Targeting and Attempting to Correct Common Misconceptions in the High School Chemistry Classroom

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Targeting and Attempting to Correct Common Misconceptions in the High School Chemistry Classroom

by

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Chapter 1: Introduction

Problem Statement

Many high school students struggle when taking a course in chemistry. All students come into the classroom with various preconceived notions about the course and the related curriculum. Their knowledge and perspective on the course is limited, but they have some prior beliefs due to vaguely being exposed to chemistry in middle school and in their daily lives. They have taken enough science by the time they get to chemistry to have their own thoughts on what the course entails. But what many students also discover, after getting more acquainted with the content, is that it is difficult. There is a great deal of material (with relation to time) in the course which they often find overwhelming. Additionally, the content is extremely abstract in comparison to the science courses they formerly studied. Considering these two factors; there is not a great deal of time to master abstract concepts before moving onto the next topic. This presents a barrier to achieving maximum success in the course. Again, this does not apply to all students, but to a vast majority of them. From a teacher’s point of view, it is also very challenging to cover all the required material and also ensure that the students are “getting it” each step of the way. The misconceptions that the students bring into the classroom, in addition to all the above-mentioned obstacles, simply compound the problem and create more hurdles for the students. Misconceptions make it very difficult for the students to be as successful as they would like to be in the course.
Significance of the Problem

It is often difficult to pinpoint what the majority of the students are having difficulties with. It also becomes an obstacle with time to then address these discovered issues. Students often get so wrapped up in all the details they sometimes fail to grasp the big picture or the main concepts that embody the course. I believe this is where the students really become lost because if the general concept is not understood it is at least difficult, if not impossible, to make the details internally meaningful. Additionally, when students have prior misconceptions about content it makes it even more challenging to grasp the big picture since they must then find a way to reconstruct those preconceptions in order to have clarity with the material. As they progress through the course they build upon these misconceptions by simply hanging on to them causing their understanding to take a turn for the worse. I like to relate it to a labyrinth. The more dead-ends you encounter and wrong turns you take, the more off-track you become and the longer it takes for you to find the exit. By addressing and attempting to overcome some of these chemistry classroom misconceptions it should be easier for students to master the course and its concepts more effectively. The misconceptions must be addressed since the natures of the other two issues (time and abstract nature of the material) are unavoidable.

Purpose

The purpose of this study is to a) identify the common misconceptions in the chemistry classroom, b) make the students aware of these misconceptions, c) create instructional activities/strategies to attempt to correct these misconceptions, d)
analyze the effectiveness of the implementations, and e) devise a few strategies for improving all future learning in the chemistry classroom. Overall, the purpose of the study is to improve learning in the chemistry classroom by addressing and attempting to correct the misconceptions that students possess.

**Rationale**

Effective approaches must exist for chemistry teachers to implement in order to prevent, eliminate, or at least minimize misconceptions in their classrooms. Identifying and attempting to alter any incorrect understandings that students possess should breed more success and mastery in the classroom. My ultimate goal as an educator is to constantly improve my teaching and student learning each and every year. By engaging in this study I am confident that I will reach my students more effectively each year and hence their learning will improve as well. It will also help me to be more preventative and aware of “thinking detours” students may embark on before they do so.

**Definition of Terms**

The term misconception can also be referred to as an alternate conception. A misconception is defined as “students ideas, manifested after exposure to formal models or theories, which are at variance with those currently accepted by the scientific community; and these include students’ ideas which arise as a result of confusion of non-formal thinking” (Boo, 1998, p.570).
Summary

The guiding questions leading the action research are as follows: a) Why do students struggle with chemistry so significantly? What is it about the nature of the subject that creates immediate obstacles for the students? b) What are the most common misconceptions my students hold regarding the subject of chemistry as it applies to my classroom? c) What instructional techniques can be implemented in order to rebuild proper conceptions of chemistry for students? and d) How can the findings from this study not only benefit my current students but my future students as well? How can the curriculum and instruction be altered to make this an everlasting benefit in my teaching? What instructional approaches can be used and built into the existing curriculum to achieve this?

In order to address these guiding questions different instructional strategies such as pretests, discrepant events, demonstrations, inquiry-based labs/activities, discussions, and posttests were experimented with in the chemistry classroom.
Chapter 2: Literature Review

Obstacles within the course of chemistry

Chemistry tends to be a very abstract science and therefore many students entering the course find it challenging and often difficult to master. Additionally, children start to try to make sense of the world around them very early on in their lives (Bransford, 2000). To them, this learning is their "truth" whether or not the interpretation is valid or not. From their early years they continue to build on these conceptions they have gathered and any synthesizing of new material continues and is highly influenced by their prior beliefs and learnings (Bransford, 2000). By the time they arrive in a junior-level course such as chemistry they have many preconceptions of how the world works. Some of these preconceptions are accurate and some are not. The danger lies in those preconceptions that are inaccurate (also known as misconceptions or alternate conceptions) especially if the student is so convinced and hangs on to the belief or learning (Bransford, 2000). This is when their correct learning begins to become clouded and it is difficult for them to effectively process new material. They venture down stray paths since they are trying to build upon false or altered knowledge. The student then believes that

Most these explanations are correct because these explanations make sense in terms of their understanding of the behavior of the world around them. Consequently, if students encounter new information that contradicts their alternate conceptions it may be difficult for them to accept the new information because it seems
wrong. The anomalies do not fit their expectations (Mulford, 2002, p.739).

When these conditions occur, the new information is hindered and may be ignored, rejected, disbelieved, deemed irrelevant to the current issue, held for consideration at a later time, reinterpreted in light of the student’s current theories, or accepted with only minor changes in the student’s concept. Occasionally anomalous information could be accepted and the alternate conception revised (Mulford, 2002, p.739).

One of the main reasons that chemistry is so complex lies in the fact it can be represented at not only the macroscopic level, but at the microscopic level as well (Gabel, 1999; Levy-Nahum, 2004). At the elementary level, students are taught the macroscopic or generalized view of chemistry, which is expected to eventually transform into the microscopic version (or detailed version) which they learn in high school (Gabel, 1999). For example, as science teachers we generally ask students to make observations (which is a macroscopic level of thinking) and then ask them to immediately convert that into a microscopic explanation or an intricate and technical version of their learning based on the content that they have recently been given. Electrolysis is a perfect example of this. When students are asked to make observations of an electrolytic cell they have built, they may respond saying that one of the electrodes grew and the other electrode emitted a gas or produced bubbles. This would be a macroscopic way of looking at the situation since it is purely based on
observations. But then in their lab report they may be asked to identify the cathode/anode, report on which direction the electrons and ions were flowing, state the site of oxidation and reduction, and so on. This is a large and challenging leap to make for them and requires a great deal of knowledge to make those connections.

Somewhere in between this point of observation and analysis they need further explanation (or possibly a visual view) of what is going on “behind the scenes” so that they are better able to understand the process and therefore analyze it. Students have a very difficult time understanding this concept to begin with as is evidenced by the following quote:

Students view and measure the volume of the gases being produced, they could be asked to represent the decomposition of the water molecules using models of atoms and molecules, and they usually are asked to write the balanced formula equation after they have completed the electrolysis, they do not link the volume ratio of hydrogen to oxygen to 2:1 because it is logical to many students that molecules of greater mass (oxygen) should occupy more space than those of lesser mass (hydrogen). Avogadro’s hypothesis is not self-evident! Many students complete the activity thinking that the whole test tube of water that the hydrogen has replaced has been decomposed (Gabel, 1999, p.549).

A large gap exists between these two types of views (macroscopic and microscopic) and there is currently minimal transitioning between these two perspectives from
elementary school to high school not to mention solely within the course of chemistry. This is yet another factor contributing to the difficulty of the course.

So how can this situation be improved? The students should first of all be aware of the three-fold nature (macroscopic, microscopic, and symbolic) of representing the matter involved in the electrolysis phenomenon. This can be done by asking them to draw particle diagrams of equal aliquots of the hydrogen and oxygen. Ask them then to relate this to the volume that each of the gases would occupy. You could then require them to calculate the volume of water that decomposed to produce the volume of each of the gases they collected. Comparing the calculated volume of water to the observed volume of water lost from the electrolysis system should present a discrepancy. The students would then be prompted to explain why based on their knowledge Avogadro’s hypothesis. This will force them to make sense of the phenomenon (Gabel, 1999).

Chemistry also involves a new common language including chemical symbols, formulas, and equations (Gabel, 1999). This is yet a third type of perspective considered symbolic representation and therefore also contributes to the complexity of learning chemistry for the students. Gabel suggests that teachers should not only be aware of this threefold relationship (macroscopic, sub-microscopic or particulate, and symbolic) but they should also relay it to their students so their students are aware of the pitfalls on their own. Teachers tend to not integrate the three levels for the students since simply delivering the material to the students is a task in itself. Often, the delivery of chemistry is constantly moving from one level to another.
within a lesson (Gabel, 1999). This leaves students assuming and making their own connections which may or may not be proper. If students are aware of these three different modes of thinking and the transitions that need to be made between them they may be better prepared to tackle the concepts and feel less confused.

The relevance, usefulness, and applicability of chemistry to students' everyday lives also have a huge impact on their attitude when teaching the subject (Treagust, 2000). Unfortunately, it is very rare that you find a chemistry course or curriculum that is capable of providing real life experiences for students regarding the concepts of chemistry. According to Treagust, a classroom that maximizes the amount of these real life experiences will improve student perceptions of chemistry.

*Identifying Misconceptions*

One method that can be utilized to quickly pinpoint areas of confusion for students is to administer a pretest of some sort. A specific pretest called the Chemistry Concepts Inventory (CCI) is an example of a comprehensive preliminary assessment that can be used at any time within the second half of the school year (Mulford, 2002). This inventory is based on the content that is traditionally covered in a typical first semester chemistry college course. It was originally given to a group of freshman college students just exiting high school to see what misconceptions they had constructed in their high school chemistry course. The topics covered include particulate nature of matter, properties of atoms, bonding, gases, liquids and solutions, conservation of mass and atoms, symbols equations, stoichiometry, chemical reactions, heat and temperature, phases changes, and macroscopic versus
atomic and molecular properties. It is a multiple choice inventory that samples the broad extent of general concepts that students have covered throughout the first main half of the school year. The inventory consists of 22 multiple-choice questions with at least 6 of these questions being a multiple choice oriented explanation to the question asked just before it. The topics missed most frequently become the ultimate areas of focus regarding misconceptions. Obviously the more incorrect responses that are collected on a particular question, the more the need to address that related concept on a class-wide basis. It is also useful to see the breakdown of the incorrect responses that are given in these particular situations. It allows you to see where the misconceptions specifically lie and possibly what most of the students are thinking, even if it is incorrect (see Appendix 1) (Mulford, 2002).

Upon its original creation, the CCI was originally taken or tested on eighteen (18) chemistry graduate students to check for length and clarity. The time needed for the students to take the inventory ranged from 15 to 25 minutes. Most were able to correctly answer all the questions. Four experienced chemical education researchers then also analyzed the survey for content and level. They concluded that it is fully suitable to test the general knowledge of any student enrolled in a basic chemistry course.

Other small sample questions or mini pretest assessments (borrowed or generated) can also be used at random times throughout instruction depending on the needs and demands of the students composing the individual classroom. For example, a large volume of research claims that student perceptions of chemical symbols,
formulas, and equations (or reactions) are pretty underdeveloped (Al-Kunifed, 1993). With this in mind, a mini pretest could be administered on dissecting a reaction by having them explain what the plus sign(s), reaction arrow, subscripts, and coefficients all symbolize and how they serve to interrelate (Al-Kunifed, 1993). This would provide a teacher with a tremendous amount of qualitative feedback from the students regarding their perspective on chemical reactions and all that they entail. This tends to be a difficult task for students due to the symbolic nature of reactions. Additionally, it is an extremely pertinent and overarching concept since they use reactions continually throughout the course.

Conservation of mass in relation to chemical reactions tends to be yet another topic that students struggle with (Barker, 1999). This concept might be assessed by giving the students open-ended essay questions and supplying them with key terms to use to help them out with their responses (Cavallo, 2003). There are also a handful of multiple-choice questions addressing this concept within the CCI mentioned above (Mulford, 2002).

Students also often experience difficulties during the oxidation-reduction unit (otherwise known as Redox). This is especially true in understanding the direction of electricity flow within electrochemical cells, electrons through the wire, and ions through the salt bridge. A small two-question survey could be used as a pretest (Sanger, 1997) to further understand student misconceptions regarding this concept. Questions 1 and 2 of the survey are multiple choice questions that require the students to understand what is flowing through the wire and the salt bridge of a particular
voltaic cell setup. They should understand that electrons flow through the wire that connects the two electrodes and positive and negative ions move within the two separated solutions which, in turn, force the circuit to operate. They must additionally understand the correct direction of the flow of electrons within the wire. Question 1 requires them to reason from which electrode the electrons are being lost and gained. It appears to be a straightforward question, but there are a lot of underlying concepts that would need to be understood to lead them to the correct answer. Question 2 requires them to understand the function of an electrolyte within a voltaic cell. They must understand that ions are moving through the electrolytes in a particular manner depending on their charge and the submerged electrode’s charge. Consequently, this study claims that students think that electrons exist to some extent in the electrolytes within voltaic cells. Only ions are present within the electrolytes. Some students also believe that ions are present within the wire. This is also untrue since only electrons run through the wire (Sanger, 1997).

As a warm-up activity or a bonus question on a unit exam, students could be supplied with questions such as “Assume that a beaker of water on a hot plate has been boiling for an hour. Within the liquid, bubbles can be seen rising to the surface. What are the bubbles made of?” (Gabel, 1999, p.548). In this particular study, it was found that 70% of the students responded by saying the bubbles were made of water vapor, steam, or molecules of water (which is a correct response). Twenty percent thought that the bubbles consisted of air or oxygen and another 5% thought it was a mixture of hydrogen and oxygen gases.
Another small “pretest” that could be utilized involves asking students seven questions about evaporation, boiling, and condensation (Hatzinikita, 1997). An example of one of the questions is as follows:

Miss Mary hangs out her laundry to dry. A few hours later the clothes are dried completely. The water of the laundry:

(a) was absorbed by the clothes  
(b) turned into hydrogen or/and oxygen and went to the air  
(c) turned into vapour and scattered in the air  
(d) disappeared  
(e) turned into air  
(f) something else

Describe it... (Hatzinikita, 1997, p.14)

This particular type of questioning not only tests student conceptions, but also provides them an opportunity to explain their reasoning, which allows the person assessing the data to see students’ train of conceptual thinking. According to Hatzinikita (1997), this type of questioning also concluded that qualitative understanding precedes quantitative understanding for students. In other words, students must be able to understand it at a level as seen above (macroscopic) before they can understand it at a more detailed level (microscopic). Since chemistry often jumps right to the details due to the limited time and the complexity of the curriculum, many students are stripped of this opportunity to make the connection between the two levels. In this particular question the answer was (c).
Student knowledge of gas laws could be assessed by asking students four conceptual questions (Lin, 2000). This study was done in Taiwan and three of the questions required upper level reasoning (possible college level) and therefore would have limited use for high school students, but the very last question (Lin, 2000) would certainly apply. It involves a diagram of two Erlenmyer flasks side by side. One of the flasks has a small Bunsen burner underneath it and the other does not. The students are told that each of the flasks has equal amounts of oxygen and carbon dioxide in them. They are also told that they are provided with a magnifying glass so that they are magically able to see anything they would like. They are then asked to draw what they would see in each flask and then explain why they would see what they saw. Now, the question resides in whether or not the students would catch on that they are expected to draw equal numbers of oxygen and carbon dioxide particles within each flask. They would additionally need to illustrate that the particles being heated are moving faster than the others (according to the kinetic molecular theory). Students at this level may need to be prompted in this type of situation. For example, a word bank could be a possible solution which would provide the students with terms such as particle diagram, kinetic molecular theory, and so on. Directions to get them started would also most likely be helpful for them. Lin and Lawrenz (2000) report on the misconceptions that the students had about this particular question. Interestingly enough, most of the students thought that the gas molecules moved away from the heat source. This common answer illustrates that a major misconception exists with regards to this particular concept.
Group discussions are another manner in which misconceptions can be identified (Schmidt, 1995). These can be useful when it becomes impossible to retrieve their reasoning on a written assessment (such as a pretest). It also serves to mix up instruction, allow the students to share their thoughts, and provides the teacher with more thorough qualitative feedback. Students should be encouraged and not be made to feel afraid to make mistakes and ask questions throughout this process. Discussions allow them to do so and also allow the teacher a “window” into their thought processes. “As potential mistakes of students are known teachers can plan strategies to clear up their thinking” (Schmidt, 1995, p.134). One thing that must be kept in mind when prompting students with questions to get them thinking is to use higher order questioning techniques. This type of questioning is proven to strengthen student achievement (Yip, 2004).

Approaches to Correcting Misconceptions

In order to begin to correct the misconceptions that students hold regarding chemistry, a couple approaches could be experimented with. One of them is termed “bridging.” It has been found to be one type of effective instructional strategy that involves using analogous situations to help unite students’ correct beliefs with their misconceptions in order to overcome their alternative and incorrect ways of thinking (Bransford, 2000). The correct beliefs would be nourished, built on, and treated as “anchoring conceptions” (Bransford, 2000). If this prior knowledge is then coupled with a misconception it can help to make the correct conceptions visible and more believable. This can contribute to helping students overcome their misconceptions.
Another instructional approach that can also be utilized is interactive lecture demonstrations. These require the students to make a prediction about what the outcome will be before the demonstration has even started (Bransford, 2000). It will be referred to as something called the POE task within this research paper (Bodner, 2001). POE is an acronym which stands for Prediction, Observation, and Explanation. Once the students’ predictions are made, they will observe the demonstration and will be asked to describe what happens. Finally, they are asked to “reconcile any conflict between what they predict[ed] and what they observe[d]” (Bodner, 2001, p.34). Usually, if their prediction is not what actually happens in the demonstration, this will force them to readjust their understanding of the phenomenon. It is difficult for them to believe something that they haven’t seen for themselves (Bransford, 2000).

POE’s will most times be accompanied with a discrepant event that either the student or teacher can carry out. It involves a prediction and then some sort of activity or demonstration to follow that may clash with their prediction or belief. It provides the student with blatant proof of what happens in reality, despite whether or not they predicted it. The students could be asked to discuss their (mis)conceptions, carry out experiments addressing these (mis)conceptions, and attempt to explain demonstrations and/or discrepant events. POE’s are implemented with the hopes of bringing students to a more scientific understanding in light of their learning experiences (Hwang, 1994). POE’s also served to get students thinking more conceptually and provide them the opportunity to learn how to apply that conceptual knowledge to different chemical situations. According to Kwen (1996), even the
brightest students think too consistently and attempt to apply the same knowledge to
different chemical scenarios. He calls this type of reasoning “event-specific” (Kwen,

An example of a discrepant event that demonstrates heat transfer to students
involves taking four identical bottles and filling two of them with cold water and the
other two with hot water (Stepans, 2003). Food coloring is placed in one of the hot
and one of the cold water bottles. Index cards are then placed on top of the two food-
colored bottles. These two bottles would then be inverted over (on top of) the other
non-colored bottles making sure that the cold is aligned with the hot and vice versa.
Next the students would be asked to predict what they think is going to happen once
the index cards are removed and the bottles are allowed to respond to one another. A
discussion would then take place to review student predictions and then the
demonstration would go forward to show the students what truly happens. Some may
have predicted correctly and some may have not. Discrepant events as such serve to
physically prove to some students internally that what they were thinking wasn’t
necessarily correct or confirm to others that they were right. So it helps both
perspectives out in the long run (Stepans, 2003).

Not only are demonstrations effective in teaching students the difficult
subject, but they also serve to keep the students interested and motivated to
understand chemistry. As one researcher stated, “Some demonstrations are so much
fun for both the students and their instructors that the term exocharmic has been used
to describe these demonstrations that are so inherently fascinating they ‘exude charm’
As humans, we are naturally interested in events that have an element of surprise since they tend to spark curiosity which in turn transfers into a desire to learn. They also "provide breaks that help students recover from the deluge of information in a typical class" (Bodner, 2001, p.31). Several college students (especially females in this particular case) came back to Breck high school (located in Minneapolis) saying that their interest in chemistry fizzled after taking freshman chemistry (Fruen, 1992). These students reported that there were no demonstrations or practical examples given by the professors and nor were there any interesting labs that correlated with the class material covered. This diverted their attentions to change their majors to other course content that were catching their attention in a better way (Fruen, 1992). This implies that we, as high school and college teachers, need to find a way to make the curriculum more interesting (for example, with discrepant events and demonstrations) in order to engage our students in chemistry and develop interest. Demonstrations are therefore beneficial in the classroom as long as they pertain to what you are presently teaching and as long as they don't take too much time out of instruction.

Computer animations could also be implemented within instruction to show the students visually what is going on behind the scenes of what they might be observing on a macroscopic level. For instance, a computer animation could be viewed of what is occurring inside a chemical reaction as it progresses (reactant particles gaining enough activation energy followed by the rearrangement that occurs at the activated complex which leads to the formation of the products). Another
example could involve showing what happens to water as it begins to boil (the particles speed up due to an increase in average kinetic energy which is supplied by the heat from the stove). These types of animations show continual motion and are said to improve students' construction of dynamic mental models rather than just the static mental models that most of them possess concerning the particulate nature of matter and its changes (Cole, 2003).

There are some approaches that could be implemented in the long run as well. ChemSense is a software program that allows the students to perform interactive experiments, observe animations, and carry out much other inquiry type of activities (Schank, 2002). There are also virtual laboratories that you can implement into instruction to break up the monotony of holding lab experiments in the actual lab room (Yaron, 2005). Again, these approaches would require an extensive amount of effort, resources, and time, but could be developed gradually over a couple years or so. This type of instruction would not only be fun for the students, but they would also be able to see animations and graphics that would hopefully help to clear up some of the confusions that they often have.

Summary

All in all, a variety of activities should be implemented into instruction so that students have the opportunity to understand concepts on a more familiar level before moving into the "scientific" level. Inductive reasoning must be used more often and direct teaching (note-taking) must be avoided when possible (Hutchinson, 2000). Lecturing is a passive act and is beneficial for some concepts, but many times
students need the opportunity to make their own connections in their own ways. They need to be an active part in their own learning process. All the above mentioned approaches, when used appropriately, should clear up or minimize the amount of misconceptions within the chemistry classroom.
Chapter 3: Applications and Evaluation.

Introduction

Misconceptions will always exist and will never be completely avoidable. Since they are something that can't fully be prevented (they are natural) teachers must be prepared to receive these misconceptions in the right way. They must know how to receive these misconceptions that students possess as they enter your room. This is where appropriate instruction must be implemented on the teacher's part. This research study was therefore chosen to address some of these prior beliefs my students possess to not only improve my own teaching, but enhance the learning of chemistry in my classroom as well. This study is also intended to raise awareness of the obstacles that students face in chemistry before they actually happen. I wanted the study to be an everlasting annual benefit for my current students, future students, and I in the classroom each consecutive year.

The solution that I opted to implement in order to identify and attempt to alter chemistry misconceptions in my classroom was chosen to ensure that the regular flow of instruction was not interrupted. I wanted it to be something that wasn't distracting to the students and would additionally help them with their understanding of the subject. The target group in this study included my students enrolled in the chemistry course for the 2005-2006 academic year. I felt allowing all my students to potentially participate was most appropriate since I wanted all the students to benefit from the study. I also wanted to gather the most representative data possible. Choosing all four classes to participate addressed this since all four classes had different classroom
dynamics and abilities with regards to the course. I therefore thought that the data would then most appropriately represent the average student enrolled in chemistry instead of an extreme from the average (low or high achieving).

Participants

The action research took place in a local public suburban high school with 74 students. Due to lack of consent, there were only eight students that were not included in this data collection. There were four participating classes. The number of students in each class, respectively from early day to late day, was 20, 22, 13, and 19. The grade levels for the participating students were as follows: six sophomores, sixty-five juniors, and three seniors. There were 46 females (62%) and 28 males (38%). Sixty-nine (or 93%) of the students were Caucasian and five (or 7%) were African American. The general socioeconomic status of the participants ranged from middle to high. There were 7 students that had special needs; one with an Individualized Education Program (IEP) and six with 504 plans requiring test modifications.

Instruction was very structured in the classroom. This must be the case in order to cover all standards and concepts required by the curriculum. The learning styles of the students from class to class were fairly balanced, but one class in particular was extremely bodily-kinesthetic. This required me to vary the lessons more often so they would stay on task.

Students that enroll in this chemistry class choose it as their third year science elective. The course requirements do not require the students to pass the Regents exam in order to successfully receive credit for the course, but they must at least
qualify to take the Regents exam which counts as their “fifth” quarter grade. They are required to score at least a 50% on the Regents exam and have an average grade of sixty-five (65%) or above at the end of the “five” quarters in order to receive credit for the class. This scenario would get them non-Regents credit for the course. They also have the added opportunity to receive Regents credit for the course as long as they pass the Regents exam with a 65%. Of the 74 participants, 72 qualified and actually took the New York State Physical Setting/Chemistry Regents exam in June 2006.

As the role of the educator in this study, I am a 31 year old Caucasian female teacher. This was my second year of teaching chemistry. Prior to becoming certified to teach I worked as a chemist in a local environmental laboratory. I therefore have a great deal of practical laboratory experience which deemed to be an advantage for me regarding this study.

Procedures of Study

The methods used to collect the data for this research were fairly straightforward. The students were given various pretests to start. The pretests were given as extra credit at the conclusion of unit exams and quizzes. Treating the pretests (surveys) as part of the regular unit assessments forced the students to generate his or her individual responses. This ensured more representative data of student knowledge. Each of these pretests was then broken down question by question to determine the percentage of students that chose each given response. These figures were then separately compared to the correct response to determine the most common
misconceptions the students hold. Once the misconceptions were identified and
tallied, the most common misconceptions were tackled by implementing instructional
approaches such as demonstrations, laboratory activities, and discrepant events to
attempt to correct these identified alternate beliefs that the students appeared to
possess. Finally, at the end of the year, the students were given posttests (similar to,
but slightly different than the pretests) to test their knowledge and beliefs of these
misconceptions. The posttests were then tallied, analyzed, and compared to the pretest
results to determine the effectiveness of the approaches implemented.

The data collected within this research project was a combination of
quantitative and qualitative data. The quantitative data collected was solely the results
from the pretests and posttests. The qualitative data that was collected included my
observations and recordings of student discussions, responses to demonstrations and
lab activities, and their general engagement when it came to these lessons that were
implemented into instruction.

Because of limited time and resources, I used mostly short fun activities here
and there within instruction to try to challenge the students' ways of thinking. The
concepts were topics that had already been covered earlier in the year. Because of
time constraints, any re-teaching that was necessary occurred intermittently and
randomly during class time, especially amidst instruction of other topics. For
example, as we approached the last couple units and were covering new material,
questions came up about surveys that covered material from earlier units. In order to
dually stay focused on the new material and also address past material I allowed for
discussion time in small spurts so not to jeopardize the original flow of the curriculum. Quick transition activities were also implemented into instruction to address this task. This also served to break the lesson up, got the students up and moving, and also aided in getting them ready for the Regents exam.

Any administered surveys counted as extra credit as long as the correct responses were given. This afforded the students the opportunity to not be held accountable for getting it correct, but instead provided them the incentive to receive extra bonus points to raise their grade. In order to keep all students participating in the action research, I individually checked to make sure they at least attempted to answer the bonus questions upon handing in the exams/quizzes. They were required to respond in some way, even if they had to guess. Those not participating due to consent reasons were eliminated from each relevant data collection, but were still required to participate in each activity. Their personal data was simply omitted from each data set.

*Instruments for Study*

There were two pretests or surveys that were initially given to identify the most common misconceptions my students held regarding the subject of chemistry. They included the Chemistry Concepts Inventory or CCI (see Appendix 1) and the two-question electrochemical cell survey (Sanger, 1997). Between the two of these pretests, most of the major concepts covered from the first half or more of the year were able to be addressed or tackled right away at the beginning of the study. This
allowed me to pinpoint any misconceptions the students were experiencing and the extent to which they were experiencing each particular identified concept.

The Chemical Concepts Inventory, also referred to as the CCI (see Appendix 1), was chosen as the very first survey to be administered with the intention of identifying several misconceptions all in one sitting. The CCI is so comprehensive that a significant amount of misconceptions were able to be identified within one class period. It contained 22-multiple choice questions and was given to the students at the end of a short unit test. It took most of the students anywhere from 15 to 25 minutes to complete. Any question answered correctly was awarded one point extra credit toward the unit test taken just prior. Incorrect responses had no penalty associated with them. This gave the students a major incentive to not only complete the survey, but also to answer the questions to the best of their ability. The CCI covered the majority of the main concepts taught in the course up until that point, except for the unit on Oxidation-Reduction (Redox), which we were covering as new material at that point in time. This survey was chosen for a few reasons. One, due to its comprehensive and objective nature, it covered many concepts and refrained from monopolizing a great deal of instruction time. Second, due to the anticipated short period of time needed to complete it, more time was left to discuss it and implement activities to address the misunderstandings that the students were found to hold. Lastly, upon handing the graded surveys back, it allowed the students to personally see be aware of their own weaknesses within the course therefore preparing them better for the Regents exam at the end of the year. The CCI was also given as a
posttest the last week of school to determine the progress that the students had made and the effectiveness of the implemented instruction intended to correct the identified misconceptions.

Once the oxidation-reduction unit was complete, the two-question multiple choice Sanger pretest was then also administered to detect misconceptions involving oxidation-reduction within an electrochemical cell. Again, the CCI did not cover oxidation-reduction concepts at all so this was needed in addition to the CCI. Again, this survey was given at the end of a unit exam (oxidation-reduction to be specific). This particular survey was also chosen since it has been documented that students struggle and therefore also develop misconceptions regarding oxidation-reduction concepts and their application within an electrochemical cell. This survey was chosen to be given a bit later in the study since upon beginning the data collection the unit of Redox was still yet to be completed.

Upon initially identifying the common misconceptions, a student-centered discrepant event in the form of a small laboratory activity was introduced into instruction regarding conservation of matter (see Appendix 2). In this example, students were asked to investigate the mass of the reactants before a reaction and the mass of the products after the reaction of zinc in hydrochloric acid. This was carried out by initially weighing all glassware/reactants, then carrying out the reaction while containing the gas produced in the reaction. This was achieved by capping the glassware with a balloon throughout the entire reaction. They then were asked to once again reweigh all the glassware and the products remaining.
Chapter 4: Results

Table 1 lists the quantitative data collected from the pretest of the CCI. Bolded numbers represent the correct response for each particular question. Percentages are calculated for each tally and are based on a total of 74 students that participated.

The results to question 1 show that only 14% of the students fully understood the concept of conservation of matter within a chemical reaction. The largest percentage of the students, thirty-four, held misconceptions regarding the number of molecules represented within the particular reaction. The number of each reactant or product (or molecule) within a reaction is represented by the coefficient in front of each member involved in the reaction. For example, in the following reaction:

\[ 2S + 3O_2 \rightarrow 2SO_3 \]

the ratio of molecules would be 2:3:2. Notice how the sum of the coefficients is not equal when comparing one side to the other. The 34% of students appeared to think that the coefficients must be (or add up to) the same number on both sides of the reaction.

The greatest percentage of students, thirty-eight, incorrectly believed that the bubbles of boiling water were made of oxygen and hydrogen gas in Question 2. Only 18% responded with the correct understanding that boiling water is simply water vapor. A significant number of students, thirty-four, thought that the bubbles only contained oxygen (choice c).
Table 1

CCI Pretest Results

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Question 3 was a complex question that required higher level thinking on the students’ behalf. It required students to reason through many concepts that were not necessarily taught to an adequate quantity throughout the school year. It was an upper level question and could be mastered by college students, but for high school I felt it was inappropriate. This question was therefore omitted when the posttest was administered. During the pretest, when asked to explain why a glass of cold milk sweats, I was therefore surprised to see that 31% of the students responded correctly saying that water vapor condenses from the air onto the glass. However, an even larger number of students, 46%, responded that the temperature difference forces oxygen and hydrogen within the air surrounding the glass to combine and form water on the surface of the glass. Thirteen students, or 18%, thought that water from the milk evaporates and then condenses onto the glass.

With regards to solutions, 27 students (36%) clearly understood that a solution consists of a solute plus a solvent. Additionally, they also clearly understood this concept in a mathematical sense. In Question 4, one pound of salt is dissolved in 20 pounds of water. These 27 students understood that the resulting solution would therefore weigh a total of 21 pounds. On the other hand, another 29 students (39%) responded saying that the resulting solution would weigh a total of 20 pounds. Either the question was read too quickly (thinking the solution instead weighed 20 pounds) or their definition of a solution was unclear. When asked to explain during a class discussion why this answer was chosen many of the students responded by saying “because the salt disappears.” This also shows the lack of true understanding of the
law of conservation of matter. This question was therefore kept and included in the posttest.

Question 5 seemed to pose the second greatest initial difficulty for the students as far as mastery went, aside from Question 21. This question again involved conservation of atoms and matter within a chemical reaction (in particle diagram form). Eighteen of the students (24%) selected the next best response which actually illustrated the correct particle diagram of the product that would indeed be formed (SO_3), but in doing so they failed to realize that there must be the same number of atoms in their response as what they started out (as reactants). The greatest percentage, 32%, of students selected the diagram that produced S_2O_3 as the product. Even more surprisingly, 19 students (26%) incorrectly chose the diagram that illustrated the production of two S_2O_6 molecules. These were both incorrect since according to the reaction provided in the question the product must be SO_3. S_2O_3 and S_2O_6 are simply not the same molecule as SO_3. This question was kept for the study since particle diagrams are heavily assessed within the curriculum. This question additionally addressed the concept of conservation of matter which had already been discovered as one of the major misconceptions that students held.

According to Question 6, half of the students thought that water breaks down into monatomic particles of hydrogen and oxygen upon evaporation. Only 11 (15%) understood that when water is evaporated into water vapor, the molecules spread out and remain fairly the same particle diagram as when they existed as liquid water. Gas molecules are just further apart within a gas particle diagram than the liquid
molecules are within a liquid particle diagram. This question was also kept within the posttest since it addresses change of states and phases of matter. Particle diagrams were verbally addressed during class time and reviewed during preparation for the Regents exam.

Question 7 was a true/false question so if a student did not know the answer to the question, or had no opinion on the content being of asked of them, they could have very easily guessed correctly. This was also the least missed question on the CCI, but it had also been thought that the question was not conceptual enough in comparison to the other twenty-one questions due to its true/false nature (Mulford, 2002). More than half (65%) of the students did indeed get the question correct saying that no matter is destroyed during the process of a match burning. Their reasoning (Question 8) followed suit with Question 7. Sixty-one percent of students understood that atoms are not destroyed but only rearranged in a reaction. This may also have been because they had repeatedly heard the phrase “matter cannot be created or destroyed.” Despite student success, I kept this question for the posttest since it addressed conservation of matter.

The greatest percentage of students, thirty-eight, understood that the formation of bonds in a chemical reaction gives off energy (Question 9). The remaining students believed that breaking bonds gives off energy in some way, shape, or form. This question was omitted from the posttest due to student success and also since it was the only question on the CCI that addressed this topic. I wanted to limit the quantity of misconceptions addressed to two or three within the study.
Question 10 illustrated that 62% of my students believed that water expands when it melts which is the opposite of what actually occurs. Their general reasoning (Question 11) was that water melting changes the water level in the end. This, on the other hand, is a correct response. Personally, I was not fond of how this question was worded. I therefore ended up omitting both questions from the study. They were very confusing for students and it seemed that Question 10 did not initially provide enough information to properly lead towards correct responses for either question.

Question 12 addressed conservation of matter. Only 35% of the students responded correctly saying the same combined mass (27 grams) would remain in the sealed tube after the reaction has transpired. An alarming 34% and 28% responded by reporting that "less than 26 grams" or "26 grams" (respectively) would remain in the tube after the reaction has taken place. Thirty-eight percent of the students reasoned (Question 13) that mass was conserved, but a surprising 45% thought that the gas weighed less than the solid. Consequently, the data observed when comparing Question 12 to Question 13 was fairly agreeable. This concept was discussed and investigated further by the students carrying out the Conservation of Matter lab activity (see Appendix 2) as discussed earlier. Students were alarmed to see that the weight of the glassware and all its contents weighed the same prior to the fairly violent and apparent reaction. Many students came to me with concerns believing they had done something wrong within their procedure. Students are so used to having data fluctuate within an experiment that the data collected in this particular experiment really seemed to catch most of them off guard since most of them
observed a very small change or no change at all with the data from start to finish of the procedure. I believe this also caused them to second guess their procedural skills and think they did something wrong within the procedure. This lab worked very effectively as a discrepant event and many students saw for themselves that there was indeed a conservation of matter within a contained reaction. This question was preserved within the posttest given at the end of the course.

Question 14 was thrown out as both a pretest and posttest question since this specific topic was not covered in class. The data collected on this question was not even tallied since I had a number of students ask what the question was referring to during the survey. The curriculum that I teach does not require that students understand the size of an atom (Avogadro’s number), even though we briefly discussed it in casual conversation when covering the concept of the mole.

For Question 15, a large percentage of students, forty-six, understood that when sugar water is diluted two-fold the space between the sugar molecules increases two-fold as well. The only other significant response (23% of the students) was choice (e) which incorrectly illustrated that the sugar molecules would become twice as closely packed and would generally increase in number when the solution is diluted to a larger volume. This question was included in the posttest since it covered a number of important topics of concern already addressed.

Question 16 involved alcohol and water and their heat capacities. Forty-one percent of the students believed that equal volumes of water and alcohol both receive the same amount of heat in order to reach 50 degrees Celsius. Only 28% responded
correctly stating that the water requires more heat (since it takes a minute longer to reach the desired equivalent temperature). Reasoning for this concept (Question 17) was scattered. Only 22% responded correctly, reasoning that water takes longer to raise its temperature than alcohol does. Due to such varied and unbiased responses, I decided to eliminate this question from the posttest. Another reason for this decision stemmed from the topic being a bit off-track from the other misconceptions identified. However, we did discuss it upon handing-back the graded pretests since the students were accountable for understanding heat capacity within the course. Question 17, which involved the reasoning behind the response to Question 16, was therefore also eliminated from the posttest.

When it came to Question 18, most students, fifty-five percent, thought that rust weighs less than the non-rusty nail that it was produced from. Only 26% understood that rust actually weighs more than the nail that it came from due to the iron combining with oxygen in order to form iron (III) oxide, or rust. With respect to their reasoning in Question 19, the greatest percentage, thirty-two, responded correctly saying that rust contains iron and oxygen. I found this strange that a greater chunk of the students answered the reasoning question and not the initial question correctly so I decided that this example would need to be investigated further. This involved another station within the Station Lab (see Appendix 3) where each lab group was provided with a pair of originally identical (by mass and content) nails, one rusted and the other not. In the activity they were asked to weigh the two
individually, compare their weights; and then give an explanation for the weight discrepancy.

Question 20 definitely proved that there exists a common misconception regarding solutions and their saturation concentrations. More than half the students (62%) believed that a saturated salt solution will increase in concentration if water is allowed to evaporate off. Only 24% correctly responded that the concentration should remain the same. This is correct since any salt that is unable to dissolve due to the lack of solvent will fall to the bottom of the solution and will therefore not contribute to the concentration of the solution. The reasoning for Question 20 that was collected (via Question 21) was not congruent with initial responses for this question (Question 20). Only 4% correctly reasoned that more solid salt falls to the bottom whereas 50% thought that there was the same amount of salt in less water. To tackle this misconception another station was implemented within the Station Lab (see Appendix 3). In this station students were asked to make a saturated solution of salt water and record general observations of their solution. They then were asked to let the solution sit until their next scheduled lab period where they would then make final observations of their solution. When they revisited their solution after 4 days they saw that some salt had formed on the bottom of the beaker. They were then asked to explain why this had occurred.

Finally in Question 22, it appeared that a great number of students, fifty-one percent, had mastered the concept that properties of atoms or large samples of the same element/atom always have the same properties (hardness, melting point,
density, reactivity with certain other elements). This question was therefore
eliminated from the posttest and not addressed within the study. We did discuss the
responses to this question and the reasoning supporting (or not supporting) each one.

Table 2 outlines the results of the posttest after different instructional
strategies and activities were implemented in order to improve or correct the
originally identified misconceptions that the students had.

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Comparing the pretest to the posttest results for the Chemical Concepts Inventory (CCI), there was a significant improvement across the board for students regarding the misconceptions identified in the beginning of the study. Some questions illustrated more improvement than others, but in general there existed an overall improvement of mastery on the students' parts.

The posttest results for question 1 illustrated a 17% improvement of student understanding of conservation of matter within a chemical reaction. Question 2 results showed that 18% of the students better grasped the concept that when water is boiled, it simply undergoes a phase change and becomes water vapor (instead of just oxygen gas, for example). There was also a significant improvement with the results gathered from question 4 as 17% of the students correctly altered their conception of how a solute dissolves within a solvent and what happens to the volume because of this dissolving. There was an extreme improvement regarding question 5. Seventeen additional students (23%) proved that they now understood particle diagrams with regards to reactions and the products that are formed. With question 6 there was a 26% improvement with what particle diagrams appear to look like when water is evaporated. It simply looks the same except the particles are just more spread out within the space provided. There was a slight improvement (9%) with question 7 which required a true or false response to determine the understanding of conservation of mass once again. Students' reasoning for this response (illustrated in question 8) also slightly improved. Seven percent more students chose the correct response saying that atoms are not destroyed, but are simply rearranged in a chemical
reaction. Question 12 addressed conservation of matter and the correct response was chosen by 18% more of the participants. Their reasoning to support this (question 13) showed an even more drastic improvement. Seventy-one percent (up from 38% in the pretest) now believed that within a sealed container the contents remain the same before and after a violent reaction took place. There was a notable decrease in students believing that gas weighs less than a liquid during a phase change. There only existed a 7% improvement with regards to mastery of Question 15. Minimal improvement was also discovered with question 18 with regards to the posttest seeing as only 6% of the students changed their perspective stating that a rusty nail weighs more than its non-rusty original form. Correct student reasoning for question 18 (demonstrated in question 19) surprisingly rose from 32% to 45%, an even more significant improvement than the original question. Question 20 saw a 17% improvement from pretest to posttest. And lastly, question 21 had a definite improvement as the correct response was answered by 27% more of the students.

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In Question 1 on the Oxidation-Reduction survey, twenty-seven (36%) of the students understood what section of an electrochemical cell electrons flow through. They also appeared to understand what direction the electrons were moving to and from within a wire. Question 2 was where the concern remained with respect to this particular survey. In this second question there were a large percentage of students, thirty-six, that believed electrons move through solutions within an electrochemical cell. This did not fall in line with the results from Question 1. Therefore, I wanted to tackle this concept with my students within the action research. I implemented an oxidation-reduction laboratory activity (see Appendix 4) whereby the students set up their own electrolytic cell, recorded observations, and made connections using their class notes. This was a very application-based activity. The students struggled with this activity since they were required to generate additional information from their macroscopic observations. It forced them to think about what is going on inside the cell and make microscopic observations. They needed to be able to transition their observations into detailed explanations of the workings of the cell. After the students gathered their data, we all convened as a class and I explained to them on the overhead how they needed to approach the analysis. When the labs were submitted I realized that the questions were a bit complex since many answered them incorrectly or not at all. We therefore tackled some more practical and relevant Regents sample questions to establish a method for dissecting an electrochemical cell. This was accompanied by a real life setup of that same exact electrochemical cell at the front of the room to make it much more realistic for the students.
The posttest was given to the students at the end of the year. There was a small, but notable difference in their understanding of the processes that occur within an electrochemical cell. Specifically, for Question 1, there was a 10% improvement of student understanding of where electrons flow within an electrochemical cell. For Question 2 seven percent (7%) of the students correctly altered their perception that ions (not electrons) are what migrate within the solutions of an electrochemical cell.

**Summary**

The three major misconceptions that were focused on included the following concepts: conservation of matter, states/phases of matter (including particle diagrams), and oxidation-reduction as it applies within an electrochemical cell. These were identified as the biggest misconceptions that my students had via pretests given at the beginning of the study. Posttests were then administered after target laboratory activities, discrepant events, and organized discussions were implemented into instruction in an attempt to improve and/or clear up these identified misconceptions. As the pretest to the posttest outcomes were compared, there was a general
improvement for each and every question analyzed, whether it be large or small. In general, the results illustrate an over-all improvement in understanding the identified misconceptions. Some questions had more improvement than others, but the students more frequently chose the correct answer during the posttests.
Discussion

The specific misconceptions that were identified and targeted at the beginning of the study saw improvement by the conclusion of the study. This was seen as an increase in mastery of the particular question from the pretest to the posttest. Some misconceptions had a more significant improvement than others, but in general there was an increase in understanding throughout the duration of the study for each misconception identified. All the misconceptions identified and focused upon were tackled with one of the following teaching approaches: POE, discrepant event, inquiry-based lab, or discussion. Since there was at least some sort of increase in the percentage of students that mastered the particular question/concept, the approaches appeared to be effective in correcting these identified misconceptions that the students possessed.

Action Plan

Because of the findings of this study, I plan on creating and implementing more and more lessons that utilize the above-mentioned instructional styles. Student learning will become more student-directed and less teacher-centered and the students will find themselves taking more ownership in their learning. Instead of supplying the students with a significant amount of content, I will actively change my lessons so that the students are able to retrieve the content for themselves more and therefore make sense of the material in their own particular manner. Student learning should
increase at least significantly if not dramatically in my classroom settings in the upcoming future.

There were limited opportunities for me in this study to create lessons for every unit and concept being covered in my classroom. Creating new, relevant, and effective lessons for student learning will be an ongoing and never-ending goal of mine throughout the upcoming years. In addition to all the different types of instructional approaches that were implemented in this study, I plan on dabbling with a few other alternative teaching approaches including virtual labs, computer simulations, and web-based lab activities. These are just a few of some inquiry-based approaches that I plan to experiment with that have proved to be effective for increased student learning. Our school has also recently acquired lab probe technologies that I plan on using to create more virtual inquiry-based laboratory activities.

Recommendations for Future Research

As I have progressed through this study, I have questioned whether or not the possibility exists that reviewing for the Regents exam (during the span of time between the pretest and posttest of this study) had an effect on the positive results seen at the end of the study. As I continue my action research throughout the remainder of my teaching career I will be able to answer that question amidst the absence of reviewing for the Regents exam (such as at the beginning of the school year). It should be interesting to see if the same degree of success is possible in the absence of this type of comprehensive review. In the future I will be implementing
these types of instructional approaches consistently throughout the school year instead of just at the end of the school year. Future research will also be more ongoing and continual throughout the school year so it should have more representative results.

The pretests and posttests given in the future will be more spread out within instruction and will have more variety. For example, the posttest will be different than the original pretest but will assess the same content at hand. This will eliminate any skepticism that the students fed off of memory from the pretest when taking the posttest. This approach will force the students to think more conceptually and therefore demonstrate whether or not they truly understand the topic of study or not.

Conclusions

In conducting this study I have learned the great value of specific instructional approaches that are useful and essential to student mastery in chemistry including POE's, discrepant events, discussions, and hands-on laboratory activities. These types of approaches have proved to allow the student to have more ownership in their own personal learning and therefore create a more true understanding of chemistry for them. Additionally, utilizing these approaches appears to increase their understanding of particular target concepts. Generally speaking, POE’s, discrepant events, hands-on laboratory activities, and discussions all force the students to assess and hopefully readjust (if necessary) their conceptions of these topics. It appears that these approaches force the students to rethink and correct their perceptions on the topics if
need be. I have generally learned that the altering of my instructional approaches in this manner can enhance student learning significantly.

In general, we can conclude that implementing POE's, discrepant events, inquiry-based labs, and discussions into the instruction of chemistry proves to be effective for increasing student learning. We can conclude this due to the consistent and widespread improvements that were seen from each of the administered pretests to the later given posttests.
References


Appendix 1: Chemistry Concepts Inventory

Name ____________________________

This inventory consists of 22 multiple choice questions. Carefully consider each question and indicate the one best answer for each. Several of the questions are paired. In these cases, the first question asks about a chemical or physical effect. The second question then asks for the reason for the observed effect.

1. Which of the following must be the same before and after a chemical reaction?
   a. The sum of the masses of all substances involved.
   b. The number of molecules of all substances involved.
   c. The number of atoms of each type involved.
   d. Both (a) and (c) must be the same.
   e. (e) Each of the answers (a), (b), and (c) must be the same.

2. Assume a beaker of pure water has been boiling for 30 minutes. What is in the bubbles in the boiling water?
   a. Air.
   b. Oxygen gas and hydrogen gas.
   c. Oxygen.
   d. Water vapor.
   e. Heat.

3. A glass of cold milk sometimes forms a coat of water on the outside of the glass (Often referred to as 'sweat'). How does most of the water get there?
   a. Water evaporates from the milk and condenses on the outside of the glass.
   b. The glass acts like a semi-permeable membrane and allows the water to pass, but not the milk.
   c. Water vapor condenses from the air.
   d. The coldness causes oxygen and hydrogen from the air combine on the glass forming water.

4. What is the mass of the solution when 1 pound of salt is dissolved in 20 pounds of water?
   a. 19 Pounds.
   b. 20 Pounds.
   c. Between 20 and 21 pounds.
   d. 21 pounds.
   e. More than 21 pounds.
5. The diagram represents a mixture of S atoms and O₂ molecules in a closed container.

Which diagram shows the results after the mixture reacts as completely as possible according to the equation:

\[2S + 3O_2 \rightarrow 2SO_3\]

(a)  
(b)  
(c)  
(d)  
(e)

6. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.

<table>
<thead>
<tr>
<th>Key</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image-url" alt="Image" /></td>
</tr>
</tbody>
</table>
What would the magnified view show after the water evaporates?

![Magnified View Diagrams]

(a) (b) (c) (d) (e)

7. True or False? When a match burns, some matter is destroyed.
   a. True
   b. False

8. What is the reason for your answer to question 7?
   a. This chemical reaction destroys matter.
   b. Matter is consumed by the flame.
   c. The mass of ash is less than the match it came from.
   d. The atoms are not destroyed, they are only rearranged.
   e. The match weighs less after burning.

9. Heat is given off when hydrogen burns in air according to the equation

   \[ 2H_2 + O_2 \rightarrow 2H_2O \]

Which of the following is responsible for the heat?

   a. Breaking hydrogen bonds gives off energy.
   b. Breaking oxygen bonds gives off energy.
   c. Forming hydrogen-oxygen bonds gives off energy.
   d. Both (a) and (b) are responsible.
   e. (a), (b), and (c) are responsible.
10. Two ice cubes are floating in water:

![Diagram of two ice cubes floating in water]

After the ice melts, will the water level be:

a. higher?
b. lower?
c. the same?

11. What is the reason for your answer to question 10?

a. The weight of water displaced is equal to the weight of the ice.
b. Water is more dense in its solid form (ice).
c. Water molecules displace more volume than ice molecules.
d. The water from the ice melting changes the water level.
e. When ice melts, its molecules expand.

12. A 1.0-gram sample of solid iodine is placed in a tube and the tube is sealed after all of the air is removed. The tube and the solid iodine together weigh 27.0 grams.

![Diagram of a tube with solid iodine]

The tube is then heated until all of the iodine evaporates and the tube is filled with iodine gas. Will the weight after heating be:

a. less than 26.0 grams.
b. 26.0 grams.
c. 27.0 grams.
d. 28.0 grams.
e. more than 28.0 grams.
13. What is the reason for your answer to question 12?

a. A gas weighs less than a solid.
b. Mass is conserved.
c. Iodine gas is less dense than solid iodine.
d. Gasses rise.
e. Iodine gas is lighter than air.

14. What is the approximate number of carbon atoms it would take placed next to each other to make a line that would cross this dot •

a. 4
b. 200
c. 30,000,000
d. $6.02 \times 10^{23}$

15. Figure 1 represents a 1.0 L solution of sugar dissolved in water. The dots in the magnification circle represent the sugar molecules. In order to simplify the diagram, the water molecules have not been shown.

Which response represents the view after 1.0 L of water was added (Figure 2).

(a) (b) (c) (d) (e)
16. 100 mL of water at 25°C and 100 mL of alcohol at 25°C are both heated at the same rate under identical conditions. After 3 minutes the temperature of the alcohol is 50°C. Two minutes later the temperature of the water is 50°C. Which liquid received more heat as it warmed to 50°C?

   a. The water.
   b. The alcohol.
   c. Both received the same amount of heat.
   d. It is impossible to tell from the information given.

17. What is the reason for your answer to question 16?

   a. Water has a higher boiling point than the alcohol.
   b. Water takes longer to change its temperature than the alcohol.
   c. Both increased their temperatures 25°C.
   d. Alcohol has a lower density and vapor pressure.
   e. Alcohol has a higher specific heat so it heats faster.

18. Iron combines with oxygen and water from the air to form rust. If an iron nail were allowed to rust completely, one should find that the rust weighs:

   a. less than the nail it came from.
   b. the same as the nail it came from.
   c. more than the nail it came from.
   d. It is impossible to predict.

19. What is the reason for your answer to question 18?

   a. Rusting makes the nail lighter.
   b. Rust contains iron and oxygen.
   c. The nail flakes away.
   d. The iron from the nail is destroyed.
   e. The flaky rust weighs less than iron.
20. Salt is added to water and the mixture is stirred until no more salt dissolves. The salt that does not dissolve is allowed to settle out. What happens to the concentration of salt in solution if water evaporates until the volume of the solution is half the original volume? (Assume temperature remains constant.)

![Diagram showing solution before and after water evaporation](image)

The concentration

a. increases.
b. decreases.
c. stays the same.

21. What is the reason for your answer to question 20?

a. There is the same amount of salt in less water.
b. More solid salt forms.
c. Salt does not evaporate and is left in solution.
d. There is less water.

22. Following is a list of properties of a sample of solid sulfur:

i. Brittle, crystalline solid.
ii. Melting point of 113°C.
iii. Density of 2.1 g/cm³.
iv. Combines with oxygen to form sulfur dioxide

Which, if any, of these properties would be the same for one single atom of sulfur obtained from the sample?

a. i and ii only.
b. iii and iv only.
c. iv only.
d. All of these properties would be the same.
e. None of these properties would be the same.

(Mulford, 2002)
Appendix 2: Conservation of Matter Laboratory Activity.

Due Date: __________________________

Name: ______________________________

CONSERVATION OF MATTER

Matter cannot be created nor destroyed by a chemical change. This very important principle is known as the Law of Conservation of Matter and it applies to any ordinary chemical reaction. During a chemical reaction (or chemical change), the atoms of one or more substances (or reactants) simply undergo some "rearrangements." The result of these rearrangements is the formation of new, different substances (otherwise known as products). All of the original atoms are still present, but are found in a different form or combination (formula). It is because of the Law of Conservation of Matter that we are able to write balanced chemical equations. Such equations make it possible to predict the masses of reactants and products that will be involved in a chemical reaction. Recall that a balanced chemical reaction is very similar to a recipe – you can't leave even one ingredient out or you will end up with a different meal/treat in the end! This experiment should give you a better understanding of the Law of Conservation of Matter and its importance in Chemistry.

In this experiment zinc will be added to acid and they will both engage in a single replacement reaction. The changes that occur during this reaction will be readily observable to you. The unbalanced chemical equation for the reaction you will observe is as follows:

____ Zn + ___ HCl $\rightarrow$ ___ ZnCl$_2$ + ___ H$_2$

The combined masses of both the reactants and the products (and their containers) will be measured before and after the reaction has occurred.

**Purpose:** To determine experimentally if mass is conserved in a particular chemical reaction.

**Procedure:**

1. Get:
   - a piece of mossy zinc - put into small Erlenmeyer flask
   - 20 mL of 1M HCl – pour into separate beaker
   - a balloon.
   **CAUTION: ACID IS CAUSTIC!!!**

2. Weigh the flask (with zinc), the beaker (with acid), and the balloon all together on an electronic balance. Record in data table.
3. Pour the HCl (from the beaker) into the flask containing the HCl. **Quickly** cover the flask with the balloon and begin to swirl. Note observations (in data table) and continue swirling until reaction has ceased. Make sure the balloon does not pop off!

4. Weigh everything again (just as you did in step 2). Be sure not to remove the balloon yet! Record weight in data table.

5. Repeat steps 1 through 4 two more times (trial 2 and 3). Record all data in data table.

**Prediction:**

**Data:**

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mass before reaction</th>
<th>Mass after reaction</th>
<th>Observation(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
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<tr>
<td>3</td>
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</table>

**Analysis:**

1. What indications of a chemical reaction did you observe each time in step 3 for each trial?

2. What caused the balloon to inflate during step 3?

3. Compare masses from before and after the reaction for each trial. Account for any differences that you may see.
4. Discuss how this experiment justifies the Law of Conservation of Matter.

5. Based on this lab, is it possible to predict the mass of products produced if the mass of the reactants are known? Explain your answer based on what you know about balancing chemical equations.

6. On the first page of the lab, balance the reaction properly.
Appendix 3: Station Lab

Name ____________________________________________

Due Date ____________________________

Station Lab

Station A:

Using a 100 mL beaker, prepare a solution of salt water consisting of 50 mL of water and 5 grams of salt (NaCl). Before mixing, be sure to record the masses of both ingredients.

Mass of 100 mL beaker = ____________________________

Mass of 50 mL water = ____________________________

Mass of 5 g NaCl = ____________________________

Now, without weighing the solution, predict was the total mass of the solution would be:

**Predicted** mass of the solution = ____________________________

Now, weigh your solution and record the actual mass of it:

**Actual** mass of the solution = ____________________________

Questions:

1) What are the two parts called that make up a solution (these are two terms that we learned in class)?

2) Explain how this station illustrates the Law of Conservation of Matter.
Station B:

You will be provided with a pair of nails. One is rusted and the other is not. First, record the letter of the set of nails you receive from your teacher. Second, weigh each nail separately and record their masses below. Lastly, explain why you observe the masses of the two different types of nails as you do.

Set of nails received (letter): ______

Mass of the regular nail = __________ Mass of the rusted nail = __________

1) What did you observe about the masses of the two nails? Were they the same? Different?

2) The reaction required to turn a regular nail into a rusted nail is as follows:

   ____ Fe + ____ O₂ → ____ Fe₂O₃

Explain, in relation to the reaction, why you observed the masses that you did above.

3) Balance the reaction in question 2. Why do we balance reactions? What law must we always follow?
Station C:

1) Place 100 mL of water into a 250 mL beaker.

2) Using a weighing boat, mass out 20–30 grams of NaCl. Record the exact mass.

3) Pour salt from the weighing boat into the beaker containing water. Stir the solution until the salt is completely dissolved. Record the approximate volume of the solution by reading the side of the beaker to the best of your ability.

4) Store the solution in your drawer until the next scheduled lab period. Leave uncovered.

   Mass of NaCl = 

   Initial volume of the solution = 

   Observations of your salt solution (initial):

5) Upon returning to your solution, make general observations and record the approximate volume of the solution.

   Observations of solution (final):

   Final volume of the solution =
Appendix 4: Oxidation-Reduction in an Electrochemical Cell Lab Activity

Name ___________________________ Due ___________________________

Electrolysis Lab – Producing Copper

**Introduction:** In electrolysis (or electrolytic cells), an external source of electrical energy is used to induce a nonspontaneous reaction. The external voltage forces electrons to flow through a wire to the electrode where reduction takes place. This electrode, called the cathode, is the negative electrode in the cell. Oxidation takes place at the positive electrode, which is called the anode. Electrolysis is often used to separate and isolate chemically active elements that are not found free in nature. For example, if an electric current is passed through a molten sample of an ionic compound, the positive ions become attracted to the cathode and the negative ions are attracted to the anode. The positive ions are reduced to free metal atoms and the negative ions are oxidized to free nonmetal atoms.

**Purpose:** To better understand the chemistry behind electrolytic cells. This will involve decomposing a compound (solution) into its elements using electrolysis.

**Safety:** Wear safety goggles and aprons. Do not complete the circuit (connecting the battery) until the teacher gives your group the OK.

**Materials:** U-tube, 250 mL beaker, 2 pencils (sharpened at both ends), 2 electrical leads, 9-volt battery, solution of copper (II) chloride.

**NOTE:** The pencils will serve as “electrodes.” They can be distinguished as + or - based on which pole of the battery they are connected to. Be sure to list as many observations as possible no matter how trivial they may seem.

**Procedure:**
1) Assemble the device as shown in the following diagram, but leave one connection to the battery undone until Mrs. Dolgos approves your setup.
2) After approval is given, make the final connection and observe the reaction for about 5 minutes. Record ALL observations in your data section. Be sure to label the + and – electrodes in your diagram.
3) Cautiously observe the odor (if any) generated. Record your observations (including which electrode the odor was generated from) in your data section.
4) Reverse the wire connections at the battery and again record all observations in your data section.
5) Disconnect the apparatus, wash off the pencils, rinse out the U-tube completely, and clean up your station.
1) What is the correct formula for the ionic compound that gets broken down in this lab?

2) How do you know that one of the products was a gas? Based on your observations and the information given to you in the introduction to the lab, what gas can you conclude it is?

3) Write the half reaction for the oxidation that occurs in this lab.

4) Write the half reaction for the reduction that occurs in this lab.

5) Sometimes if an electric current is passed through a solution of an ionic compound, the water, rather than the metallic ion, may be reduced instead. This is usually an undesirable result. Explain (by referring to Table J of your Reference Tables) why the copper in this case was reduced and the water was not.

6) If we set up an electrolytic cell with a solution of KI, which would be reduced: the potassium or the water? Why?
7) Is the reaction that you performed today spontaneous or nonspontaneous? Explain why or why not.

8) At which electrode (anode or cathode) was copper produced at?