THE USE OF MATH WORKSHEETS TO IMPROVE STUDENT LEARNING IN PREPARATORY CHEMISTRY

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A Thesis

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Department of Chemistry
Abstract

of

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by

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Statement of Problem

When am I ever going to use this?” (Pleacher, 1998) Many students ask themselves this question throughout grade school, high school, and college during math class. A scientist knows the answer, but a non-scientist may feel that math classes are a waste of time (Angel and LaLonde, 1998). There exists a correlation between math and science; that is why those who struggle with math do not pursue the sciences. Through years of data, the strongest evidence in how a student will perform in their college chemistry class is how well they scored in their high school math courses and how they performed on the math portion of their SATs (Andrews and Andrews, 1979). Fifty percent of freshman chemistry students drop out or fail chemistry; these students switch to non-science majors or drop out of college altogether (Angel and LaLonde, 1998). Often times these dejected students pursue a liberal studies degree and in turn teach elementary school, teaching math. If these teachers never saw the connection between
math and chemistry, how can they help their students understand when they are going to use the math they are learning? (Worthy, 1982) Something must be done to stop this cycle.

Sources of Data

The practices and attitudes to math related chemistry questions by 376 science-major students enrolled in an undergraduate chemistry course at California State University, Sacramento, were characterized by an introductory math quiz and survey. An additional survey and a sequence of worksheets were administered throughout the course and responses to the worksheets and worksheet related exam questions were analyzed.

Conclusions Reached

Students should have the option to complete mathematic worksheets that refresh their math knowledge and help them solve related math questions on their chemistry exams. Students’ academic performance is enhanced by the use of worksheets that aid the practical application of mathematics to chemistry education.

Jeffrey Paradis, Ph.D.
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Chapter 1

INTRODUCTION

Significance of the Study

This study was undertaken for several reasons. Education research has shown that fifty percent of freshman chemistry college students fail or dropout of freshman chemistry (Angel & LaLonde, 1998). College chemistry professors routinely teach how they were taught and do not make a large effort to lower the failing/drop-out percent. Some professors see this dropout rate as trimming the fat, therefore maintaining their programs with only serious science students. Professors must constantly perfect their teaching style and the only measure of their success is the success of their students.

Mallow (2006) attributes more and more students not choosing to pursue the sciences because of science anxiety. Science anxiety almost inevitably leads to science avoidance, and thus affects both the self-image of students and their subsequent capability as adult citizens to make informed political judgments with science and technology components (Mallow, 2010). Mallow gives practical guidelines to help alleviate science anxiety. It is important to know that students do have anxiety about science and one of the professor’s goals should be to help alleviate any anxiety the students may have.

Success in chemistry is dependent on a student’s math skills. Without the ability to go back in the student’s educational career and try to see where they did not learn the skills required of them or where the skills were forgotten, a refresher of the mathematical material at its very basic form is required. It is not the job a college chemistry professor
to waste time on information the students should have learned years previously, so a math worksheet that the students can complete on their own is most helpful. One way to increase a student’s success in freshman college chemistry is to increase their knowledge of required math skills.

**Purpose**

The thesis research work involved the design, presentation, and evaluation of four math worksheets for students in a one-semester preparatory chemistry course at the college level. The purpose of the thesis work was to demonstrate that math worksheets should increase students’ ability to solve math related chemistry problems and therefore increase their overall grade for the preparatory chemistry course. The math worksheets incorporated math work into the chemistry class helping to bridge what a student previously learned in math class to specific applications in their chemistry class. The worksheets allowed the student to see the similarities of solving a math word problem and solving a chemistry word problem. If a student had never learned how to solve a math word problem or forgot how to solve a math word problem, the worksheet would give them an opportunity to learn the math skill needed for the first time. Students tend to memorize equations in a math course and quickly forget them when the exam is finished (David, 1981). In turn, when a student enters into freshman college chemistry they do not realize that math skills are required of them. The chemistry textbook does a good job of laying out the steps needed to solve the chemistry problem but it does not emphasize how the student may have used the same steps to solve a math problem.
months earlier. The professor does not have ample class time to review math skills that the student should have already learned. However, a comprehensive math worksheet given prior to each chemistry exam can serve this purpose. This worksheet would provide a background of the key math concepts needed to solve the chemistry math problems, word problems using everyday examples (similar to word problems found in a math textbook), and the chemistry math problems going to be on the exams, solved the very same way as the everyday examples. By working through the worksheets, the student will have a chance to refresh or relearn the math knowledge required for their exams.

The effectiveness of each worksheet was assessed by evaluating the percent of correct answers on worksheet related exam problems for students who completed the worksheet compared to students who did not complete the worksheet. Each student was given the opportunity to complete each worksheet, so every worksheet related exam question was evaluated.

The first math worksheet used for this study focused on calculating atomic mass. The worksheet began with an example of an atomic mass homework question. It went on to explain the math required to solve the atomic mass problem. The next section gave a background on converting percentages to fractions or decimals. The third section provided a reminder to the fact that percentages of a whole have to add up to 100%. The next section gave many examples of solving single-variable equations, while the last sections had many examples of solving for multiple-variable equations. The goal of the first worksheet was for a student to read an atomic mass problem and understand each part of the question rather than systematically putting numbers in a memorized equation.
The second math worksheet focused on writing a number in scientific notation. The first section of the worksheet explained why scientific notation is important. This section of the worksheet went into detail of the meaning of “to the power of”, with an emphasis on the definition of “base” and “exponent”. The next section gave a background to understanding multiplying a number between 1 and 10 by a number to the power of ten. The final section gave the steps to writing a number in scientific notation. Although writing a number in scientific notation is not a difficult task, it is an important skill to know in chemistry. With the amount of multiple-choice exams given in lower division chemistry courses, if a student is not able to convert their answers correctly in scientific notation, they are susceptible to getting the problems wrong.

The third worksheet was all about significant figures. The first section of the worksheet explained the significance of significant figures. The next section gave the background of the rules to determining how many significant figures a number has. The third section gave the rules of determining significant figures when solving adding/subtracting and multiplying/dividing calculations. Knowledge of significant figures plays a large part in analytical chemistry and is a basic building block that is used in any scientific career. Without a solid understanding of significant figures, many errors can be expected throughout a science major’s college career.

The fourth worksheet focused on percent composition problems. The first section explained the meaning of “mass percent composition”. The second section gave examples of determining mass percent in everyday life. The next section gave examples of determining mass percent in chemistry. The fourth section gave examples of using
mass percent in everyday calculations, while the fifth section gave examples of using mass percent in chemistry calculations. The last section was more practice determining mass percent and using mass percent in calculations. This worksheet attempted to show the student to see that word problems used in math, such as examples of recipes, are no different from the word problems presented in chemistry. This worksheet was designed to alleviate any science anxiety the student may have by incorporating the familiar theme of trail mix to help explain mass percent problems.

Limitations of the Study

This project was designed to help alleviate any math or science anxiety a student has when entering their introductory chemistry course. Students in the course entered with a wide range of learned mathematics skills. All the students had the opportunity to complete the worksheets. A comparison of how the students who did the worksheet compared to the students who did not complete the worksheets may have produced better results if only the students who previously struggled with the worksheet related math topic completed them. It is not appropriate to isolate a subset of students who would be given the worksheet, because if the worksheets either helped or hindered the students, it would not have been fair.
In recent years, cognitive psychologists have learned a great deal about human thinking (Simon, 1995). It turns out that very complex human behaviors are produced by a small number of rather simple processes. Information processing theory suggests that people operate similar to a computer, with the process of either inputting information or outputting information (Hestenes, 1979).

The early information-processing psychologists realized that human thought depends on memory structures. Two types of memory to be specific: short-term and long-term memory. Short-term memory refers to information that is not actively maintained and often quickly forgotten. New information is constantly entered into the short-term memory through sensory registers (i.e., eyes, ears, mouth, and skin), while old information is transferred into the long-term memory or is forgotten. The characteristics of the short-term memory include small capacity and short duration (Martinez, 2000, p. 22). Little information remains in the short-term memory for more than 30 seconds unless it is retained by rehearsal or some other process (Hestenes, 1979). That is why a person forgets someone’s name they just met unless they use the name within 10 to 15 seconds of learning it. Therefore humans have limitations to handle complex information. Because the short-term memory not only stores information, but processes
it, it is more recently referred to as working memory. There is strong association between someone’s working memory and their intelligence. How well the working memory performs directly relates to someone’s mental age, in other words the capacity of someone’s working memory correlates with their IQ (Martinez, 2000, p. 22). Research has debunked this belief, as it has been proven that students with math ability can experience anxiety impairing their short-term memory, causing them difficulty when performing mathematical tasks (Ruffins, 2007).

Long-term memory defines what someone knows: words, images, strategies, procedures, and the like. The long-term memory is the mind’s warehouse having unlimited capacity. The duration of the long-term memory is unlimited except in the incidence of brain degeneration. Once an idea is stored in the long-term memory, it will be there forever, although retrieving it may prove difficult (Martinez, 2000, p. 23). Refer to the diagram in Figure 1 showing the flow of information from the working memory and the long-term memory. The movement of information between the long-term and working memory is essential to intellectual functioning. When the information is transferred from the working memory to the long-term memory it is called learning. When information moves from the long-term memory to the working memory it is referred to as remembering (Martinez, 2000, p. 23).
To better understand the information processing theory, many studies have been performed testing a person’s working memory, as well as their available long-term memory. In the article “Reexamining the relationship between working memory and comprehension: The role of available long-term memory”, Was and Woltz performed two separate tests. The first test was to analyze students’ working memory capacity and duration for information. The second test was to analyze the availability of information in their students’ long-term memory.
To test the capacity and time duration of new information in the working memory, students were given a “Numeral String” such as “9 2 4 8 3 5” through a set of headphones. After the students heard the string of digits, they were asked “what number preceded 3?”. Because this string of digits is not a familiar string and is not already stored in the students’ long-term memory, the students were forced to recall the correct answer from their working memory. To study the availability of information in a student’s long-term memory, the students were given a measure called “Category Priming”. In this test the student were given five words through their headphones, such as “robin desk hawk sparrow couch”. They were then asked “Were there more examples of birds or of furniture?”. Because the students would need to know if a robin was a bird or a piece of furniture prior to the test, they were required to pull that already learned information from their long-term memory (Was & Woltz, 2007). This study resulted in students being able to answer that more birds were given in the “Category Priming” exercise, rather than being able to recall what number preceded “3” in the “Numeral String” exercise. It was concluded that retaining information from the long-term memory came quicker and at higher accuracy than retaining information from the short term memory (Was & Woltz, 2007).

Referring to Fig. 1, when information is transferred to the long-term memory from the working memory, it is categorized into three different schemas. These different schemas are referred to as verbal ability, mathematical ability, and spatial ability. This focuses on the importance of how and where information has been transferred to the long-term memory. For example, if two students are asked “what is the sum of 9 and 7?”
and the first student learned to add numbers on their fingers (Hestenes, 1979), and the second student learned that any number added to 9 is one less than adding the same number to ten (knowing that when a number less than ten is added to ten, you simply place a one in front of the number). The second student will process in their head 10 and 7 is “17” and one less than that is “16”, while the other student is counting their fingers. Both students will come to the same answer, but the capability of the first student to learn more difficult math will require them to relearn how to add numbers. This is a very important lesson for a teacher, as intelligence relies more on the software than the hardware, meaning the way a student is taught to perform a specific task carries great responsibility (Hestenes, 1979).

Constructivism

Constructivism is a theory founded on observation and scientific study about how people learn (Brandon & All, 2010). It is a method of teaching that encourages the thought process of the student and assumes that prior knowledge, attitude, motivation, and learning style affect the learning process (Spencer, 1999). It is the idea that the learners ‘construct their own knowledge’. Constructing of knowledge is a personal process where the student is involved in their own learning by seeking to find meaning to their present and past experiences (Boghossian, 2006; Todd, 2004, p. 13). Constructivism is an alternative methodology to the traditional teaching method known as behaviorism.
The traditional method for teaching science has its roots in what is called “behaviorism”, which is the belief that an idea can be transferred intact from the mind of the instructor to the mind of the student, or that telling is teaching (Spencer, 1999). Behaviorism views the student as an unreflective responder (Boghossian, 2006). When implementing the behaviorism method, students are expected to respond to questions in class or on a test. If their answers are correct, they receive a good grade as a way to encourage their “good behavior”. If the student does not get the answer correct, they will receive a poor grade with the hope to send the message to the student that their behavior is bad and that they need to change it until they get the answer correct. There is no subjective element to learning-either in determining what to study or in how information is interpreted, used, or understood (Boghossian, 2006). Behaviorism dominated the educational landscape 25 years ago, while the foremost learning theory today is constructivism (Boghossian, 2006). Table 1 lists some comparative features of behaviorism and constructivism.

Table 1. Comparison of Behaviorism and Constructivism

<table>
<thead>
<tr>
<th>Behaviorism</th>
<th>Constructivism</th>
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<tr>
<td>Truths are independent of the context in which they are observed.</td>
<td>Knowledge is constructed.</td>
</tr>
<tr>
<td>Learner observes the order inherent in the world. Aim is to transmit knowledge experts have acquired.</td>
<td>Group work promotes the negotiation of and develops a mutually shared meaning of knowledge. Individual learner is important.</td>
</tr>
<tr>
<td>Exam questions have one correct answer.</td>
<td>The ability to answer with only one answer does not demonstrate student understanding.</td>
</tr>
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Professor Jean Piaget life’s work was the study of the nature of knowledge and the psychology of the child. Jean Piaget’s theory on the mental development of children included the concept of cognitive structures, which the child himself constructs in interaction with the environment in a continuous way from birth to adolescence (Schwebel & Raph, 1973, p. 217). Advocates of constructivism agree with Piaget claiming that constructivism is the individual’s processing of stimuli from the environment and the resulting cognitive structures that produces adaptive behavior (Brandon & All, 2010). These structures take the form of schemata, explanations, and experiences that a student uses to understand the world they experience around them (Todd, 2004, p. 13).

The philosophy of constructivist education operates by four major assumptions. The first assumption is that previous constructs are the foundation of the learning process in each student. In other words, new information is transformed and interpreted based upon what a student previously learned. Second, assimilation and accommodation processes lead to new constructions. New information may not be able to assimilate with previous knowledge, so the student accommodates the new information resulting in new zones of cognitive development or higher learning. Third, learning is not mechanical, but a process of invention. This is the idea that students hypothesize, predict, manipulate, and construct knowledge, rather than simply memorize facts. Finally, constructivists assume that meaningful knowledge occurs through reflection and the linking of new information to the existing framework of knowledge (Brandon & All, 2010).
Piaget discusses constructivism by explaining it as “intelligence”, what it means, where it comes from, and how it is developed. From Jean Piaget’s point of view, intelligence is the ability to adapt to new situations. In order to adapt to a new situation, a person must comprehend the situation and come up with a solution through their understanding. In order to understand a new situation, one must assimilate it to knowledge that has already been built and brought to the situation. Piaget calls this knowledge that is brought to the new situation as “structures”. Knowledge is in some way organized or structured for all ages. Structures become more elaborate as a person grows older (Schwebel & Raph, 1973, p. 217-218). An example of this would be “adult humor”. A 4 year old and their parent can go to the movies and there will be concepts in the movie that the adult will comprehend, that the child will not. Another example of richer structures of knowledge amongst older people can be tested by asking what the first thing that comes to mind when a 4, 10, and 20 year old hear the word “mommy”. A 4 year old may say “she loves me” or “I love her”. A 10 year old may say “she stays home and takes care of the house”. A 20 year old may respond with “motherhood”. Piaget would explain that because knowledge is an organized structure, no meaningful concept can exist in isolation (Schwebel & Raph, 1973, p. 218-219). To the contrary, a behaviorist would expect for each person to have the same answer when thinking of the word “mommy”.

The development of intelligence is a continuous process of constructions from birth to adolescence in a sequence that is the same for all children in all cultures (Schwebel & Raph, 1973, p. 222). A behaviorist would state that knowledge is absorbed
from the outside, while Piaget would see knowledge as a building of structures from inside. Piaget supports his difference to a behaviorist by explaining that children would not have similar sequences in development if information was simply absorbed. The only major difference in development amongst children has been the rate of development and not the sequence (Schwebel & Raph, 1973, p. 222). The four factors of development are: biological factors, experiences with physical objects, social factors of inter-individual coordination and cultural and educational transmission, and factors of equilibration (Schwebel & Raph, 1973, p. 223). It is the role of the teacher to teach in such a way that all the factors are at work (Schwebel & Raph, 1973, p. 224).

Constructivists have shown that the model that is the closest to how students learn is called the learning cycle. A learning cycle is illustrated in Figure 2.

<table>
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**Exploration**
- What did you do?
- Data Acquisition

**Concept Invention**
- What did you find?
- Is there any pattern to the data?
- What does it mean?

**Application**
- Organizes Information
- Predict, form a hypothesis
- Test hypothesis
- Higher level of thinking

**Figure 2. The Learning Cycle**

The constructivist-learning-cycle approach is also called inquiry-based and has been shown to facilitate retention of information and the transfer of thinking skills and content
It is through the constructivist-learning-cycle that students proceed from the concrete to the abstract (Spencer, 1999).

The constructive theory encourages learners to be active creators of their knowledge. The role of the student is to pick out and transform information, build ideas, and make decisions, while relying on cognitive structures. Rather than using the teacher’s knowledge and textbooks for solving problems, the students comes up with solutions and develops knowledge in the learning process. The student must feel connected to their teacher for constructivist learning to occur. If the student feels disconnected from their teacher, they will go back to the old ways of learning they feel most comfortable with such as rote memorization, algorithmic techniques, and cramming (Todd, 2004, p. 12). The job of the teacher is to design a learning format that is aligned with the student’s current state of knowledge. The teacher becomes a facilitator of knowledge asking, “What do students need to learn?” rather than, “What do I want to teach?” Recognizing students’ preexisting conceptions, teachers guide activities to build students’ knowledge. As each new activity is taught, the student uses previous knowledge to develop more complex ideas and integrate new information (Brandon & All, 2010). The guided inquiry curriculum begins with the assumption that knowledge is not directly transferred from the instructor to the student; that is the constructivist approach is implemented and follows the learning cycle (Spencer, 1999). A closer look at guided inquiry and its practical implication will be discussed in further detail in the next section.
Application of Learning Theory

Guided Inquiry

Guided-inquiry learning is a process by which students “discover” basic concepts through active investigation (Jin & Bierma, 2011). Guided-inquiry, commonly known as POGIL (for Process Oriented Guided-Inquiry Learning), has been shown to significantly increase student comprehension of difficult-to-understand concepts (Jin & Bierma, 2011). Guided-inquiry is an “active learning” technique that focuses on concept understanding. Recent developments in classroom research results suggest that students generally experience improved learning when they are actively engaged in the classroom and when they construct their own knowledge following a learning cycle paradigm (Farrell; Moog; Spencer, 1999). “Active learning” techniques are used by educators who recognize that students learn better by “doing” rather than “listening” (Jin & Bierma, 2011).

Guided-inquiry is commonly used in chemistry labs. The student is guided through questions in their lab assignments until they “discover” the concepts where the mechanisms at work are too small to observe with the naked eye (Jin & Bierma, 2011). The student looks for trends and patterns in the data they collect. At that point they would form a hypothesis and then test their hypothesis. The goal is to make connections between observations and principles. This approach is based on the learning cycle: data collection, concept invention, and application (Farrell et al., 1999). Throughout the entire lab the student would be asked guiding questions to require the student to think about the various steps rather than simply following instructions (Farrell et al., 1999).
With the implication of guided-inquiry methods, students work in teams with specifically designed guided-inquiry materials. The materials will either provide information or guide students through experiments, so they can collect their own information. These materials can be in the form of worksheets that serve as a tutorial to the students. The worksheets can contain questions that help to construct understanding by having the student build on previous knowledge. These guiding questions would be asked for students to “discover” by their own conclusions (Jin & Bierma, 2011). A large part of guided-inquiry is the questions asked of the students. These questions can be referred to as probing questions.

Teachers who have incorporated guided-inquiry techniques into their classroom have found that their students’ grades have improved because of it (Jin & Bierma, 2011; Kuech, 2004; Farrell et al., 1999). It is important when implementing guided-inquiry for the students to be given time when working on an answer to a probing question, the teacher should observe, but once they interject their opinion, the benefit of the inquiry-based learning is compromised. The more the students discuss amongst themselves, the more likely they will come to the correct answer and learn the concept in order to retain it. Probing questions need to be constructed in a way that students can come to their predictions before the class time is complete. The downside to guided-inquiry is that it takes more time to create the learning materials and not as much information can be covered in a class period (Jin & Bierma, 2011). Because this type of curriculum takes a lot of time for the teacher to prepare, it is very important that when a teacher finds a lesson that works well, and the students are learning, they must share their
lesson with other teachers. Teachers should not be spending time creating guided-inquiry
curriculum that has already been created, they should be creating another lesson that has
not been formatted into guided-inquiry curriculum (Jin & Bierma, 2011).

Chemistry and Math Problems

One of the greatest hindrances to the productivity of a first-year chemistry student
is the weakness of his mathematical background (Bohning, 1982). First-year chemistry
students’ shortcomings in mathematics skills can be described by two cases, an unlearned
or missing skill, or the need for mathematics skills in chemistry that have gone
unpracticed for one or two years (Pienta, 2003). The unlearned or missing skill case can be
explained by students not taking enough math and science courses in high school
(Worthy, 1982), or that the primary and secondary teachers are ill-prepared to teach math
and science (Worthy, 1982). The second case, that states the need for mathematics skills
in chemistry have gone unpracticed for one or two years (David, 1981), can be addressed
by teachers who instruct introductory college chemistry courses. These teachers do not
consider the possibility that students are only retaining the information required for a
specific course and are not remembering it for future classes.

In 1982, Ward Worthy wrote of the classroom crisis in math and science in the
United States. More and more precollege students were not choosing to take math and
science courses. He predicted that if the students are not choosing to take those courses,
in time there will be a decline in math and science literacy in the United States (Worthy,
1982). His prediction was correct. In 2009, the Paris-based Organisation for Economic
Co-Operation and Development (OECD) performed the Programme for International Student Assessment (PISA) study on 470,000 15-year-olds from 65 countries and the United States ranked 30th in Math and 23rd in Science. The United States ranked 23rd in Math in 2003 and 21st in Science in the same study in 2006.

When comparing the U.S. students to the International students, Worthy found that international students spend three times more classroom hours on biology, chemistry, physics, and earth science. This is because they are required to take one science course each year in high school. They end up taking the required course along with one or two additional science courses each year. There is no slighting of other subjects, as the students take 9 to 10 courses a year (Worthy, 1982). It is no wonder the United States is falling behind in math and science compared to other technically advanced countries.

If United States’ students have not taken enough math courses when they arrive to college, they do not have the math skills required of them to excel in their freshman chemistry course. Another factor that would explain the students’ missing or unlearned math skills required for their chemistry course may be that primary and secondary teachers are ill prepared to teach math and science.

An explanation why primary and secondary teachers may be ill prepared to teach math and science is because they themselves chose to take the minimum amount of math or science courses required of them in high school. These future teachers may enter into college and choose to major in a non-math or non-science subject. These non-math or non-science majors may go onto become elementary teachers and will be required to teach math and science on a daily basis. Primary teachers are prepared as general
education teachers; they are not grounded in science and math (Zehr, 2010). In the era of
the No Child Left Behind Act, many schools are requiring less science to be taught,
devoting more time to reading and math (Cavanagh, 2011).

Worthy’s research exposed how ill prepared primary and secondary math and
science teachers were to teach math and science courses. At the time of the article, 40%
of the teachers never attended a course or workshop since they began teaching. Among
elementary school teachers, 51% say their undergraduate training gave them no
preparation to teach science, 71% have never had in-service training in science, and 64%
had no science consultants assigned to their schools. Ill-equipped teachers result in ill-
equipped students (Worthy, 1982).

Through these circumstances, it is understood how a freshman student can enter
into college never learning the math and science required of them. It is another
possibility that the students were taught the required material, but in time they have
forgotten it. Students planning to enroll in freshman chemistry in the California State
University system are required to have already completed Algebra. Therefore, although
they may not have taken many math and science classes prior to college, they took the
math required of them to be successful in introductory college chemistry. If their high
school teacher did not have the skills to teach algebra, they may have math
misconceptions coming into college, but they may have simply forgotten what they
learned. With both cases a lot of responsibility is placed on the introductory college
chemistry teacher. Why is it the introductory college chemistry teacher’s responsibility if
students come ill-prepared to their class? It is not their responsibility, but throughout the
literature, they have contributed to the growing decline of math and science literacy in the United States by continuing to do what they have always done.

Introductory college chemistry teachers instruct in the same way that they were taught. College and university faculty were most likely successful students (Angel and LaLonde, 1998). If the college chemistry instructor entered into college with the knowledge of the skills required of them to do well, they may expect the same of their students. They are not teaching to the masses. This is most evident when one-half of students enrolled in first-semester chemistry either withdraw or fail while attempting to complete two semesters of freshman chemistry (Angel and LaLonde, 1998).

The chemistry instructor’s teaching style is part of the culture in the scientific community (Angel and LaLonde, 1998). Students who do well in this culture are also the same students that have brought with them the math skills required to be successful in chemistry. Whatever the student brings to his first year chemistry course in terms of mental equipment is more important than anything that happens during the course (Spencer, 1996). The students that do not do well in the culture have not brought with them the skills to succeed.

The students that have taken algebra, but do not have the math skills to be successful, may have not retained the math skills required of them. This may be because their question that always comes up in math classes, “Why do we need to learn these identities and when will we ever use them?” (Pleacher, 1998) was never answered. Like previously mentioned, if the primary and secondary teachers were well versed in math and science they would of answered this question clearly. The teacher could use practical
examples to explain how the math material the student was taught would be used over and over again in their math and science college courses. Because the student was not told how the material will help them in the future, they simply forgot it after taking their math exams in high school. The student was not taught that the math they were learning was a building tool for a lifetime of technical work (David, 1981).

Instructors do not want to spend time reviewing mathematics during chemistry lecture. The teacher feels that the intervention for the student who is in the bottom level of the class would be boring and unproductive for the others in the class. The instructor may fear that the motivation of his brighter students may decline if they feel their instructor’s expectations of them are lower than their own. The continuing decline of basic academic skills and the spreading of the Grade Thirteen Syndrome among college freshman produces an increasing challenge for instructors in the introductory chemistry courses (Bohning, 1982).

Knowing that the lack of mathematics skills is a great deterrent in the success of an introductory chemistry student, what can be done to equip the student with the skills they need to pass their chemistry class?

Chemistry and Math Solutions

Students of college-level general chemistry need certain mathematical skills to be successful (Spencer, 1996). Various solutions have been described throughout scientific educational journals to ensure that the introductory chemistry student has the necessary math skills to be successful. The suggested solutions identified in the literature included
new ways to teach and test math, math help in the form of a remedial math course and
online math tutorials offered by the chemistry department, and offering interdisciplinary
math and science courses in college.

It seems obvious that how a student is taught and tested math would result in the
student learning and retaining math skills. However, despite the growing evidence,
teachers continue to teach the way they always have taught (Spencer, 1999), from the
same textbooks, and using the same exams over and over again (David, 1981). It would be
helpful if math teachers taught math with chemistry in mind. How is a student to know
that the math they are learning is going to help them in college chemistry, if they are
never taught examples of how math is used in chemistry? It is important for math
teachers to make clear the importance of mathematics in all of the sciences, and the
variety of tools used by the scientists (Hohman et al., 2006). The teacher can do this by
having examples throughout their lecturers on how math is used in the sciences. For
example the lesson on graphing can incorporate collected chemistry data and/or the
lesson on dimensional analysis can be taught through examples of converting units of
measure (O’Connor, 2003). The teacher can also choose a math textbook that has many
examples of math used in the sciences. The teacher should also take a qualitative
approach to promote critical thinking by having the student explain their reason for
solving a problem, rather than having them perform multi-step “plug-and-chug”
problems. By doing this the teacher is having the student focus on the big picture rather
than the “nut-and-bolts” of the math they are learning (Pushkin, 2008). Knowledge of
mathematics means much more than just memorizing information or facts; it requires the
ability to use information to reason, think, and solve problems (Pleacher, 1998). Not only do teachers need new ways to teach math, they need new ways to test math (David, 1981).

There are errors in the ways teachers test students of their math knowledge. The first error being that the information taught is fragmented in order for the student to digest it in small chunks, which they are tested on. They forget the previously tested material and move onto the next chunk that will be tested. At the end of the course they cram and relearn all the little chunks to pass the final. When the class is through, they forget the information and it is not until years later that they wish they had not crammed the information for the exam, but truly understood what they were learning. Teachers encourage this binging and purging of knowledge by continuing to provide the student with information on their tests that a student was responsible for in a previous class, for example the equation for the area of a circle. The second error in math testing is the amount of partial credit given. A student can pass a test, without knowing an entire question on the exam. The partial credit often does not put a high value on small errors, like unit checking and algebraic silliness, that are absolutely important to proper mathematical functioning, but below a high level mathematic course. This prevents the accessing of the students’ progress and knowledge of math. Without math teachers focusing on the many little errors on examinations, college students continue to make algebra errors and cannot translate mathematical equations into meaningful knowledge (David, 1981). An idea in literature to solve the issue of partial credit would be for the student to take their test on the computer. The computer would notify the student when a
trivial mistake was made and the student would have the opportunity to correct their error or simple mark that they did not know how to correct their error. This would allow the teacher to know the truth of their students’ knowledge (David, 1981). Aside from how teachers teach and test math, the chemistry department can help the student acquire the math skills they need for their chemistry course by providing a remedial math course or online tutorials.

At Wilkes College in Pennsylvania, a remedial mathematics course for introductory chemistry students was created called “Chem. 99”. In the summer, students who were enrolled in the fall introductory chemistry course were mailed a math test containing 84 questions covering: notation, positive and negative numbers, fractions, percent, exponential numbers, linear equations, higher order equations, simultaneous equations, writing equations, deriving equations, graphing, and logarithms. The students were to take the test and grade themselves according to the included answer key. They were also given a grading scale to determine their math preparedness for the chemistry course they were about to take. They were offered the chance to enroll in Chem. 99 that would take place the week before the start of the fall semester to review the topics they were required to know for their chemistry course. Only 10% of the students enrolled in Chem. 99 scored significantly high on the math self-test. 80% of the students who completed the Chem. 99 course passed their freshman chemistry course. Of the 80% of the students who passed the freshman chemistry course, 30% percent received a B or better. 18% of the students did significantly better in the class than they did on the math
pre-test. Chem. 99 proved to be a helpful tool the first and second semester it was offered (Bohning, 1982).

Another university did not offer a pre-chemistry math course, but they offered chemistry math help via the internet. At the University of Iowa, students wanting to enroll in chemistry need to take a 30 question on-line chemistry assessment to determine what level of chemistry they would enter. Prior to this test, students predicted starting level was determined by a set of university-wide mathematics placement exams. The results of the on-line assessment showed that the universal shortcomings of the students were their mathematics and calculator skills. Because of these shortcomings the university created a mathematics and calculator skills tutorial Web site for the pre and general chemistry students. The Web site has been organized into these topics:

1. Mathematics (Numbers and their properties, Numbers in Science, Ratios and Proportions, Units, Dimensions, and Conversions, Percents, Logarithms)
2. Basic Concepts of Chemistry (Chemical Nomenclature, Atomic Structure, Stoichiometry, Acid-Base Chemistry)
3. Calculator Skills (Basic Operations, Additional Operations)
4. Further Resources

The instructor encouraged the students to go to the Web site at the beginning of the course as well as when the student is preparing for an examination (Pienta, 2003).

While some instructors are trying to teach and test chemistry differently to help their mathematically challenged students, others are creating math help in the form of a college course or a tutorial Web site. Many general chemistry programs require students to pass a math placement exam. Other teachers are going to great length to make sure their
students have the math skills required of them to be successful in Chemistry; they are offering interdisciplinary math and science courses in college.

The faculty at the University of Hartford in Connecticut revealed that students frequently do not transfer an existing skill set from one class [math] to another [science]. The university decided to offer an interdisciplinary collaboration between their pre-calculus and chemistry courses, as chemistry turned out to be the central science and the faculty found a strong and effective connection between chemistry and pre-calculus. The courses would complement each other but would retain the majority of their original identity and content. The emphasis was not to completely redesign each class but focus on the areas of overlap that existed among the courses. The pre-calculus and chemistry courses are taught separately but the matching content in both classes was taught simultaneously to aid the students. At one point in the pre-calculus course, students were taught how to use their graphing calculators to perform a linear regression to find the slope of a line. At the same time, it was necessary for the students to plot and analyze data in their chemistry lab. Instead of the lab instructor asking if anyone knew how to plot the data, the instructor would simply remind them that they learned the necessary skill in their math class. In the evaluation section of the lab reports, several students commented on the positive aspect of seeing the connection between pre-calculus and chemistry. The students also appreciated using math skills with “real-life” data. In order to assess if teaching overlapping pre-calculus and chemistry material simultaneously was a success, the university had a control group of freshman students that were enrolled in the chemistry and pre-calculus class they followed for the past five years. After their
sophomore year, the control group was tested on their pre-calculus and chemistry retention. When the overlapping material was taught simultaneously, the retention of the students was 80%, while in the past when the overlapping material was not taught simultaneously the retention was only 49%. There was some cost to succeed: the faculty needed sufficient time to work together on discovering overlapping material in their syllabus, they also needed a willingness to rearrange their syllabus so that overlapping material could be taught simultaneously, and lastly they needed a way to measure and assess the success of teaching overlapping material simultaneously (Pence, 2005).

The University of Illinois at Chicago not only taught the overlapping material presented in math and chemistry simultaneously, they developed a single curriculum to encompass math and chemistry as a single course. They went about doing this because of the challenges posed by students with developmental or remedial needs in mathematics and chemistry (Wink et al., 2000). The interdisciplinary course combines algebra and preparatory chemistry and is referred to as the MATCH program. Standard algebra courses at UIC consist of three lecture hours and two discussion hours, while a preparatory chemistry course is based on two lecture hours, a discussion hour, and one quiz hour. MATCH students have three fifty-five minute and two seventy-five minute lectures per week, three hours of discussion, and one two-hour laboratory. There is a separate grade for the two parts of the course, but otherwise the entire course is structured as “belonging” to both mathematics and chemistry instruction. This means the instructor is free to have periods that focus on chemistry, as well as periods that focus on math, and most importantly simultaneously instruct on topics that support one another in math and
chemistry. The most challenging aspect of the curriculum was developing the textbook.

A three step process was used, Year 1: Writing of a “lecturer note” textbook., Year 2:
Editing the lecture note textbook into consistent chemistry and mathematics sections;
custom publications of a pre-printed textbook by Hayden-McNeil Publishing., Year 3:
Editing of separated textbook into a single, integrated treatment of mathematics and
chemistry. Listed below are the contents for the UIC MATCH Program Text:

Chapter 1: Elements and Equations: The building Blocks of Chemistry and Mathematics
   A. Introduction to Molecular Concepts
   B. Periodicity
   C. Linear Equations
   D. Formulas in Mathematics and Chemistry
   E. Density
   F. Nomenclature: Molecular Compounds

Chapter 2: Variation and Proportionality in Mathematics and Chemistry
   A. Variation
   B. Indirect Variation
   C. Proportionality
   D. Proportional Reasoning in Chemistry
   E. Formula and Molar Mass

Chapter 3: The Interpretation of Lines and the Gas Laws
   A. Graphing and Slope in the Cartesian Coordinate System
   B. The Slope-Intercept Model and Chemical Phenomena
   C. Temperature and Linearity in Chemistry
   D. Variation and Proportionality in the Gas Laws

Chapter 4: Exponents in Counting and Calculations
   A. Working with Exponents
   B. Moles
   C. Units of Measure
   D. Recording Measurements
   E. Word Problems

Chapter 5: Mixtures in Chemistry and Mathematics
   A. The Nucleus of an Atom
   B. Isotopes and Mixtures
   C. Mixture Problems in Math
   D. Mixtures of Substances
   E. Mass Composition of Compounds
   F. Empirical Formulas

Chapter 6: Valence Electrons and the Description of Chemical Substances
   A. Lewis Structures
The text was designed in a way to show the student a math example, as present in a traditional math textbook and then followed by an example of using the same math in a chemistry problem. Not all of the algebra topics required in the class had a relationship to chemistry, as well as not all of the chemistry topics had a relationship to algebra, so those topics were presented on their own. Initially to assess the students’ knowledge throughout the semester, they were given a math test and then two weeks later a chemistry test, and repeated the cycle the next month. This led to the students cramming for one subject and then another. The program moved to a more effective combined exam. The program included “point recovery” exams the week after each test. The students had the options to re-do exam problems they did poorly previously. The
problems on the “point recovery” exams were more difficult than the original problems, but they motivated students to study missed material right away. Students who volunteered to an interview after completing the MATCH program, found the course to be helpful. They thought the group work provided a nurturing environment for learning. They also thought the course has encouraged themselves to be more verbal in the classroom. The “point-recovery” exams boosted their confidence. MATCH students on average did not necessarily receive a higher grade in the course compared to a control group who took algebra and preparatory chemistry separately, but they did score higher grades on the successor courses in algebra and chemistry compared to the control group. The other data collected showed that students who enrolled in the MATCH program during their first semester at UIC received a higher grade for their MATCH course than students who enrolled in the program later in their college career (Wink et al., 2005). Although this course was developed to address issues in remedial and developmental work in chemistry, the creators’ felt the course and the results of their efforts have important implications for how chemistry is taught independently of a mathematics course (Wink et al., 2005).

Science and Math Anxiety

In 1977, Jeffry V. Mallow recognized the phenomenon for which he coined the term Science Anxiety: a debilitating interaction of emotion-fear, with cognition-science learning (Mallow, 2010). Science anxiety often manifests itself as a crippling panic on exams in science classes, but it is distinct from general test or performance anxiety
The fear of science that many people experience as students, as early as 9 years old (Udo, 2004), and carry with them into adulthood produces a host of negative consequences. Avoidance of science, even the most basic information, precludes many from seeking a range of interesting and well-paying careers. Science-related professions and society as a whole suffer when talent is wasted. Furthermore, a scientifically uneducated citizenry cannot make technically based political decisions on such issues as nuclear energy and atmospheric pollution because it lacks the rudimentary tools to grasp the various arguments (Greenburg, 1982). Science anxiety in the most extreme cases paralyzes students who by any measure of intelligence and hard work, should do well (Udo, 2004). Science anxiety and its alleviation techniques have been researched in the Loyola Science Clinic at Loyola University Chicago, Chicago. There are many causes of science anxiety and research has been done to determine which students suffer most from science anxiety.

The causes of science anxiety are varied, including past bad experiences in science classes. Students receive negative messages about science throughout their school career. Many teachers in the elementary and secondary school system are under the impression that only a few students have the ability to be successful in science classes. High school counselors share in the negative science talk by encouraging students to not enroll in more than the necessary science courses needed, so that their grades will not be lowered, improving the student’s chance of getting into college (Mallow, 2006). At this young age, students are conditioned to think that science is hard, only a few are good at it, and that low grades are the norm.
Science anxiety is also caused by the way a student was taught science in the elementary and secondary school system. Rather than teaching a student how to be analytical in their science courses, looking at science as a mystery to be solved, students are required to memorize a list of terms or diagrams. The science demonstrations shown in class are often exciting, but do not teach much. When students are confronted with the reality of science, they become anxious (Mallow, 2006).

Not only does the school system provoke science anxiety, the science-anxious teachers in elementary and secondary schools teachers pass down their anxiety to their students. A study performed by the American Institute of Physics in 2001 found that only 47% of high school physics teachers had a minor or more in physics. Less than a third of these teachers had a bachelor’s degree in physics or physics education, resulting in inadequate preparation of the teacher in the subject matter. Who are the other teachers? Are they themselves anxious about a subject they are teaching? (Mallow, 2006) Poor preparation, possibly coupled with feelings of inadequacy manifesting themselves in some form of anxiety, may then be transmitted to the students, thus perpetuating the science anxiety cycle (Udo, 2004).

Science anxiety is also caused by a lack of role-models (Mallow, 2006). This is not to say that those who teach science are not good role-models, but that those who teach science are often similar. White males are the most common science teacher. The lack of females and minorities in the sciences can cause anxiety for female and minority students. This is a cause of science anxiety that has been changing over time.
The last cause of science anxiety can be attributed to the stereotyping of scientists in the popular media. Scientists are often depicted as geeky, intelligent but boring males (Mallow, 2010). Mallow focuses on the perceived quiet nerd. The media has even displayed them as quirky and mad. There is the funny looking, spectacled faced Muppet, Beaker, or the crazy Dr. Emmett “Doc” Brown in Back to the Future, the list goes on. When students are looking for a career to pursue, they aren’t interested in being associated with the nerds or the “mad” scientists.

Since the identification of science anxiety and the discussion of its causes, researchers have been most interested in the students most affected by science anxiety. For many years in the US, The Science Anxiety Questionnaire (Alvaro, 1978) has been the instrument used to measure science anxiety. The 44-item questionnaire asks the students to imagine themselves in various situations and rate how anxious they are in that particular situation. The rating system is a 5-degree scale: “Not at all”, “A little”, “A fair amount”, “Much”, and “Very Much”. The questions were divided between science and non-science related situations. The questionnaire has been translated to Danish, so the results of the research have been compared to data from Denmark as well.

Mallow used the questionnaire to determine if science anxiety was displayed in science and non-science majors, if it was related to gender, and if it varied across nationalities (Mallow, 2006). Generally, he found that female students were more science anxious than male students in both America and Denmark, although female students in Denmark were slightly less science anxious than American males. One possible explanation may simply be that constant exposure to science, from the early
years, makes Danish students more confident than American students. Another possibility is that Danish students keep the same teachers throughout primary school; this relationship itself might build confidence (Mallow, 2006). Note that these differences in Denmark and the US did not reflect any differences in the fact that females were more science anxious than males. It is possible that males under-reported their levels of science anxiety based on cultural expectations (Udo, 2004). Sheila Brownlow examined the influence of gender and various background factors on science anxiety using the same questionnaire Mallow used and found that gender- and anxiety-linked differences are discussed in terms of women’s and men’s differential interpretations of their abilities, the influence of parental gender typing on pursuit of science, and the gender-appropriateness of studying science (Brownlow, 2000).

Mallow also found that non-science majors had greater science anxiety than science majors. The differences between male and female students’ science anxiety was smaller amongst science majors compared to the differences between male and female students’ science anxiety amongst non-science majors (Udo, 2004). An important finding in Mallow’s research was that science courses for non-science majors did not provide a lower anxiety learning environment or lessen the gender differences in science anxiety. One likely cause is that the anxiety and its gender bifurcation long predate the college years (Udo, 2004). There may be another explanation, such that the teaching style of a scientist does not match the learning style of a non-science major. Among all of Mallow’s findings in the US is one that is most disturbing. Among the most science
anxious students are US education majors, almost all female: the teachers of the next generation (Mallow, 2010).

Not only are these next generation teachers anxious about science, they are anxious about math. As reported in Harkness et al. (2007), the preservice teachers’ mathematical autobiographies assigned to them shed light on their mathematical self-concepts. Before the preservice teachers started a lesson on problem solving, they were asked to describe their experiences with mathematics. There was a wide variety of responses about the preservice teachers’ feelings about mathematics and their own mathematical skills. One third of the preservice teachers had positive feelings towards math attributing it to good grades and teachers they had that made math fun or the thought that they acquired innate math ability. Another third reported hating math. The preservice teachers actually reported feeling sick before math class, disliking their teachers, or not having self-confidence when it came to their math skills. The last third of the preservice teachers had mixed feeling about math. They either like or disliked math until a memorable experience happened. This experience was a result of a receiving a good grade (A or B) or a bad grade (D or F) in their math class. They discussed feeling confident in some topics of math and their positive experiences were most likely from elementary school math class. Approximately 95% of the preservice teachers were female (Harkness, 2009).

Math anxiety is very similar to science anxiety. According to the University of Granada in Spain, 60 percent of university students experience some form of math anxiety (Thilmany, 2011). The symptoms of math anxiety include tension, nervousness,
concern, worry, edginess, impatience, confusion, fear, nausea, and mental block (Thilmany, 2011; Perry, 2004). Like science anxiety fewer men experience it when compared with women. Through research it has been found that students avoid majors related to math because of their anxiety (Thilmany, 2011).

Researchers have found many reasons for the cause of math anxiety. The first being the lack of role models in mathematics (Thilmany, 2011; Perry, 2004). The second is the assumption that Blacks, Hispanics, and women are poor math students, which can negatively impact these groups’ performance. A third factor is learning disabilities. Working with students with learning disabilities suggests that students’ language processing skills should not be overlooked when dealing with alleviating math anxiety (Thilmany, 2011).

One researcher of math anxiety asked students why they think they are anxious about math. Many students reported that they are not anxious in math class, but when they are given an exam, they freeze, having a mental block. Other students say that they become anxious when a teacher asks them to answer a math problem in front of the class. These students fear looking dumb in front of the other students if they do not get the problem correct. Still others claim that they are anxious because of their “poor” math teachers. The teachers continually present the how to solve the math problem, but do not spend the time to answer the why they are doing the problem causing the student anxiety (Perry, 2004).
The first step is to understand the great impact of science and math anxiety, what causes it, and who is most affected by it. The next step should be to understand what can be done to help alleviate it?

Science and Math Anxiety Alleviations

Understanding the great impact of science anxiety, what causes it, and who is most affected by it, leads to the desire to alleviate it. Jeffry V. Mallow has put together a list of nine recommended practices to aid in the alleviation of science anxiety in the classroom. The practices include: 1. *Explicit science skills teaching*, 2. *Group work*, 3. *Theme-based curricula*, 4. *Attention to wait time and gender equity in calling on students*, 5. “*Catch students doing something right!*”, 6. *Gender-equitable laboratory practice*, 7. *Balancing content and relationship in teacher-student interactions*, 8. *Explicit focus of metacognition*, and 9. *Response to the wide variety of student learning styles* (Mallow, 2006). First, a description of each of these practices will be given and then a practical example of how a teacher has incorporated many of the practices into a weeklong science lesson will be shared.

Mallow focuses on many techniques to help students with science anxiety. First, Mallow reteaches basic science skills from the standpoint of logical reasoning rather than cookbook formulas and memorization (Unknown Author, 1978), essentially using *explicit science skills teaching*. Rather than rote memorization, there are special techniques needed to solve science problems. Science is not like history and literature, so a student needs to read a science textbook and take science notes differently in order to be
successful in their labs and on their exams (Mallow, 2006). It is very important for there to be open communication in a science course with students asking questions in and out of class. There is also a strong need for hands-on learning in science courses (Mallow, 2006).

The second way Mallow helps to alleviate his students’ science anxiety is to organize his students into smaller groups to allow the students to share their common experiences with science anxiety (Unknown Author, 1978). Considerable evidence indicates that students learn better and have a more positive attitude toward the class and subject matter when working in groups than when working alone (Waldeck, 2006). This practice is also a benefit to the female students who prefer group projects over traditional lectures. Females feel group work takes away that competitive component in the class and they enjoy the interactive and cooperative component of group work (Mallow, 2006).

By placing students into groups, the teacher gives up a great deal of control over the communication in the classroom. Instructors must be confident in their ability to design group activities, and to maintain their own interactivity with the groups, so that group communication in classrooms remains focused on learning outcomes (Waldeck, 2006).

Mallow suggests as his third alleviation to science anxiety having theme-based curricula. Drawing students into science through themes is an effective way of providing them with a comfortable classroom environment (Mallow, 2006). It may not be possible to have a theme for each lesson to be learned, but a lot of topics can be covered while using a theme. If the goal in education is to produce fully literate citizens, then the convergence of subject content is fundamental. This idea is not new. As early as 1916,
John Dewey cautioned that isolations in all forms should be avoided, and teachers should strive for connectedness. Recent brain research shows that long-term memory depends upon learning experiences that make sense and are relevant to the learner. It is now known that without making connections among subjects, students struggle to understand unrelated topics and memorize isolated facts (Damien, 2002). Science curriculum and education journals provide many examples of theme-based curricula incorporating many lessons and subjects. One teacher used the need for a new water tower in town to teach the principles of water pressure, volume, flow rates, supply source, and related topics (Damien, 2002). Another teacher used the topic of art restoration and authentication to teach chemistry principles (Kelley; Jordan; Roberts, 2001). The weeklong science lesson to be discussed following the list of science anxiety alleviation used the theme of tornados. It is easy for a student to become less anxious when they are discussing topics that they are familiar with and are learning how science plays a part in what they already know.

Mallow’s fourth suggestion to help alleviate science anxiety is attention to wait time and gender equity in calling on students (Mallow, 2006). Pausing frequently during lecture allows the students to absorb more of the information (Mallow, 2006). Referring to the Information Processing System, the student will have more time to tap into their available long-term memory. This will allow the student to make connections between previously stored information to the new information given to them. This way they can remember the new information given to them rather than storing it in their short–term memory to be forgotten later (Was & Woltz, 2007). When the teacher asks a question he
should wait at least 10 seconds for a reply. The pause for answers will encourage females to answer the question as well. Because females are more science anxious than males, this wait time will give them more time to participate in the discussion. Mallow encourages the teacher to make note of who answers the question to make sure that females are answering questions at the same rate as males (Mallow, 2006). Teachers should also pay attention to students’ answers to the questions asked; this supports Mallow’s fifth alleviation, “Catch students doing something right!”

Mallow’s technique “catching students doing something right” doesn’t necessarily mean that a teacher acknowledges when a student gets a question correct. Rather when a student answers a question incorrectly the teacher should have a dialogue with the student to get them to take steps backward in the formation of their answer to find at what point they did understand and then from that place take the appropriate steps forward to the correct answer (Mallow, 2006). This would also reinforce that science builds upon itself. A student often cannot answer a science question correctly without a strong understanding of previous taught material.

Mallow’s sixth alleviation focuses on science anxiety with a focus on females’ tendency to greater science anxiety. Gender-equitable laboratory practice reminds the teacher to observe the lab to make sure the groups are not divided into doers and observers. Females often fear breaking equipment, while males have an eagerness to get their hands dirty (Mallow, 2006). In order for anxiety to be alleviated, the female needs the hands-on experience to realize they too are just as capable as anyone.
Mallow’s seventh technique recommended to alleviate science anxiety is *balancing content and relationship in teacher-student interaction*. This alleviation technique refers to the environment the teacher creates and communication they have with the student to help eliminate anxiety. The body language, tone of voice, and word selection, as well as how the classroom is organized plays a part in the students’ anxiety. The course ground rules and the teaching techniques are also important aspects of contributing to anxiety. Teacher-student interaction is very important. The teacher should really try to hear all that the student is saying without simply pushing the students words to follow the teachers agenda. Lastly, how the teacher evaluates the student will have an effect on students’ anxiety. Remarks on papers and exam should be written in a way to not diminish the students’ self-confidence (Mallow, 2006).

The eighth alleviation technique Mallow presents is to have an *explicit focus on metacognition*. This is to spend time understanding “how we learn what we learn” (Mallow, 2006). If a student is familiar with how they learn new information, they will be less anxious about it. It will also displace the myth that only certain people are gifted with the brains to learn science.

The last alleviation practice Mallow expresses is teaching with a *response to the wide variety of student learning styles* (Mallow, 2006). There are four ways that a person takes in information: visually, aurally, by reading or writing, and kinesthetically. Often the way a student prefers to take in information or espouse their knowledge to convey their learning is called their learning style. VARK, which stands for Visual-Aural-Read/Write-Kinesthetic, offers learners the opportunity to construct a profile of their
preferences (Fleming, 2001). Visual learners benefit from graphs, symbols, or concept maps. Aural learners prefer lectures and discussions. A reading/writing learner prefers outlines, lists, and definitions. A kinesthetic learner prefers labs, field trips, and role plays (Bretz, 2005). Although not every student has one learning style and has responsibility in the learning process, the teacher should not use this excuse to only teach one way, the way they were taught. This includes group work, demonstrations, hands-on experiments, discussions, presentations, lectures, note taking, etc. The more the student is engaged in the learning process, the less fearful and anxious they will be (Mallow, 2006).

Similar to how Mallow has mapped out the ways to help alleviate science anxiety, many researchers have come up with techniques to help alleviate math anxiety. Similar to a way to alleviate science anxiety the first step to help alleviate math anxiety is to provide role models in the form of women and minority instructors. If more women and minorities who excelled in math instructed the subject, more women and minorities would think that they too can excel in math. If a non-minority male is teaching, he can point out women and minorities in history that were successful mathematicians (Ruffins, 2007).

The second suggestion to alleviate math anxiety is to have students work in groups and discuss how they would solve the math problem assigned. Before any written work is done the students should share ideas on how to go about solving the problem. If they talk over their ideas, they will learn that even someone else’s wrong suggestion can assist them in the learning process (Ruffins, 2007).
An additional way to help alleviate math anxiety would be for the problems to be written in terms that are more familiar to the student. Rather giving a problem that only contains numbers like “1 + 1 =”, the problem can ask, “what is the length of two inch worms lying head to head?” Asking questions about size, distance, time, and money, will be more familiar to a student, allowing them to be less anxious about a bunch of number problems (Ruffins, 2007). This suggestion also follows the technique of writing number problems into formal English, which is also helpful in the alleviation of math anxiety (Ruffins, 2007).

Andrew B. Perry, the researcher who asked the students why they became anxious about math had a few alleviation suggestions himself. He suggests that students should work together and encourage one another. When students ask questions in class about material they find confusing, they are essentially aiding everyone else in the class to hear the confusing topic explained further. He said that instead of blaming their “poor” teachers, students need to take responsibility for their learning. Suggesting that if the textbook is confusing make sure you go to lecture and vice versus. If this does not work, go to office hours to talk with the professor. Perry suggests the student plays a large role in becoming less anxious. His most helpful suggestion is for the students to journal their successes in math class. Often times students become discouraged with poor test grades enabling them to see what they have learned. This is a wonderful suggestion, if a student realizes they did answer a few problems correct, they may be encouraged that they can continue to get more problems correct in the future, rather than just giving up (Perry, 2004).
In order for more students to be less anxious and to not be afraid to pursue careers in science and math, it is necessary for the teacher (and the student) to help alleviate their anxiety.
Chapter 3

METHODOLOGY

Theoretical Framework

Backward Design

The key to constructivism is that students need opportunities to connect their prior knowledge and experiences with new information through their own thought processes and through interactions with others and the environment. Such opportunities allow students to use their schema as a basis on which to build a framework for understanding new ideas and information. Through this scaffolding of knowledge, students can move beyond memorizing facts and develop true understanding (Childre, 2009). Why are students not able to build from their current knowledge in order to gain understanding? The answer is that instruction is too often driven by textbooks, lectures, worksheets, and activities that fail to make learning relevant (Childre, 2009). This type of instruction is based on traditional design.

Traditional design focuses on textbooks, favored lessons, and time honored activities. Many teachers focus on a checklist of topics that need to be covered. The focus is on the teaching rather than the learning (Wiggins & McTighe, 2005). Traditional design would include fun and interesting activities that have no intellectual purpose. Often with traditional design, the student is not familiar with the point of a particular lesson. Traditional design is compared to traveling purposely on a tour of major cities in Europe, instead of following an itinerary deliberately designed to meet cultural goals which would be more like backward design.
Backward design was introduced in 1998. It takes an opposite approach to traditional design, therefore explaining its name, backward design. Backward design has been highly useful for retraining teachers to design curriculum for scaffolding learning. Teacher understanding of the difference between student knowledge and student understanding is critical to implementing the backward design approach (Childre, 2009). Backward design focuses on the learning outcomes of the students, meeting the curriculum standards, and assessing if the standards were met (Childre, 2009).

When following backward design, the curriculum is designed in order to meet a specific goal (Wiggins & McTighe, 2005). The questions a teacher should ask themselves when developing curriculum when following background design are: First, what should the student understand when walking out the door? Second, what is the evidence of such ability? and Lastly what texts, activities, and methods will best enable such a result? (Wiggins & McTighe, 2005) For backward design to work, educators need to identify desired results, determine acceptable evidence, and determine appropriate action plans (McTighe, 2003).

The first step in backward design is to identify desired results. When identifying desired results, the teacher may first want to identify the learners. Knowing your learners is foundational to designing curriculum. Prior knowledge, experiences, and interests students bring to the classroom influence student learning (Childre, 2009). The teacher will want to identify the curricular priorities or the learning goal that will shape the instructional unit (Childre, 2009). After determining the learning goal of each unit, the teacher should come up with an essential question that engages their students into the
unit. For example in an introductory chemistry course where the student is learning about kinetic molecular theory, an essential question may be: *How does temperature influence the speed of particles?* Essential questions engage students in meaningful learning; they provide a conceptual lens through which to address the specific goal of the unit (McTighe, 2003). The essential question should be asked over and over throughout the unit, so that the student can consider how the content of their learning tasks contribute to their learning goal (Childre, 2009). While the teacher is determining the desired results of the unit, they may want to determine the prerequisite knowledge and skills required by the student for the unit. If the students do not process the required knowledge and skills, the teacher should address these requirements into their unit (Childre, 2009).

The second step in backward design is to consider the evidence needed to determine whether the students have achieved the desired learning (McTighe, 2003). Ongoing and frequent assessment is fundamental to scaffolding student understanding (Childre, 2009). The goal is to move beyond the students memorizing facts to true understanding. There are many ways to asses if a student has learned the required information for each unit. The teacher may ask questions on a test or a quiz that require a student to explain their answer, rather than selecting an answer from an answer given in a multiple choice question (McTighe, 2003). The teacher may also assign performance tasks or projects that allow the student to demonstrate the depth of their understanding (Chilre, 2009). Teachers may also give informal assessments in the form of class discussions, of the material.
The third step of backward design is the development of an action plan focused on obtaining the desired student achievement results (McTighe, 2003). In order for true backward design, teachers need to avoid the tendency to jump to planning activities before identifying desired results. Students need to know where they are going and what they are expected to accomplish (Childre, 2009). In order to facilitate the scaffolding process through the planned learning experiences and instruction each activity should include three steps. The first step should engage students with essential questions and unit vocabulary. This will allow the student to connect to prior knowledge as well as address any misconceptions so that the students are not building knowledge on faulty bases. The second step should break instruction and activities into manageable parts. Rather than lecturing for a long period before breaking into an activity and then discussion, each element of the unit should be segmented in a way that the unit is not frontloaded with instruction diminishing student engagement. Lastly weave assessment across the unit allowing for continuous insight into the development of student understanding (Childre, 2009).

The benefit of backward design is that the student and teacher have a clear understanding of the goal of each unit. The student no longer has to ask if what they are learning will be presented on the test, as each activity was created with the assessment in mind. The teacher can leave each day knowing that what they have presented to their students has purpose and was not for entertainment or simply a way to kill time. Traditional designed curriculum at one point was guided by a goal, but with goals and standards changing often it is best to reevaluate curriculum on a regular basis to make
sure it is in line with the current goal/standard. A good way to go about reevaluating curriculum is following the steps of backward design.

**Action Research**

To allow for the researcher to have greater say in their work and to acquire results sooner, action research was developed in 1930 by German psychologist Kurt Lewin in social science and adopted by educators in 1950. Original educational research followed a traditional form of social science research or formal research. Table 2 is a comparison of action research and formal research.
Table 2: Comparison of Action Research and Formal Research

<table>
<thead>
<tr>
<th>Action Research</th>
<th>Formal Research</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal is to solve problems of local concern.</td>
<td>Goal is to develop and test theories and to produce knowledge generalizable to wide population.</td>
</tr>
<tr>
<td>Little formal training to conduct such studies.</td>
<td>Considerable training required to conduct such studies.</td>
</tr>
<tr>
<td>Intent is to identify and correct problems of local concern.</td>
<td>Intent is to investigate larger issues.</td>
</tr>
<tr>
<td>Carried out by teacher or other local education professional.</td>
<td>Carried out by researcher who is not usually involved in local situation.</td>
</tr>
<tr>
<td>Uses primarily teacher developed instruments.</td>
<td>Uses primarily professionally-developed instruments.</td>
</tr>
<tr>
<td>Less rigorous.</td>
<td>More rigorous.</td>
</tr>
<tr>
<td>Usually value-based.</td>
<td>Frequently value-neutral.</td>
</tr>
<tr>
<td>Purposive samples selected.</td>
<td>Random samples (if possible) preferred.</td>
</tr>
<tr>
<td>Selective opinions of researcher often considered as data.</td>
<td>Selective opinions of researcher never considered as data.</td>
</tr>
<tr>
<td>Generalizability is very limited.</td>
<td>Generalizability often appropriate.</td>
</tr>
</tbody>
</table>


The largest difference between action research and formal research is that action research is done in order to solve a problem of local concern, while formal research is done to make a generalization of a larger population. This allows the action researchers to come to conclusions at a much quicker rate than a formal researcher. A formal researcher requires a great amount of time to do their research, as they are required to
complete extensive statistical analyses of the data to come to a conclusion that can be generalized to a large population.

In order for action research to occur, “the science must be flipped from formal, traditional methods or else the research runs the risk of becoming more authoritative than participatory” (Cammarota, 2009/2010). By choosing an action research approach, the researcher plays two roles, the first being a participant of the research and the second an observer and documenter of the research. Action research contains four steps. The first step an action researcher must take is to identify the research problem or question. The next step is to plan what information they need to solve the problem or answer the question. The third step is to take action to obtain the required information. The final step is to evaluate the found information. This type of research is a cyclic process, so the researcher will continue repeating the four steps until they come to a satisfactory solution to their problem or answer to their question (Bergdahl; Benzein; Ternestedt; Andershed, 2011).

Education is the perfect place for action research. For example, a fourth grade teacher may see a problem their students have that they want to solve, but do not want to do the intense research and data collection that would allow them to claim that the solution they discovered would benefit all fourth graders. If the teacher is only interested in a solution for their own class, action research would be the option to choose.

Traditionally educators would research another teacher’s practices and if the results proved favorable, they would implement the other teacher’s techniques to their own work. By following action research the teacher is no longer just an observer in their
research, but they are also the subject of their research. Instead of researching another teacher and describing and explaining someone else’s practices, they would give descriptions and explanation of their own practices by asking, “How do I improve what I am doing?”

Pedagogical Context

The Math Worksheets were created as a teaching component for an introductory chemistry course at California State University, Sacramento (CSUS). Four math worksheets were designed to be completed voluntarily by CHEM 4 students in their own time in the fall semester of 2009 and the spring semester of 2010.

CHEM 4 is a 3-unit lower division introductory chemistry class that is required of students whose major requires them to take CHEM 1A and they did not pass the placement exam required for CHEM 1A. The University’s catalog describes the course as: “CHEM 4. Chemical Calculations. Introductory chemistry for students who plan to major in a scientific field. Appropriate for students desiring to prepare themselves for Chemistry 1A. Emphasizes the techniques of problem solving and utilizes such subjects as: unit cancellation; conversions between measuring systems; weight, moles and chemical equations; density; elementary gas laws; heat and temperature; elementary acid and base chemistry; oxidation and reduction; solutions. Three hours lecture.”[CSUS 2009-2011 Catalog] The student must receive a “C” or better in CHEM 4, for the placement exam requirement to be fulfilled.
CHEM 4 is instructed by a CSUS chemistry faculty member and meets three days a week for 50 minutes. During the fall 2009 and spring 2010 semester CHEM 4 lecturers were instructed by Dr. Jeff Paradis. Dr. Paradis lists goals for CHEM 4 on his class website as the student being able to “1. Name and write the chemical formulae of ionic compounds, molecular compounds, acids, and bases. 2. Appropriately use significant figures, rounding, and scientific notation in measurements and chemical calculations. 3. Convey an understanding of dimensional analysis, unit conversion, the metric system, and the general importance of the use of units in chemistry. 4. Write a balanced chemical equation for various types of chemical reactions, predict in what physical states the products and reactants will be found, and write ionic and net ionic equations bases on the balanced reactions. 5. Perform calculations related to the mole including molar mass calculations, mole-mole calculations, mole-mass calculations, mass-mass calculations, and other stoichiometric calculations. 6. Solve chemically related word problems.” The students are assessed of their knowledge by taking three quizzes, three exams, and one final exam. They also turn in homework throughout the course.

The grading for the course was based on a total of 660 points. The three midterm exams were worth 100 points each, the cumulative final exam was worth 200 points, the three “proficiency” quizzes were worth 20 points each, and the homework was scaled to 100 points. The overall course grade was based on a straight percentage format; there was no curve because competition goes against the team-work philosophy practiced in Dr. Paradis’ CHEM 4 class. Bonus points were awarded in the form of unannounced “reading quizzes” and occasional worksheets. Students scoring less than 80% on a given
exam were required to complete the mathematics worksheets that were available for the following exam.

The 4 math worksheets were administered to one hundred and thirty-eight undergraduate students enrolled in CHEM 4 in the fall 2009 semester and two hundred and thirty-one undergraduate students enrolled in CHEM 4 in the spring 2010 semester. These were almost all science majors or minors in their freshman year, with slightly more males than females in each class section, most with the intent to pursue a science related career. All of these students attended three weekly lectures. The lecture was presented by a California State University of Sacramento Department of Chemistry faculty member. The lecture classes that the 4 math worksheets were administered to were instructed by Dr. Paradis.

Characterization of Students by Surveys

Two surveys were administered to determine characteristics in the student population relevant to math and CHEM 4.

Pre-class Math Survey: The survey was administered to all the students who attended the first CHEM 4 lecture after the first exam in the fall 2009 semester and on the first day of CHEM 4 in the spring 2010 semester. Three hundred and eight students (84%) enrolled in Dr. Paradis’ lecture in the fall 2009 and spring 2010 semesters completed the survey. The survey was administered to determine the highest math course each student was enrolled in and what grade they received. It also was used to obtain indications concerning math anxiety by the students in the course (Appendix A).
course instructor emphasized that the survey was solely to help in the improvement of the mathematics worksheets used in CHEM 4 and in no way would impact the students’ grade in the course.

This survey contained five questions. The first question asked if the student was enrolled in a math class and if so, which one. The second question asked the student what is the most recent math course they have taken and what grade they received. The third question asks the student to rate how good they considered themselves at math from a scale of one to five, one being “poor” and five being “excellent”. The fourth question asked the student how much they enjoyed math on a scale of one to five, one being “really dislike” and five being “really like”. The last question asked the student how concerned they were with their math skills impacting their chemistry grade on a scale of one to five, one being “very concerned” and five being “not at all”. The pre-class math survey and math worksheet survey were administered together on the same sheet of paper in the fall 2009. The pre-class math survey and math worksheet survey were administered separately in the spring 2010.

Math Worksheet Survey: The second survey was administered to all the students enrolled in the fall 2009 and spring 2010 semesters of CHEM 4. Two hundred and sixty-seven students who took the first exam of the course completed the survey during the lecture period following the first exam. The survey was a research tool to determine if the first worksheet aided the student in math success on their first exam (Appendix B).

This page and a half survey contained seven questions for the students enrolled in the fall 2009 semester of CHEM 4. The first three questions asked the student what
grade they received on their first exam, specifically asked how many points they received on the isotope calculation on the last page, and asked them to explain the source of their errors on the calculation problem. The next four questions on the survey asked the student questions regarding worksheet #1. It asked when the student completed the worksheet, how long it took to complete, if they referred to the answer key when it was posted, and how they felt about the worksheet overall. These last four questions were on a single page for the students enrolled in the spring 2010 semester of CHEM 4. The first exam in the spring semester only contained multiple choice questions, so the students were unable to receive partial credit on the atomic mass calculation and did not have their work written on their test to recall their source of errors.

Characterization of Students by Introductory Math Quiz

A math quiz was administered to determine the math knowledge of students enrolled in CHEM 4.

**Introductory Math Quiz:** The introductory math quiz was administered to all the students who attended the first lecture of CHEM 4 in the fall 2009 and spring 2010 semesters. Three hundred and sixty-three students enrolled in Dr. Paradis’ lecture in the fall 2009 and spring 2010 semesters completed the quiz. The math quiz was administered to determine what percentage of students were familiar with the math required to be successful in CHEM 4, as well as determine if there were particular required math skills that many students lacked. (Appendix C). The course instructor
emphasized that if the students received a 95% or better on the quiz, they would receive 5 extra credit points. This was to encourage the students to perform at their highest ability.

The introductory math quiz contained 15 multiple choice questions printed on the front and back of a single piece of paper. The questions were selected after going through the course textbook and determining what math skills were needed for the course. There are twenty-eight lessons throughout the textbook that required math skills. The math skills required ranged from basic math to more complicated algebra. Table 3 includes all the sections in the “Introductory Chemistry” by Nivaldo J. Tro that require math skills.

Table 3: Chapter Sections and Required Math Skill in CHEM 4 Textbook

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Math Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.2</td>
<td>Scientific Notation: Writing Large and Small Numbers</td>
<td>Algebra</td>
</tr>
<tr>
<td>2.3</td>
<td>Significant Figures: Writing Numbers to Reflect Precision</td>
<td>Algebra</td>
</tr>
<tr>
<td>2.5</td>
<td>The Basic Units of Measurements</td>
<td>Elementary Math</td>
</tr>
<tr>
<td>2.7</td>
<td>Solving Multistep Conversion Problems</td>
<td>Algebra</td>
</tr>
<tr>
<td>2.9</td>
<td>Density</td>
<td>Algebra</td>
</tr>
<tr>
<td>2.10</td>
<td>Numerical Problem-Solving Strategies and the Solution Map</td>
<td>Algebra</td>
</tr>
<tr>
<td>3.10</td>
<td>Temperature: Random Molecular and Atomic Motion</td>
<td>Algebra</td>
</tr>
<tr>
<td>3.12</td>
<td>Energy and Heat Capacity Calculations</td>
<td>Algebra</td>
</tr>
<tr>
<td>4.5</td>
<td>Elements: Defined by Their Numbers of Protons</td>
<td>Elementary Math</td>
</tr>
<tr>
<td>4.7</td>
<td>Ions: Losing and Gaining Electrons</td>
<td>Algebra</td>
</tr>
<tr>
<td>5.2</td>
<td>Compounds Display Constant Composition</td>
<td>Algebra</td>
</tr>
<tr>
<td>5.3</td>
<td>Chemical Formulas: How to Represent Compounds</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.2</td>
<td>Counting Nails by the Pound</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.3</td>
<td>Counting Atoms by the Gram</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.4</td>
<td>Counting Molecules by the Gram</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.5</td>
<td>Chemical Formulas as Conversion Factors</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.6</td>
<td>Mass Percent Composition of Compounds</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.7</td>
<td>Mass Percent Composition from a Chemical Formula</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.8</td>
<td>Calculating Empirical Formulas for Compounds</td>
<td>Algebra</td>
</tr>
<tr>
<td>6.9</td>
<td>Calculating Molecular Formulas for Compounds</td>
<td>Algebra</td>
</tr>
<tr>
<td>7.3</td>
<td>The Chemical Equation</td>
<td>Algebra</td>
</tr>
<tr>
<td>7.4</td>
<td>How to Write Balanced Chemical Equations</td>
<td>Algebra</td>
</tr>
<tr>
<td>7.7</td>
<td>Writing Chemical Equations for Reactions in Solution:</td>
<td>Algebra</td>
</tr>
<tr>
<td></td>
<td>Molecular, Completed Ionic, and Net Ionic Equations</td>
<td>Algebra</td>
</tr>
</tbody>
</table>
The data from the math quiz supported a need for math worksheets as well as determined what math skills needed to be represented by the math worksheets. Many students struggled with the problems that required knowledge of scientific notation, fractions, and solving for x.

**Description of Math Worksheets**

Dr. Paradis worked very closely with the development process of each math worksheet. Dr. Paradis posted the worksheets onto the class website before each related exam. He collected the worksheets prior to the exam and recorded that the student had submitted the worksheet and therefore was awarded extra credit points. Each of the worksheets was available to the students two weeks before the exam which included the topic covered in the worksheet. The worksheets were 4 to 8 pages printed on one side with sufficient white space left for problem solving and answers. The worksheets were designed for completion outside of class. The students were able to work at their own pace, alone or in groups. This was to help alleviate any anxiety the student would have to work on the math problems alone. Working in groups also supports a guided inquiry form of learning, as one student may be confident with one section of the worksheet and another student may feel confident with another section of the worksheet, and together they can help each other both complete the worksheet. Some students may prefer to work
on their own, so that choice was available as well. The worksheets were designed to cover the math needed to solve chemistry math problems correctly on the exams. The worksheets were designed to give background information about the math skill needed and then use the math skill in a chemistry example.

The data from the math quiz, as well as a review of the course syllabus helped to determine what topics would be covered in the provided worksheets. It was important that the math worksheets available would not only help with the math skills lacking through the math quiz data, but also were the skills that would be assessed on the exams throughout the semester. This approach followed backward design. Rather than just creating freshman chemistry required math skill worksheets, a great deal of time was taken in determining what topics requiring math skills would be placed on the exams. Referring to Table 3 above, the three exams and final given in the course required many math skills. Table 4 below lists one of the many math required sections assessed on each exam that were chosen to create worksheets. There were many other math required sections assessed, but with the review of the math quiz results and previous exams, these topics were chosen for the worksheet topics. The main reason atomic mass calculation was chosen was because exam 1 had an atomic mass word problem that allowed for further analysis of math errors students would make. Significant figures and scientific notation was chosen because many multiple choice answers on all three exams and the final required the student to choose an answer that was written in scientific notation and/or contained the correct number of significant figures. These topics are not overly difficult, but without a clear understanding of them, students could receive no credit for a
problem they solved correctly if they do not know how to write the answer with the correct number of significant figures and/or in scientific notation. Mass percent composition was chosen because many students struggled with fractions, percentages and solving for x on the math quiz.

Table 4: CHEM 4 Math Worksheets

<table>
<thead>
<tr>
<th>Exam 1-Worksheet 1</th>
<th>Section</th>
<th>Math Skill Required</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Exam 2-Worksheets 2 &amp; 3</th>
<th>Section</th>
<th>Math Skill Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.2 Scientific Notation</td>
<td>*To the Power, *Multiplication, *Decimal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exam 3-Worksheet 4</th>
<th>Section</th>
<th>Math Skill Required</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6.6 Mass Percent Composition</td>
<td>*Fractions, *Percentages, *Solving for X</td>
</tr>
<tr>
<td></td>
<td>6.7 Mass Percent Composition from a Chemical Formula</td>
<td></td>
</tr>
</tbody>
</table>

There were many revisions for each worksheet. Dr. Paradis would make his suggestions throughout the entire design process. It was important that the math worksheets were not simply a regurgitation of the course textbook or Dr. Paradis’ lectures. They were also not to resemble homework, but as a help tool focused specifically on math skills.
The worksheets were to perform as a private tutor, guiding the student through the information step-by-step. They focused on constructivism, where learning is a building on a students’ existing framework of knowledge. In place of a professor trying to figure out at what point the information is new to a student, the worksheet started at the basic math required for each problem, in an essence catching the student doing something right. Catching the student doing something right is a practice to help eliminate science anxiety. If the first worksheet simply contained many atomic mass calculation examples, the student may have become anxious. Those types of examples would have required the student to do the basic beginning steps on their own. They may not know how to do a simple step like converting a decimal to a percentage. The worksheets did not assume any previous math skill knowledge above elementary math and explains, for example, in the atomic mass calculation how to convert a decimal to a percentage. This allowed the worksheet to have the feel of being easy, discouraging any additional anxiety to an already stressful chemistry course.

Another reason for the many revisions of the worksheets were to make sure the student could work through them without getting stuck, making sure there existed an example of every step in the problem. The revisions also made sure that the everyday examples encouraged a connection from previous learned knowledge to new knowledge. For example, recipes were used to help the student to locate previous stored information in their long-term memory when learning how to solve percent composition problems. Once again focusing on the building of previous knowledge that constructivism deems important.
The sequence of the four worksheets is described below following individual descriptions of each worksheet.

Description of Worksheet #1: Calculating Atomic Mass

The first worksheet was designed to give background knowledge and example problems for calculating atomic mass. [a copy of Worksheet #1: Calculating Atomic Mass is at Appendix D] The example problems were listed in increasing difficulty. The problems were set-up according to the way problems were set-up in the “Introductory Chemistry” textbook by Nivaldo J. Tro that the students were required to have for the course. The textbook broke down example problems step-by-step in a table with the “steps to solving the problem” in the left hand column and the “solutions” in the right hand column. The example problems were developed by following backward design. In order to know what problems were important for the student to master, Exam 1 atomic mass problems needed to be studied. It is important to understand how the student will be assessed in order to prepare them with the required knowledge. The background was developed by dissecting each problem into the fundamental math skills required to solve the problem. This is a key point in each of the worksheets to differentiate a math worksheet from math examples given in the textbook. For example, the textbook atomic mass example problem shows that to convert 20% into a decimal, you divide 20 by 100 to get 0.20, but it does not explain why you divide 20 by 100.

The first section of the first worksheet starts out by explaining to the students what they are expected to learn by completing the worksheet. In this first section of the
worksheet the student learns that in order to solve an atomic mass problem, they will have to manipulate algebraic equations, solving for one or more variable(s). This section also lets the student know that they will have to convert percentages into fractions and decimals. It also explains that the students will need to know the relationship between the percentages of a whole. The goal of this section is help alleviate any anxiety the students have with solving an atomic mass problem. The worksheet focuses on explicit science skills when solving a problem. It also has the approach of catching the students doing something right, starting at a place where the student is comfortable with the information and building from there. If the core information needed to solve the problem is explained in detail, the student will not have anxiety of not being able to retrieve the information they may have learned before, but may have learned incorrectly or have forgotten.

The second section of the worksheet is “Background 1: Converting percentages to fractions or decimals”. This section describes how percentage means “per hundred” and explains how to convert a percentage into a fraction and further into a decimal. It contains a table with missing percentage, fraction, and decimal values throughout and encourages the student to fill in the missing values. The point of this exercise is for the student to see the similarities between the three values. With multiple examples, the students can see the pattern throughout the table. It is with practice that a student will have time to process what is in the short-term memory and transfer it to their long-term memory. Completing this table may jog the student’s memory of learning about fractions, percentages, and decimals in high school.
The third section of the worksheet is “Background 2: The %’s have to add up to 100%”. It explains how a percentage is a part of a whole. This section focuses on the fact that percentages of different isotopes of one element must add up to 100%. If the percentages are written in decimal form, they must add up to one. This section will remind students that if there are two isotopes present and the percentage of abundance of one of the isotopes is given, they can find the percentage of abundance of the second isotope by subtracting the percentage of the first isotope from 100%.

The final section covers the calculations needed to solve an atomic mass problem. This section is broken into two types of calculations. The first type of calculation is solving single-variable equations. The second type of calculation is solving multi-variable equations. This section focuses on setting up equations to solve atomic mass problems. It asks the student to fill in a table with the known information (or given information) to put into the equation. These steps allow for the student to sit back and place the information given in the problem into its proper place in the equation. It also helps the student to understand what additional information is needed to solve the problem. Many practice examples are given in this section to help the student to become more comfortable with solving algebraic equations, as well as atomic mass equations. In order for the student to not just memorize how to solve for atomic mass, working through many examples will help them store the information the worksheet just led them through into their long-term memory. This is very important when looking at information processing theory. If the student simply memorizes how to solve the problem, they may
be able to retain it for the exam, but it most likely will be forgotten by the time of the final and most definitely be forgotten after the course is complete.

If the student has no problem with elementary algebra, this first worksheet will simply allow the student to see that the chemistry atomic mass problem is no different than an algebra problem. This will hopefully alleviate any science anxiety the student may have, seeing a connection to what they’re learning to something they already know. If the student does struggle with elementary algebra, hopefully this first worksheet will give the student step by step reference for solving an algebra problem and eventually an atomic mass problem.

Description of Worksheet #2: Scientific Notation

The second worksheet was designed to give background knowledge and examples of how to write numbers in scientific notation. [a copy of Worksheet #2: Scientific Notation is at Appendix E] This is important information for the student to know, as many numerical multiple choice answers on chemistry exams are given in scientific notation and the student should be prepared to convert their calculated answer into scientific notation. Also many known chemistry constants are written in scientific notation and in order for the student to use them in equations, the student needs to understand their value.

The first section of the second worksheet explains why scientific notation is important in chemistry. Science contains some very large (speed of light) and very small (mass of a proton) numbers, scientific notation is an abbreviated way to write very small
or very large numbers. Instead of counting zeros, scientific notation was created as a short cut.

The second section of Worksheet #2 is “Background 1: “To the power of”. This section focuses on the meaning of “to the power of”. It is a thorough explanation of a base number and an exponent. There are many examples of 10 as the base and various numbers as the exponent. The students are asked to fill-in a table of three columns, “Original number”, “Written in terms of 10’s”, and “Written as an exponent”. An example would be that the “Original number” would be 100, “Written in terms of 10’s” would be 10 x 10, and “Written as an exponent” would be $10^2$. The table contained eight different “Original number” examples ranging from 0.00000001 to 100,000,000,000. By filling in the missing pieces of the table the student is guided to see how one number can be written three different ways.

The third section is “Background 2: In addition to understanding “to the power of”, you must also understand multiplying a number between 1 and 10 by a number that is a power of ten”. For example, the examples in this section show the student that the number 6,500 is the same as 6.5 x 1,000, where “6.5” is between 1 and 10 and “1,000” is a power of ten number. The students were given examples to try on their own.

The fourth and final section combined what the students learned in background 1 and 2 to write a number in scientific notation. This section focused on examples of placing a decimal after the first non-zero number and counting the number of places the decimal was moved to determine what exponent of 10 the number is multiplied by. These steps were clearly listed in a table for the student to follow.
This last section of the worksheet explains how to write a number in scientific notation similarly to how a chemistry textbook explained it. The second and third sections, give the building blocks to the understanding of what a number written in scientific notation actually means. This worksheet was written with the information processing model in mind. In order for a student to remember how to write scientific notation, it is important to connect to their long term memory of multiplication of tens. This worksheet contains very simplistic math skills, but it is these simplistic topics a professor will not spend a great amount a classroom time explaining. If the student is not familiar with what an exponent represents, they could struggle with scientific notation throughout their scientific career.

Description of Worksheet #3: Significant Figures

The third worksheet was designed to give background knowledge and example problems for determining the number of significant figures a number has or should have. [a copy of Worksheet #3: Significant Figures is at Appendix F] Determining the number of significant figures a number has is very important in chemistry. For example, if active drug amounts in pharmaceuticals are not measured to the correct significant figure, the drug is capable of having adverse effects.

The first section of Worksheet #3 explains how significant figures represent the precision of a measured quantity. The greater the number of significant figures in a number, the greater the precision of the measurement. This section gives an example of
using a ruler with hash marks for each cm and using a ruler with hash marks for each mm when measuring 1.5 cm.

The second section is “Background 1: To determine how many significant figures a number has, follow these rules:”. This section goes through the rules of determining the number of significant figures a number has and provides examples for each rule. These rules are listed in the textbook with slightly different wording. The difference is that the textbook gives only a couple examples for each rule and does not give problems for the student to work through relating to each rule individually. This section gives the student the time to review each rule and work through problems to make sure they understand what each rule means. This continued practice will encourage the students to not only memorize the rules, but transfer the knowledge of the rules into their long-term memory, so they will know how to write a number with the correct number of significant figures on their exam.

The third section of Worksheet #3 focuses on determining significant figures when performing calculations. This skill is important in chemistry because the precision of a calculated answer is based on the precision of the measurements given to solve the calculation. To determine how many significant figures a result has, different rules must be followed depending on whether the calculation involves adding/subtracting, multiplying/dividing or both. This section goes through the three types of calculations and the rules that must be followed. There is a guided example of each type of calculation and three problems per each calculation for the student to solve on their own. Once again this continued practice allows the student to process the information and store
it in their long-term memory. This will encourage the retention of the information lasting through the course and beyond.

Worksheet #3 parallels the two significant figure sections in the textbook, but gives a lot more examples and problems for each rule. This worksheet is trying to alleviate science anxiety by focusing on metacognition (how the student learns) with a focus on practice makes perfect. The worksheet is assuming a student can count and knows what a zero is. If the student has those two basic building blocks, solving for significant figures is no more than a list of rules and the best way to master a list of rules is to go over them many times until they become part of the student’s long-term memory.

Description of Worksheet #4: Percent Composition

The fourth worksheet was designed to give examples of determining percentage of a whole in everyday life and in chemistry. [a copy of Worksheet #4: Percent Composition is at Appendix G] The goal of the fourth worksheet is for the student to be able to solve percent composition problems. This worksheet was also designed according to backward design by first researching how the student will be tested on solving percent composition problems. The worksheet asked the final percent composition questions in the same way they would be asked on an exam. The worksheet takes the student from solving percent composition problems in everyday life to solving problems similar to how they will be assessed. These everyday examples will help to alleviate anxiety, by giving the problem a theme. Most students are familiar with food and recipes, so starting out with recipe examples and then having the students see the relationship to chemistry,
should help relieve anxiety. Also this plays a role in constructivism, a building upon previous learned information.

The first section of the worksheet gives the background to determining how much of an element is in a given compound. It reinforces that the element’s mass percent composition is constant no matter the amount of compound available. The example given is H₂O. The mass percent of hydrogen in a teaspoon of H₂O is equivalent to the mass percent of hydrogen in a bath full of H₂O. The student is asked to write the definition of “mass percent composition”, so they are familiar with the goal of the worksheet. This is also a part of backward design. It is beneficial for a student to know their destination in order to encourage them to stay on the right path. It also gives purpose to their learning.

The second section of the worksheet is “Part 1: Determining mass percent in everyday life”. This section starts out with a guided example of determining the mass percent of chocolate chips in trail mix. This section is concluded with two problems for the student to try on their own determining the mass percent of raisins and peanuts in the trail mix. This section is geared to eliminate science anxiety. It also follows a theme of non-science related problems. Determining the mass percent of different ingredients in trail mix may be more familiar to a student than dealing with the mass percent of hydrogen in water.

The third section of Worksheet #4 is “Part 2: Determining mass percent in chemistry”. This section starts out with a guided example of determining the mass percent of hydrogen in ammonia. The students are no longer asked what percentage of
the trail mix are raisins, but what is the mass percent of oxygen (O) in carbon dioxide (CO₂)?

The fourth section is “Part 3: Using mass percent in everyday calculations”. This sections starts out with a guided example of using the mass percent of the chocolate chips determined in Part 1 guided example to determine how many grams of trail mix can be made by a given mass of chocolate chips. The student is this asked to determine how many grams of raisins are needed to make a give mass of trail mix using the mass percent of raisins in trail mix determined in Part 1.

The fifth section is “Part 4: Using mass percent in chemistry calculations”. This sections starts out with a guided example determining how many grams of nitrogen are in a given mass of nitric acid. This section was concluded with a problem for the students to work on their own to determine how many grams of sulfuric acid can be made with a given mass of oxygen.

The sixth and final section is “Part 5: More practice determining mass percent and using mass percent in calculations”. This section included four examples for the students to work on their own that resembled examples in Parts 2 and 4.

The vision of Worksheet #4 was for students to look at mass percent problems and not freeze because they were confused by all the scientific jargon: “element”, “mass percent”, “compound”, etc. The worksheet was to allow students to see that an element is simply a part of the whole compound and that solving mass percentage problems were no different in chemistry class than they were in math class. The trail mix examples were to relieve anxiety amount unfamiliar science terminology in a basic math problem.
Chapter 4

RESULTS AND DISCUSSION

Surveys

Fall 2009 Survey Results

During the lecture after the first exam in fall 2009, the semester that this research began, the faculty member, Dr. Paradis, who was instructing CHEM 4, administered two surveys to students enrolled in the course. Dr. Paradis told the students that the surveys were to help in the improvement of Worksheet #1 for subsequent CHEM 4 semesters. He emphasized that the answers given on the surveys will not impact their grade in the course. The two surveys were placed together on the same page (front and back), so each student who completed the first survey, completed the second.

One hundred and twenty nine completed surveys were received. All responses were tallied. Analysis of the first survey showed that the students were enrolled in or previous took one of thirteen different math courses. Seventy-one students are currently in a math course. Sixty-two students recorded what math course they are currently enrolled in at CSUS; this information is recorded in Table 5.
Table 5: Fall 2009 Number of Students Currently Enrolled in Math

<table>
<thead>
<tr>
<th>Math class currently enrolled in at CSUS</th>
<th>Number of students (%) who dropped out or failed (received an F) CHEM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS 7A (Pre-Algebra)</td>
<td>3</td>
</tr>
<tr>
<td>LS 10A (Elementary Algebra)</td>
<td>8</td>
</tr>
<tr>
<td>Math 9 (Essentials of Algebra and Trigonometry)</td>
<td>13</td>
</tr>
<tr>
<td>Stat 1 (Introduction to Statistics)</td>
<td>1</td>
</tr>
<tr>
<td>Math 26A (Calculus for College Students)</td>
<td>6</td>
</tr>
<tr>
<td>Math 29 (Pre-Calculus Mathematics)</td>
<td>20</td>
</tr>
<tr>
<td>Math 30 (Calculus I)</td>
<td>7</td>
</tr>
<tr>
<td>Math 31 (Calculus II)</td>
<td>3</td>
</tr>
<tr>
<td>Math 45 (Differential Equations for Science and Engineering)</td>
<td>1</td>
</tr>
</tbody>
</table>

One hundred and six students recorded what math course they most recently took prior to their CHEM 4 course. Refer to Table 6 of math course most recently completed.

Table 6: Fall 2009 Number of Students Who Recorded Most Recent Math

<table>
<thead>
<tr>
<th>Math class most recently completed</th>
<th>Number of students (%) who dropped out or failed (received an F) CHEM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS 7A (Pre-Algebra)</td>
<td>1</td>
</tr>
<tr>
<td>Algebra (or LS 10A)</td>
<td>6</td>
</tr>
<tr>
<td>Math 1 (Mathematical Reasoning)</td>
<td>1</td>
</tr>
<tr>
<td>Math 11 (Algebra for College Students)</td>
<td>1</td>
</tr>
<tr>
<td>Algebra 2/Trigonometry (or Math 9)</td>
<td>18</td>
</tr>
<tr>
<td>Statistics (or Stat 1)</td>
<td>28</td>
</tr>
<tr>
<td>Business Finance</td>
<td>1</td>
</tr>
<tr>
<td>Finite Math</td>
<td>2</td>
</tr>
<tr>
<td>Pre-Calculus (or Math 29)</td>
<td>28</td>
</tr>
<tr>
<td>Calculus (or Math 30)</td>
<td>19</td>
</tr>
<tr>
<td>Math 31 (Calculus II)</td>
<td>1</td>
</tr>
</tbody>
</table>
One hundred and fifteen students recorded at which institution they completed their last math course. Sixty-four students (56%) completed their most recent math course in high school, twenty-six students (22%) completed their most recent math course at CSUS, twenty-four students (21%) completed their most recent math course at a junior college, and one student (1%) either completed their most recent math course at another California State University or at a University of California.

Of the one hundred and twenty two students who recorded their grades for math courses they were most recently enrolled in forty students (30%) received an A, thirty-nine students (32%) received a B, thirty-four students (28%) received a C, nine students (7%) received credit, one student (1%) received a D, one student (1%) received an F, and one student (1%) received no credit for the course.

All one hundred and twenty nine students who completed the surveys filled in answers to the second portion of the first survey, questions three through five. Zero students considered themselves “poor” at math, although eleven students (8%) were very concerned with their math skills impacting their chemistry grades. (Table 7)
Table 7: September 2009 CHEM 4 Survey After Completion of First Exam

<table>
<thead>
<tr>
<th>Item</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>3)</td>
<td>0</td>
<td>8</td>
<td>37</td>
<td>74</td>
<td>10</td>
</tr>
<tr>
<td>4)</td>
<td>4</td>
<td>13</td>
<td>41</td>
<td>44</td>
<td>27</td>
</tr>
<tr>
<td>5)</td>
<td>11</td>
<td>20</td>
<td>25</td>
<td>33</td>
<td>40</td>
</tr>
</tbody>
</table>

(Answers that appear to be inconsistent indicated by **boldface**)

Analysis of the second survey found the grade for the first exam without including any bonus points. Of the one hundred and twenty nine students who completed the survey, thirty of the students (23%) scored 90% or better, forty-one of the students (32%) scored 80-89%, twenty-seven of the students (21%) scored 70-79%, seventeen of the students (13%) scored 60-69%, eight of the students (6%) scored 50-59%, four of the students (3%) scored 40-49%, and two of the students (2%) scored 30-39% on the first exam (not including any bonus points).

The students were then asked how many points they received on the isotope calculation for antimony. The question was worth seven points on the exam. Of the one hundred and twenty seven students who recorded the point value they received, sixty-nine of the students (54%) earned the full 7 points, nine students (7%) received 6 points, nine students (7%) received 5 points, one students (1%) received 4 points, none of the
students received 3 points, four students (3%) received 2 points, thirteen students (10%) received 1 points, and twenty three students (18%) received zero points. If the students did not receive the full seven points, they were to write down the source of their errors. Of the fifty-nine students who recorded that they did not receive full credit on the isotope calculation, fifty-two students recorded the source of their errors. Of all the errors recorded, the most common was that the students forgot the equation. 10 students “forgot the equation” to use, 4 students “switched their answers” for the two separate isotopes or “could not set-up the problem”, 3 students “switched x and y in the equation”, solved the problem by “a different method” or “did not set-up the problem correctly”, 2 students “did not review enough”, “did not finish the problem”, “forgot how to solve for multiple variable equations”, “did not study”, “forgot the percentage sign”, or “did not show their work”, 1 student each recorded that they “flopped”, “went blank”, “froze”, “winged it”, “did not cross out old work”, “did not have a calculator”, “did not use the correct mass number”, “did not do the worksheet”, “not sure” of how they missed the points, went “too fast”, “did not pay attention”, “forgot to place their answer in the box”, and performed a “small error”.

The last four questions of the second survey referred to the mathematics worksheet #1 and calculating atomic mass. Of the one hundred and twenty seven students who answered question nine (the first of the four questions) which asked for the students to put a check mark next to the box that describes when they completed the worksheet, seventy-six of the students (60%) checked “In time to earn the 5 bonus points”, ten of the students (8%) checked “Before the exam (but too late to earn the 5
bonus points)”, and forty-one of the students (32%) checked “I did not complete the worksheet”. Question ten asked the students how long it took for them to complete the worksheet. Of the eighty-six students who recorded that they completed the worksheet, sixty-three students (73%) completed it in less than one hour, twenty-two students (26%) completed it in 1-2 hours, and one student (1%) completed it in 2-3 hours. The eleventh question asked the students how they used the worksheet answer key that was posted online after the due date for the worksheet. Of the one hundred and seven students who replied, forty-eight of the students (45%) checked “I did not look at the answer key”, forty of the students (37%) checked “I looked at the answer key and saw I had done the worksheet correctly”, fifteen of the students (14%) checked “I looked at the answer key, saw I did it incorrectly, and used the key to understand my mistake(s)”, and four students (4%) checked “I looked at the answer key, saw I did it incorrectly, but could not figure out from the key how to correct my mistake(s)”. The last question on the asked the students to describe what they thought of the mathematics worksheet overall, checking all the answers that applied. Refer to Table 8 to find the percentages of each answer selected by one hundred and twenty-seven students.
Table 8: Fall 2009 Students’ Responses to Math Worksheet #1 Survey Question 12

<table>
<thead>
<tr>
<th>What the student thought of the mathematics worksheet</th>
<th>Number of students who replied (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did the worksheet primarily for the 5 bonus points.</td>
<td>61 (48%)</td>
</tr>
<tr>
<td>The Worksheet was very useful for me.</td>
<td>58 (46%)</td>
</tr>
<tr>
<td>I did better on the exam because of the worksheet.</td>
<td>46 (36%)</td>
</tr>
<tr>
<td>The mathematics covered on the worksheet was too basic for me.</td>
<td>28 (22%)</td>
</tr>
<tr>
<td>I would do similar worksheets in the future only if they were for bonus points.</td>
<td>53 (42%)</td>
</tr>
<tr>
<td>I would do similar worksheets in the future only if I was required to.</td>
<td>30 (24%)</td>
</tr>
<tr>
<td>I would do similar worksheets in the future even if they were not for bonus points.</td>
<td>72 (57%)</td>
</tr>
<tr>
<td>Other comments:</td>
<td>11 (9%)</td>
</tr>
</tbody>
</table>

Spring 2010 Survey Results

During the first lecture in spring 2010, which this research was done, the faculty member, Dr. Paradis, who was instructing CHEM 4, administered a survey to students enrolled in the course. Dr. Paradis told the students that the survey was to help in the improvement of mathematics worksheets for CHEM 4 semester. He emphasized that the answers given on the survey will not impact their grade in the course. The survey was printed on one side of a single page of paper.

One hundred and eighty-one completed surveys were received. All responses were tallied. Ninety-seven students are currently in a math course and recorded what math course they are currently enrolled in at CSUS, this information is recorded in Table 9 along with number of these students who dropped out of or failed CHEM 4.
Table 9: Spring 2010 Number of Students Currently Enrolled in Math

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Math class currently enrolled in at CSUS</th>
<th>Number of students (%) who dropped out or failed (received an F) CHEM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>LS 7A (Pre-Algebra)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Math 9 (Essentials of Algebra and Trigonometry)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Math 11 (Algebra for College Students)</td>
<td>9 (30%)</td>
</tr>
<tr>
<td>1</td>
<td>Math 19B</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Stat 1 (Introduction to Statistics)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Math 26A (Calculus I Social and Life Sciences)</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Math 29 (Pre-Calculus Mathematics)</td>
<td>15 (23%)</td>
</tr>
<tr>
<td>8</td>
<td>Math 30 (Calculus I)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Math 31 (Calculus II)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Math 45 (Differential Equations for Science and Engineering)</td>
<td></td>
</tr>
</tbody>
</table>

One hundred and sixty-three students recorded what math course they most recently took prior to their CHEM 4 course. Refer to Table 10 for number of students who recorded most recent math completed and number of these students who dropped out or failed CHEM 4.

Table 10: Spring 2010 Number of Students Who Recorded Most Recent Math

<table>
<thead>
<tr>
<th>Number of students</th>
<th>Math class most recently completed</th>
<th>Number of students (%) who dropped out or failed (received an F) CHEM 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>LS 7A (Pre-Algebra)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Algebra (or LS 10A)</td>
<td>18 (35%)</td>
</tr>
<tr>
<td>10</td>
<td>Math 1(Mathematical Reasoning)</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Algebra 2/Trigonometry (or Math 9)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Math 11(Algebra for College Students)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Math 15H (Honors Math Reasoning)</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>Statistics (or Stat 1)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Math 24 (Modern Business Math)</td>
<td>24 (22%)</td>
</tr>
<tr>
<td>41</td>
<td>Pre-Calculus (or Math 29)</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Calculus (or Math 30)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Math 31 (Calculus II)</td>
<td></td>
</tr>
</tbody>
</table>
One hundred and seventy-one students recorded at which institution they completed their last math course. Thirty-eight students (22%) completed their most recent math course in high school, one hundred and two students (60%) percent completed their most recent math course at CSUS, and thirty-one students (18%) completed their most recent math course at a junior college.

Of the one hundred and seventy-seven students who recorded their grades for math courses they were most recently enrolled in, thirty-five students (20%) received an A, sixty-five students (37%) received a B, thirty-seven students (21%) received a C, twelve students (7%) received a D, twenty-two students (12%) received credit, and six students (3%) received no credit for the course.

All one hundred and eighty-one students who completed the surveys filled in answers to the second portion of the first survey, questions three through five. One student considered themselves “poor” at math, although ten students were very concerned with their math skills impacting their chemistry grades. (Table 11)
During the lecture after the first exam in spring 2010, the second survey was given. Dr. Paradis told the students that the surveys were to help in the improvement of Worksheet #1 for subsequent CHEM 4 semesters. He emphasized that the answers given on the surveys will not impact their grade in the course. The survey was placed on one page.

The four questions of the second survey referred to the mathematics worksheet #1 and calculating atomic mass. Of the one hundred and forty students who answered the first question which asked for the students to put a check mark next to the box that describes when they completed the worksheet, one hundred and two of the students (73%) checked “In time to earn the 5 bonus points”, nineteen students (13.5%) checked “Before the exam (but too late to earn the 5 bonus points)”, and nineteen students (13.5%) checked “I did not complete the worksheet”. The second question asked the

| Table 11: Spring 2010 CHEM 4 Survey After Completion of First Exam |
|------------------------|--------|--------|--------|--------|--------|
| (n=181)                | 1      | 2      | 3      | 4      | 5      |
| -Items concern attitude toward math |        |        |        |        |        |
| 3) On a scale of 1 to 5 with “1” = “poor” and “5” = “excellent”, how good do you consider yourself at math? | 1      | 6      | 74     | 87     | 10     |
| 4) On a scale of 1 to 5 with “1” = “really dislike” and “5” = “really like”, how much do you enjoy math? | 11     | 38     | 59     | 76     | 20     |
| 5) On a scale of 1 to 5 with “1” = “very concerned” and “5” = “not at all concerned”, how worried are you about your math skills impacting your chemistry grades? | 10     | 27     | 52     | 57     | 36     |

(Answers that appear to be inconsistent indicated by **boldface**)

During the lecture after the first exam in spring 2010, the second survey was given. Dr. Paradis told the students that the surveys were to help in the improvement of Worksheet #1 for subsequent CHEM 4 semesters. He emphasized that the answers given on the surveys will not impact their grade in the course. The survey was placed on one page.

The four questions of the second survey referred to the mathematics worksheet #1 and calculating atomic mass. Of the one hundred and forty students who answered the first question which asked for the students to put a check mark next to the box that describes when they completed the worksheet, one hundred and two of the students (73%) checked “In time to earn the 5 bonus points”, nineteen students (13.5%) checked “Before the exam (but too late to earn the 5 bonus points)”, and nineteen students (13.5%) checked “I did not complete the worksheet”. The second question asked the
students how long it took for them to complete the worksheet. Of the one hundred and twenty-one students who recorded that they completed the worksheet, eighty students (66%) completed it in less than one hour, thirty-five students (29%) completed it in 1-2 hours, and six students (5%) completed it in 2-3 hours. The third question asked the students how they used the worksheet answer key that was posted online after the due date for the worksheet. Of the one hundred and forty students who replied, forty-three of the students (31%) checked “I did not look at the answer key”, eight students (6%) checked “I looked at the answer key and saw I had done the worksheet correctly”, fifty-three students (37%) checked “I looked at the answer key, saw I did it incorrectly, and used the key to understand my mistake(s)”, and thirty-six students (26%) checked “I looked at the answer key, saw I did it incorrectly, but could not figure out from the key how to correct my mistake(s)”. The last question on the asked the students to describe what they thought of the mathematics worksheet overall, checking all the answers that applied. Refer to Table 12 to for students’ responses to math Worksheet #1 survey for question 4.

Table 12: Spring 2010 Students’ Responses to Math Worksheet #1 Survey Question 4

<table>
<thead>
<tr>
<th>What the student thought of the mathematics worksheet</th>
<th>Number of students (%) who replied</th>
</tr>
</thead>
<tbody>
<tr>
<td>I did the worksheet primarily for the 5 bonus points.</td>
<td>90 (64%)</td>
</tr>
<tr>
<td>The Worksheet was very useful for me.</td>
<td>87 (62%)</td>
</tr>
<tr>
<td>I did better on the exam because of the worksheet.</td>
<td>85 (61%)</td>
</tr>
<tr>
<td>The mathematics covered on the worksheet was too basic for me.</td>
<td>21 (15%)</td>
</tr>
<tr>
<td>I would do similar worksheets in the future only if they were for bonus points.</td>
<td>64 (46%)</td>
</tr>
<tr>
<td>I would do similar worksheets in the future only if I was required to.</td>
<td>56 (40%)</td>
</tr>
<tr>
<td>I would do similar worksheets in the future even if they were not for bonus points.</td>
<td>83 (59%)</td>
</tr>
<tr>
<td>Other comments:</td>
<td>18 (13%)</td>
</tr>
</tbody>
</table>
Survey Discussion

Two surveys were given to the fall 2009 and spring 2010 CHEM 4 students. The first survey was a tool to determine how many students have completed the math most needed to be successful in CHEM 4 and if students entering into CHEM had math anxiety. Three hundred and ten total students completed the first survey in fall 2009 and spring 2010.

Fall 2009 Surveys

The first survey determined that twenty-five students enrolled in CHEM 4 in fall 2009, were currently enrolled in pre-algebra or algebra. Knowledge of algebra is required to be successful in many of the math related topics in the course. Of these twenty-five students, only eighteen completed the course. 29% either dropped out or failed (received a F). Of the students currently enrolled in a math class more advanced than algebra, four students (11%) either dropped out or failed.

Looking over the math courses most recently taken by the students enrolled in CHEM 4 in fall 2009, who completed the survey, twenty-seven students most recently took pre-algebra or algebra. Of these twenty-seven students, only thirteen completed the course. The remaining fourteen students (52%) dropped out or failed the course. Of the seventy-nine students who more recently took a math class more advanced than algebra, seven students (9%) either dropped out or failed CHEM 4. These data have a strong
correlation to what math level a student has achieved and how well they will perform in the CHEM 4 course.

The next section of the first survey given was focused on math anxiety. These results appeared to support that even though students have competent math skills, they still felt anxious about the subject. As only 8 students reported being less than average at math, 31 students were very concerned that their math skills will impact their chemistry grade.

The second survey was given to aid in the improvement of Worksheet #1. The first question asked the students to record their score without any bonus points added, resulting in 23% of the students receiving an A on the exam. 54% of the students who took the survey gained all 7 points on the Atomic Mass Calculation problem. The students who missed points on the question recorded why. Hopefully this was helpful to some of the students, as if they made small errors; they would be reminded of them and maybe would not make these errors later on. A few responses that stick out are “flopped”, “froze”, and “went blank”, as these are all forms of math anxiety at work during an exam.

The second part of the survey had the students check all answers that applied to their experience with Worksheet #1. The majority of the students who took the survey completed the worksheet in time for the 5 bonus points. It took the majority of the students less than 1 hour to complete the worksheet. That is good, as the worksheet is supposed to aid the student in learning and would not want to take away from their time
needing to be spent reading the textbook or doing homework. Only 55% of the students checked the answer key on-line to check their answers. Of these responses were many students who did not do the worksheet. This was good for them, but the students who did the worksheet, but did not check the key would not have known if they did the worksheet correctly, as a graded copy was not returned to them. The largest response that the students had about the worksheet was that they would complete more if they were not given bonus points. This was very encouraging, along with the handwritten comments that the worksheet was very helpful.

Spring 2010 Surveys

The first survey determined that thirty students enrolled in CHEM 4 in spring 2010, were currently enrolled in pre-algebra or algebra. Of these thirty students, only twenty-one students completed the course. 30% either dropped out or failed. Of the students currently enrolled in a math class more advanced than algebra, fifteen students (23%) either dropped out or failed CHEM 4.

Looking over the math courses most recently taken by the students enrolled in CHEM 4 in spring 2010, who completed the survey, fifty-two students most recently took pre-algebra or algebra. Of these fifty-two students, only thirty-four completed the course. The remaining eighteen students (35%) dropped out or failed the course. Of the one hundred and one students who more recently took a math class more advanced than algebra, twenty-four students (22%) either dropped out or failed CHEM 4. These data
display a slight correlation between how well a student will perform in CHEM 4 and the most recent math they have completed.

The next section of the first survey given was focused on math anxiety. These results appeared to support that even though students have competent math skills, they still fell anxious about the subject. As only 7 students reported being less than average at math, 37 students were very concerned that their math skills will impact their chemistry grade.

The second survey was given to aid in the improvement of Worksheet #1. The students checked all that applied to their experience with Worksheet #1. The majority of the students who took the survey completed the worksheet in time for the 5 bonus points. It took the majority of the students less than 1 hour to complete the worksheet. It was good that it only took the majority of the students a short period of time to complete the worksheet, as the worksheet is supposed to aid the student in learning and would not want to take away from their time needed to be spent reading the textbook or doing homework. 63% of the students checked the answer key on-line to check their answers, half of these students recorded that even though they looked at the key, they could not figure out how to correct their answers. This is a good explanation to why students who did the worksheet did not receive full credit for the exam related questions. For spring 2010, the largest response that the students had about the worksheet was that they completed it in time to receive the five bonus points. The second largest response was that the students
felt that the worksheet was helpful. It is encouraging to hear that the students thought the worksheet was helpful.

Introductory Math Quiz

Introductory Math Quiz Results

Fall 2009 Introductory Math Quiz Results: During the first lecture in fall 2009, which this research was done, the faculty member, Dr. Paradis, who was instructing CHEM 4, administered an Introductory Math Quiz (Appendix C) to students enrolled in the course. Dr. Paradis told the students that the quiz was to aid in understanding what specific math help would be needed for their success in the course. He emphasized that five extra credit points would be awarded to any students who received a score of 90% or better on the quiz. The incentive was to encourage students to perform at their greatest ability. The fifteen question quiz was printed front and back on a single sheet of paper.

One hundred and thirty eight completed quizzes were received. All responses were tallied. Of the one hundred and thirty eight students who completed the quiz, thirty-four of the students (25%) received a score of 93% or greater on the quiz (or answered 14 or 15 questions correctly). Refer to figure 3 for the number of correct answers per each student who took the math quiz.
The questions most frequently missed by the students were questions 1, 2, 3, and 5. This was determined by a quick analysis, as the students were returned their quizzes during the following lecture. This proved a lack of judgment on the researcher’s part, so the completed quizzes received in the spring 2010 semester, were not returned to the students so further analysis could be taken.

**Spring 2010 Introductory Math Quiz Results:** During the first lecture in spring 2010, which this research was done, the faculty member who was instructing CHEM 4 administered an Introductory Math Quiz to students enrolled in the course. Dr. Paradis told the students that the quiz was to help in aiding in specific math help that would be needed for the course. He emphasized that five extra credit points would be awarded to
any students who received a score of 90% or better on the quiz. The incentive was to encourage students to perform at their greatest ability. The fifteen question quiz was printed front and back on a single sheet of paper.

Two hundred and twenty two quizzes were received. Table 13 displays the number of students who received each question correct.

Table 13. Number of Students Receiving Each Question on the Math Quiz Correct in Spring 2010

<table>
<thead>
<tr>
<th>Question</th>
<th>Number of Students (%) getting question correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Which of these is the largest number?</td>
<td>144 (65%)</td>
</tr>
<tr>
<td>2. Which of these is the largest number?</td>
<td>131 (59%)</td>
</tr>
<tr>
<td>3. Which of the following is equal to 6,327?</td>
<td>204 (92%)</td>
</tr>
<tr>
<td>4. A proton has a +1 charge, an electron has a -1 charge, and a neutron has 0 charge. What is the total charge on an atom that is made up of 12 protons, 10 electrons, and 11 neutrons?</td>
<td>182 (82%)</td>
</tr>
<tr>
<td>5. Solve $\frac{a}{b + x} = c$ for $x$.</td>
<td>131 (59%)</td>
</tr>
<tr>
<td>6. Solve the following equation for $x$:</td>
<td>189 (85%)</td>
</tr>
<tr>
<td>$25 = (54)(x-1) + (18)(x)$</td>
<td></td>
</tr>
<tr>
<td>7. Convert 0.7 L to cups.</td>
<td>157 (66%)</td>
</tr>
<tr>
<td>Note: 4 cups = 1 qt, 1.057 qt = 1 L</td>
<td></td>
</tr>
<tr>
<td>8. A grain of sand is found to weigh $3.0 \times 10^{-3}$ g. Which of the following mathematical operations could you perform to determine how many grains of sand it would take to weigh $4.5 \times 10^4$ g?</td>
<td>138 (62%)</td>
</tr>
<tr>
<td>9. Convert a temperature of -20 °C to °F.</td>
<td>144 (65%)</td>
</tr>
<tr>
<td>Note: $^\circ C = \left(\frac{^\circ F - 32}{1.8}\right)$</td>
<td></td>
</tr>
<tr>
<td>10. The chemical formula for magnesium nitrate is Mg(NO$_3$)$_2$. How many total atoms are present in 1 unit of magnesium nitrate?</td>
<td>107 (48%)</td>
</tr>
<tr>
<td>11. One mole of oxygen atoms has a mass of 16.00 g. What is the mass of one mole of ozone molecules? Note: the chemical formula for ozone is O$_3$.</td>
<td>175 (79%)</td>
</tr>
</tbody>
</table>
12. A newly discovered compound is found to have only carbon, hydrogen, and oxygen. If a 4.5 g sample of the compound is found to have 0.56 g of hydrogen and 1.2 g of oxygen, what percentage of the mass of the sample is due to the carbon?

13. Which of the following pitchers of KoolAid will taste the strongest?

14. What percentage of the number of coins in your pocket are dimes if you have five dimes, two nickels, seven pennies, and one quarter?

15. What is the coefficient in front of the H2O when the following chemical equation is balanced?

<table>
<thead>
<tr>
<th>12.</th>
<th>A newly discovered compound is found to have only carbon, hydrogen, and oxygen. If a 4.5 g sample of the compound is found to have 0.56 g of hydrogen and 1.2 g of oxygen, what percentage of the mass of the sample is due to the carbon?</th>
<th>118 (53%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.</td>
<td>Which of the following pitchers of KoolAid will taste the strongest?</td>
<td>151 (68%)</td>
</tr>
<tr>
<td>14.</td>
<td>What percentage of the number of coins in your pocket are dimes if you have five dimes, two nickels, seven pennies, and one quarter?</td>
<td>182 (82%)</td>
</tr>
<tr>
<td>15.</td>
<td>What is the coefficient in front of the H2O when the following chemical equation is balanced? (_ \text{CH}_4(g) + _ \text{O}_2(g) \rightarrow _ \text{CO}_2(g) + _ \text{H}_2\text{O}(g))</td>
<td>135 (61%)</td>
</tr>
</tbody>
</table>

Of the two hundred and twenty two students who turned in the quiz, twenty-six of the students received the 5 bonus points. In other words, 12% received 14 or 15 questions correct out of 15 questions.

**Discussion of Introductory Math Quiz**

The introductory math quiz was given to the students enrolled in CHEM 4 to determine what math skills the majority of the students were missing prior to the start of the fall 2009 and spring 2010 semesters. The results of the math quiz given in fall 2009 helped with the formation of the 4 math worksheets.

**Fall 2009 Discussion of Introductory Math Quiz:** The questions most frequently missed by the students in the fall were questions 1, 2, 3, and 5. The first question on the quiz required knowledge of scientific notation. It was determined to create a worksheet instructing the student on the background knowledge and the steps to write a number in scientific notation. The second question on the quiz required knowledge of a base number and an exponent, as well as understanding fractions. This supported a worksheet
about scientific notation describing base numbers and exponents. It also supported a worksheet on atomic mass calculations, because atomic mass calculations required knowledge of percentages (or fractions). The third question once again supported the fact that students had difficulty writing numbers in scientific notation and that a worksheet on scientific notation would be helpful. Question five was an algebraic equation asking the students to solve for “x”. The difficulty the students had with this particular problem, prompted a worksheet on percent mass composition and also supported a worksheet on atomic mass, as both calculations require solving for x.

**Spring 2010 Discussion of Introductory Math Quiz:** The Introductory Math Quiz was given in spring 2010, so additional analysis could be done to determine what CHEM 4 math skills the students who entered the course were lacking. The math worksheets had already been drafted, so the data was collected to see if the students would benefit from the previous created worksheets. It was also given, so the students would understand what math skills would be required of them for the course, so if they had difficulty on certain problems, they could study those topics further to be successful in the course.

According to the data, less than 70% of the students selected the correct answer for questions 1, 2, 5, 7, 8, 9, 10, 12, 13, and 15. With one hundred and forty-four of the students (65%) answering number one correct, one hundred and thirty-one of the students (59%) answering number two correct, and one hundred and thirty-one of the students (59%) answering number five correct, the worksheets deemed to be appropriate for the spring 2010 students as well. Questions seven and nine were conversion problems, so if additional worksheets were to be created, a worksheet on converting would prove helpful.
Question eight requires knowledge of scientific notation, so the current worksheet will help with this lacking skills. Only one hundred and seven of the students (48.5%) received credit for the tenth question that asked how many atoms are present in 1 unit of magnesium nitrate. Part of the percent composition worksheet will help aid in answering this question. Question twelve is simply a mass percent problem, deeming the worksheet appropriate. Question thirteen requires knowledge of fractions, which are explained in the atomic mass worksheet. And lastly question fifteen is a balancing equation question. It would have been beneficial to create a balancing equation worksheet as well.

With only thirty-four students (25%) in fall 2009 and twenty-six students (12%) in spring 2010 having a strong understanding of the math skills required for the CHEM 4 course, it is concluded that some form of math help would be beneficial for the students to be successful.

Worksheet #1 Calculating Atomic Mass

Results of Worksheet #1: Calculating Atomic Mass Results

Two weeks prior to the first exam in the fall 2009 and spring 2010 semesters, when this research was done, the faculty member who was instructing CHEM 4 posted Worksheet #1: Calculating Atomic Mass (Appendix D) on the class website. Dr. Paradis told the students during lecture that they could find Worksheet #1 on the class website. To encourage the students to complete Worksheet #1, Dr. Paradis offered five bonus points to students who turned in the completed worksheet one week prior to the first exam.
Fall 2009 Results of Worksheet #1: Eighty-one completed worksheets were received in fall 2009. Of the eighty-one students who turned in the first worksheet, forty-four students (54%) received an A, twenty students (24%) received a B, nine students (11%) received a C, two students (3%) received a D, and six students (8%) received an F on Exam 1. Of the remaining sixty-five students who did not complete the worksheet, twelve students (18.5%) received an A, nineteen students (29%) received a B, ten students (15.5%) received a C, twelve (18.5%) received a D, and twelve (18.5%) received an F on Exam 1.

Exam 1 given in the fall 2009 semester contained a written atomic mass calculation problem worth 7 points. Because the problem was a written problem, the students had the opportunity to receive partial credit for any correct portion of their answer. The question asked, “The metalloid, antimony (Sb) has two naturally occurring isotopes. The lighter isotope, Sb-121, has a mass of 120.90 amu. The other isotope, Sb-123 has a mass of 122.90 amu? What are the percent abundances of the two isotopes. You must show all of your work to receive credit. Your final answer must be written in the provided box.” [Answer: Sb-121 = 55%, Sb-123 = 45%] This is the only problem discussed in this results and discussion section that allowed for partial points; the remaining problems discussed are multiple choice questions, allowing no partial point option to the students. Analysis of the points awarded to each of the students was done to compare the scores of students who completed Worksheet #1 on the atomic mass calculation to the scores of the students who did not turn in a completed Worksheet #1.
The number of points awarded to the students who took Exam 1 in fall 2009 is displayed in Table 14.

Table 14: Fall 2009 Number of Students Earning a Score of 0-7 Points

<table>
<thead>
<tr>
<th>Points received on Atomic Mass Calculation</th>
<th>Number of students (%) who turned in completed Worksheet #1</th>
<th>Number of students (%) who did not turn in completed Worksheet #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>53 (65%)</td>
<td>26 (40%)</td>
</tr>
<tr>
<td>6</td>
<td>7 (9%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>5</td>
<td>8 (10%)</td>
<td>5 (8%)</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>2 (3%)</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1 (1%)</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>7 (8%)</td>
<td>11 (16%)</td>
</tr>
<tr>
<td>0</td>
<td>3 (4%)</td>
<td>22 (34%)</td>
</tr>
</tbody>
</table>

Additional analysis was made of the twenty-seven students who completed Worksheet #1, but did not receive the full 7 points on the atomic mass calculation on Exam 1. This additional analysis was done to determine what math errors the students made on the math calculation on the exam. Table 15 shows the possible errors made and the number of students who made them.

Table 15: Fall 2009 Possible Errors Made on Atomic Mass Calculation

<table>
<thead>
<tr>
<th>Possible errors made on atomic mass calculation</th>
<th>Number of students (%) who turned in Worksheet #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major math errors</td>
<td>11 (41%)</td>
</tr>
<tr>
<td>Wrote correct equation, but incorrectly solved equation</td>
<td>7 (26%)</td>
</tr>
<tr>
<td>Minor math errors</td>
<td>5 (19%)</td>
</tr>
<tr>
<td>Transposed answers for the two isotope percentages</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>Did not show work</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Left answer blank</td>
<td>1 (3%)</td>
</tr>
</tbody>
</table>

During the fall 2009 semester, each worksheet turned in was evaluated for the number of students who answered the exam related questions correctly on the worksheet. This was to determine if students who correctly completed the worksheet received a
higher percentage of points on the worksheet related problem(s) compared to the students who turned in the worksheet, but incorrectly answered the exam related questions on the worksheet. Of the eighty-one who completed Worksheet #1 in the fall 2009, fifty-seven (70%) of them had the correct answers for the atomic mass calculation problems on the last page. The average point value these fifty-seven students (70%) received on exam 1 out of the 7 possible points for the atomic mass calculation was 6.1 points (87%). Of the remaining twenty-four students (30%) who turned in the worksheet, but incorrectly answered the atomic mass calculation problems on the last page, the average point value received on exam 1 out of the 7 possible points for the atomic mass calculation was 4.9 points (70%).

In order to see if Worksheet #1 helped in the retention of the math material, the answers given to the atomic mass calculation on the fall 2009 final exam were analyzed. Seventy-six students who turned in Worksheet #1 took the final exam. The final exam multiple choice question asked, “Silicon has three naturally occurring isotopes, two of which are Si-28 (27.98 amu) and Si-29 (28.98 amu). If Si-28 has a 92.23% abundance and Si-29 has a 4.68% abundance, what is the mass of the third isotope?” [Answer: 30.03 amu] Of these seventy-six students, fifty-two students (69%) selected the correct answer. Of the remaining fifty students who took the final, but did not turn in a completed Worksheet #1, thirty-five students (70%) selected the correct answer. Overall 69% of the students enrolled in Dr. Paradis’ fall 2009 CHEM 4 course selected the correct answer for the Worksheet #1 question on the final exam.
Spring 2010 Results of Worksheet #1: One hundred and fifty students turned in Worksheet #1 in the spring of 2010. Of the one hundred and fifty students who turned in the first worksheet, twenty-four students (16%) received an A, forty-five students (30%) received a B, thirty-eight students (25%) received a C, twenty-four students (16%) received a D, and nineteen students (13%) received an F on the first exam. Of the eighty-two students who did not turn in a worksheet, two students (2%) received an A, fourteen students (17%) received a B, nineteen students (23%) received a C, seventeen students (21%) received a D, and thirty students (37%) received an F on the first exam.

There were two multiple choice questions that contained atomic mass calculations on Exam 1 given to the spring 2010 CHEM 4 students. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #1 performed on the atomic mass calculations to the students who did not turn in a completed Worksheet #1. Table 16 displays the number of students who selected the correct answer for both the worksheet related questions on Exam 1.

Table 16: Exam 1: Spring 2010 Number of Students Who Selected the Correct Answers for Worksheet #1 Related Questions

<table>
<thead>
<tr>
<th>Exam 1: Spring 2010 Worksheet #1 related questions</th>
<th>Number of students (%) who selected the correct answer who turned in Worksheet #1</th>
<th>Number of students (%) who selected the correct answer who did not turn in Worksheet #1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubidium has two naturally occurring isotopes. One isotope, RB-85, has a mass of 84.91 amu and a natural abundance of 72.17%. What is the mass of the other isotope? [Answer: 86.92 amu]</td>
<td>128 (85%)</td>
<td>34 (41%)</td>
</tr>
<tr>
<td>Naturally occurring lithium has two isotopes: lithium-6 with a mass of 6.0151 amu and lithium-7 with a mass of 7.0160 amu. Determine the percent abundance of lithium-6? [Answer: 7.5%]</td>
<td>98 (65%)</td>
<td>49 (60%)</td>
</tr>
</tbody>
</table>
For the spring of 2010, rather than comparing how the students who correctly answered the exam related questions on the worksheets compared to the students who incorrectly answered the exam related questions on the worksheets, analysis of average percentages of worksheet related questions correct were compared to the average percentages of non-worksheet related questions correct for students who completed the worksheets compared to those who did not do the worksheets. (Table 17)

Table 17: Spring 2010 Exam 1 Average Percentages of Worksheet #1 Related Questions Correct Compared to Non-Worksheet #1 Related Exam Questions Correct

<table>
<thead>
<tr>
<th></th>
<th>Average percentage of Worksheet #1 related questions</th>
<th>Average percentage of non-Worksheet #1 related questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who turned in</td>
<td>76%</td>
<td>76%</td>
</tr>
<tr>
<td>Worksheet #1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students who did not turn in</td>
<td>51%</td>
<td>67%</td>
</tr>
<tr>
<td>Worksheet #1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In order to see if Worksheet #1 helped in the retention of the math material, the answers given to the atomic mass calculation on the spring 2010 final exam were analyzed. One hundred and thirty-eight students who turned in Worksheet #1 took the final exam. The final exam multiple choice question asked, “Silicon has three naturally occurring isotopes, two of which are Si-28 (27.98 amu) and Si-29 (28.98 amu). If Si-28 has a 92.23% abundance and Si-29 has a 4.68% abundance, what is the mass of the third isotope?” [Answer: 30.03 amu] Of these one hundred and thirty-eight students, ninety-nine students (72%) selected the correct answer. Of the remaining sixty-one students who took the final, but did not turn in a completed Worksheet #1, thirty-eight students (62%) selected the correct answer. Overall 69% of the students enrolled in Dr. Paradis’
Spring 2010 CHEM 4 course selected the correct answer for the Worksheet #1 question on the final exam.

Fall 2008 Results without Implementing Worksheet #1: All students in Dr. Paradis’ fall 2009 and spring 2010 CHEM 4 lecturers were given the option to complete Worksheet #1. All results collected were a comparison between students who turned in the worksheet with the students who did not turn in the worksheet. It was not determined if the students who did not turn in a worksheet actually did not complete the worksheet on their own before the exam. Because of this the Worksheet #1 related question on the final exam for Dr. Paradis’ fall 2008 CHEM 4 semester was analyzed, as none of the students enrolled in the fall 2008 semester were offered the opportunity to complete Worksheet #1. The Worksheet #1 related question on the fall 2008 final exam was, “Silicon has three naturally occurring isotopes, Si-28 (27.977 amu), Si-29 (28.977 amu), and Si-30 (29.974 amu). If Si-29 has a 4.69% abundance, what is the % (to 3 sig figs) of Si-28?” [answer: 92.0%] Of the one hundred and eighty-eight students who took the CHEM 4 fall 2008 final exam, seventy-seven students (41%) selected the correct answer.

Discussion of Worksheet #1: Calculating Atomic Mass

Correctly calculating an atomic mass problem was the goal of the first worksheet (Appendix D). The worksheet acted as a personal tutor to any student who may have forgotten or never learned how to convert a number written as a fraction or a decimal into a percentage, solve a single variable equation, and solve a multiple variable equation.
Two hundred and thirty-two students completed Worksheet #1 and handed it in a week prior to the first exam in fall 2009 and spring 2010.

Fall 2009 Discussion of Worksheet #1: Looking over the results of the first exam, Worksheet #1 appeared to be helpful to the students who completed it. Reviewing fall 2009 data, 25% more students who turned in a completed worksheet received full credit on the atomic mass calculation problem on exam 1, than students who did not turn in a completed worksheet. 5% more students who turned in a completed worksheet received partial credit on the atomic mass calculation, than students who did not turn in the worksheet. And 30% more students who did not turn in the worksheet received zero points, compared to those students who did complete the worksheet. The success of the students who turned in Worksheet #1 on the 7 point atomic mass calculation resulted in 36% more students receiving an A on the first exam compared to those students who did not turn in a completed worksheet.

The fact that the atomic mass calculation on the first exam required a hand written answer allowed for further analysis. Unlike a multiple choice question, where a student can either get the question right or wrong, a written problem enables the student to receive partial credit. It is also helpful to see what math errors students frequently make.

Of the students who completed the worksheet, but did not receive full credit for the first exam’s atomic mass calculation question, eleven students (41%) made major math errors. These errors included students solving for $x$ in the equation $x + y = 1$, as $x = y - 1$, resulting in a wrong answer. Another major error included adding a negative and positive integer incorrectly, simply adding the numbers together without regarding that
one of them has a negative sign in front of it, this resulted in a lot smaller number when solving for “y”. These students may have learned the procedure of how to go about solving an atomic mass calculation, but the basic background of Worksheet #1 may not have been basic enough for them. Referring to constructivism, these students may not have the basic structure the worksheet started building from, such as skills of adding negative integers.

Another seven students (26%) who completed the worksheet, but did not receive full credit wrote the correct equation to solve the problem, but could not complete the operations to solve the equation. This is an example of behaviorism, as the students took a piece of information, the equation, given to them in class, in the textbook, and on the worksheet and memorized it. The information was transposed from one place to another without building upon already stored information in their memory. The students possibly did not understand the process of finding all the pieces of the puzzle to ultimately come to a solution. These students did not use the worksheet as a constructivism focused tool that tried to start with the students most basic knowledge of the problem and build upon it, so when they were at the point of writing the equation, they would have all the available parts to place into the equation in order to solve it. These students might also have had anxiety when confronted with a math problem, they may have frozen and wrote the equation and could not think of what else to do. Although these students did not know how to go about solving the atomic mass equation, it is still encouraging that they were able to retain some knowledge presented to them prior to the exam.
Another five students (19%) who completed the worksheet, but did not receive full credit made minor math errors. These errors included finding the percentage of one isotope and not correctly subtracting it from 100% to find the percentage of the second isotope. This could simply have been done by entering an incorrect number in the calculator. Other minor math errors included students not correctly converting a decimal to a percentage. Minor math errors can be major if they are not caused by miss entering data into a calculator. A student may not know how to convert a decimal into a percentage, but because the decimal moved two places to the left rather than the right, it might appear that the student accidently punched in divided by one hundred, rather than multiply by one hundred. If any of these students were to go back and review their work, it would appear that they could have corrected their errors.

Two students (8%) who completed the worksheet, but did not receive full credit transposed answers for the two isotope percentages. These students solved the problem correctly, but when placing the percentages in the answer boxes, switched them around. Because this was something minor, but also something that would benefit from a reminder, Worksheet #1 was revised to warn the students to place the correct percentage with the correct isotope. It might also be a good idea to have the students look at their answer to see if it made sense. For example, if the molecular weight of the compound is closest to the weight of one of the isotopes, that isotope would have a larger percentage compared to the other isotopes. This is a minor error and does not reflect on any specific learning issue with the material.
One student (3%) who completed the worksheet, but did not receive full credit reported the correct answer, but did not show their work. The interesting thing about not showing work is that this student would have received full credit for the problem if it has been a multiple choice question. Because it was a written as a word problem, the students were expected to show how they obtained their answer. Showing work eliminates suspicion of cheating, as well as aids in the student not making too many calculation errors. Although additional errors can be made if the student writes down the number retrieved from the calculator incorrectly and then uses the number they wrote down in the next calculation. Analysis of this student not showing their work is difficult, they could be performing a plug and chug process in their graphic calculator, not requiring them to write their work before the next step. These students could be lazy, as they know word problems require work to be shown. They could have forgotten to show their work. Or they could be cheating, but that is an assumption far too great for this discussion.

Lastly one student (3%) who did not receive full credit, but completed the worksheet left the problem blank. Without the student explaining why, they could have forgotten how to solve the problem, ran out of time, or had math anxiety, causing them to go blank.

Further analysis of the turned in worksheet was taken to see if the students who correctly completed Worksheet #1 in fall 2009, scored a higher percentage on the worksheet related question on exam 1. Of the eighty-one students who turned in the first worksheet, fifty-seven students (70%) correctly completed the worksheet. The average
point value that these students received for the atomic mass calculation at the end of exam 1, was 1.2 more points (17%) greater than the average point value received by the students who did not correctly complete the Worksheet #1 they turned in. Although the worksheets are not intended to be graded, as there is already enough graded material for the course, it was good to see that correctly completing the worksheet seemed to have a positive effect on the score on the worksheet related question on the test.

It is inconclusive whether Worksheet #1 helped in the retention of the math material on the fall 2009 final exam. It appears that there was an insignificant decrease in the students’ scores who turned in Worksheet #1 to those who did not turn in Worksheet #1 on the worksheet related question on the final exam. It is important to point out that only five students who turned in Worksheet #1 did not take the final, while fifteen of the students who did not turn in Worksheet #1 did not take the final. With this large number of poor students missing, the percentage difference cannot be compared to that of exam 1 for a good representation of the material. It is encouraging that 70% of the students did receive full credit on a math calculation problem on the exam.

**Spring 2010 Discussion of Worksheet #1:** Worksheet #1 appeared to be helpful for the students who completed it in spring 2010 as well. Reviewing the spring data, 44% more students who turned in a completed worksheet selected the correct answer for the first atomic mass calculation problem on exam 1, than students who did not turn in a completed worksheet. 5% more students who turned in a completed worksheet selected the correct answer for the second atomic mass calculation problem on exam 1, than students who did not turn in a completed worksheet. The success of the students who
turned in Worksheet #1, on the atomic mass calculations, resulted in 14% more students receiving an A on the first exam compared to those students who did not turn in a completed worksheet.

Because the atomic mass calculations on the first exam in spring 2010 were multiple choice questions, not much additional analysis can be done. It is interesting that thirty more students (20%) who completed the worksheet solved the first atomic mass calculation correct when compared to the second atomic mass calculation. What is the difference between the two questions that would cause such a decline in correct answers selected? The major difference between the two problems is that the first problem, the Rubidium isotope problem is a single variable calculation, while the second problem, the lithium isotope problem is a multiple variable calculation. Students who completed the worksheet may not have been able to fully understand how to solve a multiple variable problem. Their current math skill knowledge may have hindered them from grasping the more advanced algebra variable problem. This is only a guess, as it is unclear when a student solves a multiple choice question, where the misunderstandings lie.

An analysis of the average percentage of worksheet related problems correct was compared to the average percentage of non-worksheet related problems correct for students who turned in a worksheet compared to students who did not turn in a completed worksheet. Because students of all aptitudes were given the opportunity to turn in the worksheet, this would determine if there was a bigger gap between percentages of correctly answered worksheet related questions to correctly answered non-worksheet related questions. Exam 1 data showed just that. Of the students who completed the
worksheet, they had average equal average percentage correct on worksheet related questions compared to non-worksheet related questions, while the students who did not do the worksheet scored 16% lower on worksheet related questions compared to non-worksheet related questions. One would imagine that the greater percentage difference would be better, but because there were only two worksheet related questions, total of 13 points, and 28 non-worksheet related questions, total of 84 points, it was easier to miss more problems and have a higher percentage on the non-worksheet related questions than to the related. It showed the worksheet was helpful as average percentage for the students who completed the worksheet was 25% higher on the worksheet related problems, and only 9% higher on the non-worksheet related problems compared to those students who did not complete the worksheet.

It appears Worksheet #1 helped in the retention of the math material on the spring 2010 final exam. 10% more students who turned in Worksheet #1 selected the correct answer to the worksheet related question on the final exam given spring 2010. It is important to point out that only twelve students who turned in Worksheet #1 did not take the final, while twenty-two of the students who did not turn in Worksheet #1 did not take the final.

Discussion of Fall 2008 without Implementing Worksheet #1: 28% more students, who were enrolled in CHEM 4 during the fall 2009 and spring 2010 semesters, correctly answered the Worksheet #1 related question on the final exam compared to the students enrolled in CHEM 4 in the fall of 2008 semester.
Results of Worksheet #2: Scientific Notation

Two weeks prior to the second exam in the fall 2009 and spring 2010 semesters, when this research was done, the faculty member, Dr. Paradis, who was instructing CHEM 4, posted Worksheet #2: Scientific Notation (Appendix E) on the class website. Dr. Paradis told the students during lecture that they could find Worksheet #2 on the class website. To encourage the students to complete Worksheet #2, Dr. Paradis offered two bonus points to students who turned in the completed worksheet one week prior to the second exam.

Fall 2009 Results of Worksheet #2: One hundred and one completed worksheets were turned in one week prior to Exam 2 in fall 2009. Of the one hundred and one students who completed the worksheet, thirty-six students (35%) received an A, twenty-seven students (27%) received a B, seventeen students (17%) received a C, five students (5%) received a D, and sixteen students (16%) received an F on Exam 2. Of the thirty-seven students who did not hand in a completed worksheet, five students (14%) received an A, six students (15%) received a B, six students (15%) received a C, six students (15%) received a D, and fourteen students (41%) received an F on Exam 2.

The multiple choice questions on Exam 2 given in the fall of 2009 required knowledge of scientific notation, as all the available answers were written in scientific notation. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #2 performed on the questions requiring scientific notation knowledge to the students who did not turn in a completed
Worksheet #2. Table 18 displays the number of students who selected the correct answers for both the worksheet related questions on Exam 2.

Table 18: Exam 2: Fall 2009 Number of Students Who Selected the Correct Answers for Worksheet #2 Related Questions

<table>
<thead>
<tr>
<th>Exam 2: Fall 2009 Worksheet #2 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #2</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>A classroom has a volume of 285 m³. What is its volume in in³? [Answer: 1.74 x 10⁷ in³]</td>
<td>78 (77%)</td>
<td>28 (76%)</td>
</tr>
<tr>
<td>How many Ms are in 55 ns? [Answer: 5.5 x 10⁻¹⁴ Ms]</td>
<td>65 (64%)</td>
<td>16 (43%)</td>
</tr>
</tbody>
</table>

Of the one hundred and one students who turned in a completed Worksheet #2 in fall 2009, ninety-two students (91%) turned in correctly completed worksheets. Of the ninety-two students who completed the worksheet correctly, seventy-one students (77%) selected the correct answer for the first scientific notation related question on exam 2 and fifty-seven students (62%) selected the correct answer for the second scientific notation related question on exam 2. Of the remaining nine students (9%) who turned in the worksheet, but made errors or left sections blank, seven students (77%) selected the correct answer for the first scientific notation related question of exam 2 and five (55%) selected the correct answer for the second scientific notation related question.

In order to see if Worksheet #2 helped in the retention of the scientific notation knowledge, the answers to the two multiple-choice questions with answers written in scientific notation on the fall 2009 final exam were analyzed. Ninety-six students who turned in Worksheet #2 took the final exam. Table 19 displays the number of students
who selected correct answers for both the worksheet related questions on the fall 2009 final exam.

Table 19: Final Exam: Fall 2009Number of Students Who Selected the Correct Answers for Worksheet #2 Related Questions

<table>
<thead>
<tr>
<th>Question</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #2</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many nm² are in 4.8 inches²? [Answer: 3.1 x 10^{15} nm²]</td>
<td>61 (64%)</td>
<td>17 (57%)</td>
</tr>
<tr>
<td>How many total atoms are there in 15g of copper(II) dihydrogen phosphate? [Answer: 5.3 x 10^{23}]</td>
<td>52 (54%)</td>
<td>13 (43%)</td>
</tr>
</tbody>
</table>

Spring 2010 Results of Worksheet #2: One hundred and fifty-five completed worksheets were turned in one week prior to Exam 2 in spring 2010. Of the one hundred and fifty-five students who turned in a completed worksheet, twelve students (8%) received an A, thirty-one students (20%) received a B, twenty-nine students (19%) received a C, thirty-six students (23%) received a D, and forty-seven (30%) received an F on Exam 2. Of the seventy-one students who did not turn in a completed worksheet, two students (3%) received an A, ten students (14%) received a B, fifteen students (21%) received a C, thirteen students (19%) received a D, and thirty-one students (43%) received an F on Exam 2.

At least two multiple choice questions on Exam 2 given in spring 2010 required knowledge of scientific notation, as the correct answers were written in scientific notation. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #2 performed on the questions
requiring scientific notation to the students who did not turn in a completed Worksheet #2. Table 20 displays the number of students who selected the correct answers for both the worksheet related questions on Exam 2.

Table 20: Exam 2: Spring 2010 Number of Students Who Selected the Correct Answers for Worksheet #2 Related Questions

<table>
<thead>
<tr>
<th>Exam 2: Spring 2010 Worksheet #2 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #2</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Report the answer to this calculation with the correct significant figures: (4.5 x 10^4) x (107-98) [Answer: 4 x 10^5]</td>
<td>79 (51%)</td>
<td>26 (37%)</td>
</tr>
<tr>
<td>57.0 calories are added to a lead block. If the temperature of the lead increases from 53°C to 79°C, what must be the mass, in g, of the lead block? [Answer: 1.3 x 102 g]</td>
<td>98 (63%)</td>
<td>25 (35%)</td>
</tr>
</tbody>
</table>

In order to see if Worksheet #2 helped in the retention of the math material, the answers given to the scientific notation related question on the spring 2010 final exam were analyzed. One hundred and fifty students who turned in Worksheet #2 took the final exam. The final exam multiple choice question asked, “What is the mass (in µg) of a 1.43 x 10-2 millimole sample of potassium chromate?” [Answer: 2.78 x 10^3 µg] Of these one hundred and fifty students, one hundred and nineteen students (79%) selected the correct answer. Of the remaining fifty-two students who took the final, but did not turn in a completed Worksheet #2, thirty-six students (69%) selected the correct answer.
Discussion of Worksheet #2: Scientific Notation

Correctly writing a very large number or very small number in scientific notation was the goal of the second worksheet (Appendix E). The worksheet guided the students through the background knowledge of “to the power of” explaining exponents and base numbers and through the steps of writing numbers in scientific notation. It acted as a personal tutor to any student who may have forgotten or never learned how to write a number in terms of 10’s. Two hundred and fifty-six students completed Worksheet #2 and handed it in a week prior to the second exam in fall 2009 and spring 2010.

Fall 2009 Discussion of Worksheet #2: Looking over the results of the second worksheet, it appeared to be helpful to the students who completed it. Reviewing fall 2009 exam 2 data, while the same percentage of students who turned in the work and did not turn in the worksheet selected the correct answer for the first scientific notation related question, 21% more students who turned in the worksheet selected the correct answer for the second scientific notation related question. 21% more students who turned in the worksheet received an A on the second exam, compared to the students who did not turn in a worksheet.

Out of the one hundred and one students to turn in the worksheet, ninety-two students correctly answered all the questions on the worksheet. This proved that Worksheet #2 was self-guided, allowing the students to receive the correct answer without the direction of the professor. This is not to say that the student did not receive the information in lecture, as well as the textbook, but that they were able to successfully execute what they knew in the worksheet. Of the nine students who did not correctly
complete the worksheet, their mistakes were minor. They may have missed counted zeros or left the table blank. This is why the results of the two students seemed fairly close except for the 7% difference in answers correct for the second worksheet related question on exam 2.

The 2009 final exam was also analyzed to see how well the scientific notation information was retained throughout the course. 7% more students who turned in the worksheet selected the correct answer for the first scientific notation related question compared to the students who did not turn in a worksheet. Thirty-nine more students (11%) who turned in the worksheet selected the correct answer for the second scientific notation related question. The percentage of scientific notation related correct answers for the fall 2009 final exam for the students who completed the worksheet, dropped 10% from the percentage of scientific notation related correct answers on the fall 2009 exam 2.

**Spring 2010 Discussion of Worksheet #2:** Looking over the results of the second worksheet, it appeared to be helpful to the students who completed it. Reviewing spring 2010 exam 2 data, fifty-three more students (14%) who turned in the worksheet selected the correct answer for the first scientific notation related question, compared to the students who did not turn in the worksheet. Seventy-three more students (28%) who turned in the worksheet selected the correct answer for the second scientific notation related question, compared to the students who did not turn in the worksheet. Ten more students (5%) who turned in the worksheet received an A on the second exam, compared to the students who did not turn in a worksheet.
The final exam was also analyzed to see how well the scientific notation information was retained throughout the course. Fifty-three more students (14%) who turned in the worksheet selected the correct answer for the first scientific notation related question compared to the students who did not turn in a worksheet. Seventy-three more students (28%) who turned in the worksheet selected the correct answer for the second scientific notation related question. The percentage of scientific notation related correct answers for the spring 2010 final exam for the students who completed the worksheet remained the same for the students who turned in Worksheet #2, but dropped an average of 14% points for the students who did not turn in Worksheet #2.

Aside from the greater percentage of correct answers related to scientific notation if a student turned in a worksheet, analyzing the benefit of Worksheet #2 proved difficult. There were no example problems on the worksheet that compared to the exam and final exam scientific notation related problems. The exam scientific notation related problems also required the students to perform some additional calculation, so although they may know how to correctly write a number in scientific notation, they may not have known how to or remembered how to perform the calculation required of them in the problem. In order to determine if students were able to write a number in scientific notation, the completed worksheets that were turned in spring 2010 were analyzed. The students proved to be successful at writing numbers in scientific notation, as one hundred and forty-four students (93%) correctly answered all six sample problem asking the students to write a small or large number into scientific notation.
Worksheet #3 Significant Figures

Results of Worksheet #3: Significant Figures

Two weeks prior to the second exam in the fall 2009 and spring 2010 semesters, when this research was done, the faculty member who was instructing CHEM 4 posted Worksheet #3: Significant Figures (Appendix F) on the class website. Dr. Paradis told the students during lecture that they could find Worksheet #3 on the class website. To encourage the students to complete Worksheet #3, Dr. Paradis offered three bonus points to students who turned in the completed worksheet one week prior to the second exam.

Fall 2009 Worksheet #3 Results: One hundred and one completed worksheets were turned in one week prior to Exam 2 in fall 2009. Of the one hundred and one students who completed the worksheet, thirty-six students (35%) received an A, twenty-seven students (27%) received a B, seventeen students (17%) received a C, five students (5%) received a D, and sixteen students (16%) received an F on Exam 2. Of the thirty-seven students who did not hand in a completed worksheet, five students (14%) received an A, six students (15%) received a B, six students (15%) received a C, six students (15%) received a D, and fourteen students (41%) received an F on Exam 2.

Three multiple choice questions on Exam 2 given in fall 2009 required knowledge of significant figures. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #3 performed on the questions requiring significant figure knowledge to the students who did not turn in a completed Worksheet #3. Table 21 displays the number of students who selected the correct answers for all of the three worksheet related questions on Exam 2.
Table 21: Exam 2: Fall 2009 Number of Students Who Selected the Correct Answers for Worksheet #3 Related Questions

<table>
<thead>
<tr>
<th>Exam 2: Fall 2009 Worksheet #3 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #3</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many significant figures are in each of the following measurements: 0.001001 and 56.00010? [Answer: 4 and 7]</td>
<td>71 (70%)</td>
<td>26 (70%)</td>
</tr>
<tr>
<td>Report the answer to this calculation with the correct significant figures: (5005-0.9)/325 [Answer: 15.4]</td>
<td>93 (92%)</td>
<td>32 (86%)</td>
</tr>
<tr>
<td>Report the answer to this calculation with the correct significant figures: 2.13 x 18.0 x 2.6 [Answer: 1.0 x 10^2]</td>
<td>88 (87%)</td>
<td>28 (76%)</td>
</tr>
</tbody>
</table>

Of the one hundred and one students who turned in a completed Worksheet #2 in fall 2009, thirty-six students (36%) turned in correctly completed worksheets. Of the thirty-six students who completed the worksheet correctly, twenty-three students (65%) selected the correct answer for the first significant figure question on exam 2, thirty-six students (100%) selected the correct answer for the second significant figure question on exam 2, and thirty-four students (95%) selected the correct answer for the third significant figure question on exam 2. Of the remaining sixty-five students (64%) who turned in the worksheet, but made errors or left sections blank, forty-seven students (72%) selected the correct answer for the first significant figure question on exam 2, fifty-seven students (88%) selected the correct answer for the second significant figure question on exam 2, and fifty-three students (82%) selected the correct answer for the third significant figure question on exam 2.
In order to see if Worksheet #3 helped in the retention of the knowledge of significant figures, the answers to the three multiple choice questions related to significant figures on the fall 2009 final exam were analyzed. Ninety-six students who turned in Worksheet #3 took the final exam. Table 22 displays the number of students who selected the correct answers for the three worksheet related questions on the fall 2009 final exam.

Table 22: Final Exam: Fall 2009 Number of Students Who Selected the Correct Answers for Worksheet #3 Related Questions

<table>
<thead>
<tr>
<th>Final Exam: Fall 2009 Worksheet #3 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #3</th>
<th>Number of students (%) who selected the correct answer who did not turn in Worksheet #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many significant figures are in the answer to the following calculation: ((8.05 + 5.8)/0.166?) [Answer: 3]</td>
<td>72 (75%)</td>
<td>25 (83%)</td>
</tr>
<tr>
<td>Which of the following conversion factors does not have an infinite number of significant figures? [Answer: 1 kg/2.205 lb]</td>
<td>48 (50%)</td>
<td>6 (20%)</td>
</tr>
<tr>
<td>How many sig figs are in the answer to the following calculation: ((120.90)(0.55) + (122.90)(0.45)?[Answer: 3]</td>
<td>24 (25%)</td>
<td>8 (27%)</td>
</tr>
</tbody>
</table>

Spring 2010 Worksheet #3 Results: One hundred and fifty-five completed worksheets were turned in one week prior to Exam 2 in spring 2010. Of the one hundred and fifty-five students who turned in a completed worksheet, twelve students (8%) received an A, thirty-one students (20%) received a B, twenty-nine students (19%) received a C, thirty-six students (23%) received a D, and forty-seven (30%) received an F on Exam 2. Of the seventy-one students who did not turn in a completed worksheet, two
students (3%) received an A, ten students (14%) received a B, fifteen students (21%) received a C, thirteen students (19%) received a D, and thirty-one students (43%) received an F on Exam 2.

Three multiple choice questions on Exam 2 given in spring 2010 required knowledge of significant figures. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #2 performed on the questions requiring significant figure knowledge to the students who did not turn in a completed Worksheet #2. Table 23 displays the number of students who selected the correct answers for the three worksheet related questions on Exam 2.

Table 23: Exam 2: Spring 2010 Number of Students Who Selected Correct Answers for Worksheet #3 Related Questions

<table>
<thead>
<tr>
<th>Exam 2: Spring 2010 Worksheet #3 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #3</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many significant figures are in the following measured values: 45,010 and 0.0009099? [Answer: 4 and 4]</td>
<td>88 (57%)</td>
<td>35 (49%)</td>
</tr>
<tr>
<td>Report the answer to this calculation with the correct significant figures: 85 + 99 + 0.09</td>
<td>88 (57%)</td>
<td>34 (48%)</td>
</tr>
<tr>
<td>Report the answer to this calculation with the correct significant figures: (4.5 x 10^4) x (107 – 98)</td>
<td>79 (51%)</td>
<td>26 (37%)</td>
</tr>
</tbody>
</table>

After reviewing the data for the spring exam 2, it appeared that the students, who handed in a completed Worksheet #3, did not score well on the majority of the significant figure related questions. The question most of the students did not score well on was the question that involved adding/subtracting and multiplying. Because of this, the
completed third worksheets handed in in spring 2010 were analyzed. Of the one hundred and fifty-five students that turned in a completed worksheet, seventy-six students (49%) incorrectly answered at least one of the Type III example problems on the third page. There were three example questions that combined multiplying/dividing and addition/subtraction in the determining of the correct number of significant figures. It appeared that many of the students who incorrectly answered one or all of these questions could execute the math, but did not take in consideration reporting their answer to the correct number of significant figures. Of the seventy-nine students who incorrectly answered the third significant figure related question on the spring 2010 exam 2, forty students (51%) did not solve the related problem correct on Worksheet #3.

For spring 2010 exam 2 analyses of average percentages of Worksheet #2 and Worksheet #3 related questions correct were compared to the average percentages of non-Worksheet #2 and non-Worksheet #3 related questions correct for students who completed the worksheets compared to those who did not do the worksheets. (Table 24)

<table>
<thead>
<tr>
<th></th>
<th>Average percentage of Worksheet #2 and Worksheet #3 related questions</th>
<th>Average percentage of non-Worksheet #2 and non-Worksheet #3 related questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who turned in</td>
<td>54%</td>
<td>71%</td>
</tr>
<tr>
<td>Worksheet #2 and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Worksheet #3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Students who did not</td>
<td>41%</td>
<td>65%</td>
</tr>
<tr>
<td>turn in Worksheet #2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>and Worksheet #3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In order to see if Worksheet #3 helped in the retention of the math material, the answers given to the significant figure questions on the spring 2010 final exam were analyzed. One hundred and fifty students who turned in Worksheet #3 took the final exam. Table 25 displays the spring 2010 final exam data of the number of students who selected the correct answers for the Worksheet #3 related questions.

Table 25: Final Exam: Spring 2010 Number of Students Who Selected the Correct Answers for Worksheet #3 Related Questions

<table>
<thead>
<tr>
<th>Final Exam: Spring 2010 Worksheet #3 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #3</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many significant figures are in the answer to the following calculation: (8.05 + 5.8)/0.166” [Answer: 3]</td>
<td>116 (77%)</td>
<td>33 (63%)</td>
</tr>
<tr>
<td>How many sig figs are in the answer to the following calculation: (120.90)(0.55) + (122.90)(0.45)” [Answer: 3]</td>
<td>52 (35%)</td>
<td>15 (29%)</td>
</tr>
</tbody>
</table>

Fall 2008 Results without Implementing Worksheet #2 and Worksheet #3: All students in Dr. Paradis’ fall 2009 and spring 2010 CHEM 4 lecturers were given the option to complete Worksheets #2 and #3. All results collected were a comparison between students who turned in the worksheet with the students who did not turn in the worksheet. It was not determined if the students who did not turn in a worksheet actually did not complete the worksheet on their own before the exam. Because of this the Worksheets #2 and #3 related question on the final exam for Dr. Paradis’ fall 2008 CHEM 4 semester was analyzed, as none of the students enrolled in the fall 2008 semester were offered the opportunity to complete Worksheets #2 and #3. The
Worksheets #2 and #3 related question on the fall 2008 final exam was, “Report the following sum with the correct significant figures: 952 + 47.6” [answer: $1.000 \times 10^3$] Of the one hundred and eighty-eight students who took the CHEM 4 fall 2008 final exam, twenty-six students (14%) selected the correct answer.

Discussion of Worksheet #3: Significant Figures

Determining how many significant figures a result of a calculation has was the goal of the third worksheet (Appendix F). The worksheet guided the students through the rules to determine how many significant figures a number has, as well as the rules to determine how many significant figures a result of a calculation has. It acted as a personal tutor to any student who may have forgotten or never learned how to determine how precise a number is. Two hundred and forty-eight students completed Worksheet #3 and handed it in a week prior to the second exam in fall 2009 and spring 2010.

Fall 2009 Discussion of Worksheet #3: Looking over the results of the third worksheet, it appeared to be helpful to the students who completed it. Reviewing fall 2009 exam 2 data, while the same percentage of students who turned in the worksheet and did not turn in the worksheet selected the correct answer for the first significant figure related question, sixty-one more students (6%) who turned in the worksheet selected the correct answer for the second significant figure related question, sixty more students (11%) who turned in the worksheet selected the correct answer for the third significant figure related question. Thirty-one more students (21%) who turned in the worksheet received an A on the second exam, compared to the students who did not turn in a worksheet.
Of the one hundred and one students who turned in Worksheet #3 only thirty-six of the students (36%) correctly answered the exam related questions correct on the worksheet. This seemed to only affect the scores received on the second and third related significant figure questions on exam 2. Of the thirty-six students who successfully completed Worksheet #3, 100% got the second related question right, where thirty-four students (95%) got the third related question right. This was an average of 12.5% more students who completed Worksheet #3 getting the questions correct compared to students who did not turn in a correct Worksheet #3. Regarding the first worksheet related question, forty-seven students (72%) of the sixty-five who turned in incorrect worksheets received full credit. Only twenty-three students (65%) of the students who turned in a correct worksheet received full credit on the first Worksheet #3 related question. It does seem to make a difference if the worksheet is completed correctly. The worksheets were written in a way to make solving the questions very simple, but with the amount of students who are not completing Worksheet #3 correct, it appears this worksheet is not as helpful.

The 2009 final exam was also analyzed to see how well the significant figure information was retained throughout the course. 8% fewer students who turned in the worksheet selected the correct answer for the first significant figure related question compared to the students who did not turn in a worksheet. 30% more students who turned in the worksheet selected the correct answer for the second significant figure related question. 2% fewer students who turned in the worksheet selected the correct answer for the third significant figure related question. The percentage of significant figure related correct answers for the fall 2009 final exam for the students who completed
the worksheet dropped compared to the significant figure related correct answers on the fall 2009 exam 2.

Spring 2010 Discussion of Worksheet #3: Reviewing spring 2010 exam 2 data, fifty-three more students (8%) who turned in the worksheet selected the correct answer for the first significant figure related question, compared to the students who did not turn in the worksheet. Fifty-four more students (9%) who turned in the worksheet selected the correct answer for the second significant figure related question, compared the students who did not turn in the worksheet. Fifty-three more students (14%) who turned in the worksheet selected the correct answer for the third significant figure related question, compared the students who did not turn in the worksheet. Ten more students (5%) who turned in the worksheet received an A on the second exam, compared to the students who did not turn in a worksheet.

Comparing the average percentage of Worksheet #2 and Worksheet #3 related questions to non-Worksheet #2 and non-Worksheet #3 related questions on exam 2 to the students who turned in both worksheets to those who did not. There is only a 17% difference between the averages of percent correct worksheet related questions to non-worksheet related questions for the students who completed the worksheets. While there is a 24% difference between the averages of percent correct worksheet related questions to average percent correct of non-worksheet related questions. It appears by completing the worksheet, students receive a higher percentage for worksheet related questions compared to students who did not do the worksheet.
Of all the results given for each worksheet, Worksheet #3 produced the least favorable data with less than sixty percent of the students who turned in the worksheet selecting the correct answers for the significant figure related questions on exam 2. Because of this, each Worksheet #3 that was turned in spring 2010 was analyzed. 49% of the turned in worksheets had incorrect answers for the significant figure example questions that were similar to the questions accessed on the exams. Before analyzing the worksheets, it could be hypothesized that the student knows how to write a number with the correct number of significant figures, but does not know how to perform the calculation associated with the significant figure question. This proved not to be the case, as all of the one hundred and forty-six (one student left the example problems blank), calculated the problems involving addition/subtraction and multiplication/division correctly, but forty-seven students incorrectly wrote their results with the correct amount of significant figures. The majority of these incorrect answers appeared as if the student forgot or decided not to take in account significant figures, as many answers had a great amount of significant figures, when the correct answer would be two or three significant figures.

The 2010 final exam was also analyzed to see how well the significant figure information was retained throughout the course. Eighty-three more students (14%) who turned in the worksheet selected the correct answer for the first significant figure related question compared to the students who did not turn in a worksheet. Thirty-seven more students (6%) who turned in the worksheet selected the correct answer for the second significant figure related question. The percentage of significant figure related questions
correct answers for the spring 2010 final exam for the students who completed the worksheet increased by 20% for the first related question and remained the same for the second related question when compared to the percentages correct on spring 2010 exam 2.

Discussion of Fall 2008 without Implementing Worksheet #2 and Worksheet #3: An average of 45% more students, who were enrolled in CHEM 4 during the fall 2009 and spring 2010 semesters, correctly answered the Worksheet #2 and Worksheet #3 related questions on the final exam compared to the students enrolled in CHEM 4 in the fall of 2008 semester.

Worksheet #4 Percent Composition

Results of Worksheet #4: Percent Composition

Two weeks prior to the third exam in the fall 2009 and spring 2010 semester, in which this research was done, the faculty member who was instructing CHEM 4 posted Worksheet #4: Percent Composition (Appendix G) on the class website. Dr. Paradis told the students during lecture that they could find Worksheet #4 on the class website. To encourage the students to complete Worksheet #4, Dr. Paradis offered five bonus points to students who turned in the completed worksheet one week prior to the third exam.

Fall 2009 Worksheet #4 Results: Ninety completed worksheets were turned in one week prior to Exam 3 in fall 2009. Of the ninety students who turned in the completed worksheet, thirty-two students (36%) received an A, twenty students (22%) received a B, seventeen students (19%) received a C, eleven students (12%) received a D, and ten
students (11%) received an F on Exam 3. Of the forty-six students who did not complete the spreadsheet, twelve students (26%) received an A, six students (13%) received a B, nine students (20%) received a C, eight students (17%) received a D, and eleven students (24%) received an F on Exam 3. No further analysis of Worksheet #4 and the third exam were analyzed for fall 2009, as the exams were returned to the students before additional analysis could take place. Instead Fall 2009 Worksheet #4 data was in reference to the final exam.

In order to see if Worksheet #4 helped in the retention of correctly solving percent composition calculations, the answers to the percent composition multiple choice question on the fall 2009 final exam were analyzed. Eighty-eight students who turned in Worksheet #4 took the final exam. The percent composition question asked, “What is the mass % (to 3 sig figs) of O in potassium carbonate?" [Answer: 34.7%] Of the eighty-eight students who turned in a completed worksheet, sixty-five students (74%) selected the correct answer. Of the remaining forty-one students who took the final, but did not turn in a completed Worksheet #4, twenty-six (63%) selected the correct answer.

Of the eighty-eight students who turned in Worksheet #4 and took the fall 2009 final exam, seventy-three students (83%) turned in a correct Worksheet #4. Of these seventy-three students, fifty-three students (78%) received full credit for the Worksheet #4 related question on the fall 2009 final exam. Of the fourteen students who turned in incorrect or incomplete Worksheet #4, seven students (50%) received full credit for the Worksheet #4 related question on the fall 2009 final exam.
Spring 2010 Worksheet #4 Results: One hundred and thirty nine completed worksheets were turned in one week prior to Exam 3 in spring 2010. Of the one hundred and thirty nine students who turned in the completed worksheet, thirty-six students (26%) received an A, twenty-six students (19%) received a B, thirty-two students (23%) received a C, twenty-four students (17%) received a D, and twenty-one students (15%) received an F on Exam 3. Of the sixty-nine students who did not turn in a completed worksheet, eight students (12%) received an A, eighteen students (26%) received a B, eighteen students (26%) received a C, eight students (12%) received a D, and seventeen students (24%) received an F on Exam 3.

There were two CHEM 4 sections in the spring of 2010. All of the data has been combined up until this point, as the exams given have been the same for both sections. For exam 3, two separate exams were given to the two different sections, so spring 2010 exam 3 data will be divided accordingly.

Spring 2010 8 am: Two multiple choice questions on Exam 3 required knowledge of percent composition. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #4 performed on the percent composition calculation questions to the students who did not turn in a completed Worksheet #4. Table 26 displays the number of students who selected the correct answers for the two worksheet related questions on Exam 3.
What is the mass percent of O in sodium carbonate? [Answer: 45.29%]

Which of the following has the smallest mass percent P? [Answer: Na₃PO₄]

What is the mass percent of O in sodium nitrate? [Answer: 56.47%]

Which of the following has the greatest mass percent S? [Answer: H₂S₂O₃]

Spring 2010 10 am: Two multiple choice questions on Exam 3 required knowledge of percent composition. Analysis of the correct answers selected by each of the students was done to compare how well the students who completed Worksheet #4 performed on the percent composition calculation questions to the students who did not turn in a completed Worksheet #4. Table 27 displays the number of students who selected the correct answers for the two worksheet related questions on Exam 3.

<table>
<thead>
<tr>
<th>Exam 3: Spring 2010 8 am Worksheet #4 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #4</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the mass percent of O in sodium carbonate?[Answer: 45.29%]</td>
<td>59 (86%)</td>
<td>27 (75%)</td>
</tr>
<tr>
<td>Which of the following has the smallest mass percent P?[Answer: Na₃PO₄]</td>
<td>42 (61%)</td>
<td>23 (63%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Exam 3: 10 am Worksheet #4 related questions</th>
<th>Number of students (%) who selected the correct answers who turned in Worksheet #4</th>
<th>Number of students (%) who selected the correct answers who did not turn in Worksheet #4</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the mass percent of O in sodium nitrate? [Answer: 56.47%]</td>
<td>66 (94%)</td>
<td>29 (88%)</td>
</tr>
<tr>
<td>Which of the following has the greatest mass percent S?[Answer: H₂S₂O₃]</td>
<td>59 (84%)</td>
<td>18 (54%)</td>
</tr>
</tbody>
</table>

At this point the data for the spring 2010 8 am and 10 am sections will be combined. Analysis of exam 3 average of percent correct of Worksheet #4 related
questions and average of percent correct of non-Worksheet #4 related questions for the students who turned in Worksheet #4 compared to average of percent correct of Worksheet #4 related questions and average of percent correct of non-Worksheet #4 related questions for the students who did not turn in Worksheet #4. (Table 28)

Table 28: Spring 2010 Exam 3 Average Percentages of Worksheet #4 Related Questions Correct Compared to Non-Worksheet #4 Related Questions Correct

<table>
<thead>
<tr>
<th></th>
<th>Average percentage of Worksheet #4 related questions</th>
<th>Average percentage of non-Worksheet #4 related questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students who turned in Worksheet #4</td>
<td>80%</td>
<td>74%</td>
</tr>
<tr>
<td>Students who did not turn in Worksheet #4</td>
<td>76%</td>
<td>71%</td>
</tr>
</tbody>
</table>

The 2010 final exam was also analyzed to see how well the percent composition information was retained throughout the course. The percent composition question on the final exam asked, “What is the mass % (to 3 sig figs) of O in potassium carbonate?” [Answer: 34.7%] Of the one hundred and thirty-nine students who completed Worksheet #4, one hundred and thirty-seven took the final exam. Of the one hundred and thirty-seven students who took the final exam, one hundred and twenty-seven students (93%) selected the correct answer for the Worksheet #4 related question. Of the sixty-nine students who did not turn in the worksheet, sixty students took the final exam. Of the sixty students who took the final exam, forty-nine students (82%) selected the correct answer for the percent composition question.

Fall 2008 Results without Implementing Worksheet #4: All students in Dr. Paradis’ fall 2009 and spring 2010 CHEM 4 lecturers were given the option to complete
Worksheet #4. All results collected were a comparison between students who turned in the worksheet with the students who did not turn in the worksheet. It was not determined if the students who did not turn in a worksheet actually did not complete the worksheet on their own before the exam. Because of this the Worksheet #4 related question on the final exam for Dr. Paradis’ fall 2008 CHEM 4 semester was analyzed, as none of the students enrolled in the fall 2008 semester were offered the opportunity to complete Worksheet #4. The Worksheet #4 related question on the fall 2008 final exam was, “What is the mass % of O in Sn(OH)\(_2\)?” [answer: 20.95%] Of the one hundred and eighty-eight students who took the CHEM 4 fall 2008 final exam, one hundred and sixty-six students (89%) selected the correct answer.

Discussion of Worksheet #4: Percent Composition

Determining an element’s mass percent composition for a compound was the goal of the forth worksheet (Appendix G). The worksheet guided the students through the definition of mass percent composition, determining the percentage of a whole, and calculating totals using percentages. Two hundred and twenty-nine students completed Worksheet #4 and handed it in a week prior to the third exam in fall 2009 and spring 2010.

Fall 2009 Discussion of Worksheet #4: Looking over the results of the forth worksheet, it appears to have been helpful to the students who completed it. Reviewing fall 2009 final exam data was done to determine if the information received on the worksheet was retained for the final. Sixty-five students (74%) answering the percent
composition question correct proving the information was retained. Thirty-nine more students (11%) answered the question correct compared to students who did not turn in Worksheet #4. Twenty more students (10%) turned in the worksheet received an A on the exam, compared to the students who did not turn in a worksheet.

83% of the students, who completed the worksheet, completed it completely and correctly. Only fourteen students incompletely or incorrectly turned in the worksheet. Of the seventy-three students who correctly filled-in the worksheet, 78% selected the correct answer for the percent composition problem on the final. Of the fourteen who did not fill-in the worksheet correctly, 50% selected the correct answer on the final. This is a 28% increase for correctly filling-in the worksheet. This makes sense that in order to benefit from the worksheet, one must complete it correctly.

Spring 2010 Discussion of Worksheet #4: Reviewing spring 2010 8 am exam 2 data, thirty-two more students (11%) who turned in the worksheet selected the correct answer for the mass percent question and 2% less students who turned in the worksheet selected the correct answer for the second mass percent question when compared to the students who did not turn in a worksheet.

Reviewing spring 2010 10 am exam 2 data, thirty-seven more students (6%) who turned in the worksheet selected the correct answer for the first mass percent question and forty-one more students (30%) who turned in the worksheet selected the correct answer for the second mass percent question compared to the students who did not turn in a completed worksheet. Twenty-eight more students (14%) who turned in the worksheet
received an A on the third exam, compared to the students who did not turn in a worksheet.

The average percent correct of worksheet related questions was 4% greater for the students who completed the worksheet compared to the students who did not complete the worksheet. The average percent correct of non-worksheet related questions was 3% greater for the students who completed the worksheet compared to the students who did not complete the worksheet.

Worksheet #4 shows positive results, as for all the exam questions analyzed on the spring 2010 10 am exam, at least 80% of the students who turned in a worksheet selected the correct answer for either of the percent composition question. There was not large differences in percentages of correct answers for students who turned in the worksheet compared to those who did not turn in a worksheet, except for the 30% difference on second mass percent question asked on the spring 2010 10 am exam 2. It can be determined that either the worksheet was helpful or the majority of the students in the class understood the lesson on percent composition in lecture and in their textbook. As there was not a survey referring to Worksheet #4, it is not known if the students who did not turn in a completed worksheet referred to the answer key on-line.

Discussion of Fall 2008 without Implementing Worksheet #4: An average of 10% less students, who were enrolled in CHEM 4 during the fall 2009 and spring 2010 semesters, correctly answered the Worksheet #4 related question on the final exam compared to the students enrolled in CHEM 4 in the fall of 2008 semester.
Results of Introductory Math Quiz Score and Final grade in CHEM 4 Course

The students who scored below 90% on the Introductory Math Quiz at the beginning of the fall 2009 and spring 2010 semesters were analyzed to determine if doing any of the four worksheets helped in their final grade for the CHEM 4 course. Of the ninety-eight students who completed at least one worksheet in fall of 2009, the average overall score for the course was 72%. Of the seventeen students who did not turn in any of the four worksheets in the fall of 2009, the average overall score for the course was 55%. Of the one hundred and seventy-nine students who turned in at least one worksheet in the spring 2010, the average overall score for the course was 69%. Of the thirty-eight students who did not turn in any of the four worksheets in the spring of 2010, the average overall score for the course was 42%.

Discussion of Introductory Math Quiz Score and Final grade in CHEM 4 Course

Students who scored below a 90% on the Introductory Math Quiz and turned in at least one worksheet in fall 2009 scored on average 17% points higher on their course grade compared to students who scored below 90% on the Introductory Math Quiz and did not turn in any worksheet in fall 2009. Students who scored below a 90% on the Introductory Math Quiz and turned in at least one worksheet in spring 2010 scored on average 27% points higher on their course grade compared to students who scored below 90% on the Introductory Math Quiz and did not turn in any worksheet in spring 2010.
Individual Case Studies

Individual Case Studies Results

A total of nine hundred and seventy-two mathematics worksheets were turned in during the fall 2009 and spring 2010 semesters. Analysis of each worksheet was taken to determine if the students who turned them in correctly answered more worksheet related questions on their exams than the students who did not turn in the worksheets. All students were given the option to complete the first worksheet. Students receiving a score of less than 80% on their first exam were required to turn in the second and third worksheets. Students receiving a score of less than 80% on their second exam were required to turn in the fourth worksheet. Students receiving 80% or above on exams 1 and 2 had the option to turn in the second, third, and fourth worksheets. Because not all of the students who turned in one worksheet, turned them all in and because students with overall lower grades for the course were required to turn in the second, third, and fourth worksheet, because of low exam scores, it is difficult to determine how helpful completing all worksheets were for the students without looking at individuals who completed all four worksheets. Three individual students who completed all four worksheets and received three different passing grades for the course were analyzed. Additionally one student who did not complete Worksheet #1, but received a 77% on the first exam and was required to complete Worksheets #2 and #3, and chose to complete worksheet #4 was analyzed, to see if completing the worksheets improved her exam grades.
Student 1

The first student chosen was a female, who turned in all four math worksheets and received a final grade of an A for the CHEM 4 course in fall 2009. Student 1 is currently enrolled in Math 26A-Algebra for College Students at CSUS, and most recently received an A in Stats 1-Statistics at CSUS. She selected “4” on a scale of “1” to “5”, with one being “poor” and five being “excellent” on how well she considered herself in math. She selected “3” on a scale of “1” to “5”, with one being “really dislike” and five being “really like” on how much she enjoyed math. Lastly she selected a “2” on a scale of “1” to “5”, with one being “very concerned” and five being “not at all concerned” about how concerned she was with her math skills impacting her chemistry grade.

Student 1 correctly answered all but two questions on Worksheet #1. For the two guided example problems on page 3 and 4 of the first worksheet, she wrote the known isotope values in the table as decimal numbers rather than fractions like the table asks. Student 1 received a 99% on the first exam and received all 7 points for the atomic mass calculation. On the survey concerning Worksheet #1, Student 1 chose that she completed the worksheet in time to receive the five extra credit points. It took her 2 to 3 hours to complete the worksheet. She said that she looked at the answer key, saw what questions she answered incorrectly and used the key to correct her mistakes. When she was asked what she thought about the worksheet, she identified the following: 1. she completed the worksheet for the five extra credit points, 2. she thought the worksheet was useful, 3. She thought the worksheet helped her to do better on the exam, 4. she would complete future
worksheets for bonus points, 5. She would complete future worksheet for no bonus points.

Student 1 correctly filled in Worksheets #2 and #3, and received a score of 99% for exam 2. She only missed one point on the written portion of the exam. She correctly answered all the multiple choice questions, both the worksheet related and non-worksheet related questions.

Student 1 answered all the questions on Worksheet #4 correctly. She received a score of 100% for exam 3, receiving full credit for all worksheet related questions. She earned 185 points out of 200 on the final and received full credit for the questions related to the worksheets.

Student 2

The second student chosen was a female, who turned in all four math worksheets and received a final grade of a B for the CHEM 4 course in spring 2010. Student 2 is currently enrolled in Math 30-Calculus at CSUS. She was most recently enrolled in Math 29-Pre-Calculus a year and half prior to her Chem 4 course and received the grade of C. She received 13 out of 15 questions correct on the introductory math quiz. She selected “4” on a scale of “1” to “5”, with one being “poor” and five being “excellent” on how well she considered herself in math. She selected “4” on a scale of “1” to “5”, with one being “really dislike” and five being “really like” on how much she enjoyed math. Lastly she selected a “4” one a scale of “1” to “5”, with one being “very concerned” and five
being “not at all concerned” about how concerned she was with her math skills impacting her chemistry grade.

Student 2 correctly answered all but four questions on Worksheet #1. For the two guided example problems on page 3 and 4 of the first worksheet, she wrote the known isotope values in the table as decimal numbers rather than fractions like the table asks. Also on the last page, she correctly solved for the isotope percentages, but only reported the percentages and did not label which percentage belong to each isotope. Student 2 received an 81% on the first exam missing seven points for the last atomic mass calculation on exam 1A. Student 2 received the full six points on the first atomic mass calculation on the exam, but answered incorrectly the second calculation. The question read, “Naturally occurring lithium has two isotopes: lithium-6 with a mass of 6.0151 amu and lithium-7 with a mass of 7.0160 amu. Determine the percent abundance of lithium-6?”, rather than correctly choosing the correct answer of 7.5% abundance for lithium-6, Student 2 chose 92.5%. Because 100% - 92.5% = 7.2%, Student 2 appears to have transposed her answer for the lithium-6 with her answer for lithium-7. It appears student 2 performed the calculation correctly, but switched her answers for the percentages for the two isotopes at some point. On the survey concerning Worksheet #1, Student 2 chose that she completed the worksheet in time to receive the five extra credit points. It took her 2 to 3 hours to complete the worksheet. She said that she looked at the answer key, saw what she answered incorrectly and could not use the key to correct her answers. When she was asked what she thought about the worksheet, she identified the following: 1. she completed the worksheet for the five extra credit points, 2. she thought the
Student 2 correctly completed Worksheet #2, but did have an error on Worksheet #3 and received a score of 72% for exam 2. The error on Worksheet #3 was on the first of the three example problems for determining number of significant figures for the result of a calculation using both multiplying/dividing and adding. Student 2’s answer contained two significant figures, when it should have contained three. Student 2 incorrectly answered one of the two exam 2 problems that related to Worksheet #2, for the question that asked, “57.0 calories are added to a lead block. If the temperature of the lead increases from 53°F to 79°F, what must be the mass, in g, of the lead block?” Student 2 answered “31g” rather than the correct answer, “1.3 x 10^2 g”. She also missed one of the three questions related to Worksheet #3. The question asked, “How many significant figures are in the following measured values: 45,010 and 0.0009099?” Student 2 answered “5 and 4”, rather than the correct answer of “4 and 4”.

Student 2 turned in Worksheet #4 and received a score of 90% for exam 3. Student 2 selected the correct answers for all three mass percent composition related questions on exam 3. Student 2 received 170 points out of 200 on the final and received full credit on the four worksheet related questions.

**Student 3**

The third student chosen was a female, who turned in all four math worksheets and received a final grade of a C+ for the CHEM 4 course in spring 2010. Student 3 is
not currently enrolled in a math course. She was most recently enrolled in Stats 1-Statistics a year prior to her CHEM 4 course and received the grade of D. She received 9 out of 15 correct answers on the introductory math quiz. She selected “4” on a scale of “1” to “5”, with one being “poor” and five being “excellent” on how well she considered herself in math. She selected “3” on a scale of “1” to “5”, with one being “really dislike” and five being “really like” on how much she enjoyed math. Lastly she selected a “5” one a scale of “1” to “5”, with one being “very concerned” and five being “not at all concerned” about how concerned she was with her math skills impacting her chemistry grade.

Student 3 correctly answered all questions on Worksheet #1. Student 3 received an 84% on the first exam missing seven points for the first atomic mass calculation on exam 1B. Student 3 received the full six points on the last atomic mass calculation on the exam, but answered incorrectly the first calculation. The question read, “Naturally occurring lithium has two isotopes: lithium-6 with a mass of 6.0151 amu and lithium-7 with a mass of 7.0160 amu. Determine the percent abundance of lithium-6?”, rather than correctly choosing the correct answer of 7.5% abundance for lithium-6, Student 3 chose 92.5%. Because 100% - 92.5% = 7.2%, Student 3 transposed her answer for the lithium-6 with her answer for lithium-7. It appears student 3 performed the calculation correctly, but switched her answers for the percentages for the two isotopes at some point. On the survey concerning Worksheet #1, Student 3 chose that she completed the worksheet in time to receive the five extra credit points. It took her 1 to 2 hours to complete the worksheet. She said that she looked at the answer key, saw what she answered
incorrectly and used the key to correct her answers. When she was asked what she thought about the worksheet, she identified the following: 1. she completed the worksheet for the five extra credit points, 2. she thought the worksheet was useful, 3. She thought the worksheet helped her to do better on the exam, 4. she would complete future worksheets for bonus points, 5. She would complete future worksheets for no bonus points, and 6. she would complete future worksheets if she was required to. She also included a statement about the worksheet, “The worksheet was very helpful; I have not taken chemistry in three and half years, so it was a good refresher”.

Student 3 correctly completed Worksheet #2, but did have an error on Worksheet #3 and received a score of 56% for exam 2. The error on Worksheet #3 was on the first of the three example problems for determining number of significant figures for the result of a calculation using both multiplying/dividing and adding. Student 3’s answer contained six significant figures, when it should have contained only three. Student 3 incorrectly answered one of the two exam 2 problems that related to Worksheet #2, for the question that asked, “57.0 calories are added to a lead block. If the temperature of the lead increases from 53°F to 79°F, what must be the mass, in g, of the lead block?”

Student 3 answered “72 g” rather than the correct answer, “1.3 x 10² g”. She also missed one of the three questions related to Worksheet #3. The question asked, “How many significant figures are in the following measured values: 45,010 and 0.0009099?”

Student 3 answered “5 and 4”, rather than the correct answer of “4 and 4”.

Student 3 turned in Worksheet #4 and received a score of 80% for exam 3. Student 3 selected the correct answers for two of the related mass percent composition
questions on exam 3. She missed one related question that asked, “Which of the following has the smallest mass percent P?” Student 3 chose, “H₃P”, rather the correct answer, “Na₃PO”. Student 3 received 160 points out of 200 on the final and received full credit on all of the worksheet related questions.

Student 4

The fourth student chosen was a female, who did not turn in worksheet #1, but because her grad on exam 1 was less than 80%, was required to complete Worksheets #2 and #3. Student 4 received a final grade of an A in the CHEM 4 course in Spring 2010. Student 4 did not turn in the first survey, but she did only receive 8 out of 15 questions on the Introductory Math Quiz.

Student 4 received a 77% on the first exam and received all 0 points for the atomic mass calculations. For the first question, “Rubidium has two naturally occurring isotopes. One isotope, RB-85, has a mass of 84.91 amu and a natural abundance of 72.17%. What is the mass of the other isotope?”, she answered “86.48 amu”, rather than “86.92 amu”. For the second question, “Naturally occurring lithium has two isotopes: lithium-6 with a mass of 6.0151 amu and lithium-7 with a mass of 7.0160 amu. Determine the percent abundance of lithium-6?”, she answered “23.2%”, rather than the correct answer “7.5%” On the survey concerning Worksheet #1, Student 4 chose that she completed the worksheet, but not in time to receive the five extra credit points. It took her 1-2 hours to complete the worksheet. She said that she did not look at the answer
key. She listed one thought concerning Worksheet #1; she would only complete the worksheet for the extra bonus points.

Student 4 only partially completed worksheet #2, she did not fill in the table on page 2. She completed Worksheet #3, solving the multiplying/dividing and adding/subtracting calculations correctly, but did not record the answers to the correct number of significant figures. She received an 85% on exam 2. She missed one question that related to Worksheet #2 and #3, “Report the answer to this calculation with the correct significant figures: \((4.5 \times 10^4) \times (107-98)\)”, she answered “4.1 \times 10^5” rather than the correct answer “4 \times 10^5”. She missed additional question that related to Worksheet #3, “Report the answer to this calculation with the correct significant figures: 2.13 \times 18.0 \times 2.6”, she answered, “180”, rather than the correct answer, “184”.

Student 4 turned in Worksheet #4 in time for the five bonus points. She received a score of 95% for exam 3, receiving full credit for all worksheet related questions. She earned 165 points out of 200 on the final and received 3 out of 4 of the worksheet related questions correct. The problem she missed was, “How many sig figs are in the answer to the following calculation: \((120.90)(0.55) + (122.90)(0.45)\)” She answered “2” rather than the correct answer “3”.

Discussion of Individual Case Studies

Student 1

The first student appears to be a bright student, most recently scoring an A in her Stat1-Statistics course. She considers herself better than average at math. She is
indifferent about the subject, but she is slightly concerned about how her math skills will affect her chemistry grade. This is an example of a student who is competent in math, but still has math anxiety. She may be anxious because the math she is currently enrolled in is required for the course (algebra).

The first student successfully completed all four math worksheets she turned in with only two small errors on Worksheet #1. She recorded that the worksheet took 2 to 3 hours to complete, but that she found it useful and helped her to do better on the exam. It is difficult to determine how helpful the worksheets were for Student 1, besides her saying so herself, as she only missed 16 points at of possible 500 points total on all of her exams. Understanding that there are far more math concepts covered on the exams than are on the worksheets, she was able to successfully answer those questions without a worksheet.

One point to make here is that there was no student in the fall 2009 or spring 2010 semesters of CHEM 4 who received an A in the course without turning in at least one mathematic worksheet.

Student 2

Student 2 is currently taking Math 30-Calculus at CSUS and most recently took Math 29-Pre-Calculus a year and a half before entering in CHEM 4 and received a C in the course. She received an 87% on the Introductory Math Quiz. With the math this student has completed and her score on the introductory math quiz, her math skills should be sufficient for the math skills required for CHEM 4. She claims to be above average in
math. She likes math and is almost not at all concerned that her math skills will impact her chemistry grade.

Student 2 had four minor errors on Worksheet #1. Two of her errors on Worksheet #1 may have contributed to her missing one of the two atomic mass problems on exam 1. Student 2 solved the atomic mass calculations on the worksheet up until the percentages but did not assign the percentages to the isotope which belonged to them. On her exam it appears she solved the problem correctly, but incorrectly assigned the proper percentage found to the correct isotope (essentially switching the answers). This may have been something that could have been corrected if Student 2 looked at the answer key and asked for help on how to find the correct answer to the problem she had difficulty with on the worksheet. The worksheet warned the students of this possible error and to be aware of it. Student 2 said that she looked at the answer key, but was unable to correct her mistakes. In the survey asking about Worksheet #1, Student 2 recorded that it took her 2 to 3 hours to complete the worksheet. She also said that it was useful and helped her to do better on the exam. She completed it for the bonus points and will do more worksheets in the future for more bonus points.

Student 2 correctly completed Worksheet #2, but had an error on Worksheet #3. She did miss one of the two questions related to Worksheet #2. The question she missed that related to scientific notation required additional math that was not covered on the worksheet, so it can be concluded that it may not of been from a miss understanding of scientific notation, but a miss understanding of the problem. She also missed one of the two problems relating to Worksheet #3. The question Student 2 missed was a simple
significant figure question, “How many significant figures are in the following measured values: 45,010 and 0.0009099?” Student 2 answered “5 and 4”, rather than the correct answer of “4 and 4”. It is obvious that Student 2 counted the last zero in 45,010 as a significant figure. She answered these types of questions correctly on Worksheet #3, so Student 2 must of forgot the information or did not take the time to correctly analyze the problem.

Student 2 completed worksheet #4 and received full credit for all worksheet related problems on exam 3. She also received full credit for all the related final questions.

Student 3

Student 3 started out in CHEM 4 by scoring 60% on the Introductory Math Quiz. Her most recent math course was Stats 1-Statistics and was taken a whole year earlier resulting in a D for a grade. She considers herself better than average at math. She is indifferent about the subject, but she is very concerned that her math skills will impact her chemistry grade. It is interesting that even though she feels she considers herself better than average at math, that she is concerned about her skills. Once again it doesn’t seem to matter how a student performs in math, there exist some form of anxiety.

Student 3 successfully completed Worksheet #1, but still missed one of the atomic mass calculations on exam 1. Similar to Student 2, Student 3 appears to have transposed her percentages for the two separate isotopes. Student 3 recorded that Worksheet #1 took her 1 to 2 hours to complete. She thought the worksheet was useful and helped her
receive a better grade on exam 1. She did the worksheet for the extra points, but would do additional worksheets in the future for points, no points, and if she was required too. Student 3 also wrote, “The worksheet was very helpful; I have not taken chemistry in three and half years, so it was a good refresher”. Although Student 3 missed one of two atomic mass calculation, they still thought that the worksheet was helpful to the success of getting the one question right.

Student 3 correctly completed Worksheet #2, but had an error on Worksheet #3. Student 3 missed one of the two Worksheet #2 related exam 2 questions, but like Student 2, this could have been a math error unrelated to understanding scientific notation or not. Student 3 also missed the same Worksheet #3 related question that Student 2 missed, “How many significant figures are in the following measured values: 45,010 and 0.0009099?” Student 3 answered “5 and 4”, rather than the correct answer of “4 and 4”. It is obvious that Student 23 counted the last zero in 45,010 as a significant figure. Although this question was not similar to the one Student 3 missed on Worksheet #3, it does seem to suggest that Worksheet 3 was not very helpful for this particular question that seems so basic for Student 2 and Student 3. They both correctly answered the significant figure questions for the question requiring a calculation, but had difficulty with determining number of significant figures a number has. The results of all of the students completing Worksheet #3 and their results on exam 2 Worksheet #3 related questions suggest that the worksheet should be revamped to promote better success.

Student 3 completed Worksheet #4, but missed one mass percent composition problems on exam 3. It appears that the student mistakenly chose the answer of the
largest mass percent for P, rather than the smallest mass percent. This could have simply
been a reading error on Student 3, but without work being shown, it is unclear if the
student knew how to execute the problem. Student 3 received all possible points for the
exam worksheet related problems.

Student 4

Student 4 did not turn in the first survey answering questions about the current
math she is taking and her feelings towards math. She did score a 53% on the
Introductory Math Quiz, suggesting that she only obtains 50% of the math skills required
for CHEM 4. Student 4 did not complete Worksheet #1 in time for the bonus points, but
did say that it took her 1-2 hours. She never looked at the answer key and said she would
only complete the worksheet for the bonus points. Without turning in the worksheet, it is
hard to determine how well she performed on it. She did not perform well on the atomic
mass calculations on the test receiving 0 out of possible 13 points. Her answer to the first
question was “86.48 amu”, while the correct answer was “86.92 amu”, so she could of
set-up the problem correctly and calculated it wrong or guessed. The second answer was
“23.2%”, while the correct answer was “7.5%”, which makes it harder to determine what
her error was on this question. Because she scored a 77% on the exam, she was required
to complete Worksheets #2 and #3.

Student 4 partially completed Worksheet #2 and successfully completed
Worksheet #3. Although one of the problems she missed on exam 2 related to both
worksheets, her greatest issue lie with Worksheet #3, as she answered “4.1 x 10^{5}”, rather
than “$4 \times 10^5$”. It appears she did not have an issue with writing a number in scientific notation, but included too many significant figures for the solution. The other worksheet related problem she missed was a multiplication problem that required the answer to be written with the correct number of significant figures. She answered “184” rather than “180”, so it shows she is performing the math correctly, but chose the incorrect number of significant figures. This continues to support that significant figure worksheet was only helpful for about 50% of the related exam problems.

Student 4 successfully completed Worksheet #4 and answered all related questions correctly on exam 3. She did however miss one of the four worksheet related questions on the final. Both questions were significant figure related errors. She answered “2”, when the correct number of significant figures was “3”. These incorrect answers support that Worksheet #3 is not as helpful in being successful on the related exam questions.
Chapter 5

CONCLUSION AND RECOMMENDATIONS FOR FUTURE WORK

This project attempted to demonstrate that students’ performance in a chemistry course could be enhanced by helping them apply previously learned math skills to math related chemistry concepts. The results of this study indicate the use of worksheets to achieve this goal was beneficial. It was also observed that the better the student did in correctly completing the worksheet the better they did on the related exam.

It was observed that chemistry is a difficult subject for many students. A significant number of students do poorly or dropout of classes. The inability to readily apply previously learned math concepts to the subject is one hindrance to doing well. As such, it immediately became clear that well designed aids to learning have a place in the chemistry classes. Students welcomed the opportunity to participate in an experiment to help improve their performance.

The pre-class math survey concluded that students are entering into CHEM 4 without the required math. A larger percentage of these ill-prepared students are failing or dropping out of CHEM 4 compared to those entering into CHEM 4 with the required math. The pre-class math survey also found that students entering into CHEM 4 have math anxiety.

The worksheets used in this study were for the most part very useful and effective. However, refinements may be needs to some of the material to more clearly relate math knowledge to chemistry concepts. Worksheet #3 needed to include more
example problems that provide a table for the student to step-by-step determine the correct amount of significant figures for a result of a calculation. This would help to eliminate student error of not completing each step of the problem.

Additional worksheets could be developed for help solving balancing equation and conversion calculation problems. Computerized worksheets would be good, so students can see immediately if they did not answer each question correctly, and the computer could offer suggestions on how to apply math correctly.
APPENDIX A

Surveys
<table>
<thead>
<tr>
<th>CHM 4 survey</th>
<th>Last Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mathematics Worksheet #1 (Atomic Mass)</td>
<td>First Name:</td>
</tr>
</tbody>
</table>

The purpose of this survey is solely to help us improve the Mathematics Worksheets used in CHM 4. This survey will not in any way impact your grade in the course.

1) Are you currently taking a math course? YES NO
   * If YES: What are you taking? Where are you taking it?

2) What was the most recent math course you completed?
   Where did you take it? What grade did you earn?

3) On a scale of 1 to 5 with "1" = "poor" and "5" = "excellent", how good do you consider yourself at math?
   "poor" 1 2 3 4 5 "excellent"

4) On a scale of 1 to 5 with "1" = "really dislike" and "5" = "really like", how do much do you enjoy math?
   "really dislike" 1 2 3 4 5 "really like"

5) On a scale of 1 to 5 with "1" = "very concerned" and "5" = "not at all concerned", how worried are you about your math skills impacting your chemistry grades?
   "very concerned" 1 2 3 4 5 "not at all concerned"

6) Take out your exam #1. What grade did you earn (not including bonus points)? ________/100 pts

Reminder: Students scoring < 80% on exam #1 will be required to complete the Mathematics Worksheet for the next exam (though they can still earn 5 bonus points). For students earning ≥ 80% on exam #1, completing the Worksheet for bonus points will remain optional.

7) Turn to the last page of exam #1. How many points (out of 7 possible) did you earn on the isotope calculation for antimony (question #2 on Version A; question #1 on Version B)?
   0 1 2 3 4 5 6 7

8) If you did not earn a perfect 7 pts, how would you best explain the source of the errors you made?

Continued on back ➔

Questions (9 - 12) refer to the Mathematics Worksheet on Calculating Atomic Mass.
9) Place a check in the box that describes when you completed the Worksheet. (check only one box)

- In time to earn the 5 bonus points.
- Before the exam (but too late to earn the 5 bonus points).
- I did not complete the worksheet.

10) If you did the Worksheet, roughly how long did it take you to complete? (circle the best choice)

less than 1 hour 1 - 2 hours 2 - 3 hours more than 3 hours

11) Place a check in the box that best describes your use of the Worksheet answer key that was posted online after the Worksheet was due. (check only one box)

- I did not look at the answer key.
- I looked at the answer key and saw I had done the worksheet correctly.
- I looked at the answer key, saw I did it incorrectly, and used the key to understand my mistake(s).
- I looked at the answer key, saw I did it incorrectly, but could not figure out from the key how to correct my mistake(s).

12) Place a check next all of the boxes that describe what you thought of the Mathematics Worksheet overall (check all that apply):

- I did the Worksheet primarily for the 5 bonus points.
- The Worksheet was very useful for me.
- I did better on the exam because of the Worksheet.
- The mathematics covered by the Worksheet was too basic for me.
- I would do similar Worksheets in the future only if they were for bonus points.
- I would do similar Worksheets in the future only if I was required to.
- I would do similar Worksheets in the future even if they were not for bonus points.
- Other comments:
APPENDIX B

Introductory Math Quiz
CHEM 4, Introductory Math Quiz  
Name:  
Write CAPITAL letter corresponding to the best answer in the boxes provided.

1) Which of these is the largest number?  
A) $7.0 \times 10^{-2}$  B) 0.014  C) 0.0083  D) $9.2 \times 10^{-3}$  

2) Which of these is the largest number?  
A) $0.3^4$  B) $2^{-1}$  C) $\frac{4}{5}$  D) $10^0$  

3) Which of the following is equal to 6,327?  
A) $6.327 \times 10^0$  B) $6.327 \times 10^1$  C) $632.7 \times 10^2$  D) $632.700 \times 10^3$  

4) A proton has a +1 charge, an electron has a -1 charge, and a neutron has 0 charge. What is the total charge on an atom that is made up of 12 protons, 10 electrons, and 11 neutrons?  
A) -2  B) 2  C) 22  D) 33  

5) Solve $\frac{a}{b+x} = c$ for $x$.  
A) $x = \frac{a-c}{b}$  B) $x = a - bc$  C) $x = \frac{a+bc}{c}$  D) $x = \frac{a}{bc}$  

6) Solve the following equation for $x$:  
$25 = (54)(x-1) - (18)(x)  
A) -0.40  B) 0.40  C) 1.1  D) 72$  

7) Convert 0.7 L to cups.  
Note: 4 cups = 1 qt, 1.057 qt = 1 L  
A) 2 cups  B) 0.2 cups  C) 3 cups  D) 5 cups  

8) An grain of sand is found to weigh $3.0 \times 10^{-3}$ g. Which of the following mathematical operations could you perform to determine how many grains of sand it would take to weigh $4.5 \times 10^5$ g?  
A) $(3.0 \times 10^{-3})(4.5 \times 10^5)$  B) $(3.0 \times 10^3)/(4.5 \times 10^5)$  
C) $(4.5 \times 10^5)/(3.0 \times 10^{-3})$  
OVER →
9) Convert a temperature of -20 °C to °F. Note: \[ C = \frac{(F - 32)}{1.8} \]
   A) -68 °C  B) -29 °C  C) -4 °C  D) 68 °C

10) The chemical formula for magnesium nitrate is Mg(NO₃)₂. How many total atoms are present in 1 unit of magnesium nitrate?
   A) 5  B) 8  C) 9  D) 10

11) One mole of oxygen atoms has a mass of 16.00 g. What is the mass of one mole of ozone molecules? Note: the chemical formula for ozone is O₃.
   A) 16.00 g  B) 32.00 g  C) 48.00 g  D) 64.00 g

12) A newly discovered compound is found to have only carbon, hydrogen, and oxygen. If a 4.5 g sample of the compound is found to have 0.56 g of hydrogen and 1.2 g of oxygen, what percentage of the mass of the sample is due to the carbon?
   A) 12%  B) 27%  C) 39%  D) 61%

13) Which of the following pitchers of KoolAid will taste the strongest?
   A) A pitcher made by dissolving 2 scoops of KoolAid powder in 5 cups of water.
   B) A pitcher made by dissolving 4 scoops of KoolAid powder in 3 cups of water.
   C) A pitcher made by dissolving 8 scoops of KoolAid powder in 6 cups of water.
   D) A pitcher made by dissolving 3 scoops of KoolAid powder in 2 cups of water.

14) What percentage of the number of coins in your pocket are dimes if you have five dimes, two nickels, seven pennies, and one quarter?
   A) 12%  B) 25%  C) 33%  D) 50%

15) What is the coefficient in front of the H₂O when the following chemical equation is balanced?
   \[ _1CH_4(g) + _2O_2(g) \rightarrow _4CO_2(g) + _5H_2O(g) \]
   A) 1  B) 2  C) 4  D) 5
APPENDIX C

Worksheet #1 Calculating Atomic Mass
Math Worksheet #1: Atomic Mass

Imagine you open your textbook and see the following homework question: "Naturally occurring lithium consists of two isotopes, Li-6 with a mass of 6.015 amu and an abundance of 7.42% and Li-7 with a mass of 7.016 amu. Calculate the atomic mass of lithium and compare your value to the value found on the periodic table." Walking you through the mathematics involved with solving this type of problem is the goal of this worksheet.

In addition to requiring you to manipulate algebraic equations and to sometimes solve equations with two variables, the equation that is used to calculate atomic mass also requires you to be able to convert percentages into fraction or decimal form (see Background 1 below) and to understand the relationship between the percentages of a whole (see Background 2 below). Once you are proficient with these background skills, we will examine the mathematics needed to solve both single and multiple variable algebraic equations within the context of performing atomic mass calculations.

Background 1: Converting percentages to fractions or decimals
Percentage means "per hundred" so, 75.5% is the same as "75.5 per 100". This can also be written as the fraction \( \frac{75.5}{100} \) or as the decimal, 0.755 (found by typing 75.5 in your calculator and dividing by 100). Another way to covert 75.5% into decimal form is to move the decimal two places to the left and remove the % sign:

\[
75.5\% = 75.5\% = 0.755
\]

You Try #1: Fill in the blank boxes in the table below [Answers to all "You Try" questions are found on pages 7-9 of this worksheet.]

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Fraction</th>
<th>Decimal</th>
</tr>
</thead>
<tbody>
<tr>
<td>75.5%</td>
<td>75.5/100</td>
<td>0.755</td>
</tr>
<tr>
<td>89.6%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.098</td>
</tr>
<tr>
<td>67.9%</td>
<td>67.9/100</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.5746</td>
</tr>
<tr>
<td>7.36%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Math Worksheet #1: Atomic Mass

Background 2: The %'s have to add up to 100%
To solve some atomic mass calculations, it will be useful to remember that the percentages of a whole must add up to 100%. In our case, that means the sum total of the percent abundances of all of the isotopes of an element must equal 100%. For instance, if there is 75.5% of one isotope and the element only consists of two isotopes there must be 24.5% of the other isotope:

\[ 100\% - 75.5\% = 24.5\% \]

If there are three isotopes present for an element, and we have one isotope present at 4.3%, and the second isotope is present at 56.8%, to solve for the percentage of the third isotope, you would have to subtract 34.3% and 56.8% from 100%. You should be able to show that there is 8.9% of the third isotope present:

\[ 100\% - 34.3\% - 56.8\% = 8.9\% \]

If the percentages are written in decimal form, they will add up to 1, so the above equation could be written:

\[ 1 - 0.343 - 0.568 = 0.089 \]

You Try #2: Answer the following questions in the spaces provided.
1) If there are only three isotopes for a particular element, determine the percentage of the third isotope present if there is 45.7% of the first isotope and 23.9 % of the second isotope present.

2) If there are only two isotopes for a particular element, determine the percentage of the second isotope present if there is 89.7% of the first isotope present.

Now we are ready to work on calculations involving atomic mass. The general equation for calculating atomic mass can be found on page 111 in your text book. We will refer to this as Equation #1:

\[ \text{Atomic mass} = (\text{Fraction of isotope 1} \times \text{Mass of isotope 1}) + \\
(\text{Fraction of isotope 2} \times \text{Mass of isotope 2}) + \\
(\text{Fraction of isotope 3} \times \text{Mass of isotope 3}) + \ldots \]

On the next page we will learn how to do solve the most straight-forward type which requires us to solve single-variable equations.
Math Worksheet #1: Atomic Mass

Type 1: Solving single-variable equations
Using Equation #1 is straightforward when the mass and percentage of each isotope is given and you are asked to solve for the atomic mass (i.e. your single, unknown variable).

You Try #3: Naturally occurring lithium consists of two isotopes, Li-6 with a mass of 6.015 amu and an abundance of 7.42% and Li-7 with a mass of 7.016 amu. Calculate the atomic mass of lithium and compare your value to the value found on the periodic table.

Begin by filling in a table of our known values:

<table>
<thead>
<tr>
<th>Fraction of isotope 1 (Li-6)</th>
<th>Mass of isotope 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of isotope 2* (Li-7)</td>
<td>Mass of isotope 2</td>
</tr>
</tbody>
</table>

* This value is not directly provided in the question, but can be found using what you learned about percentages in Background 2 above.

Plug the values into the atomic mass equation (Equation #1) and solve for the atomic mass of lithium. Does it match the value found on the periodic table?

Solving a single variable equation is more difficult when the variable lies within the equation. Before we try one, let's just focus on the math involved. For example, imagine we need to solve the following equation for $x$:

$$10 = (2 \cdot x) + (1 \cdot 2)$$

Steps to solving for $x$:

1. Simplify the problem:
   $$(1 \cdot 2) = 2$$

2. Combine like terms:
   Subtract 2 from both sides of the equation:
   $$10 - 2 = 8$$
   $$2 \cdot x + 2 - 2 = 2 \cdot x$$

3. Solve for $x$:
   Divide each side by 2
   $$8/2 = 4$$
   $$2 \cdot x/2 = x$$

<table>
<thead>
<tr>
<th>Steps to solving for $x$:</th>
<th>Solution:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Simplify the problem:</td>
<td>10 = (2 \cdot x) + 2</td>
</tr>
<tr>
<td>2. Combine like terms:</td>
<td>8 = 2 \cdot x</td>
</tr>
<tr>
<td>3. Solve for $x$:</td>
<td>4 = x</td>
</tr>
</tbody>
</table>

3
Math Worksheet #1: Atomic Mass

You Try #4: For each equation below (a - c) solve for x. Do not continue until you can correctly solve all of these equations for x.

a) \( 9 = 3 \cdot x \)

b) \( 60 = (5 \cdot 6) + (3 \cdot x) \)

c) \( 25 = (x \cdot 5) + (3 \cdot 5) \)

Now we are ready to apply this same mathematics to another atomic mass calculation.

You Try #5: Magnesium has three naturally occurring isotopes: there is 10.03% of isotope Mg-25 with a mass of 24.9858 amu and 11.7% of isotope of Mg-26 with a mass of 25.9826 amu. The remaining isotope is Mg-24. What is the mass of Mg-24?

Fill in the following table with the known values:

<table>
<thead>
<tr>
<th>Fraction of isotope 2 (Mg-25) =</th>
<th>Mass of isotope 2 =</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of isotope 3 (Mg-26) =</td>
<td>Mass of isotope 3 =</td>
</tr>
<tr>
<td>Fraction of isotope 1* (Mg-24) =</td>
<td>Atomic mass of Mg* =</td>
</tr>
</tbody>
</table>

* Again, this value can be found using what you’ve learned about percentages.
* This value can be found on the periodic table.

Plug the values into the atomic mass equation (Equation #1). Before going on, check the starting equation on the last page of this worksheet. Once you have the correct starting equation, solve for mass of isotope Mg-24 (isotope 1).
Math Worksheet #1: Atomic Mass

Student name:

Type II: Solving multi-variable equations

All of the above problems had one variable to solve for. Some atomic mass calculations, however, have more than one variable. This type of problem occurs when you are given each isotope's mass, you have the atomic mass (from the periodic table), and you are asked to solve for the % of the isotopes. Let's look at an example, with an emphasis on understanding the mathematics.

Guided example: Boron has two naturally occurring isotopes: B-10 with the mass of 10.013 amu and B-11 with the mass of 11.009 amu. What are the natural % abundances of the two isotopes?

We begin by filling in the table below with any known values, using the periodic table when needed:

<table>
<thead>
<tr>
<th>Mass of isotope 1 (B-10)</th>
<th>Mass of isotope 2 (B-11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.013 amu</td>
<td>11.009 amu</td>
</tr>
</tbody>
</table>

| Atomic Mass of B = 10.810 amu |

Follow the solution side of the table and if any of the steps are confusing refer to the notes in the left side of the table. To allow us to focus on the mathematics in this problem we will be leaving off the “amu” units. Always make sure you answer has the correct units though.

<table>
<thead>
<tr>
<th>Steps to solving the problem:</th>
<th>Solution:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Plug the knowns into Equation #1 and simplify the equation. Let (fraction of isotope 1) = x and (fraction of isotope 2) = y</td>
<td>10.810 = (x * 10.013) + (y * 11.009)</td>
</tr>
<tr>
<td>2. Write a second equation that relates x and y. The key to solving multi-variable equations is to have a second equation. We know from what we learned from Background 2 that the sum of the fractions of each isotope is equal to one.</td>
<td>x + y = 1 or x = 1 - y</td>
</tr>
<tr>
<td>3. Use the equation from step 2 to convert the multi-variable equation in step 1 to a single variable equation. Plug in (1-y) for x:</td>
<td>10.810 = ((1-y) * 10.013) + (y * 11.009)</td>
</tr>
<tr>
<td>4. Solve for y:</td>
<td></td>
</tr>
<tr>
<td>b. Combine like terms on each side of the equation. Subtract 10.013 amu from both sides of the equation. Add -10.013y to 11.009y. Remember y needs to be by itself.</td>
<td>0.797 = 0.996y</td>
</tr>
<tr>
<td>c. Solve for y by dividing each side by 0.996</td>
<td>0.800 = y</td>
</tr>
<tr>
<td>5. Use equation from step 2 to solve for x. This is done because the problem asks for the percentages of both isotope 1 and isotope 2.</td>
<td>x = 1 - y or x = 1 - 0.800 = 0.200</td>
</tr>
<tr>
<td>6. Convert decimal form into percentage (Remember: x = fraction of isotope 1 (B-10) and y = fraction of isotope 2 (B-11), as you do not want to switch your answer by accident)</td>
<td>% of isotope B-10 = 20.0% % of isotope B-11 = 80.0%</td>
</tr>
</tbody>
</table>
Math Worksheet #1: Atomic Mass

Answer the following exam-type questions in the space provided. Feel free to use the periodic table as needed.

You Try #6: Copper has two naturally occurring isotopes, Cu-63 with a mass of 62.940 amu and Cu-65 with a mass of 64.928 amu. What are the percentages of the two isotopes in naturally occurring copper?

You Try #7: Nitrogen contains two naturally occurring isotopes, N-14 with a mass of 14.003 amu and N-15 with a mass of 15.000 amu. What are the percentages of the two isotopes in naturally occurring nitrogen?
APPENDIX D

Worksheet # 2 Scientific Notation
Mathematics Worksheet #2: Scientific Notation

Writing numbers in scientific notation is an abbreviated way to write very large or very small numbers. This is particularly important in science where we often use very small and very large numbers. For example, the mass of a proton \( = 0.0000000000000000000000000167 \) kg and the distance light travels in 1 year = 954000000000000 m.

It wouldn't take more than a few of these numbers before you'd grow tired of counting zeros and would be looking for a short cut. Luckily for us, Scientific Notation is just the key for dealing with really large or really small numbers.

**Background 1: "To the power of"**

In order to understand scientific notation we must first understand what "to the power of" means. When we say "10 to the power of 4", it is the same things as writing "10^4". Which means we are going to multiply 10 by itself, four times (in other words, \(10 \times 10 \times 10 \times 10\)). In this example, 10 is the base and 4 is the exponent.

You Try #1: Type the following in your calculator and record your answer:

a) \(10^0 = \)

b) \(10 \times 10 \times 10 \times 10 = \)

Here are two more examples of "ten to the power of":

- \(10^2 = 10 \times 10 \times 10 \times 10 \times 10 = 1000000\)
- \(10^3 = 1\)

You Try #2: Review the above examples.

a) What is the pattern between the exponent and number of zeroes in the final answer?

For smaller numbers (less than one), 10 is raised to a negative number. Here are a couple examples:

- \(10^{-4} = 10^{-1} \times 10^{-1} \times 10^{-1} \times 10^{-1} = \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = 0.0001\)

- \(10^{-2} = 10^{-1} \times 10^{-1} = \frac{1}{10} \times \frac{1}{10} = 0.01\)

You Try #3: Type the following in your calculator and record your answer:

a) \(10^{-4} = \)

b) \(\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} \times \frac{1}{10} = \)

You Try #4: Review the above examples.

a) What is the pattern between the exponent and the number of digits behind the decimal?
Mathematics Worksheet #2: Scientific Notation

You Try #5: Fill in the missing boxes of the table:

<table>
<thead>
<tr>
<th>Original number</th>
<th>Written in terms of 10's</th>
<th>Written as an exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000</td>
<td>$10 \times 10 \times 10 \times 10$</td>
<td>$10^4$</td>
</tr>
<tr>
<td>100,000</td>
<td>$10 \times 10 \times 10 \times 10 \times 10$</td>
<td>$10^5$</td>
</tr>
<tr>
<td>1,000,000,000</td>
<td>$10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$</td>
<td>$10^8$</td>
</tr>
<tr>
<td>0.0000001</td>
<td>$\frac{1}{10} \times \frac{1}{10} \times \frac{1}{10}$</td>
<td>$10^{-6}$</td>
</tr>
</tbody>
</table>

Background 2: When writing a number in scientific notation, we will need to express the original number as a number between 1 and 10 multiplied by a number that is a power of ten.

Here are a few examples:
- $6,500 = 6.5 \times 1,000$ (Note: 6.5 is between 1 and 10 and 1,000 is a power of ten number)
- $790 = 7.9 \times 100$
- $5,690,000 = 5.69 \times 1,000,000$

You Try #6: Fill in the blank for the equations below

a) $35,000 = \ldots \times 10,000$

b) $670 = 6.7 \times \ldots$

c) $\ldots = 6 \times 0.1$

d) $0.053 = \ldots \times 0.01$

Now we are ready to write numbers in scientific notation.
In order to write a number in scientific notation, you would combine what you learned in Parts 1 and 2.

If: $6,000 = 6 \times 1,000$ and $1,000 = 10 \times 10 \times 10 = 10^3$

Then, we can conclude that $6,000 = 6 \times 1,000 = 6 \times 10 \times 10 \times 10 = 6 \times 10^3$

You Try #7: Type the following in your calculator and record your answer:

a) $6 \times 10 \times 10 \times 10 = \ldots$

b) $6 \times 10^3 = \ldots$
Mathematics Worksheet #2: Scientific Notation

If you have trouble writing a number in scientific notation based on the above examples, follow the steps in the tables below:

**Write 2735 in scientific notation**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Write a decimal directly after the first non-zero number on the left.</td>
<td>2.735</td>
</tr>
<tr>
<td>2)</td>
<td>Count the number of places you moved the decimal. (If there is initially no decimal, as in the above example, count from the digit furthest to the right.)</td>
<td>$\times 10^3$</td>
</tr>
<tr>
<td>3)</td>
<td>The number counted in step 2 is the exponent of 10. The exponent is positive if the decimal was moved to the left. The exponent is negative if the decimal is moved to the right.</td>
<td>$2.735 \times 10^3$</td>
</tr>
</tbody>
</table>

Here, the exponent is positive 3, as the decimal was moved 3 places to the left.

**Write 0.00089 in scientific notation**

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1)</td>
<td>Write a decimal directly after the first non-zero number on the left.</td>
<td>8.9</td>
</tr>
<tr>
<td>2)</td>
<td>Count the number of places you moved the decimal. (If there is no decimal, count from the digit furthest to the right.)</td>
<td>$\times 10^{-4}$</td>
</tr>
<tr>
<td>3)</td>
<td>The number counted in step 2 is the exponent of 10. The exponent is positive if the decimal was moved to the left. The exponent is negative if the decimal is moved to the right.</td>
<td>$8.9 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

The exponent is negative 4, as the decimal was moved 4 places to the right.

**You Try #8:** Write the following numbers in scientific notation

a) 548 =

b) 0.0000769 =

c) 4567923 =

d) 0.00675 =

e) The mass of a proton, $0.0000000000000000000000000000000167$ kg =

f) The distance light travels in 1 year, $954000000000000$ m =
APPENDIX E

Worksheet #3 Significant Figures
Mathematics Worksheet #3: Significant Figures

Student name:

Significant Figures represent the precision of a measured quantity. The greater the number of significant figures, the greater the precision of the measurement.

You Try #1: If you have two rulers, one with only hash marks for each cm and one with hash marks for each mm. Which ruler would you select if you had to measure 1.5 cm? Why?

If you used the ruler that only had hash marks per each cm and you measured 1.5 cm, you could only be certain your measurement is greater than 1 cm and less than 2 cm. In this case you might report your length as 1.5 cm, with the last digit being uncertain.

If you used the ruler with hash marks for each mm, then you could be certain that your measurement is greater than, for example 1.5 cm but less than 1.6 cm. Now you might report the length as 1.52 cm. In this case, you are certain about the "5", and it is the "2" that you are uncertain about. With the second ruler, the uncertainty of the measurement has been narrowed down and there are more significant figures for the measurement. This greater level of precision should be conveyed when reporting the measurement and in all calculations that involve the measurement.

Background 1: To determine how many significant figures a number has, follow these rules:

Rule I. All non-zero digits are significant. For example:

567 has three significant figures
49832 has five significant figures

You Try #2: How many significant figures do the numbers below have?

a) 6798 has _____ significant figures
b) 9 has _____ significant figures

Rule II. Interior zeros are significant. For example:

1.09867 has six significant figures
34098 has five significant figures

You Try #3: How many significant figures do the numbers below have?

a) 3400.098 has _____ significant figures
b) 309 has _____ significant figures

Rule III. Zeros to the right of a non-zero number and following a decimal are significant (these zeros represent the precision of the measurement). For example:

5.0 as two significant figures
6780.000 has seven significant figures

You Try #4: How many significant figures do the numbers below have?

a) 7009.00 has _____ significant figures
b) 8.00 has _____ significant figures
Mathematics Worksheet #3: Significant Figures

Student name:

Rule IV. All other zeroes are insignificant (these zeroes are place holders and are eliminated when the number is written in scientific notation). For example:

- 0.56 has two significant figures
- 7840000 has three significant figures

You Try #5: How many significant figures do the numbers below have?

a) 0.000004 has _____ significant figures
b) 900 has _____ significant figures
c) 0.0005789 has _____ significant figures

You should now be ready to try some examples using all of the above Rules I - IV.

You Try #6: How many significant figures do the numbers below have?

a) 346098 has _____ significant figures
d) 9.006 has _____ significant figures
b) 0.00405600 has _____ significant figures
e) 2.00 has _____ significant figures
c) 101,000 has _____ significant figures

Now we are ready to determine significant figures when performing calculations. This skill is important in chemistry because you will often be given different measurements and will need to determine the precision of a calculated answer based on the measurements given. To determine how many significant figures a result has, we must follow different rules depending on whether we are adding/subtracting or multiplying/dividing our measurements.

Type I. When adding and subtracting numbers, the result has the same number of decimal places as the quantity having the fewest decimal places.

Guided example: \( 9.09 + 8.00 + 5.6 = 22.69 \div 22.7 \)

The answer was 22.69 when using my calculator, but because the quantity 5.6 only has one decimal place, the result can only have one decimal place. The answer was rounded to 22.7.

You Try #7: Refer to page 18 of your text book and record the rounding rules and give three examples of rounding:

---

You Try #8: Determine the correct result of the following calculations:

a) \( 0.89 + 67,500.896 + 75.768 = \)
b) \( 785.985 - 34.9867 - 267.78 = \)
c) \( 45.9 \times 87 - 31 = \)
Mathematics Worksheet #3: Significant Figures

Student name:

Type II. When multiplying or dividing the result has the same number of significant figures as the factor with the fewest significant figures.

Guided example: \(5.500 \times 2.0 \times 36.2 = 398.2 = 400 = 4.0 \times 10^2\)
The calculator answer was 398.2. The actual answer can only have two significant figures (so it should be cut off before the "8") because the factor 2.0 only had two significant figures. When we do this, the "39" becomes "40". Because the trailing zeros are not counted as significant, we need to write it scientific notation to make it clear that the answer has 2 significant figures.

You Try #9: Determine the correct result for the following calculations:

a) \(6.78 \times 45 \times 28.9 = \)

b) \(45.987 \times 65.4897 = 3.4\)

c) \(78.45 + 345.09 + 54.387 = \)

Type III. When performing calculations that involve a combination of both multiplying/dividing and addition/subtraction, both sets of rules must be considered. For example, consider the following calculation which is worked out in the table below: \((7.89 - 4.8)/(5 + 5.67)\)

<table>
<thead>
<tr>
<th>Step</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Solve the operations in parentheses first. Carry one extra significant figure for the next step in the calculation. Underline the last significant figure so you can keep track.</td>
</tr>
<tr>
<td></td>
<td>7.89 - 4.8 = 3.09</td>
</tr>
<tr>
<td></td>
<td>Because 4.8 only has one decimal place, our answer technically has one decimal place (noted by underlining it), but we keep the extra significant figure for the next step to avoid rounding errors.</td>
</tr>
<tr>
<td></td>
<td>5 + 5.67 = 10.67 = 10.7</td>
</tr>
<tr>
<td></td>
<td>Because &quot;5&quot; has no decimal place, our answer technically has no decimal place (noted by underlining it), but we keep the extra significant figure (here, the 6 rounded up to a 7).</td>
</tr>
<tr>
<td>2.</td>
<td>Use the results from step one to solve the equation.</td>
</tr>
<tr>
<td></td>
<td>The calculated answer was rounded to 2 significant figures from both factors in the calculation. Remember although we wrote &quot;3.09&quot;, the &quot;9&quot; was not actually significant.</td>
</tr>
</tbody>
</table>

You Try #10: Write the results of the equations with the correct number of significant figures:

a) \((789.923/4.78) + (234.98/45) =\)

b) \((6745 + 4.78) \times 3.56 =\)

c) \(98.70068 - 34.67903 + (4567.8904/56.3452) =\)
APPENDIX F

Worksheet #4 Percent Composition
Mathematics Worksheet #4: Percent Composition

Student name:

**Background:** To determine how much of an element is in a given sample of a compound we need to determine the element's mass percent composition for that compound. The element's mass percent composition is constant for each compound no matter how much of the compound you have. For example, whether you have a teaspoon of H₂O or a whole swimming pool of H₂O, the percent of the total mass of the sample that is due to the hydrogen is always the same.

You Try #1: Write the definition for the term mass percent composition.

---

**Part I: Determining mass percent in everyday life.**

**Guided example:** You are going to the river with your friends for the weekend. You volunteer to bring the trail mix. Your favorite recipe for making a big batch of trail mix requires 350 g of chocolate chips, 210 g of raisins, and 840 g of peanuts. What is the mass percent of chocolate chips in your trail mix?

| Step | Description | Calculation
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Determine the total mass of 1 batch of trail mix.</td>
<td>350. g + 210. g + 840. g = 1400. g</td>
</tr>
<tr>
<td>2.</td>
<td>Determine the fraction of chocolate chips in 1 batch of trail mix. Do this by dividing the mass of chocolate chips in 1 batch of trail mix by the total mass of 1 batch of trail mix (from Step 1).</td>
<td>350. g / 1400. g</td>
</tr>
<tr>
<td>3.</td>
<td>Percentage means per hundred. Set the fraction from Step 2 equal to X/100% and solve for X.</td>
<td>350. g / 1400. g = X / 100%</td>
</tr>
</tbody>
</table>

You Try #2: What is the mass percent of raisins in your trail mix?

You Try #3: Can you think of an easy way to determine the mass percent of peanuts in your trail mix?
Mathematics Worksheet #4: Percent Composition

Part 2: Determining mass percent in chemistry.

Guided example: What is the mass percent of H in NH₃?

1. Determine the total mass of 1 mol of NH₃. Do this by adding up: (1 x mass N) + (3 x mass H).
   \[
   \text{mass of 1 mol NH}_3 = (1 \times 14.01 \text{ g}) + (3 \times 1.008 \text{ g})
   \]
   \[
   = 14.01 \text{ g} + 3.024 \text{ g}
   \]
   \[
   = 17.03 \text{ g}
   \]

2. Determine the fraction of H in NH₃ by dividing the mass of H in 1 mol of NH₃ (note: there are 3 moles of H in 1 mole of NH₃) by the mass of 1 mol of NH₃ (from Step 1).
   \[
   \frac{3 \times 1.008}{17.03}
   \]

3. Percentage means per hundred. Set the fraction from Step 2 equal to X/100% and solve for X.

   \[
   \frac{3.024}{17.03} = \frac{X}{100%}
   \]

   For any sample of NH₃, 17.76% of the mass will be due to H.

You Try #4: What is the mass percent of O in CO₂?

Part 3: Using mass percent in everyday calculations.

Guided example: Using the trail mix from Part 1, how many grams of trail mix could you make with 475 g of chocolate chips? Remember, our trail mix is 25.0% chocolate chips by mass.

1. Since the trail mix is 25.0% chocolate chips by mass, every 100 g of trail mix has 25.0 g of chocolate chips. Start by writing this as a fraction.
   \[
   \frac{25.0 \text{ g chocolate chips}}{100 \text{ g trail mix}}
   \]

2. Use the fraction in Step 1 to solve for how many grams of trail mix can be made from 475 g of chocolate chips. Let the units guide you to indicate whether to use the fraction from Step 1 as written or whether to flip it.

   \[
   \frac{475 \text{ g choc. chips}}{25.0 \text{ g choc. chips}} \times \frac{100 \text{ g trail mix}}{1 \text{ g trail mix}}
   \]
   \[
   = 1900 \text{ g trail mix}
   \]

   With 475 g of chocolate chips, you can make 1900 g of trail mix (1.90 x 10³ g with correct sig figs).
You Try #5: Continuing with our trail mix, how many grams of raisins would be needed to make 280 g of trail mix? Remember, we found in Part 1 that our trail mix is 15.0% raisins by mass.

Part 4: Using mass percent in chemistry calculations.

Guided example: How many g of N are there in a 43.6 g sample of nitric acid (HNO₃)? Nitric acid is 22.23% N by mass (you can verify this for extra practice).

1. We are told that HNO₃ is 22.23% N by mass, so every 100 g of HNO₃ has 22.23 g of N. Write this as a fraction.

   \[
   \frac{22.23 \text{ g N}}{100 \text{ g HNO}_3}
   \]

2. Use the fraction in Step 1 to find how many grams of N are in 43.6 g of HNO₃. Let the units guide you to indicate whether to use the fraction from Step 1 as written or whether to flip it.

   \[
   \left( \frac{43.6 \text{ g HNO}_3}{100 \text{ g HNO}_3} \right) \cdot \frac{22.23 \text{ g N}}{100 \text{ g HNO}_3} = 9.69 \text{ g N}
   \]

   43.6 g of HNO₃ contains 9.69 g of N.

You Try #6: If you have 8.00 g of O, how many grams of sulfuric acid (H₂SO₄) can be produced? H₂SO₄ is 65.25% O by mass (you can verify this for practice).
Mathematics Worksheet #4: Percent Composition

Student name:

Part 5: More practice determining mass percent and using mass percent in calculations.

You Try #7: What are the mass percents of Na, O, and H in sodium hydroxide, NaOH?

You Try #8: If you have 6.80 g of Na, how many grams of NaOH can you produce?

You Try #9: What are the mass percents of Li, S, and O in lithium sulfate, Li₂SO₄?

You Try #10: How many g of Li are there in a 27.60 g sample of Li₂SO₄?
BIBLIOGRAPHY


