link in formulating new knowledge. Therefore, students need help in assessing their existing knowledge and competence. They need frequent opportunities during class to receive feedback, otherwise known as formative assessment, on their performance and then adjust accordingly. This link between metacognition and feedback was witnessed in a study by Glenberg et al. (1987). In their study, students used feedback from pretest questions to improve their understanding of closely related posttest items.

Madeline Hunter (1982) classifies instructional feedback as checking for understanding. Hunter describes the process as a determination of whether students have "got it" before proceeding. Hunter also notes that the teacher must know that students understand before proceeding. In other words, collecting feedback, analyzing feedback, and making an assessment of whether or not learning has occurred is a critical step in the teaching and learning process. Doing the three aforementioned tasks in an efficient and useful manner is very daunting, even for the most experienced educator.

The Michigan Merit Curriculum (Anderson and Poel, 2007) states the assessment process can be a powerful tool for learning when students are actively involved in the process. Both summative (assessment *of* learning) and formative (assessment *for* learning) are essential. Reliable formative and summative assessments provide teachers with information they need to make informed instructional decisions that are more responsive to students' needs.

Feedback, formally known as formative assessment, appears to be a crucial component of learning, as witnessed by the following insights in the literature. Bellon, Bellon, and Blank (1992) claim that "academic feedback is more strongly and consistently related to achievement than any other teaching strategy. This relationship is consistent regardless of grade, socioeconomic status, race, or school setting. When feedback and corrective procedures are used, most students can attain the same level of achievement as the top 20% of students."

According to Wiggins (2008), feedback is useful information about performance. Feedback is critical, and perhaps the key element, in effective learning. No goal worth meeting is ever met without good feedback and opportunities to use it. It describes what the learner did and did not do in relation to her goals. It empowers the student to make intelligent adjustments when she applies it to her next attempt to perform. Wiggins (2008) states: "It's not the teaching that causes successful, eventual learning. It's the attempts and adjustments by the learner to perform that cause accomplishment. Without feedback all of the teaching, no matter how extensive, remains theoretical to the learner."

In a nutshell, proper and prompt formative assessment is the key to learning. It should be done frequently and used to guide the learner through the reconstruction of current knowledge and the accommodation of new knowledge. However, effective assessment is difficult due to the sheer volume of students and material that needs to be assessed. Yet according to Desrochers (2005), "if students are to benefit from feedback, it must be timely and frequent".

Foremost to our endeavor to transform our students into metacognitive thinkers as they create new knowledge, is the degree to which our students are actively involved in their learning. In essence "the effectiveness of any educational practice is directly related to the capacity of that practice to increase involvement in learning" (Gardiner, 1996). Although the literature expounds many types of constructivism (Ernest, 1995), all embrace the principle that "learning is not a passive receiving of ready-made knowledge but a process of construction in which the students themselves have to be the primary actors" (von Glasersfeld, 1995). Engagement empowers students to take ownership of their learning and builds confidence over time (Anderson and Poel, 2007).

In the past, engagement often meant a show of hands for each option presented. This method saved time and allowed students to gauge their relative understanding, but did not fully eliminate intimidation as some peer pressure remained (Poulis et al., 1998). In the 1990's, Eric Mazur (1997) embraced peer interaction when problem solving, as well as using sets of flashcards in response to multiple choice questions. The instructor would then estimate the proportion of students holding each alternative answer and adjust the instruction accordingly. Mazur's method both engaged students in dialog while problem solving while, at the same time, offered valuable formative assessment to both the student and the teacher. To further enhance the efficiency of the formative assessment, Mazur (2009) has since replaced his original flashcards for modern day personal response systems or clickers.

Immediate feedback to the student and the teacher is a major benefit of using personal response systems in the classroom (Brewer, 2004). Personal response systems, or clickers, are handheld devices that allow students to immediately enter answers to a posed question. The submitted answers are then tabulated and displayed for all to see. With the use of personal response systems, teachers can immediately determine weaknesses and strengths of the class or of individual students, and students can easily identify errors in their knowledge base.

Brewer (2005) also notes that using personal response systems provides an avenue for strengthening the teaching-learning connection, as evidenced by improved student attitudes. As reported by Barrett et al. (2005), the use of personal response systems in the classroom enhances the communication between the students and the instructor and helps instructors assess student comprehension. In addition, the students display satisfaction toward course work in class, feel they learn the material better, and prefer classes that use personal response systems. The personal response systems apparently helped students feel empowered by encouraging them to answer questions anonymously as a way of letting the teacher know which concepts were mastered and which needed more work, while at the same time they helped students identify their own gaps in content material.

Many students are shy or easily embarrassed. Personal response systems afford students anonymity. The instructor also often feels freer to encourage student engagement and interaction when they can do so without offending any student because student responses would be anonymous. Increased engagement is more likely to result in a deeper approach to learning, and is therefore more likely to lead to increased understanding and learning outcomes (Freeman and Blayney, 2005). Murphy and Smark (2006) concluded that personal response systems had a positive effect especially on those quieter students that educators always encounter and often fail to develop meaningful contact with them. In essence, the personal response system isn't what is important, for novelty will wane, but how the technology is used to engage students in the thought process (Draper & Brown, 2004).

Encouraging students to engage earnestly in learning is an instructional challenge worth meeting, because quality learning outcomes are most likely to occur when students adopt a deep approach to learning (Ramsden, 2003). Freeman and Blayney (2005) also revealed in their study that students perceived a much greater increase in understanding of the material using a personal response system vs. the traditional raising of hands, as well as a greater ability to gauge their own understanding of the material. Allowing students to remain anonymous during some of the feedback can be an effective method for engaging students in their learning and equipping them with the tools they need to increase their understanding and create knowledge that is meaningful and lasting.

Science Taught

The ChemCom curriculum is divided into seven units that introduce chemistry concepts as they relate to a common theme. Student performance data were collected during the second unit, *Materials: Structure and Uses.* This unit examines properties of and changes in matter.

Compounds, elements, and mixtures are categories used to organize matter. Matter is grouped into these categories based on its chemical and physical behavior. The structure of the atom is used to make predictions about the physical and chemical properties of various elements and the types of compounds those elements will form. Differences in the physical and chemical properties of substances are explained by the arrangement of the atoms, ions, or molecules of the substances and by the strength of the forces of attraction between the atoms, ions, or molecules.

Electrons, protons, and neutrons are parts of the atom and have measurable properties, including mass and, in the case of protons and electrons, charge. The nuclei of atoms are composed of protons and neutrons. A neutral atom of any element will contain the same number of protons and electrons. Ions are charged particles with unequal numbers of protons and electrons. Isotopes are atoms of the same element with different numbers of neutrons and essentially the same chemical and physical properties.

In the periodic table, elements are arranged in order of increasing number of protons, called the atomic number. Vertical groups in the periodic table, called families, have similar physical and chemical properties due to the same outer electron structures. The rows, or periods, in the periodic table represent the main electron energy levels of the atom.

Changes in matter involve both physical and chemical changes. In chemical changes, two or more substances interact and produce one or more different substances whose physical and chemical properties are different from the interacting substances. When substances undergo chemical changes, the number of atoms in the reactants is the same as the number of atoms in the products.

During Section B, *Earth's Mineral Resources,* students covered the concepts of electron configurations, oxidation numbers, redox reactions, and how redox reactions can be used to recover metals trapped in ores.

Chemical reactions are classified according to the fundamental molecular or submolecular changes that occur. Reactions that involve electron transfer are known as oxidation/reduction or redox reactions. An oxidation number (oxidation state) usually is the charge an atom would carry if the molecule or ion were completely ionic. In a redox reaction, one element is oxidized or loses electrons and another element is reduced or gains electrons. Gaining and losing electrons changes each element's oxidation number. Common oxidation states can be determined by an element's location on the periodic table or by its electron configuration.

Understanding an element's electron configuration is one of the most important tools to use in prediction and explanation of the structure and behavior of atoms. An atom's electron configuration, particularly of the outermost electrons, determines how the atom can interact with other atoms. The interactions between atoms that hold them together in molecules or between oppositely charged ions are called chemical bonds.

The metal reactivity series is used to predict whether a redox reaction will occur spontaneously. The more reactive metals lose electrons readily and are quickly oxidized.

These elements are seldom found in their pure state in nature, likewise the less reactive metals can often be found in their pure state.

Demographics

This study was conducted at Clinton High School located in Clinton, Michigan. Clinton High School had a 9-12 enrollment of 386 in 2009 – 2010 of which 97% of students were White, 2% Hispanic, 1% African American and 1% Asian. Nineteen percent of the students received free or reduced lunch.

The surrounding community is predominantly rural. The town of Clinton has a population of 4,802 with 24% having a post-secondary degree. The median family income is $57,000 compared to a national average of $52,000.

The class in which I conducted my research consisted entirely of juniors who were predominantly not pursing science related careers after high school. All of the students had taken Biology their freshman year, and most of them had taken Physical Science their sophomore year. All but five students were taking this class to fulfill the State of Michigan's science requirement. Those five students had chosen the class as an elective.

Twenty-seven students volunteered to be in the study. Forty-five percent of the cohort had poor attendance, which was identified by having ten or more absences per semester. Fifteen percent qualified for special education services.

Implementation

Clinton High School's academic year is divided into two semesters. Each semester is two quarters in duration, with each quarter lasting nine weeks. Students have seven forty-nine minute class periods per day. This research was conducted during the 2nd and 3rd quarters of the 2009-2010 school year. The students participating were juniors and seniors enrolled in General Chemistry. The ChemCom curriculum was used as a foundation with additional enrichment activities added. During the first section (A) of this unit, *Why We Use What We Do*, students used iClickers several times a day as a means of formative assessment for both the student and teacher. The same students did not use iClickers for the second section (B) of this unit, *Earth's Mineral Resources.* Pre- and post- tests and student surveys were evaluated and compared.

Prior to beginning the research, students had been trained in class on the use of iClickers. Training was accomplished by using the clickers to answer general knowledge questions and to peer grade student presentations. During Section A students used iClickers daily during warm up questions, throughout the lesson, and at the culmination of the lesson. During Section B students never used the iClickers. In lieu of the iClickers, students were randomly selected to answer questions or called on after voluntarily submitting an answer.

Sections A & B each lasted approximately two weeks (Tables 1 & 2) with a pretest (Appendix C & D) given at the beginning of each section and a posttest (Appendix C & D) given at the conclusion of each section. During Section A students used the iClickers daily to answer approximately fifteen to twenty questions. Of those questions, three to five were warm up questions at the beginning of class. The warm up questions were usually follow-up questions from the previous' days concepts, with one or two questions on new concepts to assess prior knowledge. Warm ups lasted approximately five minutes. Students also used the iClickers throughout the hour to either answer five to ten questions embedded in a lecture or to answer questions during or at the end of an activity or lab. These questions were to clarify directions, assess understanding, review previous concepts, and preview future concepts and prior knowledge. At the end of every day during Section A, students were given three to five exit clicker questions to test their understanding of the day's concepts. The exit questions lasted less than five minutes. Sample warm up questions, lecture/activity questions, and exit questions can be found in the Appendix C. Students were given an initial survey questionnaire (Appendix B) at the inception of section A about the value of participating in class and their views on lectures. They were given a final survey questionnaire (Appendix B) about the value of the iClickers at the culmination of Section B.

Table 1 outlines the scope and sequence followed during Section A. Each day's objectives and activities are listed. Activities that are unique to this research and not part of the ChemCom curriculum are asterisked. Each of the activities can be referenced further in Appendix C.

Section A Schedule: Why We Use What We Do

Day	Objective(s)	Activities
1	➢ Draw pictures to distinguish the relationships between atoms in physical and chemical changes (atoms) making up the substance. ➢ Draw a picture of the particles of an element or compound as a solid, liquid, and gas. ➢ Describe the various states of matter in terms of the motion and arrangement of the molecules	➢ Survey I ➢ Pretest ➢ Lecture (Physical & Chemical Properties & Changes) ➢ Demonstrations* (Physical & Chemical Changes)
2-3	➢ Distinguish between and classify examples of chemical and physical properties and chemical and physical changes.	➢ Lab*- (Physical & Chemical Changes)
4	➢ Classify selected elements as metals, nonmetals, or metalloids based on observations of chemical and physical properties	➢ Lecture-(Metal, Nonmetal, Metalloid) ➢ Lab- (Metal or Nonmetal)
5	➢ Identify metals, non-metals, and metalloids using the periodic table. ➢ Describe the organization of the periodic table	➢ Group Activity- (Grouping the Elements) ➢ Lecture-(Periodic Table History & Future)
6	➢ Use the periodic table to a) predict physical and chemical properties of an element b) locate periods and groups (families) of elements	➢ Group Activity*- (Alien Periodic Table)
7	➢ List the number of protons, neutrons, and electrons for any given ion or isotope. ➢ Recognize that an element always contains the same number of protons. ➢ Write the symbol for an isotope, *XZA*, where *Z* is the atomic number, *A* is the mass number, and *X* is the symbol for the element.	➢ Lecture: (Isotopes) ➢ Group Activity*: (Easter Egg Isotopes)
8	➢ Predict trends in atomic radius, first ionization energy, and electronegativity of the elements using the periodic table.	➢ Group Lab*: (Experimentally predict Density of Ge)
9	➢ Review all objectives	
10		➢ Posttest

Table 1: Class schedule for Section A, iClickers. Activities that are unique to this research and not part of the ChemCom curriculum are asterisked.

Summary of Section A-iClickers

Section A contained numerous labs and activities for the students to do. Students liked the "idea" of a lab or activity because it allowed them more freedom to socialize about personal matters, but the actual academic benefit of them is to be debated. Students were randomly placed in groups of three or four. In some groups, there was good dialog and problem solving that occurred amongst the students. However, in most groups there was a lead student that most of the other group members followed.

Physical and Chemical Changes Lab*: (Appendix C) This was an enrichment activity I added to the ChemCom curriculum. The objective of this lab was to distinguish between and classify examples of chemical and physical changes. It entailed performing various changes to matter then classifying whether the observed changes where physical or chemical in nature. I purposely gave students two days to do this lab because past experience in similar labs revealed many mistakes in the analysis when they weren't given proper time to discuss what happened. The students genuinely enjoyed this lab because of the many different types of reactions that took place, such as color changes, temperature changes, losing magnetism, and giving off gases. With the extra time allotted, they also came away with some concrete practical examples of physical and chemical changes. In the future I would add a component where students would be asked to draw a picture of the particles before and after a physical and a chemical change took place. This would help them to visualize what is actually happening between the elements and molecules.

Metal or Nonmetal Lab: (Appendix C) The objective of this lab was to classify selected elements as metals, nonmetals, or metalloids based on observations of chemical and physical properties. In this lab students were given samples of elements. They recorded physical and chemical properties of the elements and grouped them into the appropriate category of metal, nonmetal, or metalloid. This lab made students think critically and use the content they had previously learned to make predictions. It was especially noteworthy when metalloids were tested, because they didn't fit neatly into a category. They also liked seeing samples of the elements. I wouldn't change much about this lab except to get more unique elements each year. Some students inevitably knew the identity of some elements before testing them, but overall most had to use their observations to classify them.

Grouping the Elements Activity: (Appendix C) The objective of this activity was to describe the organization of the periodic table. Students were given twenty-four cards with element properties on them. They then had to arrange the elements in order of increasing atomic mass and then use similar properties to place them into groups. Within each group, they had to look for a trend and arrange the elements based on that trend. This activity was very time consuming and frustrating for the students. There were too many anomalies on the element cards that distracted the students from the big picture of how the periodic table is organized. I liked having the properties of the elements on the cards and having the students see the relationships and anomalies. In the future I will have the cards already arranged so the students will then have to analyze the group properties and trends present and predict the properties of a missing element card.

Alien Periodic Table Activity*: (Appendix C) This was an enrichment activity I added to the ChemCom curriculum. The objective for this activity was to use the organization of the periodic table to group other objects (aliens) into a "periodic table" based on the same principles as the periodic table of elements. Students were then asked to predict the properties of an unknown "alien" on their periodic table. At the onset students were given eighteen drawings of aliens and instructed to organize them into eight groups, much like the current periodic table. Students easily grouped the aliens, but had a difficult time arranging them correctly within the groups and periods to reflect trends seen on the periodic table. Unfortunately, once one group got the correct arrangement, all other groups followed suit fairly quickly. There are other variations of this type of activity that use different items to organize. In the future I will try to give groups of students different items to help generate discussion amongst the groups of students to facilitate reasoning versus copying.

Easter Egg Isotopes Activity*: (Appendix C) This was an enrichment activity I added to the ChemCom curriculum. The objectives for this activity were to recognize that an element always contains the same number of protons and to write the symbol for an isotope. In this activity groups of students were given eight plastic eggs containing different numbers of colored beads that represent protons and neutrons. Students had to write the correct isotope symbol, including the atomic number, mass number, and element symbol for each egg. They then had to determine which eggs were the same element and which eggs were different elements. This activity was very easy for students. I would definitely modify it to make the students think more instead of simply following the same process each time. For example: I would have them construct their own isotopes (eggs). They could then switch eggs with another group and check for understanding.

Experimentally Predict the Density of Germanium*: (Appendix C) This was an enrichment activity I added to the ChemCom curriculum. The objective for this lab was to predict the property of an element based on the properties of other elements in its group. This lab was a class lab in which each group of students was responsible for finding the density of an element in group 4A. Once all groups reported their data, we graphed the data using Excel and used the curve to predict the density of germanium. Students then calculated the percent error and as a class came up with sources of error. This lab was the most successful. Each group had less to accomplish, which made them take their time, and it allowed for multiple trials to be completed. Each team's data were also of utmost importance to everyone in the class. Without each team's data we would not have been able to find the unknown density. Students realized this at the onset, and therefore were very serious and focused on procuring accurate data. This format led to a richer class discussion and analysis. There definitely was a heightened sense of collaboration.

During section A students were given minimal homework each night. Most of the questioning was done in class in the form of clicker questions. (Appendix C) Students were given fifteen to twenty clicker questions daily. Approximately five clicker questions were given at the beginning of class, five at the end of class, and five to ten dispersed throughout the hour. Students were usually given 30 seconds to 1 minute to answer the beginning of the hour warm up questions and the end of the hour exit questions. More time was allotted, depending on the difficulty, for the questions that were dispersed throughout the hour. The day before the post test was a review day in which we went through all the previous clicker questions; therefore, they were exposed to many more questions on that day.

Table 2 outlines the scope and sequence of Section B, the no iClicker section. This section immediately followed Section A. Students did not use iClickers at all during Section B. Each day's objectives and activities are listed. Activities that are unique to this research and not part of the ChemCom curriculum are asterisked. Each of the activities can be referenced further in Appendix D.

Section B Schedule: Earth's Mineral Resources

Day	Objectives	Activities
1	➢ Describe or recognize factors that determine the feasibility of mining an ore at a specific site ➢ Name the two most important metals that shaped Michigan's past	➢ Pretest ➢ Lecture: (Sources & uses of metals) ➢ Inquiry Activity*: (Properties of Copper Ores)
2	➢ Explain the process of oxidation and how it affects mining	➢ Lab: (Converting Cu to CuO)
3	➢ Write the complete electron configuration of elements in the first four rows of the periodic table ➢ Write kernel structures for main group elements ➢ Predict oxidation states and bonding capacity for main group elements using their electron structure.	➢ Demo*: Floating Penny ➢ Lecture: (Stability/Electron Configurations) ➢ Worksheet Practice-In Class
4	➢ Explain why minerals of more active metals are more difficult to refine and process than minerals of less active metals	➢ Demo*: Floating Penny discussion ➢ Lecture: (Metal Reactivity/ Metallurgy)
5	➢ Explain why minerals of more active metals are more difficult to refine and process than minerals of less active metals ➢ Describe the metal reactivity series	➢ Lab*: (Predicting Metal Activity Series)
6	➢ Predict single replacement reactions.	➢ Lecture: (Metal Activity Series/Single Replacement Rxns) ➢ Computer Animation*: (Activity Series Animation)
7	➢ Predict single replacement reactions.	➢ Demo*: Combustion of Mg ➢ Worksheet-Predicting Products Group Work
8	➢ Balance half-reactions and describe them as oxidations or reductions.	➢ Lecture: (Half Reactions) ➢ Redox Concepts Practice Wkst
9	➢ Review all objectives	➢ Jeopardy Review Game
10		➢ Post Test ➢ Survey II

Table 2: Class schedule for Section B, no iClickers. Activities that are unique to this research and not part of the ChemCom curriculum are asterisked.

Summary of Section B-no iClickers

The content in Section B proved to be much more difficult for students to master. The concepts presented were predominantly newly introduced during this class, so the students had very little prior knowledge to draw upon. The format of Section B was also different. There were more teacher demonstrations in this section versus group activities. Since iClickers were not used in this section, there also were more handouts and worksheets given for practice versus practicing as a class as we did in the first section with the use of iClickers.

Although students really like demonstrations, they have a difficult time getting any meaningful content connections out of what they see. When asked to explain the purpose of a demonstration, most students could tell you with good clarity what they saw happen, but were unable to elaborate about the relevant science behind it.

Properties of Copper Ores* (Appendix D) This was an enrichment activity I added to the ChemCom curriculum. The objectives for this lab were to identify common physical properties among oxide and sulfide copper ores and to name several varieties of copper ores that were important to Michigan's economy. In this lab students were given a variety of copper ores. They were instructed to identify various physical properties of each ore and then attempt to sort them into sulfide ores and oxide ores. Students were intrigued by the vivid colors of the copper ores. It was a good introductory activity because it got students thinking about differences in the ores.

Converting Copper to Copper Oxide (Appendix D) The objective for this lab was to demonstrate the formation of an oxide ore. In this lab students took a known mass of copper powder and heated it in the presence of oxygen to produce copper oxide, as indicated by a color change and mass change. This lab was really boring for the students and the mass gain was negligible for most of them to be convinced that oxygen was added. The color change was very evident, but this could have been accomplished by using a lot less copper and time. If I include this lab in the future, I would attempt to make it more of an inquiry lab giving the students different samples of metals and seeing which ones oxidized the best under high heat or do this as a teacher led demonstration. The students didn't correlate that this lab simulated processes that occur in nature over much longer time periods.

Floating Penny Demonstration* (Appendix D) This was an enrichment demonstration I added to the ChemCom curriculum. The objectives for the demonstration were to show the difference in activity between copper and zinc and to describe factors that dictate the type of metal used in certain applications. In this demonstration pre-1982 and post-1982 pennies are etched with a file and then left in 6M hydrochloric acid overnight. The next day the post-1982 pennies are floating because they contain a zinc core which has reacted with the hydrochloric acid. The pre-1982 pennies are pure copper and since copper is less reactive than zinc the hydrochloric acid doesn't react with it and those pennies stay on the bottom of the cylinder. This was a good demonstration. It is easy to set up and perform, and it works every time. The students were all talking about the results before class even started the next day. This demonstration also led to a great discussion on the cost of certain metals and recycling.

Predicting the Metal Activity Series* (Appendix D) This was an enrichment activity I added to the ChemCom curriculum. The objective for this lab was to experimentally determine the metal activity series. In this lab students were given samples of six metals and a solution of copper (II) chloride. By testing the reactivity of the metals in the copper (II) chloride, they came up with their version of the metal activity series by ranking the metals from most reactive to least reactive. This was by far the best lab in Section B. The lab procedure was short enough that it allowed students an opportunity to repeat parts of it and confer with other groups to try and determine the correct order. This activity did an excellent job of connecting application and theory.

Activity Series Computer Animation* (Appendix D) The objective for this activity was to use the metal activity series to predict the products of single replacement reactions. Students performed various simulations where they added metals to different nitrate salts. They watched the reactions and analyzed what they saw by comparing it to the metal activity series. They then had to predict if various single replacement reactions would happen and then test their predictions. This computer simulation worked well for reinforcement of the inquiry lab they had performed the day before. It provided the avenue for students to proceed at their own pace and to go back and check their answers. It also gave them immediate feedback without needing a teacher or peer present.

Combustion of Magnesium Demonstration* (Appendix D) This was an enrichment demonstration I added to the ChemCom curriculum. The objectives of this demonstration were to observe a vigorous oxidation reaction, as compared to the oxidation of copper they performed earlier; to write oxidation numbers; and determine which element was oxidized and which was reduced. The students had already seen what happens when magnesium is burned in oxygen in a lab they performed in Section A. However, it was used here in a different context and the purpose was to build on their prior knowledge and further explain the chemical change that occurred in light of the new concepts we were studying. The demonstration always is a great attention grabber.

During Section B I had to find another way to offer students the amount of formative assessment they were afforded in Section A with the clickers. To accomplish this, students were assigned more in-class problems to solve in their respective groups. Students would work together on solutions to various problems and then come and get an answer key. At the end of a designated amount of time, any questions left unanswered in their groups would be directed to the teacher or class as a whole. Any work not finished in class would then be assigned for homework.

Section B contained fewer labs and activities, but more demonstrations and group work time. There were numerous students who commented that they liked this format better than Section A because they had a chance to work at a slower pace. The second survey was given to students at the culmination of this section. Its purpose was to gather student impressions on the use of the iClickers. At the time of taking the second survey, students had two weeks of extensive use of iClickers followed by another two weeks of no use.

Results/Evaluation

At the start of the unit, students were given a survey (Appendix B) that asked general questions regarding the importance of class participation and their attitudes toward participating in class. These questions and the results are shown in Figure 1.

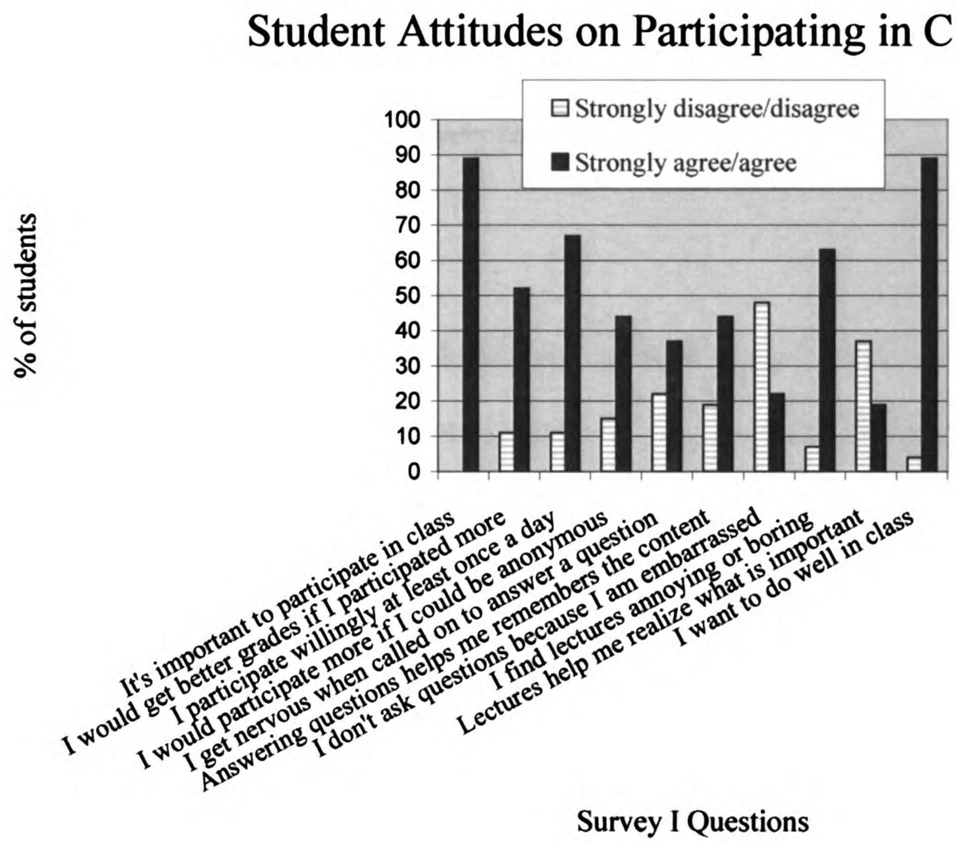


Figure 1: Results of Survey I on student participation. This survey was conducted before the inception of Section A, the iClicker section.

The survey strongly suggests that the majority of students want to do well in class and believe that participating is important, yet only 52% of students believe that they would increase their grade if they participated more. Sixty-seven percent of students believe that they already participate at least once a day.

The survey also suggests that a minority of students, 37%, get nervous when called on to answer questions, and only 22% are embarrassed to ask questions during class. These results did surprise me. However, the results could be attributed to the fact that I have had a majority of the students at least once before in a different science class. Another factor could be that Clinton is a small school in which most students have known each other for many years and are very comfortable around each other.

Section A Results-iClickers

Quantitative data were collected and analyzed using a paired t-test on pre- and post- tests for Section A. In Section A, where n = 27, six out of the eight pre- and post-test question comparisons analyzed showed a significant p value of 0.01 or less. (Table 3) This implies that roughly 75% of the time data supports the hypothesis that using clickers will increase student achievement in the science classroom.

Pre- and Posttest Questions for Section A	t score	p value
#1: ID elements with similar chem and phys properties	4.91	0.0
#2: Predict general trends of elements in groups using the p. table	0.711	0.484
#3: Identify that neutral atoms contain the same # of p+ and e-	0.284	0.832
#4: Distinguish between chemical and physical changes	5.02	0.0
#5: ID metals, non-metals, and metalloids on the periodic table.	2.95	0.007
#7: Draw water as a solid, liquid, and gas with correct spacing, motion, and # of particles	3.45	0.002
#8: Draw pictures to distinguish atoms in phy and chem changes	2.82	0.009
#11: Write the symbol for an isotope, using XZA	4.23	0.0

Table 3: t and p values for paired t test. Section A pre- and posttest analysis. n = 27

P values for question 2 and 3 were above the cut off value of 0.01. Therefore, I would have to consider the null hypothesis that there potentially is no difference between performance with or without the use of iClickers for these two questions. A possible explanation for the discrepancy seen in question 2 could be due to this question requiring more processing and problem solving, as it involved estimating an element's physical property based on the physical properties of two or more elements in the same group. I witnessed a drop in student attention and focus when mathematical computations were involved in determining an answer. In regard to question 3 (Figure 2) about neutral elements having the same number of protons as electrons, there was minimal increase of 3% in performance from pre- to post- test scores, as approximately 67% of students came into this section already knowing this concept.

Student performance improved on all questions analyzed on the pre- and post-tests (Figure 2) in Section A, with only two questions having fewer than 70% of students responding correctly. At the culmination of this section, student achievement was at or above 70% on 75% of the analyzed questions. One possible contributing factor could be the regular use of clickers.

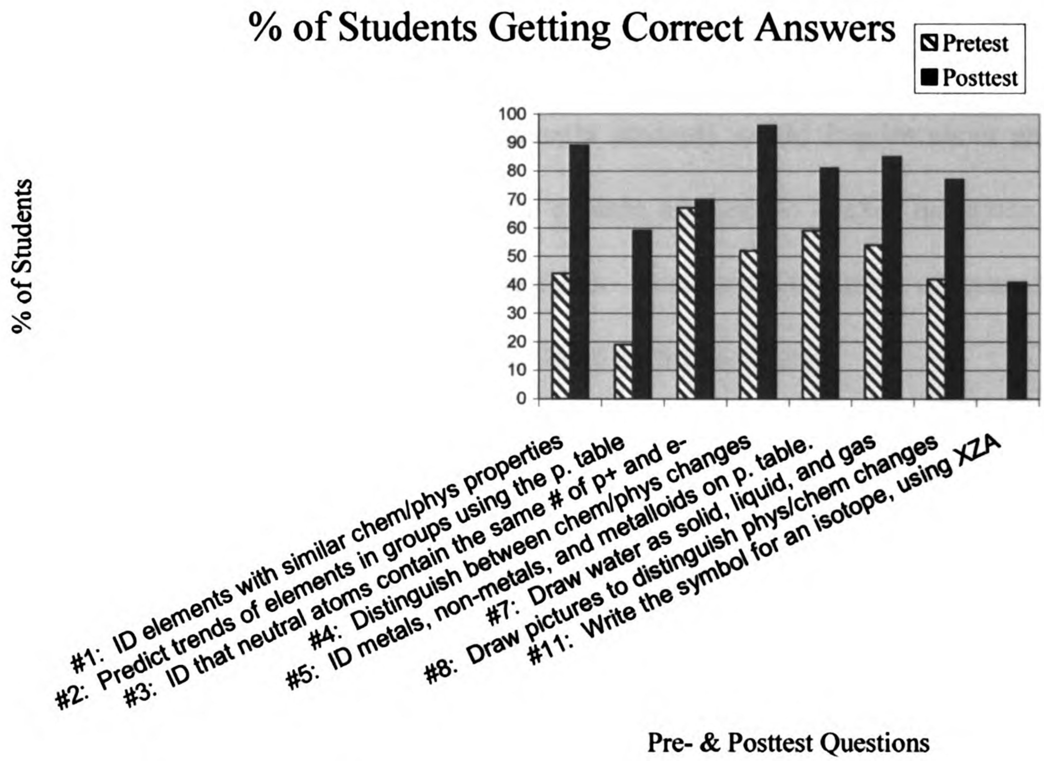


Figure 2: Percent of students with correct answers in Section A as witnessed on pre- and posttest analysis. n = 27

I really benefited from using the clickers as a means of formative assessment on a daily basis. Often by looking at the responses that students gave, I could determine immediately where many misconceptions were for students. If I was unable to discern students' misconceptions, I would solicit reasons for wrong answers from the class. This helped many otherwise very quiet students verbalize their questions. It was an invaluable way for me to immediately assess whether the majority of students got it or not. I didn't have to rush to grade papers, try to parse out overarching misconceptions, and then remember to discuss those misconceptions the next day.

Initially students were very enthusiastic about using the clickers because they were a novelty. Nevertheless, as we continued to use them, I rarely heard negative remarks about using them. I noticed that frequently students would inquire about an answer on days that I didn't stop and explicitly explain answers to clicker questions, indicating students wanted to understand their mistakes. A common comment expressed by students was that the clickers made it easier for them to ask questions.

Section B Results-No iClickers

Analysis of Section B showed that eight out of the thirteen pre- and post- test questions had a significant p value of 0.01 or less as indicated by Table 4. These data imply that using random questioning techniques during class improves student achievement approximately 62% of the time.

Pre- and Posttest Questions for Section B	t value	p value
#1: Interpret metal reactivity series	0.273	0.787
#2: ID products of single replacement reaction	4.31	0
#3: Define oxidation/reduction	9.54	0
#4: Recognize oxidation/reduction half reactions	1.2	0.24
#5: Identify oxidized/reduced element	1.22	0.232
#6: Write oxidation/reduction reactions	2.89	0.008
#7: Predict products of single replacement reaction	8.28	0
#8: ID metals important to MI	0.901	0.376
#9: ID most abundant elements in Earth's crust	3.41	0.002
#10: ID oxidation/reduction half reactions	1.64	0.114
#11: Write complete electron configurations	6.65	0
#12: Write kernel electron configurations	4.56	0
#13: Determine oxidation #'s	2.79	0.01

Table 4: t and p values for paired t test on pre/posttest questions in Section B, no iClickers. n=27

Student achievement during Section B (Figure 3) was noticeably less than the Section A. This could be due to a couple of factors. First, many of the concepts introduced in Section A had been previously introduced in other courses previously taken by the students so they had some prior knowledge. The content taught in Section B was completely new for a majority of the students. Therefore, they had little, to no, prior knowledge from which to draw. The content presented in Section B was also more abstract and challenging for students to understand, therefore potentially contributing to the relatively lower achievement.

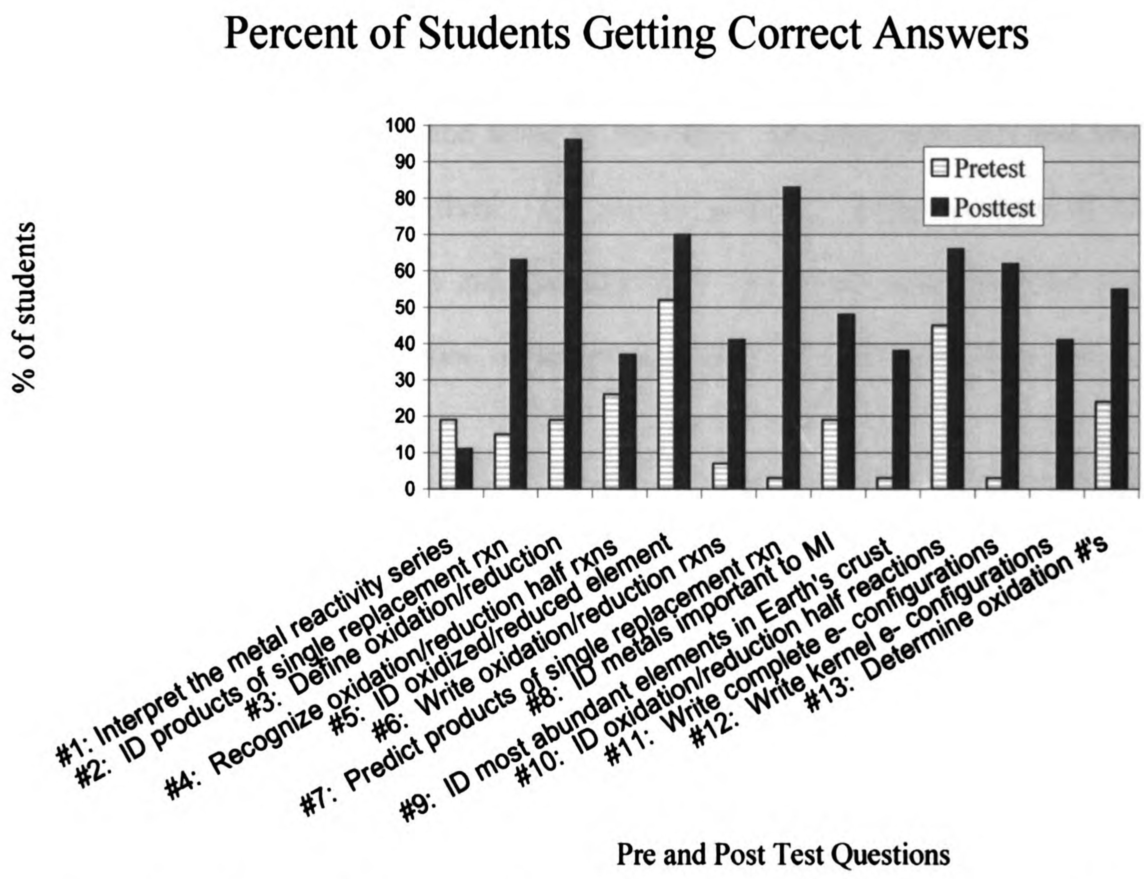


Figure 3: Percent of students with correct answers in Section B as witnessed on pre-and post- test analysis. n = 27

Student achievement improved on twelve of the thirteen items tested or 92% in Section B. Student achievement improved on all eight items tested in Section A. The difference in level of achievement for Section A questions versus Section B questions could be partially attributed to not using iClickers for regular formative assessment during Section B, which gives the students very valuable feedback. It can also be attributed to the fact that the content in Section B was also more challenging.

Analysis of Students

Three groups of students were identified based on their grades in the class. High achievers had an 84% or better in the class. Average achievers had 70% to 83% in the class. Low achievers had 69% and lower in the class. The high achievers and low achievers both had 7 students in them. The average achievers' group consisted of 13 students. Each group's surveys and pre- and post- test results were analyzed and compared to look for any correlation in the group data and the effect iClickers had on their specific performance.

My initial hypothesis was that low achievers would benefit the most from the use of iClickers because I believe they have greater difficulty verbalizing their trouble areas and often get far behind quickly. They ultimately give up instead of seeking out additional help. The initial survey supported this claim. As indicated by Figure 4, the lowest achievers are the most nervous subgroup when called on to answer questions. They frequently do not ask questions because they are embarrassed to do so, and find lectures extremely boring.

The results of question 2, "I willingly participate in class daily", are intriguing. The low achievers were the ones who indicated they willingly participated in class at least once a day. It would be interesting to explore that notion in further detail to determine the manner and context of their perception of participation.

There was an interesting correlation with question 4, "I would get better grades if I participated in class more", as well. The highest achieving students appear to have the strongest belief that there is some correlation between class participation and grades. That correlation decreases in the average achievers and decreases even further in the low achievers. All subgroups found lectures to be boring and not important to their ability to deduce what material is important or not.

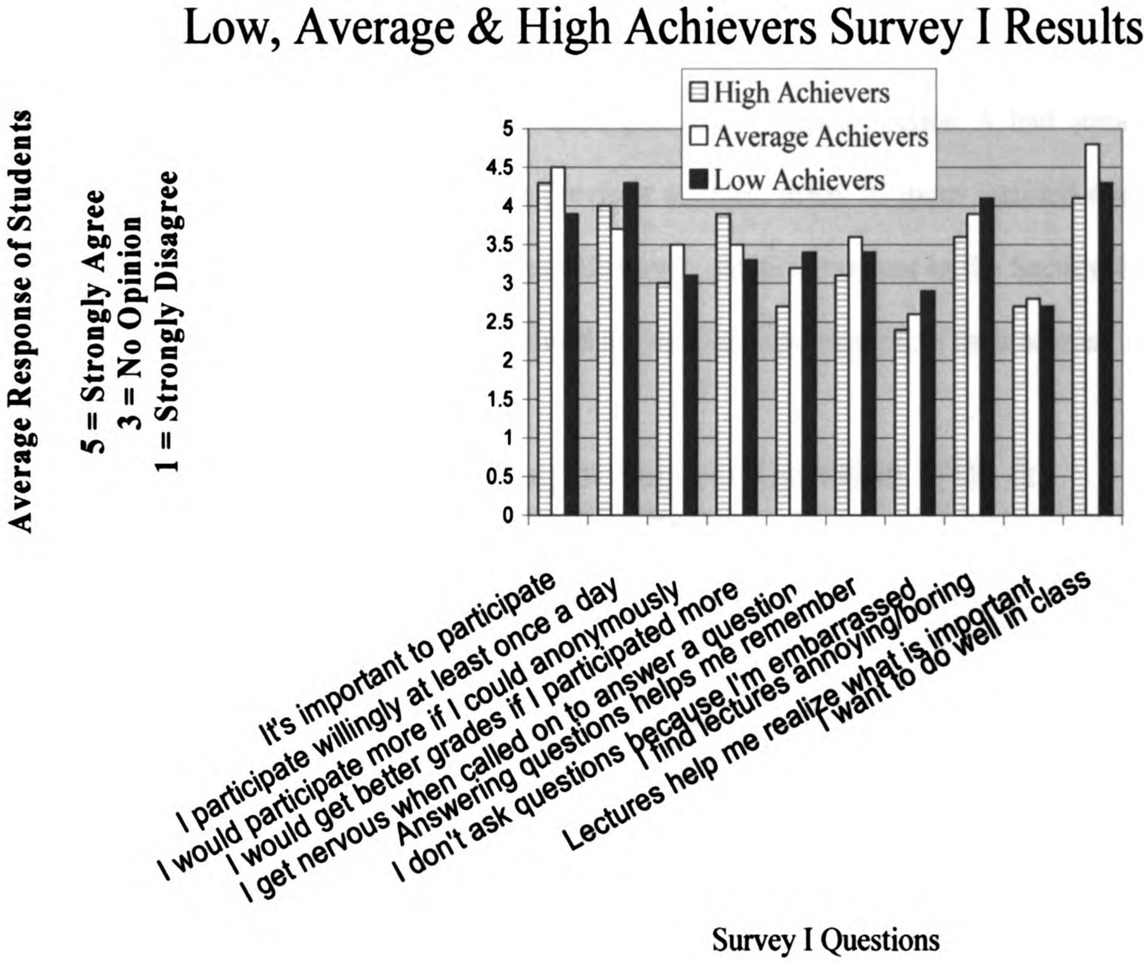


Figure 4: Results of Survey I on student participation as seen in the three subgroups- High Achievers, Average Achievers, Low Achievers. This survey was conducted before the inception of Section A.

My initial hypothesis was that the lowest achievers would benefit the most from the use of iClickers. This was based on my perception that these students don't participate as much, don't study for tests outside of class, and generally don't have sound study skills. Figure 5 shows the average number of students in each subgroup that improved per question. Improvement was defined as having a higher score on the posttest question compared to the pretest question. After comparing the pre- and posttest data from both Sections A and B (Figure 5), the average achievers appeared to have benefited the most from using the iClickers followed by the low achievers. The high achievers appeared to have benefited the least, presumably since Section A had some material that had already been covered in previous courses, many of them retained that information and didn't improve their scores. However, since all content in the Section B was new, more of the highest achievers showed noticeable improvement in their scores.

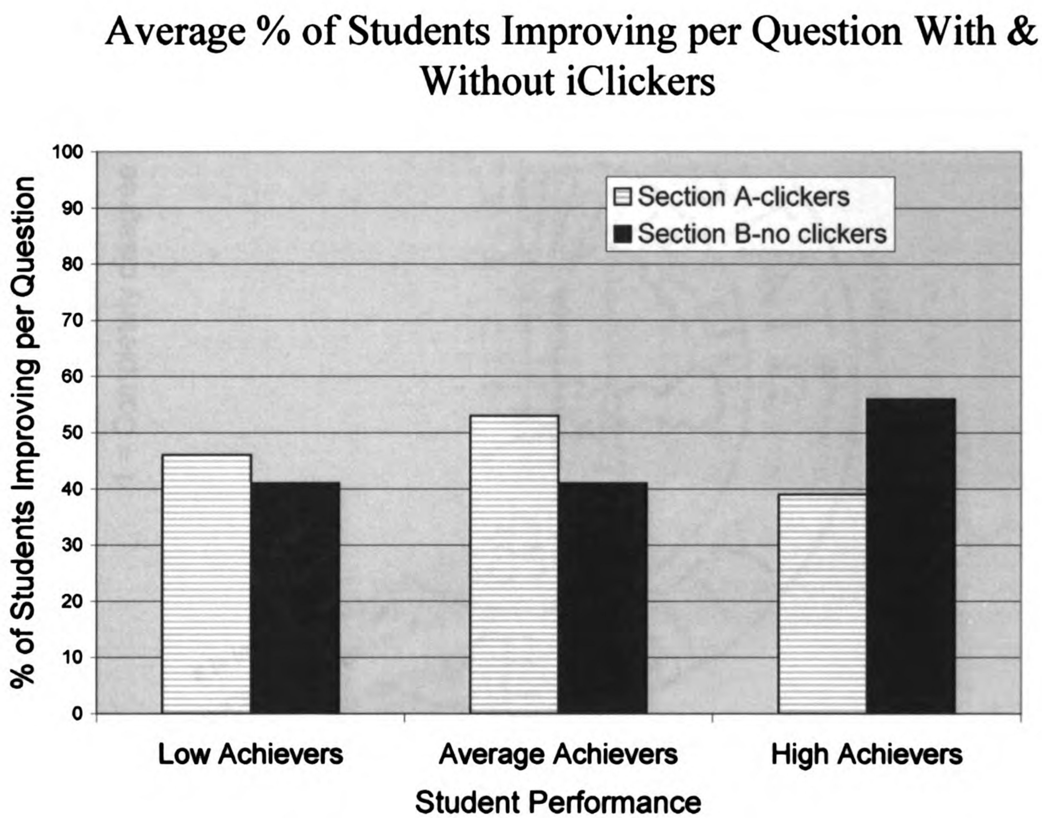


Figure 5: Comparison of student improvement per question between the subgroups of High Achievers, Average Achievers, and Low Achievers on Sections A and B.

The Survey II data of the three subgroups (Figure 6) show that most students in this class do not study for tests at home, but rely on class time to prepare. All subgroups liked using the iClickers. There was a strong consensus from all three groups that the immediate feedback afforded by the iClickers was very helpful. The low achievers agreed that using the Clickers allowed them to determine essential and nonessential content easier. Although this information is self reported, it helps validate the assumption that low achievers have difficulty in organizing the vast amounts of information that comes at them and selecting the concepts that are most important and filtering out the nonessentials.

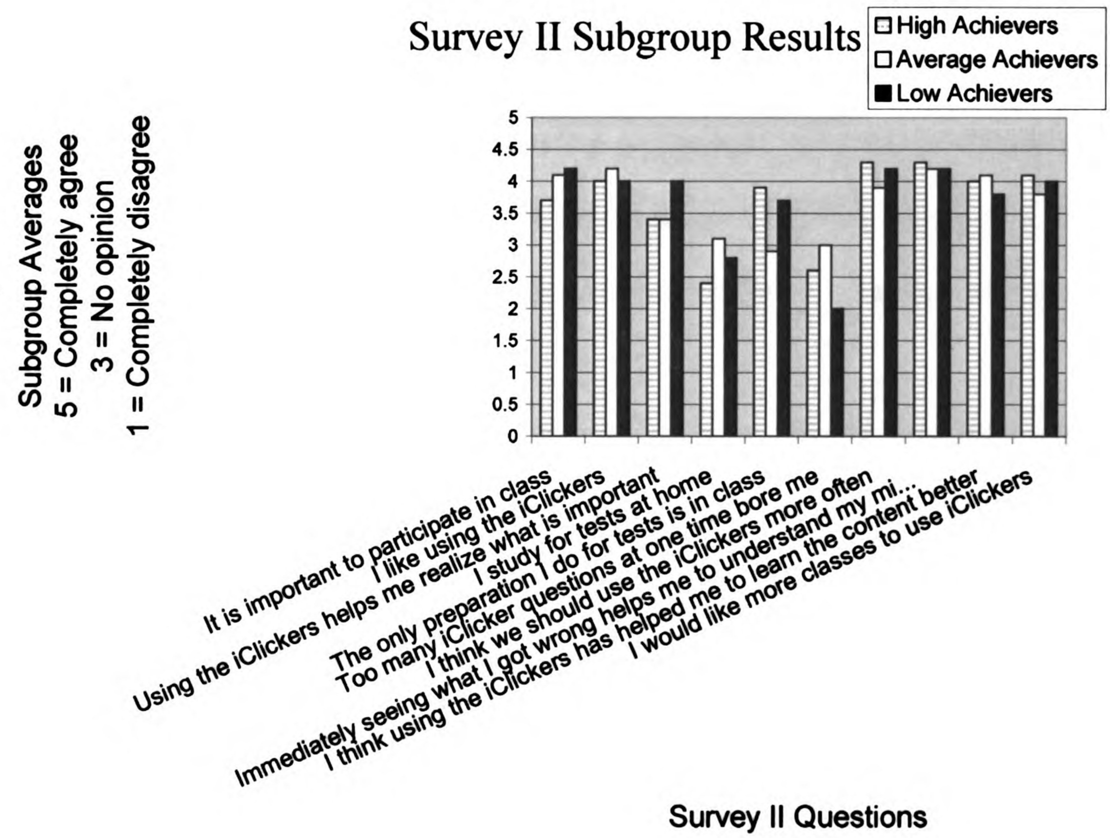


Figure 6: Results of Survey II on the use of iClickers as seen in the three subgroups-High Achievers, Average Achievers, and Low Achievers. This survey was conducted after the completion of Sections A and B.

Discussion and Conclusion

Due to the different concepts and difficulty of the concepts presented in Sections A and B, it is very difficult to compare the differences between the two sets of data. Therefore, I will attempt to discuss each section as a separate entity and draw conclusions from each of them separately.

At the conclusion of this research there are some notable observations that can be gleaned from both the self-reported survey data and the quantitative paired t test data from the pre- and post- test question comparison. The two general areas that will be discussed are whether or not the use of clickers increased student engagement and student achievement. Within the category of student engagement, the areas of attitude toward class and value of formative feedback will be discussed. Within the category of student achievement, I will evaluate whether students improved their performance and increased their metacognition.

The qualitative Survey II data (Figure 6) indicate that students like using the iClickers. It has been my experience that if you can get students to like something, then they are going to be more engaged, and according to the research of Brewer (2005) if students feel empowered by helping the teacher determine which concepts are mastered and which need more work, students feel they learn the material better, and it helps them identify their own gaps in the material. This self-awareness, or metacognition, will positively influence the course of the students' learning (Anthony, 1996) and allow the learners to be "architects building their own knowledge structure" (Wang, Haertel and Walberg, 1993).

Contrary to Survey II results (Figure 6) in which students disagreed that too many iClicker questions get boring, I believe they must be used in moderation. On days that we did the most clicker questions, many students were much less focused and less apt to take the questions seriously. Another variable to consider is the quality of the question. I found that lengthy questions or ones that required complex calculations had less students focused on deducing the correct answer. There were many guesses entered to these two types of questions as witnessed by the very fast response time.

Student Survey II data (Figure 6) also showed that immediate feedback was very valuable and appreciated by the students. The link between formative feedback and improvements in achievement are widespread in the literature. One such notable example was from Bellon et al. (1992) in which they claim that "academic feedback is more strongly and consistently related to achievement than any other teaching strategy. This relationship is consistent regardless of grade, socioeconomic status, race, or school setting. When feedback and corrective procedures are used, most students can attain the same level of achievement as the top 20% of students". My data (Figure 2) shows that students improved their performance with the increase in feedback from the use of clickers. However, there were still many students who did not attain that level of achievement professed by Bellon et al. (1992).

Informally, it was also evident that after students got an answer wrong they wanted to know why their answer was wrong. It opened up many opportunities for quality classroom discussions that most likely would not have occurred if questions were answered on an individual basis or on a written assignment. This was invaluable to all students, as well as for me as a teacher.

Therefore, I would like to conclude that using iClickers improved student engagement. The Survey II data (Figure 6) indicate that they liked using the clickers and would like to take other classes that use clickers. During Section A, all students answered ten to twenty questions every day. There was never a day when they could passively sit back and listen or let others do the work. They had to participate. This formative assessment increased the number of questions students asked and helped them realize what they did and didn't understand. (Figure 6)

Student engagement is an important component of learning. According to Gardiner (1996) "the effectiveness of any educational practice is directly related to the capacity of that practice to increase involvement in learning". However, not all engagement potentially leads to advances in learning as witnessed by my lowest achievers having the highest self reported response stating that they participate willingly in class at least once a day. (Figure 4) Therefore, as stated by Wiggins (2008), "It's not the teaching that causes successful, eventual learning. It's the attempts and adjustments by the learner to perform that cause accomplishment". My assertion is that the clickers helped prompt students to make the attempts and adjustments that they otherwise wouldn't attempt to make.

Student achievement improved during Section A on all of the eight compared pre- and posttest questions (Figure 2). Six out of eight questions, or 75%, showed a significant p value (Table 3) of 0.01 or less as indicated on a paired t test. These data reveal that clickers may enhance student achievement.

Unfortunately, much more difficult to quantitatively measure are the increases in metacognition that came with the use of clickers. According to Freeman and Blayney

(2005), with an increase in student engagement there is more likely to be a deeper approach to learning, which is more likely to lead to increased understanding and improved learning outcomes. This was witnessed by student responses on the survey (Figure 6), in which they reported that immediately seeing what they got wrong helped them understand their mistakes better.

My initial hypothesis was that the lowest achievers would make the greatest gains in achievement. The results can be interpreted a couple ways. According to Figure 5, it appears that the average achievers made the greatest gains in achievement. I interpreted this data based on question type. You can separate questions into two broad categories: low level thinking skills such as vocabulary and matching and high level thinking skills such as analysis and problem solving. The average achievers benefited from using the clickers on both types of questions because they would take the time to at least try to figure out the analytical questions and not just guess. The average achievers have the confidence that they can offer an educated guess. I witnessed the low achievers making noticeable gains in lower level thinking skills type questions such as the vocabulary or matching. However, they failed to take the time to work out the more complex analytical problems before answering. Instead, they would most often guess. The high achievers benefited from the immediate feedback and the repetition. However, they tend to be good problem solvers already, thus making the iClickers just another tool to get them more engaged.

One area of noticeable importance for the lowest achievers came in the increase in their ability to determine what they will be tested on (Figure 6). Often times it was the lower level questions that they would get correct on the posttest, but even that small amount of success at predicting what they needed to know was priceless in their eyes. According to Chickering and Ehrmann (1996), understanding what you do and don't know is a critical link in formulating new knowledge. The lowest achievers made improvements in this area with the help of the clickers. This improvement in metacognition should prove valuable as they construct new knowledge in the future.

Using iClickers clearly is a beneficial tool in the classroom, but, it is not a panacea for improving critical thinking and allowing students to construct new knowledge. My students and I believe that immediate feedback is the clickers strongest asset. Students also love the anonymity of the devices, and I like the ability to discuss wrong answers without any student names attached to them as well. At a later time I can pull up individual student data and see who did well and who didn't. This opens the door to improving the class by differentiating future lessons for the three subgroups. It allows movement between the subgroups and an efficient mechanism for identifying members of each subgroup. iClickers worked well to break up extended lectures or activities and gave me an opportunity to quickly assess student misconceptions.

One drawback to the iClickers is the inability for students to work at their own pace. They work well for large group discussions and for general polling, but for the many times in a science classroom were students are working independently or in small group settings, it would be ideal to have a set of personal response systems that allow students to enter data at their own pace and then bring it up as a whole to discuss later.

In the future I need to construct more effective clicker questions. It was evident after completing a few days of questions, which ones were more effective than others at getting the students to think and analyze data versus the questions that were either too complex and took too long to answer or those that were too easy and required no real thinking whatsoever. An example of an effective clicker question on physical and chemical changes was one where the students had to identify which option showed a chemical change. What was challenging was each option was a picture representation showing the atoms and molecules involved in either a physical or chemical change, thus making the students apply knowledge without any complex calculations needed.

Technology is the means of communication and expression for virtually every teenager. Unfortunately most high schools lag unacceptably behind in purchasing and using technology to engage and educate today's youth. The use of iClickers is one way to engage students in what is often a mundane classroom. This engagement coupled with immediate feedback improves student achievement and should allow them to better assess what they know and don't know as they construct new knowledge and become world class problem solvers in the 21st century.

APPENDICES

APPENDIX A

CONSENT LETTER

Dear Parents/Guardians and Students:

During this school year, I will be implementing a unit on the effectiveness of personal response systems in the high school classroom. I have developed this unit as the major portion of my Master's thesis through Michigan State University's Department of Science and Mathematics Education (DSME). The students will be using "clickers" in the unit and I will assess their value as a questioning technique and assessment tool.

In order to evaluate the effectiveness of this unit and tool, routine class data will be collected from students through pre and post tests, surveys, semester exams, and daily clicker questions. With your permission, I would like to include your child's data in my thesis. Your child's privacy will be a foremost concern and will be protected to the maximum extent allowable by law. All data generated shall remain confidential. At no time will your child's identity be associated with the data nor will they be identified in any pictures taken to be used in the thesis presentation.

Participation in this study is voluntary. Your child will receive no penalty in regard to their grade should you deny permission for the use of their data. Participation in this study will not increase or decrease the amount of work that is required of your child. You may request that your child's information not be included in this study at any time and your request will be honored.

If you are willing to have your child participate in this study, please complete the attached form and return it to the high school office by October 1, 2009. If you have any questions, please feel free to contact me at Clinton High School (517) 456-6511 or by email at renee.gilson@clinton.k12.mi.us. Questions regarding the thesis project can also be directed to Dr. Merle Heidemann at DSME, 118 N. Kedzie, Michigan State University, East Lansing, MI 48824, by phone at (517) 432-2152 or by email at heidma2@msu.edu. If there are any questions regarding your rights as a study participant, please contact the Institutional Review Board by phone (517) 355-2180, fax (517) 432-4503, e-mail ucribs@msu.edu, or mail 202 Olds Hall, East Lansing, MI 48824.

Sincerely,

Renee Gilson
Science Teacher
Clinton High School

The effectiveness of personal response systems at increasing the engagement and achievement of students in a science classroom

Name of Student: ____
(print student name)

Please read the following permission statements carefully and check all that apply:

Parental Permission
Data Use:
______ I volunteer to give Mrs. Gilson permission to use data generated from my child's work in this class in this thesis project. All data from my child shall remain confidential.

______ I do not wish to have my child's work used in this thesis project. There is no penalty for choosing to withhold data.

Pictures:
______ I give Mrs. Gilson permission to use pictures of my child, taken during laboratory experiments and activities, in the presentation of her thesis defense.

______ I do not wish to have my child's picture used at any time during this thesis.

____ ___________
(Parent/Guardian Signature) (Date)

I voluntarily agree to participate in this thesis project.

____ ___________
(Student Signature) (Date)

APPENDIX B

SURVEYS I & II

Interest Survey I

1- Strongly Disagree
2- Disagree
3- No Opinion
4- Agree
5- Strongly Agree

1. It is important to participate in class	1	2	3	4	5
2. I participate willingly in class at least once a day	1	2	3	4	5
3. I would participate more if I could do so anonymously	1	2	3	4	5
4. I would get better grades if I participated more in class	1	2	3	4	5
5. I get nervous when I am called on to answer a question.	1	2	3	4	5
6. Answering questions helps me remember the content	1	2	3	4	5
7. I don't ask questions because I am embarrassed to	1	2	3	4	5
8. I find lectures annoying or boring	1	2	3	4	5
9. Lectures help me realize what is important	1	2	3	4	5
10. I want to do well in class	1	2	3	4	5

Name: ________________________________ Hour: __________________

Interest Survey II

1- Strongly Disagree
2- Disagree
3- No Opinion
4- Agree
5- Strongly Agree

1. It is important to participate in class	1	2	3	4	5
2. I like using the iClickers	1	2	3	4	5
3. Using the iClickers helps me realize what is important	1	2	3	4	5
4. I study for tests at home	1	2	3	4	5
5. The only preparation I do for tests is in class	1	2	3	4	5
6. Too many iClicker questions at one time bore me.	1	2	3	4	5
7. I think we should use the iClickers more often.	1	2	3	4	5
8. Immediately seeing what I got wrong helps me to understand my mistakes better.	1	2	3	4	5
9. I think using the iClickers has helped me to learn the content better.	1	2	3	4	5
10. I would like more classes to use iClickers.	1	2	3	4	5

APPENDIX C

SECTION A MATERIALS

Name: ______________________________ Date: ______________ Hr: ____

Unit 2- Materials: Structure and Uses Pre-Test
Section A (iClickers) -Why We Use What We Do

Reference materials: Periodic Table

1. _____ Of the following the element most chemically similar to phosphorus is ___. Explain your answer. (2 points) *C4.9A*
   A. silicon B. carbon C. sulfur D. nitrogen

2. _____ The boiling point of HCl is -85 ^{0}C while the boiling point of HI is -36 ^{0}C. Estimate the boiling points of HBr in ^{0}C. Explain your answer. (2 points) *C4.9c*
   A. -49 ^{0}C B. -51 ^{0}C C. -25 ^{0}C
   D. -61 ^{0}C E. -121 ^{0}C

3. _____ Since an atom is electrically neutral, the number of protons is equal to the number of ___. Explain your answer. (2 points) *C4.10A*
   A. neutrons C. neutrons + electrons
   B. electrons D. neutrons – electrons

4. _____ Fact 1: Iron is silvery. Fact 2: Iron becomes red after it is exposed to oxygen. The 1st fact describes a _____________, and the 2nd fact describes a _______________. Explain your answer. (2 points) *C5.2B*
   A. physical change, physical property
   B. chemical change, chemical property
   C. physical property, chemical change
   D. physical property, physical property
   E. physical property, physical change

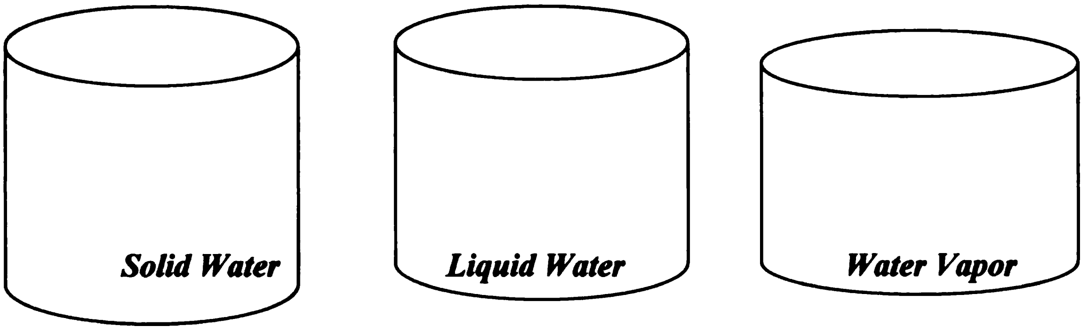
5. ______Which list of elements consists of metals only? Explain your answer. (2 points) *C4.9b*
   A. sulfur, carbon, iron, copper B. sodium, copper, iron, calcium
   C. potassium, carbon, lead, bismuth D. uranium, iron, silicon, chlorine

6. _____ Which of the following represent the same element? Explain your answer. (2 points) *C4.10B*

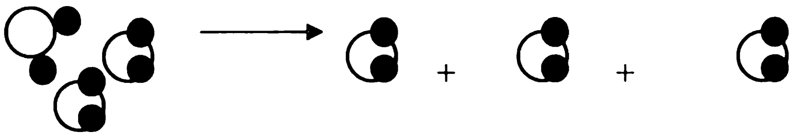
Element	Protons	Neutrons	Electrons
W	6	5	6
X	7	5	7
Y	5	8	5
Z	7	8	7

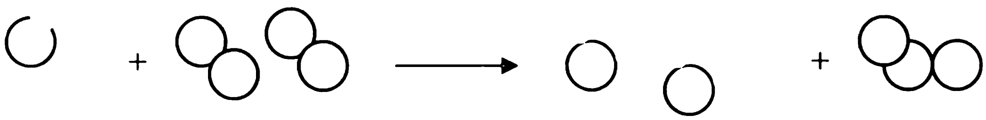
   A. Element W & Element X B. Element Y & Element Z
   C. Element X & Element Y D. Element X & Element Z

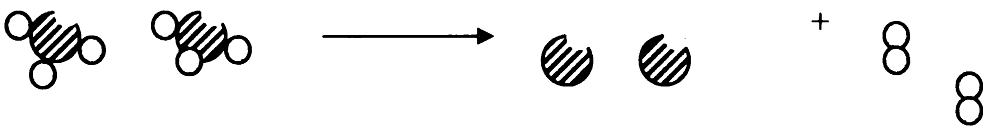
7. In each of the following beakers, draw what the same sample of water would look like on a molecular scale as a solid, liquid, and gas. Explain your drawings on the basis of motion and arrangement of the molecules. (3 points) *P4.p1, P4.p1C, C2.2B*



8. _____ Which picture shows a physical change? Explain your answer. (2 points) C5.2C

A.) 

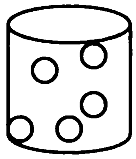
B.) 

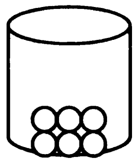
C.) 

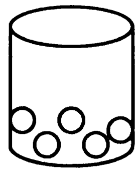
9. Complete the table. (1 point each/15 points) *C4.10A*

Substance	Atomic number	Protons	Neutrons	Mass number	Metal/Nonmetal/Metalloid
Sodium (Na)					
Iron (Fe)					
Phosphorus (P)					

10. ____ Which of the following drawings depicts a solid? Explain your answer. (2 points) *C4.3B*

A.) 

B.) 

C.) 

11. _____ Which of the following is the correct isotopic representation for a hydrogen isotope. (1 point) *C4.10e*

A.) $^{1}_{0}H$ B.) $^{0}_{1}H$ C.) $^{1}_{2}H$ D.) $^{3}_{1}H$

Name: ______________________________ Date: ___________ Hr: _______

Unit 2 – Materials: Structure and Uses Post-Test Section A(iClickers) -Why We Use What We Do

Reference Materials: Periodic Table

1. _____ Which of the following elements is most chemically similar to magnesium? Explain your answer. (2 points) *C4.9A*
   A. calcium B. manganese C. sodium D. aluminum

2. _____ The density of tin is 7.3 g/mL. The density of lead is 11.35 g/mL. The density of silicon is 2.33 g/mL . Therefore, the density of germanium must be ____. Explain your answer. (2 points) *C4.9c*
   A. 1.5 g/mL B. 5.3 g/mL C. 13.7 g/mL D. 6.99 g/mL

3. _____ Since an atom is electrically neutral, the number of protons is equal to the number of ____. Explain your answer. (2 points) *C4.10A*
   A. neutrons B. electrons
   C. neutrons + electrons D. neutrons – electrons

4. _____ Fact 1: Zinc releases hydrogen gas when exposed to hydrochloric acid. Fact 2: Zinc's density is 7.14 g/mL. The 1st fact describes a _____________, and the 2nd fact describes a ___________. Explain your answer. (2 points) *C5.2B*
   A. physical change, physical property
   B. physical property, chemical change
   C. chemical change, chemical property
   D. physical property, physical property
   E. chemical change, physical property
   F. chemical property, physical change

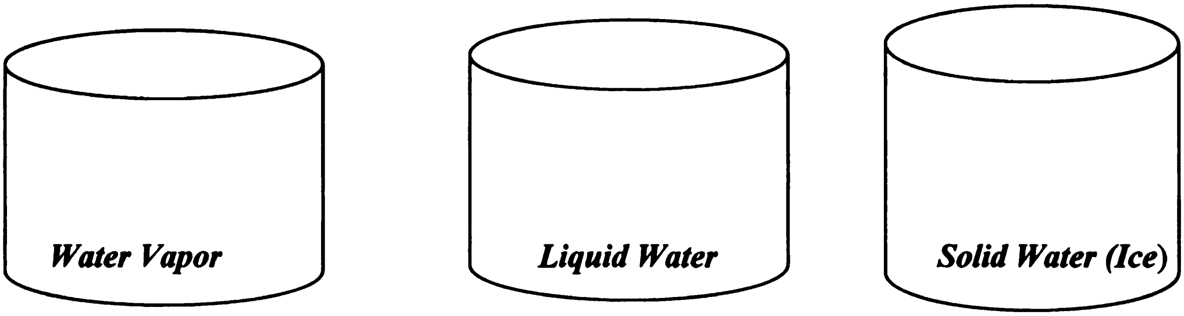
5. _____ Which list of elements consists of metalloids only? Explain your answer. (2 points) *C4.9b*
   A. boron, gallium, germanium B. oxygen, sulfur, selenium
   C. aluminum, boron, silicon D. boron, silicon, germanium

6. _____ Which of the following atoms represent the same element? Explain your answer. (2 points) *C4.10B*

Atoms	Protons	Neutrons	Electrons
A	6	5	6
B	7	5	7
C	5	8	5
D	7	8	7

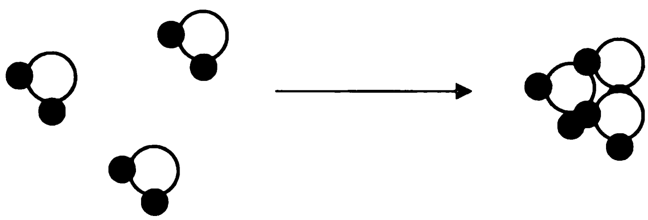
   A. Element A & Element B B. Element C & Element D
   C. Element B & Element C D. Element B & Element D
   E. Element A & Element C F. Element A & Element D

7. In each of the following beakers, draw what a sample of water (H_2O) would look like on a molecular scale. For each beaker explain the motion of the particles and their spacing. (3 points)

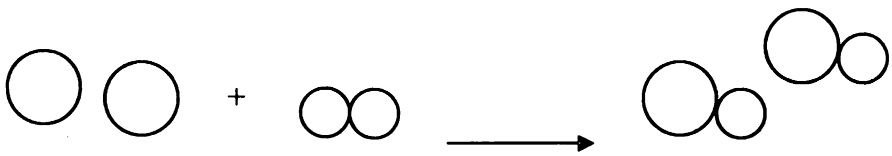


8. __________ Which picture shows a chemical change? Explain your answer. (2 points) *C5.2C*

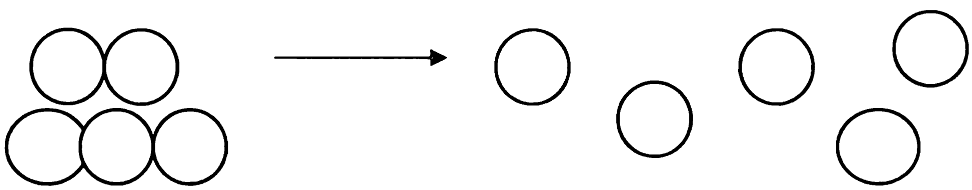
A.



B.



C.



9. Complete the table. (1/2 point each/9 points) *C4.10A*

Substance	Atomic Number	Protons	Neutrons	Electrons	Mass Number	Metal Nonmetal Metalloid
Carbon–14 (C-14)						
Fluoride ion (F^{-1})						
Antimony atom (Sb)						

10. Identify each of the following as being either a **physical (P)** change or a **chemical (C)** change. (4 points) *C5.2B*

A. A cut apple left out in the air turns brown: _______________________

B. Dry cleaning removes oils from clothing: ___________________________

C. An opened carbonated beverage fizzes: _____________________________

D. As shoes wear out, holes appear in the soles: _________________________

11. _____ Which of the following isotopes will be in greatest abundance in nature? Explain your answer. (2 points) *C4.10b*

A. P-30 B. P-31 C. P-15 D. P-30.97

12. Write the correct symbol for an isotope of sulfur that contains 16 protons and 17 neutrons. Include the atomic number and mass number in your symbol. (2 points) *C4.10e*

13. _____ Which of the following elements has the largest radius? Explain your answer. (2 points) *C4.9c*

A. Ca B. Fe C. Br D. Mg

14. ____ In an atom of argon-40, the number of protons ___. (1 point)

A. equals the number or electrons
B. equals the number of neutrons
C. is less than the number of electrons
D. is greater than the number of electrons

15. _______ Which statement describes a chemical property of bromine? (1 point)

A. bromine is soluble in water
B. bromine has a reddish-brown color
C. bromine combines with aluminum to produce $AlBr_3$
D. bromine changes from a liquid to a gas at 23 ^0C

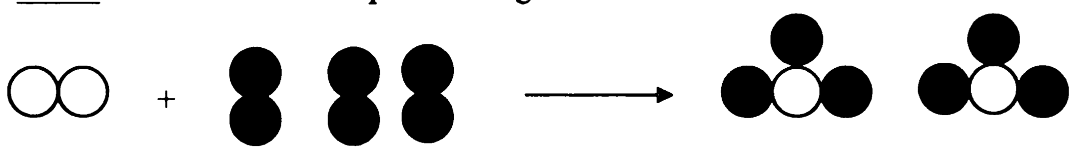
16. _____ A beaker contains both alcohol and water. These liquids can be separated by distillation because the liquids have separate ____. (1 point)

A. boiling points B. freezing points C. solubilities D. particle size

17. _____ A sample of an element is malleable and can conduct electricity. This element could be ___. (1 point)

A. H B. He C. S D. Sn

18. _____ Given the balanced particle diagram below:



Which statement describes the type of change and the chemical properties of the product and reactants? (1 point)

A. the equation represents a physical change, with the product and reactants having different chemical properties
B. The equation represents a physical change, with the produce and reactants having identical chemical properties
C. The equation represents a chemical change, with the product and reactants having different chemical properties
D. The equation represents a chemical change, with the product and reactants having identical chemical properties

19. ______ An element that is malleable and a good conductor of heat and electricity could have an atomic number of ____. (1 point)

A. 16 B. 29 C. 18 D. 35 E. 1

20. _____ On the modern Periodic Table, the elements are arranged in order of increasing ____. (1 point)

A. atomic mass B. mass number C. charge D. atomic number

21. _____ What can be determined if only the atomic number of a neutral atom is known? (1 point)

A. the total number of neutrons only
B. the total number of protons only
C. the total number of protons and neutrons
D. the total number of protons and electrons

22. _____ Chlorine-37 can be represented as ____. (1 point)

A. $^{17}_{35}Cl$ B. $^{20}_{37}Cl$ C. $^{35}_{20}Cl$ D. $^{37}_{17}Cl$

23. _____ Sodium and potassium have similar chemical properties because an atom of each element has the same total number of ___. (1 point)

A. valence electrons B. neutrons C. protons D. mass number

24. ____ Which quantity identifies an element? (1 point)

A. atomic number
B. mass number
C. number of neutrons
D. total number of electrons

25. _____ What is the total charge of the nucleus of a nitrogen atom? (1 point)

A. +5 B. +14 C. 0 D. +2 E. +7

26. _____ Which metal is more active than Ni and less active than Zn? (1 point)

A. Cu B. Cr C. Mg D. Pb

27. In an investigation, a dripless wax candle is weighed and then lit. As the candle burns, a small amount of liquid was forms near the flame. After 10 minutes, the candle's flame is extinguished and the candle is allowed to cool. The cool candle is weighed.

a. Identify one physical change that takes place in this investigation. (1 point)

b. State one observation that indicated a chemical change has occurred. (1 point)

28. _____ What is the net charge on an ion that has 9 protons, 11 neutrons, and 10 electrons?(1 point)

A. +1 B. +2 C. -1 D. -2

29. _____ What is the total number of electrons in a Mg^{+2} ion? (1 point)

A. 10 B. 12 C. 14 D. 24 E. 2

Examples of clicker questions

Unit 2
Materials: Structure & Uses

Why We Use What We Do

Day One-Warm Up

1. Which statement describes a chemical property of iron? (C5.2B)

A) Iron can be flattened into sheets.
B) Iron conducts electricity and heat.
C) Iron combines with oxygen to form rust.
D) Iron can be drawn into a wire.

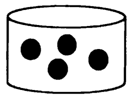
Day One-Warm Up

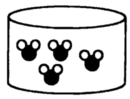
2. What is a property of most metals?

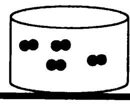
A) They tend to gain electrons easily when bonding.
B) They tend to lose electrons easily when bonding.
C) They are poor conductors of heat.
D) They are poor conductors of electricity.

Day One-Warm Up

3. Which of the following depicts a compound as a gas?

A) 

B.) 

C.) 

Day One-Lecture

1. Which of the following is a physical property of matter? (C5.2B)

A) Density
B) Boiling Point
C) Melting Point
D) Size
E) All are physical properties

Day One - Lecture

2. Which of the following does not describe a chemical property? (C5.2B)

A) Copper turns green with age
B) Hydrogen is very flammable
C) Metals are ductile
D) Calcium produces hydrogen gas in acids

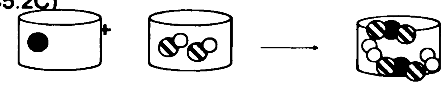
Day One-Lecture

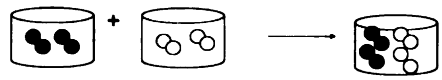
3. Which statement describes a chemical property of hydrogen gas? (C5.2B)

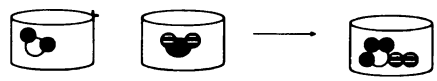
A) Hydrogen gas burns in air.
B) Hydrogen gas is colorless.
C) Hydrogen gas has a density of 0.000 09 g/cm3 at STP.
D) Hydrogen gas has a boiling point of 20. K at standard pressure.

Day One - Lecture

4. Which picture shows a physical change? (C5.2C)

A.) 

B.) 

C.) 

Day One - Lecture

5. The best definition of a physical change would be (C5.2B)

A) You can change the material back to what you started with
B) You only change the appearance of the substance
C) You change the substance into another substance
D) You change the substance so it temporarily looks different

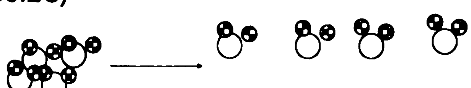
Exit ?'s Day One

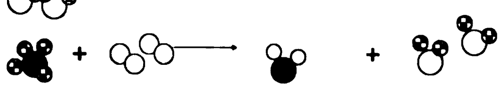
1. A chemical change ______ produces a physical change. (C5.2B)

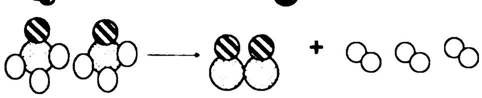
A.) always
B.) never
C.) sometimes

Exit ?'s Day One

2. Which picture shows a physical change? (C5.2C)

A.) 

B.) 

C.) 

Exit ?'s Day One

3. Phase changes such as dry ice sublimating are all __________ changes.

A.) physical
B.) chemical

Exit ?'s - Day One

4. Is dissolving salt in water a physical or chemical change? (C5.2B)

A) Physical
B) Chemical

Exit ?'s - Day One

5. You have two gases at room temperature. You mix them together and increase the temperature. Your products are also two gases. (C5.2B)

A.) nothing happened
B.) a physical change occurred
C.) a chemical change occurred
D.) not enough information to determine whether a physical or chemical change occurred

Physical and Chemical Changes Lab

Objective(s):
- □ Perform chemical reactions
- □ Classify changes in matter as being physical or chemical based on visual observations

Introduction:

Chemistry is the study of matter and the changes it undergoes. These changes can be broken down into 2 categories – physical changes and chemical changes. In a *physical change*, one or more physical properties of a substance are altered. Examples of such physical properties include size, shape, color and physical phase. Grinding, melting, dissolving and evaporating are all physical changes. No new substance or substances are formed as a result of a physical change.

A *chemical change* results in the formation of one or more 'new' substances. These new substances differ in chemical properties and composition from the original substance. The resulting of iron and the burning of paper are two examples of chemical change. This experiment will help you to understand the difference between physical and chemical change and to recognize each type of change when it occurs.

Equipment:

Bunsen burner	scoopula	safety goggles	magnet
stirring rod	4 test tubes	wash bottle	test tube holder
test tube rack			

Materials:

Copper Sulfate pentahydrate ($CuSO_4 \cdot 5\ H_2O$)	Iron Filings (Fe)
Sodium Chloride (NaCl)	Magnesium ribbon (Mg)
Hydrochloric Acid (6 M HCl)	Sulfur Powder (S)
Silver Nitrate (0.1 M $AgNO_3$)	

Procedure:

Perform the following experiments and record your observations.

1.) Compare the ground and un-ground copper sulfate pentahydrate ($CuSO_4 \cdot 5\ H_2O$) record your observations. Next, put a scoopula tip of the ground and unground copper sulfate pentahydrate ($CuSO_4 \cdot 5\ H_2O$) into separate test tubes. Begin heating the test tubes in the Bunsen burner, slowly at first. Heat the test tubes for about 2 minutes and record your observations. Put the hot test tubes into the wooden test tube rack to cool. You will need these test tubes in step 5.

2.) Put two scoopula tips of iron (Fe) and three scoopula tips of sulfur (S) into a test tube. Mix the contents with a stirring rod. Run a magnet from the bottom of the test tube to the mid point of the test tube, record your observations. Mix the test tube again. Begin heating the test tube slowly at first, in a flame for 2 minutes. Set the test tube into the wooden test tube rack to cool. You will need this test tube in step 6.

3.) Add a scoopula tip of sodium chloride (NaCl) to about 10 mL of water. Mix the contents of the test tube with a stirring rod, record your observations. Next, add 5 drops of Silver Nitrate (0.1 M $AgNO_3$) to the test tube. Record your final observations and rinse the test tube contents down the sink.

4.) Place one piece of magnesium (Mg) into a test tube. Add ~10 drops of Hydrochloric Acid (6 M HCl). **CAUTION: hydrochloric acid (HCl) can cause severe burns to the skin.** Touch the bottom of the test tube and record your observations. Rinse the test tube contents down the sink.

5.) Check to see that the test tubes from step 1 is cool. When cool add a few drops of water to the test tubes and mix, record your observations. Rinse the test tube contents down the sink.

6.) Check to see the test tube form step 2 is cool. When cool run the magnet from the bottom of the test tube to mid point of the test tube, record your observations. Throw this test tube away.

7.) Please make sure that all the chemicals have been properly returned into their appropriate locations.

Questions:

1.) Indicate whether each of the following procedures from lab is a chemical or physical change. Support your conclusions.

A.) dissolving sodium chloride (NaCl)

B.) mixing sodium chloride (NaCl) and silver nitrate ($AgNO_3$)

C.) adding hydrochloric acid (HCl) to magnesium (Mg)

D.) Heating copper sulfate pentahydrate ($CuSO_4 \cdot 5\ H_2O$)

E.) Mixing iron (Fe) and sulfur (S)

F.) Heating iron (Fe) and sulfur (S)

2.) Describe two indicators of a chemical reaction which you witnessed in the experiment.

3.) Explain when the following changes **DO NOT always** indicate a chemical change has occurred. Please give an example from the experiment.

A.) Change of color

B.) Apparent disappearance of a substance

Metal or Nonmetals Lab

Objective-

- Explore physical and chemical properties of metals and nonmetals
- Classify elements as metals, nonmetals, or metalloids on their physical properties

Materials-

- Element samples (Magnesium, Silicon, Tin, Copper, Sulfur, Iron, Zinc, Carbon)
- Conductivity tester
- Hammer
- 0.1 M $CuCl_2$ solution
- 0.5 M HCl
- well plate

Procedure-

1. *Appearance*: observe and record the appearance of each element including physical properties such as color, luster, and form.
2. *Conductivity:* use the electrical conductivity tester to determine whether the element conducts electricity or not.
3. *Crushing:* Gently tap each sample with a hammer. Determine if it is malleable (able to be flattened without shattering) or brittle (shatters into pieces)
4. *Reactivity with copper(II) chloride:* Add 15 drops of 0.1 M $CuCl_2$ to eight labeled wells of the spot plate. Place 1 cm samples of each element into the wells. Observe each system for 3-5 minutes-changes may be slow. A change in a sample's appearance may indicate a chemical reaction. Decide which elements reacted with the copper (II) chloride and which did not.
5. *Reactivity with acid:* Add 10 drops of 3 M HCl to 8 wells in your spot plate. Place 1 cm samples of each element into the wells. Observe each system for 3-5 minutes-changes may be slow. A change in a sample's appearance may indicate a chemical reaction. Decide which elements reacted with the hydrochloric acid and which did not.

Data-

Element	Appearance (color/luster/form)	Crushing (malleable/brittle)	Conductivity (conductor/Non)	React with $CuCl_2$	React with HCl
Mg					
Si					
Sn					
Cu					
S					
Fe					
Zn					
C					

Analysis-

1. Classify each property tested as either a physical property or a chemical property. Explain your reasoning.

2. Using the following information, classify each tested element as a metal, nonmetal, or metalloid.
   Metals: have a luster, are malleable, conduct electricity, many react with acids, many react with copper (II) chloride solution.
   Nonmetals: dull in appearance, brittle, do not conduct electricity
   Metalloids: have some properties of both metals and nonmetals

Grouping the Elements

Objective:
*Identify trends in the periodic table

Materials:
*20 element cards
*Blank paper

Procedure:

1. Arrange the cards in order of increasing atomic weight.
2. Sort the cards into several different groups. Each group should include elements with similar properties. You might needs to try several methods of grouping according to their properties before you find one that makes sense to you.
3. Examine the cards within each group for any patterns. Arrange the cards within each group in some logical sequence. Again, trial and error may be a useful method for accomplishing this task.
4. Observe how particular element properties vary from group to group.
5. Arrange all the card groups into some logical sequence.
6. Select the most reasonable and useful patterns within and among the card groups. Then tape the cards onto a sheet of paper to preserve your pattern for later classroom discussion.

Grouping the Elements Cards

Appear.: Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 27 **Melting Point:** 660.3 °C **Boiling Point:** 2,519 °C **O's in Oxide:** 1.5 **Cl's in Chloride:** 3	**Appear.:** Grey powder **Phys. State:** Solid **Classification:** Metalloid **Atomic Weight:** 122 **Melting Point:** 630.8 °C **Boiling Point:** 1587 °C **O's in Oxide:** 2.5 **Cl's in Chloride:** 3	**Appear.:** Black crystals **Phys. State:** Solid **Classification:** Metalloid **Atomic Weight:** 75 **Melting Point:** 817 °C **Boiling Point:** 614 °C **O's in Oxide:** 2.5 **Cl's in Chloride:** 3	**Appear.:** Lead-grey **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 9 **Melting Point:** 1287 °C **Boiling Point:** 2649 °C **O's in Oxide:** 1 **Cl's in Chloride:** 2
Appear.: Black **Phys. State:** Solid **Classification:** Metalloid **Atomic Weight:** 11 **Melting Point:** 2,076 °C **Boiling Point:** 3,927 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1	**Appear.:** Reddish-brown **Phys. State:** Liquid **Classification:** Nonmetal **Atomic Weight:** 80 **Melting Point:** -7.2 °C **Boiling Pt:** 59 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1	**Appear.:** Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 40 **Melting Point:** 842 °C **Boiling Point:** 1,484 °C **O's in Oxide:** 1 **Cl's in Chloride:** 2	**Appear.:** Black powder **Phys. State:** Solid **Classification:** Nonmetal **Atomic Weight:** 12 **Melting Point:** 3,527 °C **Boiling Point:** 4,027 °C **O's in Oxide:** 2 **Cl's in Chloride:** 4
Appear.: Pale yellow **Phys. State:** Gas **Classification:** Nonmetal **Atomic Weight:** 35.5 **Melt Pt:** -101.5 °C **Boiling Point:** -34.04 °C **O's in Oxide:** 2 **Cl's in Chloride:** N/A	**Appear.:** Clear, colorless **Phys. State:** Gas **Classification:** Nonmetal **Atomic Weight:** 1 **Melt Pt:**-259 °C **Boiling Pt:**-252 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1	**Appear.:** Silvery-grey **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 115 **Melting Point:** 156.6 °C **Boiling Point:** 2,072 °C **O's in Oxide:** 1.5 **Cl's in Chloride:** 3	**Appear.:** Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 7 **Melting Point:** 180 °C **Boiling Point:** 1342 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1

Appear.: Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 24 u **Melting Point:** 650 °C **Boiling Point:** 1,090 °C **O's in Oxide:** 1 **Cl's in Chloride:** 2	**Appear.:** Clear, colorless **Phys. State:** Gas **Classification:** Nonmetal **Atomic Weight:** 14 u **Melting Point:** -210 °C **Boiling Point:** -196 °C **O's in Oxide:** 2.5 **Cl's in Chloride:** 3	**Appear.:** Clear, colorless **Phys. State:** Gas **Classification:** Nonmetal **Atomic Weight:** 16 u **Melting Point:** -219 °C **Boiling Point:** -183 °C **O's in Oxide:** N/A **Cl's in Chloride:** 2	**Appear.:** Red powder **Phys. State:** Solid **Classification:** Nonmetal **Atomic Weight:** 31 u **Melting Point:** 44.2 °C **Boiling Point:** 277 °C **O's in Oxide:** 2.5 **Cl's in Chloride:** 3
Appear.: Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 39 u **Melting Point:** 63.4 °C **Boiling Point:** 759 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1	**Appear.:** Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 85 u **Melting Point:** 39.3 °C **Boiling Point:** 688 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1	**Appear.:** Black lumps **Phys. State:** Solid **Classification:** Nonmetal **Atomic Weight:** 79 u **Melting Point:** 221 °C **Boiling Point:** 685 °C **O's in Oxide:** 2 **Cl's in Chloride:** 2	**Appear.:** Grey, lustrous **Phys. State:** Solid **Classification:** Metalloid **Atomic Weight:** 28 u **Melting Point:** 1,414 °C **Boiling Point:** 2,900 °C **O's in Oxide:** 2 **Cl's in Chloride:** 4
Appear.: Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 23 u **Melting Point:** 97.72 °C **Boiling Point:** 883 °C **O's in Oxide:** 0.5 **Cl's in Chloride:** 1	**Appear.:** Silvery **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 88 u **Melting Point:** 777 °C **Boiling Point:** 1382 °C **O's in Oxide:** 1 **Cl's in Chloride:** 2	**Appear.:** Yellow powder **Phys. State:** Solid **Classification:** Nonmetal **Atomic Weight:** 32 u **Melting Point:** 115 °C **Boiling Point:** 445 °C **O's in Oxide:** 2 **Cl's in Chloride:** 2	**Appear.:** Slightly golden **Phys. State:** Solid **Classification:** Metal **Atomic Weight:** 119 u **Melting Point:** 231.9 °C **Boiling Point:** 2603 °C **O's in Oxide:** 2 **Cl's in Chloride:** 4

Beryllium **Be**	**Arsenic** **As**	**Antimony** **Sb**	**Aluminum** **Al**
Carbon **C**	**Calcium** **Ca**	**Bromine** **Br**	**Boron** **B**
Lithium **Li**	**Indium** **In**	**Hydrogen** **H**	**Chlorine** **Cl**
Phosphorus **P**	**Oxygen** **O**	**Nitrogen** **N**	**Magnesium** **Mg**
Silicon **Si**	**Selenium** **Se**	**Rubidium** **Rb**	**Potassium** **K**
Tin **Sn**	**Sulfur** **S**	**Strontium** **Sr**	**Sodium** **Na**

Alien Periodic People

Objectives:

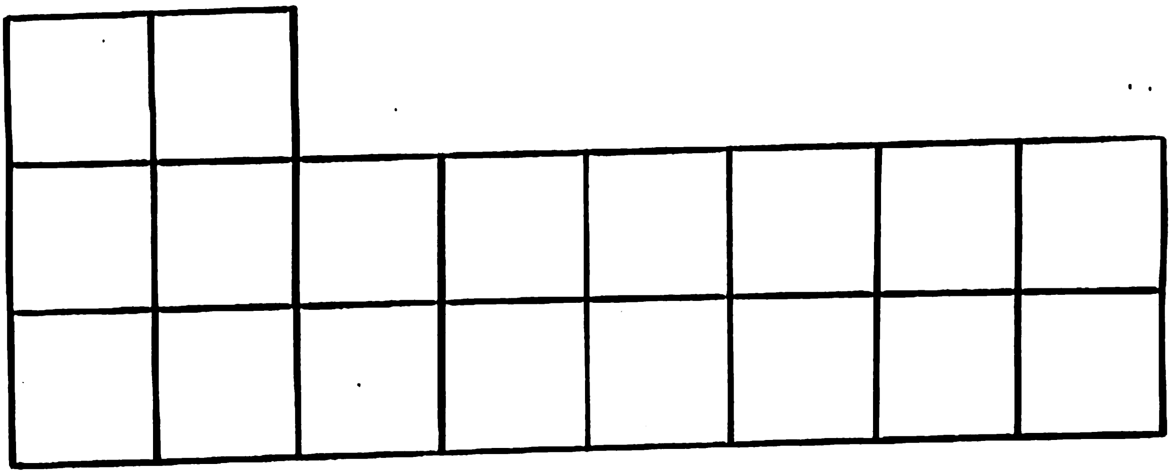
- Identify periodic patterns similar to those on the periodic table

Materials:

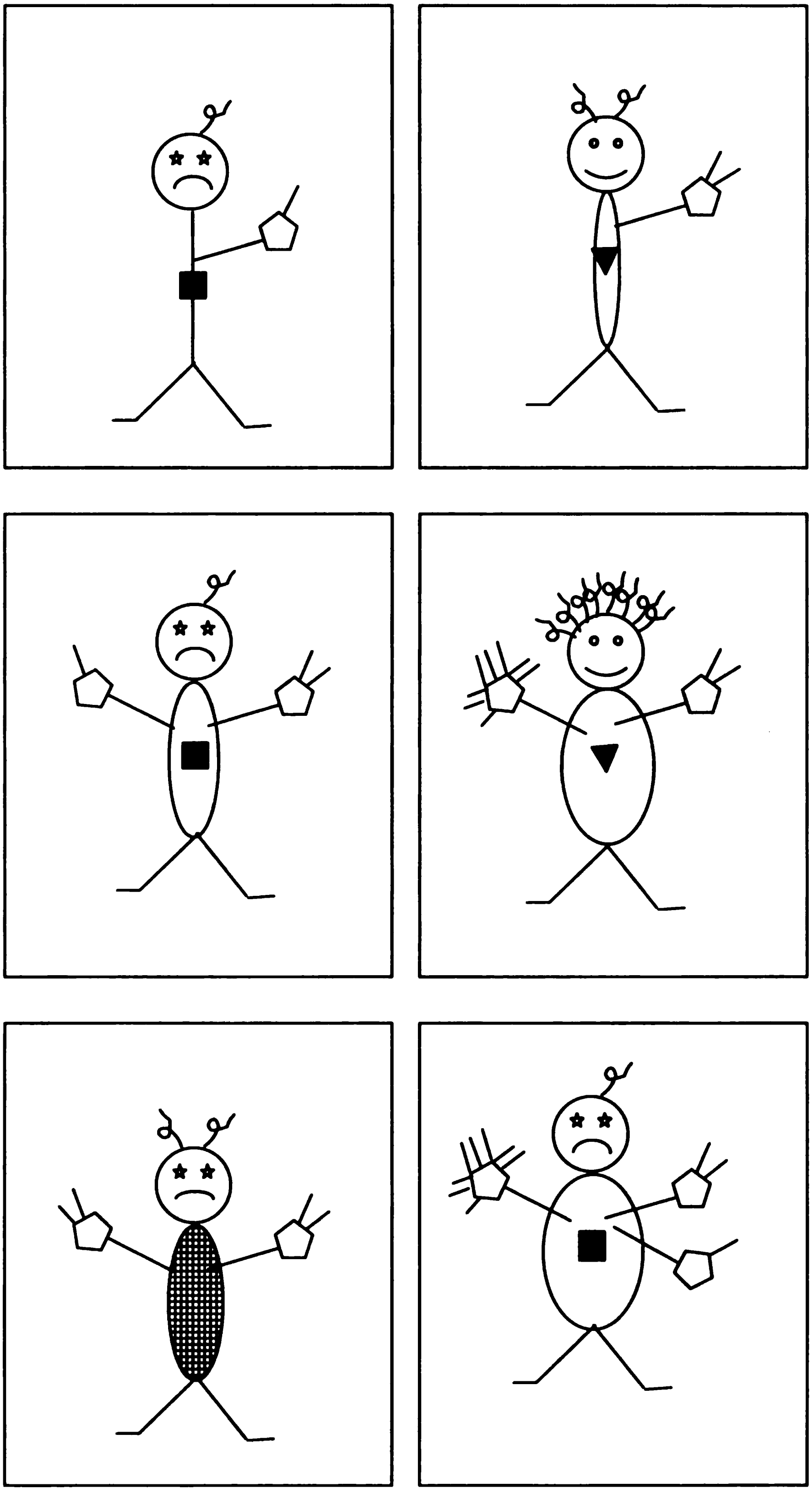
- Scissors
- Glue/Tape
- Copies of Aliens
- Blank paper

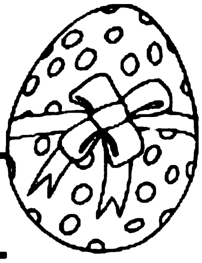
Procedure:

1. Cut out the squares of aliens.
2. Arrange them according to the diagram below. Each group (vertical column) must have similar properties and a predictable trend from top to bottom of a group. Each period (horizontal row) must also have a predictable trend from left to right across the row.
3. Loosely tape your finished pattern of aliens on a blank sheet of paper.



Aliens





EASTER EGG ISOTOPES

Blue beads = protons
White beads = neutron

PURPOSE –

- The purpose of this lab is to allow you to examine models of isotopes and determine various quantities for these isotopes.

MATERIALS –

- 8 labeled plastic Easter eggs (containing a different number of protons and neutrons)

PROCEDURE –

- Examine each of the eight "isotopes" and fill in the correct information for each in the table below. Then answer the questions that follow.

DATA

Egg #	# protons	# neutrons	atomic #	mass #	Isotope Symbol (include symbol, atomic # and mass #)
1					
2					
3					
4					
5					
6					
7					
8					

ANALYSIS-

1. There are isotopes of the same element among the eight isotopes. Which numbers are they? Explain.
2. What elements do they represent?
3. List two isotopes which have the same number of neutrons.
4. Do these represent the same element? Explain.
5. Look at isotope #8. How would you make another isotope of this element?
6. Is there only one way that this can be done? Explain.
7. You want to make an egg which represents an isotope of aluminum. How many blue beads will it contain? How many electrons would a neutral atom of this isotope contain?
8. How many white beads could it contain?

Experimentally Predict the Density of Germanium
Class Lab

Objective:

- Use experimental data and periodic trends to predict the density of germanium

Materials:

- Metal Samples (lead, silicon, tin)
- Electronic scales
- Graduated cylinders (large enough to fit the metal samples)
- Water
- Paper Towels
- Calculators
- Excel

Procedure:

1. Assign groups of students one of the metals to calculate the density of.
2. Record class data and get the average densities.
3. Graph data using Excel.
4. Determine the density of Germanium off the graph.
5. Compare experimental result to actual density.
6. Discuss possible places for error.

APPENDIX D

SECTION B MATERIALS

Name: ______________________________ Date: ___________ Hr: ____

Unit 2 – Materials: Structures and Uses Pre-Test
Section B (No iClickers) -Earth's Mineral Resources

Reference Materials: Periodic Table. Metal Activity Series

1. _____ Many underground pipes are made out of iron. An engineer wants to attach a piece of material to an iron pipe to prevent rust formation (oxidation). Based on the diagram, which of the following materials should the engineer use? Explain your answer. (2 points) *C5.6c*

A. gold B. copper C. silver D. zinc

2. ______ Which of the following is the products side of the chemical equation of solid aluminum in aqueous lead (II) nitrate is shown below. (1 point) *C5.6b*

$$2\ Al_{(s)} + 3\ Pb(NO_3)_{2\ (aq)} \longrightarrow$$

A. $2\ Al_{(aq)} + 3\ Pb_{(aq)} + 3\ N_{2\ (g)} + 9\ O_{2\ (g)}$
B. $Pb_3Al_2\ (s) + 3\ N_2O_{6\ (aq)}$
C. $2\ Al_{(s)} + 3\ Pb_{(s)} + 3\ N_2O_{6\ (aq)}$
D. $3\ Pb_{(s)} + 2\ Al(NO_3)_{3\ (aq)}$

3. _____ During which process does an atom gain one or more electrons? (1 point)

A. transmutation B. oxidation
C. reduction D. neutralization

4. _____ Which half-reaction equation represents the reduction of a potassium ion? Explain your answer. (2 points) *C5.6a*

A. $K^+ + e^- \longrightarrow K$
B. $K^+ \longrightarrow K + e^-$
C. $K + e^- \longrightarrow K^+$
D. $K \longrightarrow K^+ + e^-$

5. ____________________________ In the following reaction which element is oxidized? (1 point) *C5.6a*

$$Cu_{(s)} + 2\ Ag^+_{(aq)} \longrightarrow Cu^{+2}(aq) + 2\ Ag_{(s)}$$

6. For the following reaction, write the oxidation half reaction and the reduction half reaction. (2 points) *C5.6a*

$$Cu_{(s)} + 2\ Ag^{+}_{(aq)} \longrightarrow Cu^{+2}(aq) + 2\ Ag_{(s)}$$

Oxidation ½ reaction:

Reduction ½ reaction:

7. Using the metal reactivity diagram on the front page, circle the reactions that would occur as written. For the reactions that will occur, write the products of the reaction. (4 points) *C5.6b*

A. $Mg_{(s)} + Cu(NO_3)_{2\,(aq)} \longrightarrow$

B. $Cu_{(s)} + Al(NO_3)_{3\,(aq)} \longrightarrow$

C. $Zn_{(s)} + AgNO_{3\,(aq)} \longrightarrow$

D. $Fe_{(s)} + Mg(NO_3)_{2\,(aq)} \longrightarrow$

8. What two metals did Michigan's economy depend heavily on in the past? (2 points)

9. ______ What are the three most abundant elements in Earth's crust? (1 point)

A. Mg, O, Al
B. O, Fe, Al
C. O, Si, Al
D. Fe, Cu, Ni

10. Identify each of the following equations as representing either an oxidation or a reduction reaction. (1 point each) *C5.6a*

A. ________________________ $Fe^{+2} + 2\ e^- \longrightarrow Fe$

B. ________________________ $Cr \longrightarrow Cr^{+3} + 3\ e^-$

11. Write the complete electron configuration for Mg, magnesium. (1 point) *C4.8e*

12. Write the kernel (noble gas) electron configuration for Mg, magnesium. (1 point) *C4.8f*

13. What is magnesium's oxidation number (charge)? 1 point *C4.8g*

Name: ______________________________ Date: __________ Hr: ____

Unit 2 – Materials: Structures and Uses Post-Test
Section B (No iClickers)-Earth's Mineral Resources

Reference Materials: Periodic Table, Metal Activity Series

1. _____ Most hot water heaters are made out of iron. The cost of the water heater is due mostly to the length of the warranty which is often a 6 year or a 12 year warranty. The warranty is directly related to the number of metal rods inserted into the hot water heater that prevent oxidation of the iron tank. What would be a suitable metal to make the rods out of? Explain. (2 points) *C5.6c*

2. ______ Which of the following is the correct product side of the chemical equation of solid calcium in aqueous copper (II) nitrate as shown below. (1 point) *C5.6b*

$$Ca_{(s)} + Cu(NO_3)_{2\,(aq)} \longrightarrow$$

A. $Cu_{(s)}$ + $Ca(NO_3)_{2(aq)}$
B. $Ca_{(aq)}$ + $Cu_{(aq)}$ + 3 $N_{2\,(g)}$ + 9 $O_{2\,(g)}$
C. Cu_3Al_2 (s) + 2 $NO_{3\,(aq)}$
D. $Ca_{(s)}$ + $Cu_{(s)}$ + $N_2O_{6\,(aq)}$
E. $Cu_{(s)}$ + $CaNO_{3\,(aq)}$

3. _____ During which process does an atom lose one or more electrons? (1 point)

A. transmutation B. oxidation C. reduction D. neutralization

4. _____ Which half-reaction equation represents the oxidation of a potassium ion? Explain your answer. (2 points) *C5.6a*

A. $K^+ + e^- \longrightarrow K$
B. $K^+ \longrightarrow K + e^-$
C. $K + e^- \longrightarrow K^+$
D. $K \longrightarrow K^+ + e^-$

5. ____________________________ In the following reaction which element is reduced? (1 point) *C5.6a*

$$Cu_{(s)} + 2\,Ag^+_{(aq)} \longrightarrow Cu^{+2}_{(aq)} + 2\,Ag_{(s)}$$

6. For the following reaction, write the oxidation half reaction and the reduction half reaction. (2 points) *C5.6a*

$$Cu_{(s)} + 2\ Ag^{+}_{(aq)} \longrightarrow Cu^{+2}_{(aq)} + 2\ Ag_{(s)}$$

Oxidation ½ reaction:

Reduction ½ reaction:

7. Using the metal reactivity diagram on the front page, ***write the products of the reactions that will occur***. If a reaction will not occur, write NR after the arrow. (4 points) *C5.6b*

A. $Au_{(s)} + Cu(NO_3)_{2\,(aq)} \longrightarrow$

B. $Al_{(s)} + Cu(NO_3)_{3\,(aq)} \longrightarrow$

C. $K_{(s)} + NaNO_{3\,(aq)} \longrightarrow$

D. $Pb_{(s)} + Sn(NO_3)_{2\,(aq)} \longrightarrow$

8. What two metals did Michigan's economy depend heavily on in the past? (2 points)

9. ______ What are the three most abundant elements in Earth's crust? (1 point)

A. O, Si, Al
B. Mg, O, Al
C. O, Fe, Al
D. Fe, Cu, Ni

10. Identify each of the following equations as representing either an oxidation or a reduction reaction. (2 points) *C5.6a*

A. ______________________ $Cr \longrightarrow Cr^{+3} + 3e^-$

B. ______________________ $Fe^{+2} + 2e^- \longrightarrow Fe$

11. Write the complete electron configuration for S, sulfur. (1 point) *C4.8e*

12. Write the kernel (noble gas) electron configuration for S, sulfur. (1 point) *C4.8f*

13. What is sulfur's oxidation number (charge)? (1 point) *C4.8g* ______________

14. ______Ores containing metals are composed of what types of bonds? (1 point) (C4.3e)

A.) metallic B.) polar covalent C.) non polar covalent D.) ionic

15. ______ What element on the periodic table will have very similar properties to copper, Cu? (1 point) (C4.9A)

A. iron B. silver C. nickel D. zinc E. aluminum

16. _____ What is the most common gas in the atmosphere at around 80%? (1 point)

A.) carbon dioxide B.) water vapor C.) nitrogen
D.) oxygen E.) hydrogen

17. _____ How many protons, neutrons, and electrons does copper have? (1 point) (C4.10A)

A.) 64 p+, 64 e-, 29 n B.) 29 p+, 29 e-, 35 n C.) 35 p+, 29 e-, 64 n
D.) 35 p+, 35 e-, 29 n E.) 29 p+, 29 e-, 64 n

18. _____ What trend in metallic reactivity is apparent as you move from left to right across a horizontal row (period) of the periodic table? (1 point)

A. Reactivity decreases B. Reactivity increases
C. Reactivity stays the same D. Impossible to predict

19. _____ Which of the following metals would be the most difficult to extract from their ores? (1 point)

A.) aluminum B.) silver C.) gold D.) iron

20. _____ In which part of the periodic table are the most reactive-metals found? (1 point)

A. Bottom left B. Top right C. Middle
D. Top left E. Bottom right

21. _____ Consider this reaction:

$$Zn + Cu^{+2} \longrightarrow Zn^{+2} + Cu$$

What is the half reaction for Zn? (1 point) (C5.6a)

A.) $Zn \longrightarrow Zn^{+2} + 2\,e-$

B.) $Zn + 2\,e- \longrightarrow Zn^{+2}$

C.) $Zn + 1\,e- \longrightarrow Zn$

D.) $Zn \longrightarrow Zn^{+2} + 1\,e-$

22. _____ Does the following reaction represent an oxidation or reduction? (1 point) (C5.6a)

$$Fe^{+3} + 3\,e- \longrightarrow Fe$$

A.) oxidation B.) reduction C.) neither D.) both

Properties of Copper Ores

Minerals from which copper can be extracted to make money are called **copper ores**. There are several copper ores, but they all fall into two main categories: oxide ores and sulfide ores. **Oxide ores** contain oxygen. **Sulfide ores** contain sulfur. Azurite ($Cu_3(CO_3)_2(OH)_2$, malachite ($CuCO_3 \cdot Cu(OH)_2$, and chrysocolla ($(Cu,Al)_2H_2Si_2O_5(OH)$) are a few examples of oxides ores. Chalcocite (Cu_2S), bornite (Cu_5FeS_4), and chalcopyrite ($CuFeS_2$) are all examples of sulfide ores.

Physical properties of a substance are properties that can be observed but do not result in a change in composition. Physical properties include color, texture, shape, odor, density, solubility, melting point, boiling point, electrical conductivity, hardness, and malleability.

Physical properties are an important factor in determining a method for mining copper. Some considerations that must be discussed are
• What type of ore is present?
• What are some physical properties used to classify ores?

Objectives:

- List several physical characteristics of each ore that will allow you to distinguish them from each other.
- Given a rock sample, identify the mineral present based on its physical characteristics.

Materials:

- Samples of each ore (azurite, chalcopyrite, chrysocolla, and malachite)
- Magnifiers

Procedure

1. Obtain each of the following mineral samples: azurite, chrysocolla, malachite, and chalcopyrite from the instructor.

2. Note the physical appearance of each ore sample, paying close attention to color, clarity, and any other distinguishing characteristics. Record your observations.

3. What are some differences between an oxide ore and a sulfide ore?

Converting Copper to Copper Oxide

$$2\ Cu_{(s)} + O_{2(g)} \longrightarrow 2\ CuO_{(s)}$$

Objectives:

- Convert copper to copper oxide
- Perform a chemical reaction
- Observe a chemical change

Materials:

- 1 gram Cu powder
- evaporating dish
- electronic scale
- hot plate
- tongs
- 100 mL beaker

Procedure:

1. Measure and record the mass of a clean, empty evaporating dish. Add approximately 1 gram copper powder to the evaporating dish. Record the mass of the evaporating dish with the copper powder in it within the nearest 0.1 g. Find the actual mass of copper powder by subtracting the mass of the empty evaporating dish from this value. Record the mass of the copper powder
2. Which properties of copper can you directly observe? Record your observations of the copper powder.
3. Set the evaporating dish on a hot plate. Set the hot plate to high.
4. Heat the evaporating dish and its contents two minutes. Use tongs to hold the evaporating dish and gently use a spatula to break up the solid. Caution: The evaporating dish is extremely fragile. Use care.
5. Continue heating for about 10 minutes more. Keep removing the evaporating dish from the hot plate and breaking up the solid every 2 minutes.
6. When you are finished heating, remove the evaporating dish from the hot plate and allow it to cool. Answer questions #1-2 while you are waiting.
7. After the evaporating dish and its contents have cooled, determine their mass. Use this value and the empty evaporating dish to calculate the mass of the contents. Record in data table.
8. Label a clean 100 mL beaker with your name, class, and mass of copper obtained. Transfer your product to the beaker. Store the labeled beaker as indicated by your teacher.
9. Wash your hands thoroughly before leaving lab

Data Table:

Object	*Mass(g)*
Evaporating dish mass (g)	
Evaporating dish + copper mass before heating (g)	
Amount of copper before heating (g)	
Evaporating dish + copper compound after heating (g)	
Mass of copper compound after heating (g)	
Mass gained by copper through heating (g)	

Analysis Questions:

1. Describe changes you observed as you heated the copper.

2. Did the copper atoms remain in the evaporating dish? Explain using evidence from your observations.

3. Were the changes you observed physical changes or chemical changes?

4. What observational evidence leads you to that conclusion?

5. How did the mass of the evaporating dish contents change after you heated the copper?

6. Explain why the mass of the evaporating dish contents changed in that manner?

The Floating Penny

Introduction

Pennies minted before 1982 were made entirely of copper. Pennies minted after 1982 have a core of zinc that is plated with a very thin layer of copper. This experiment demonstrates the different reactivity of zinc and copper with an acid.

Materials

- Hydrochloric acid solution, 6 M, HCl, 20 mL
- Forceps or tongs
- Beaker, 100-mL
- Graduated cylinder, 50-mL
- Beaker of water
- One post-1982 penny
- File, triangular
- One pre-1982 penny

Procedure

1. Obtain both a pre-1982 and a post-1982 penny. Use a file to make four 1-mm indentations
90° apart into each penny. Make sure the indentations on the post-1982 penny extend through the outer copper layer into the shiny zinc core.
2. Place both pennies into a 100-mL beaker. Place the beaker in an operating fume hood.
3. Add 20 mL of 6 M hydrochloric acid solution to the beaker. Observe.
4. Leave the reaction undisturbed overnight in the fume hood. The next day, the post-1982 penny should be floating, while the pre-1982 penny appears unchanged. Observe any bubbles on either penny.
5. Carefully remove the pennies using forceps or tongs and place the pennies in a beaker of water to rinse off any excess acid. Be careful not to crush the hollow post-1982 penny. Make sure the inside of the penny is well rinsed to remove all the acid.

Explanation

Hydrochloric acid reacts readily with the zinc core of the newer pennies, according to the reaction: $Zn(s) + 2H+(aq) \rightarrow Zn^{2+(}aq) + H_{2(g)}$

Zn^{2+} has a lower reduction potential than H+; therefore, zinc is more "active" than hydrogen in the activity series. This means that the zinc core of the penny will reduce the H+ ions from the acid solution to hydrogen gas, H2. The zinc metal is oxidized to Zn^{2+} ion and dissolves in solution. Copper, on the other hand, is less "active" than hydrogen in the activity series (Cu^{2+} has a higher reduction potential than H+). Copper metal, therefore, will not reduce the H+ ions in solution and the copper metal does not dissolve. The average post-1982 penny contains approximately 2.5 g of zinc. This amount of zinc requires almost 13 mL of 6 M hydrochloric acid to fully react. Therefore, it is important that approximately 20 mL of 6 M hydrochloric acid solution be used to ensure the reaction of all of the zinc.

Predicting the Metal Activity Series

Objectives:

- Rank a list of metals in order of increasing activity
- Relate metallic activity to its strength as a reducing agent
- Relate metallic activity to the rate of oxidation

Materials:

- 0.1 M $CuCl_2$ solution
- 6 test tubes
- test tube rack
- Metal samples (Al, Mg, Sn, Zn, Pb, Fe) All need to be ~ the same size samples.
- Disposable pipet

Procedure:

1. Using a pipet put ~ 2 mL of the $CuCl_2$ solution into each test tube. The important part is that you have the same amount in each test tube and there is enough solution in the test tubes to completely cover the metal samples.
2. Label each test tube with the type of metal it will contain.
3. At ~ the same time drop the metal samples into their respective test tubes and immediately start observing and recording the reactions.
4. Based on your observations of the reaction rates, rank the metals from least to most reactive with $CuCl_2$

Questions:

1. List the metals in order placing the least reactive metal first.
2. Which metal reacted the fastest?
3. Which metal reacted the slowest?
4. Which of the metals used in this investigation might be an even better choice than copper for the outside surface of a penny? What observational evidence supports your conclusion.
5. Why do you think the metal you chose in #4 isn't used as the outside surface of a penny?
6. Which of the metals used in most likely to be found in an uncombined, or "free" metallic state in nature? Explain.
7. Which metal is least likely to be found chemically uncombined with other elements? Explain.

Activity Series Computer Animation

1. Perform the metal activity simulations on the following website. When finished fill in the chart below using the metal activity series.

http://www.chem.iastate.edu/group/Greenbowe/sections/projectfolder/flashfiles/redox/home.html

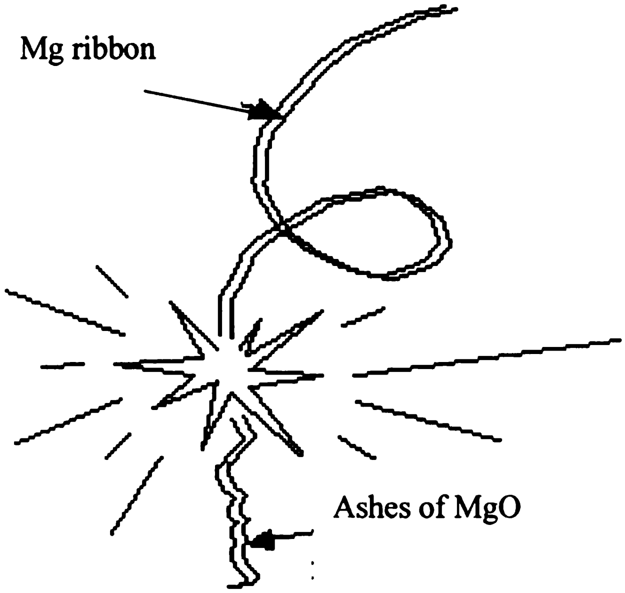
Use the activity series to predict if the following reactions will occur. If a reaction will occur, write the formulas of the products in the box. If no reaction occurs, write NR in the box

	Mg	Cu	Zn	Ag	Fe	Pb	Ni	Sn
$Mg(NO_3)_2$								
$Zn(NO_3)_2$								
$Cu(NO_3)_2$								
$AgNO_3$								
$Fe(NO_3)_2$								
$Pb(NO_3)_2$								
$Ni(NO_3)_2$								
$Sn(NO_3)_2$								

Combustion of Magnesium Mg

Hold a bit of magnesium ribbon 3 - 5 cm long with a pair of pliers or tongs. Set fire to it using the tip of inner cone of a Bunsen burner flame. The flame is dazzling and rich in UV light. Don't look directly on the flame !

$$2\ Mg + O_2 \dashrightarrow 2\ MgO$$



Questions:

1. Write and balance the equation for the combustion of magnesium.

$$\overset{0}{2\ Mg_{(s)}} \quad + \quad \overset{0}{O_{2(g)}} \quad \longrightarrow \quad \overset{+2-2}{2\ MgO_{(s)}}$$

2. Write oxidation numbers over each element.
3. What element is oxidized? magnesium What element is reduced? oxygen
4. What is the oxidizing agent? oxygen What is the reducing agent? magnesium

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