

FRONT LOADING SCIENCE-RELATED MATH SKILLS IN
HIGH SCHOOL CHEMISTRY

by

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A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2018

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DEDICATION

I would like to dedicate this paper to my loving, supportive husband who was my biggest fan and editor. Without his encouragement and motivational words, it would have been a longer, harder endeavor. I would also like to dedicate this accomplishment to my daughter, mother and parents-in-law who checked in with me every step of the way. You never outgrow the love and advice of mom and dad and you should never underestimate the power of family.

ACKNOWLEDGEMENT

I would like to take this opportunity to acknowledge my administration staff at Erie High School for their support and approval of this project. In particular, I appreciate the encouragement from my principal, Matt Buchler, and the interest and advice from my rater and assistant principal, Liz Russell. They both convey the message that we, as teachers, make a positive difference in our work.

I would be remiss if I did not recognize my reader, Dr. Steve Holmgren, who was willing to take the time to look over my work and give advice in a very kind manner.

And most importantly, I would like to thank Dr. John Graves for his patience, compassion and expert guidance throughout this adventure. He gladly shared his experiences and used his own techniques of inquiry to help guide his students, no matter the age. I appreciate the clear passion he has for his work and the kindness he shows to all. This blend of traits makes for a great mentor and role model.

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ABSTRACT

Student achievement in a chemistry curriculum can be greatly impacted by whether they have an understanding of critical math concepts and the skills to perform those concepts. The purpose of this study was to determine the effectiveness of frontloading the required math concepts, practicing the skills involved in problem solving and providing the relevance of the concepts to chemistry. Tests, surveys, formative assessments and interviews were used to compare a treatment and a non-treatment group. The treatment group received the specific math lessons and practice at the beginning of a unit along with the application to the chemical topic. The non-treatment group was taught with conventional methods of learning the chemistry formulas through lectures and textbook assignments with the assumption that their math skills were adequate. The tests were utilized to determine the increase in content knowledge as well as mathematical strengths in problem solving. Surveys, formative assessments and interviews were used as qualitative data to measure chemistry and math attitudes and confidences. The results of this study showed no statistical difference in overall achievement averages or confidence/attitudes among the treatment and non-treatment groups when taught math up front as compared to within the unit.

INTRODUCTION AND BACKGROUND

I currently teach at Erie High School, located in Erie, Colorado, 20 miles north of Denver and just east of Boulder. Erie is a small town with an estimated population of 26,250 and a median household income of \$112,000. We are still considered a rural area, but have a fast-growing population, from 6,300 in 2000 to 26,250 in 2018, with over 19.6 square miles (incorporated). The town estimates the population in 2020 will be around 29,500 (Town of Erie, 2018). Erie's ethnic makeup is roughly 89% Caucasian, 8% Hispanic, an Asian population of 4% and an African-American population of about <1%. Sixty percent of the population has a bachelor's degree of education or higher, with a large percentage of individuals working in medical or professional careers (Suburban Stats, 2018). We have over 1,200 students at Erie High with demographics similar to the town's. The school offers many Advanced Placement courses, has an aerospace engineering/computer science focus, established sports, music, and drama programs. Our free- or reduced-lunch population is very small at 18% (Buchler, 2018). We have very little trouble with bullying or fighting, and have a strong student government that makes the school feel like a community/family. The climate of my classroom is safe and energetic, with most of the kids having gone to school together through one feeder middle school and four elementary schools.

Our school operates on an alternating block schedule where the students have a total of eight classes, four on an A day and four on a B day. The classes are 89 minutes in length Monday through Wednesday and 82 minutes on Thursday and Friday with a 25-minute advisory period worked into the day. The advisory time is used for assemblies,

grade check-ins and counseling events such as resume building and college exploration. I typically teach various levels of chemistry to include general, honors and Advanced Placement. The particular classes with which I conducted my research were honors chemistry courses with a total of 104 students divided into four classes. The only prerequisite or co-requisite for this curriculum is Algebra II which is required to ensure the students have the math background to work with proportions, conversions, formulas to solve for unknown variables and to understand logarithms presented in word problems. In the first two years of teaching chemistry, I realized how difficult the concept of dimensional analysis, converting a quantity of one unit to another unit using equivalent factors, was for about a third of my honor students and over half of my general chemistry students. I found they also struggled with solving for an unknown variable when confronted with a word problem involving new chemistry vocabulary. I also realized that many of the students who could easily do the math did not understand the meaning of the mathematical result or the concept behind the math, therefore were not able to explain their approach. In order to address this issue, I chose to study the effect of purposefully frontloading and reviewing the math needed within each unit, and then relating the chemistry concepts and mathematical applications as they were introduced in the lessons. Before solving a mathematical problem, students need to first describe the solution process without using quantitative values. My experience with my classes this year led to the creation of my focus statement: What are the effects of front loading science-related math skills used in a Chemistry unit on student achievement and attitudes?

I believed that if the students had a better grasp of mathematical concepts and could express their reasoning and approach to problem solving, this would remove a major barrier to understanding and internalizing the chemistry concepts and would lead to higher performance by these students.

CONCEPTUAL FRAMEWORK

Mathematical applications and abilities, as well as critical thinking, are essential in the scientific disciplines, especially engineering, physics and chemistry. Lack of proficiency with these skills seems to be a major theme among high school and college students in introductory and general chemistry courses (Potgieter, Harding & Engelbrecht, 2008). In order to better prepare individuals for the demands of science classes, education must lay the groundwork to enable students to become successful at questioning, reasoning and analyzing all types of data. It is this belief that initiated the framework laid out in the Next Generation Science Standards (NGSS) that educators from 26 states culminated into a set of guidelines and practices to enrich science education across grades K-12. These guidelines help to connect the math and science/engineering practices that increase understanding and complement each other across the four main science content areas of physical, life, Earth/space and engineering design. Students in today's science classroom should be able to define a problem, use models to explain, develop and perform an investigation and then evaluate the outcome (NGSS Lead States, 2013). In a chemistry setting, that involves analytical thought, an understanding of math algorithms and the ability to evaluate an answer.

For years, researchers have noticed a gap in students' abilities to apply what they learned in math classes to chemistry problems, starting in high school and continuing through freshmen year of college (O'Connor, 2003). The topics in a high school chemistry year can vary greatly from first semester to second semester, as can the necessary math skills required of the students. Most of the first semester is understanding concepts such as atomic structure, periodic table characteristics and trends, naming compounds and writing formulas. Second semester involves dimensional analysis with molar conversion, stoichiometry, dilutions and molarity, gas laws, pH calculations with logarithms and enthalpy formulas. This shift can cause a noticeable difference in students' grades between the semesters.

College chemistry instructors have noticed deficiencies among the incoming freshmen classes for years and have introduced introductory courses as interventions (Bohning, 1982). Many of these courses are voluntary and non-credited, with the expectations of the students themselves recognizing a need to attend. That need can be obvious through self-testing or standardized tests scores in math. At the college level, math and chemistry departments have worked together to help increase retention and academic success in freshman courses through development of interdisciplinary programs. These collaborative efforts have addressed not only the math/chemistry connection, but also the culture, attitudes of academic success and strategies to overcome student attitudes of fixed achievement (Angel & LaLonde, 1998). Some programs go as far as complete integration of math and chemistry, with developed textbooks that blend the two curriculums. The MATCH program, a combined math and chemistry course at

the University of Illinois at Chicago, took three years to plan, develop and adopt. The University did not use it as an intermediate class; instead, the students earned separate credits for a standard algebra course and an introductory chemistry course. The merged curriculum was complete with a lab and included a total of nine hours of contact time per week for the students to work on both subjects. When these students took the next level of chemistry, they performed better than their contemporaries who took a separate introductory chemistry course and intermediate algebra course. In addition to academic success, the majority also felt more confident to speak up in class. The benefits of a deeper understanding of mathematical relationships from the course continued in more advanced math classes as well (Wink & Gislason, 2000).

Some universities conducted studies to look at the correlation between math abilities using SAT or ACT scores and passing rate of freshmen chemistry students. The University of Akron, an open-enrollment institution, found their attrition rate of chemistry students that had not successfully completed a course in college algebra or higher was 23.7%. The department set prerequisites in place for their Principles of Chemistry I course to increase students' chance of success, and found their number of students passing the course with a C or higher went up by almost twenty percent (Donovan & Wheland, 2009).

The lack of mathematical proficiency is not the only factor that has been examined as it relates to poor grades in introductory chemistry courses. Researchers at Dublin City University investigated students' abilities in transferring mathematical abilities to chemistry. The premise was that students with competent mathematical skills

were having trouble relating those skills to a similar example in a chemistry format. The students were tested on similar math and chemistry problems to see if the context affected the students' abilities to solve those problems and to determine whether or not they could explain their answers in a clear and meaningful way. The results supported the belief that students can transfer mathematical knowledge across curricula, if they have an understanding of what their mathematical answer portrays (Hoban, Finlayson, & Nolan, 2013). In other words, if students just plug in numbers and chug out calculations without knowing what the answer signifies, it has less of an impact and students cannot carry over that information (Preininger, 2017). The students are considered proficient in math, yet cannot convey what the answer means in terms of application. There are published method approaches to teach problem-solving skills specifically to chemistry students. These methods help learners try to formulate the problem in their minds without immediately looking for a formula to plug in numbers blindly. One method encourages students to physically sketch the problems and break them down into simpler parts (Genyee, 1983). The key is to avoid the feeling caused by anxiety of not knowing where to start and therefore giving up or just guessing.

Another belief about the cause of poor chemistry performance is lack of metacognition, the ability to reflect on one's own thinking and skills, such as one's strengths and weaknesses or ability to organize a learning task. An effective learner must recognize when there is a problem with their solution or with the process that they used to get there. This transition of self-awareness, to understand what they don't know before the instructor assesses them, is key to an accomplished learner. This research examined

the effect of teaching students how to study by giving them different tools to approach the college-level chemistry class, compared to what they used in high school. Some of the tools included prior exposure to the material before lecture, working problems without relying on the examples, working effectively in a group study and rewriting notes after lecture. The students that applied these new techniques with fidelity did much better in the class than those who chose to not use them. These techniques were taught in one 50-minute class at the beginning of the semester (Cook, Kennedy & McGuire, 2013).

Universities are not the only institutions noticing the lack of success, as high schools see their students having the same difficulty applying their math skills in high school chemistry. Some chemistry courses require prerequisites or co-requisites, to ensure the student has attained the math level expected for the rigorous lessons. Completion of these required courses lend to the assumption that students have what it takes to master the mathematical problems in chemistry. Using pre- or co-requisites also help, because chemistry teachers do not feel they have the time to fit in the review necessary to help students recall or acquire these skills. Polancos (2009) discovered that whether math review happens at the beginning of the lesson or at the point of introduction of the chemistry concept and algorithms within the lesson, the results appear to be the same. Student gender, attitude and math ability were not considered in this research.

The key seems to be the cognitive connection that students make within their own learning; the transfer of information into understanding, not memory. -Approaches such as thinking out loud, writing the algorithmic approach down in words instead of just

numbers, and simulations with graphical interpretation may help students make those connections (Lobato, 2006). Understanding of concepts and processes seems to strengthen when students share or act as the teachers themselves.

Nokes-Malach and Mestre (2013) worked on the framework of knowledge transfer, whether in a math, physics or chemistry curriculum. They reiterated the importance of a student's background knowledge and experiences on their ability to transfer their proficiencies from one type of problem to one in a different subject or situation. When asked to describe what is going on in a problem or situation, many students are unsure of how to answer, as they struggle with a quantitative or a qualitative explanation and don't know where to start.

Researchers in a study in Australia used two approaches, text editing and worked examples, to determine how easily high school students could break down and understand a chemistry word problem. Text editing involves having students find necessary information within the text of the problem and assess whether all the components are there to answer the question. Some word problems were purposefully missing information and some had extraneous information, which the students had to recognize. Worked examples are sample problems that are solved and paired up with word problems that have all the necessary information. Students then worked similar problems and used the examples for help. The results of the experiment were limiting, as sample size was small and students' math abilities were not determined in advance. The researchers, though, did find that text editing was useful in improving students' overall

problem-solving abilities, as those using text editing made significantly fewer conceptual errors (Ngu, Yeung & Phan, 2015).

Additional research is needed to determine the best way to build and support the necessary framework to help students become more cognizant of their number sense and ability to apply it to a situation. Many students who have achieved a proficient level in mathematics still struggle with applying those math skills to various chemistry problems and lab preparations in high school and into college. A method or approach to closing this missing gap should to be explored further in order to help students make connections and develop a deeper understanding of how math relates to their natural world.

METHODOLOGY

The purpose of this study was to test a treatment that would help chemistry students with their knowledge base in the applied math concepts and skills needed to be successful and confident in each of the units in a high school chemistry course. I have noticed throughout my six years as a high school teacher that, although the students have taken the required prerequisite math classes to get into chemistry, they don't necessarily recall how to use or understand why they are using particular formulas or calculations; and therefore, do not perform as well as they could. My goal was to determine the level of the students' math skills needed for the upcoming chemistry unit, then address and enhance those skills through math lessons taught at the beginning of the unit. I then assessed retention and application of the math used to solve the chemistry problems within and after the unit. The treatment (Tx) groups started out each unit with math instruction specifically designed to impart the math skills necessary to solve the

chemistry problems found within that unit. The warm ups for this group included more math-based practice problems, with chemistry word problems that followed along with some chemistry concepts. The non-treatment (Non-Tx) groups worked with the math as it was introduced within the unit, and did not receive front-loaded instruction on the basic math concepts. Their warm ups were chemistry word problems and more chemistry concepts. All of the students included in the project, treatment and non-treatment, were given unit pre-tests to establish prior knowledge and a follow-up summative chemistry unit post-test with similar embedded post-test math questions for comparison and analysis. The research methodology for this project received an exemption by Montana State University's Institutional Review Board, and compliance for working with human subjects was maintained (Appendix A).

For this research project, I used my four honors chemistry classes, which contained 104 total students. Within the classes overall, there were 53 females and 51 males, broken down into 88 sophomores, 14 juniors and 2 seniors. The math skills varied, with 5.7 % of the students currently taking geometry, 52.4% Algebra II and 41.9% advanced math classes such as trigonometry/pre-calculus, statistics or calculus (Figure 1). While not exact, my student population is similar to the town's racial demographics.

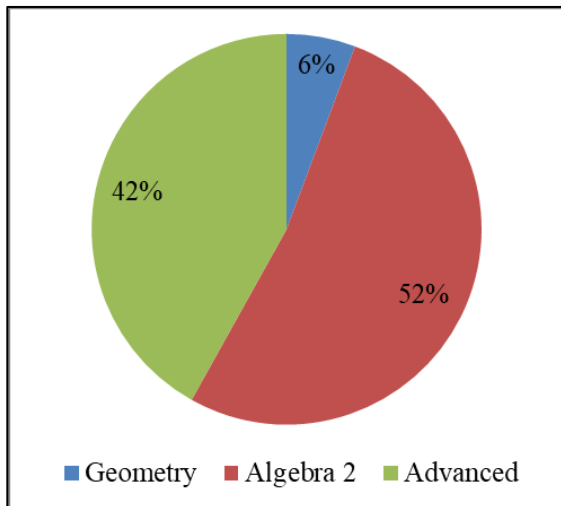


Figure 1. Math skill levels of students, ($N=104$).

The Spring Semester Math in Chemistry Pre-Test, containing necessary algebra, conversion and basic math computation used in chemistry calculations, was administered before and after the two focused chemistry units. The objective of the assessment was to measure students' math aptitudes pertaining to the necessary skills specific to the Moles Unit and the Solutions Unit (Appendix B). This test contained problems with basic numerical calculations such as conversions, order of operations, exponents, proportions and percentages and solving for single, unknown variables. The treatment and non-treatment groups were switched after the first unit to ensure that variables such as abilities or work ethic were not the driving factors in differences. The math pre- and post-test scores were compared at the end of the three-month project time-line to look for overall improvement and retention of math skills among the students.

The Attitudes and Confidences in Math and Chemistry Survey was developed based on the Colorado Learning Attitudes about Science Survey Index (Barbera, Adams, Weiman & Perkins, 2008) and used to determine students' mindsets toward the two subjects (Appendix C). The survey was initially administered to each of the groups,

treatment and non-treatment, before the Mole Unit was taught. The students were asked to choose between strongly agree, agree, disagree, and strongly disagree. Each question was scored according to the impact it had on the student's attitude and confidence. Questions that indicated a negative attitude or response were scored a 4 for strongly disagree and a 1 for strongly agree; therefore, corresponding the higher score to a more positive confidence or attitude. Questions that showed a positive attitude or confidence result scored a 4 for strongly agree and a 1 for strongly disagree. Five of the questions were informational only, to determine what students thought was the easiest part about solving chemistry problems; the algebra, identifying the necessary information or finding the right equation. Due to assigning values to the four categories and changing the negative distributions to positive values, the Welch's Paired Two-Sample t-test was performed to examine differences among the data sets.

The first unit studied was the Mole Unit, which started off with a short, 12-question Moles Unit Pre-Test to determine prior knowledge (Appendix D). Within this unit, students were expected to be able to measure matter by count (number of particles), mass and volume, as well as convert between the measurement units, using known values such as Avogadro's number and volume of one mole of any gas at STP. Additional expectations were to calculate the percent, by mass, of an element in a compound, find the empirical formula of a given compound and mathematically relate molecular formula to the empirical formula. I chose to use my third and fifth block classes as the treatment groups for this first trial. First and second blocks did not receive the math introduction or math-only lessons, and did not have warm-up questions that were related to only math

concepts and practice. The pre- and post-test for the Mole Unit was analyzed with a Welch's t-test.

The initial math lesson included students partnering up to find the mass of a dozen various objects around the classroom, which they recorded on a 4 x 6 notecard that they placed on the front board. The class discussed equivalences that could be made from the information collected on the front board, such as one dozen equals 12, one dozen pencils equals 140.0 g, one dozen paperclips equals 13.6 g, etc. Pairs of students were challenged to find the mass of 0.50 dozen paperclips from the information presented. The partners were given chalk markers and allowed to take turns working the questions out on their lab tables while the instructor traveled throughout the room making observations. This was followed up with, "Can you find the number of pencils that have a mass of 89.9 g?" The students were then allowed to challenge other groups around them with questions. The lesson and concept was concluded with, "Can you find the mass of one pencil, paper clip or marker with only the information given?"

The students were transitioned to percentages with the prompt, "Can someone describe what a percentage is and how it may be useful?" The class worked on percentages with days of the week and other examples. Once all students were comfortable with a few more similar prompts, they were handed a bag of various U.S. coins. Their task was to find the percentage of their money that was made up of pennies (or nickels, dimes, quarters, half-dollars, etc.). The Making "Cents" of Percentages and Ratios activity sheet guided them through the different questions (Appendix E).

A Common Assessment Technique (CAT) called Punctuated Lecture was administered during this unit to help students become cognitive of their own listening skills and focus. Students are posed two questions during a lecture on the new material: “How fully were you concentrating on the lecture just now?” and “What were you doing to record the information?” The answers were assessed and placed into one of three categories: focused/on task, off task and confused. These categories were averaged and compared between the groups. A Molar Mass and Representative Particles Quiz was given as a summative assessment after students worked on mole/grams/volume conversion lessons for several blocks (Appendix F). The expectation was that they understood how to convert by setting up the problem correctly, used appropriate significant figures, and had the right unit and correct value for the answer. Each of those components earned them one point. This grading method was used because it did not punish them if they got a wrong answer, especially if they incorrectly operated their calculator. The grade percentages of the quiz results were compared between the treatment and non-treatment groups. The 11 questions on the short pre-unit test appeared again in questions #15 – 20 with different values on the Moles Unit Post Test (Appendix G). These 11 questions from both assessments were compared within the same class with boxplots and paired two-sample t tests. The two data sets, treatment and non-treatment, were then analyzed with a Welch’s t-test to observe any statistical difference between the groups.

The Solutions Unit was the second unit that was used in the project. Students were required to determine what influences the rate of dissolving and the amount of

solute that will go into a solvent. They also had to calculate the solubility of a gas, molarity of a solution, dilution of a solution and percent concentration expressions in mass/mass and volume/volume units.

A short pretest with eight questions was administered as a warm up, to determine prior knowledge and mathematical confidence in solving for an unknown variable, manipulating an equation and calculating percentages before the unit instruction (Appendix H). Similar questions were used within the post test for comparison purposes (Appendix I). The questions from both assessments were compared within the same class with box and whisker plots, and paired two-sample t-tests. The two data sets, treatment and non-treatment, were then analyzed with an independent two-tailed t test to observe any statistical difference between the groups.

The initial math lesson for the Solutions Unit began with students in the treatment groups sharing their plan of attack to solving general word problems. A power point with key points and strategies on breaking down word problems was presented. The students partnered up to solve various algebra problems using the Back to Basics math activity (Appendix J). The next lesson involved using lab procedures to help students visualize the math used within the unit. Eight stations were posted throughout the classroom with different descriptions of a procedure that the students had to use to calculate final concentrations, moles, molarity and volume (Appendix K).

The Documented Problem Solutions CAT (Angelo & Cross, 1993) was used midway through the unit to assess how well students understood and could explain, in a descriptive manner versus just showing calculations, their problem-solving techniques.

Two representative problems were assigned for students to solve: one that all students should have been able to solve and one that was more challenging, requiring a two-step process. Once solved, students documented a step-by-step written explanation of how they arrived at their answer. The results were scored by awarding one point for a correct answer and one point for well-documented solutions. The treatment vs. non-treatment groups were compared by looking at the percentages of correct answers among the students in each group.

The Solutions Quiz was used as a summative assessment and feedback tool to determine the level of understanding of each of the students midway through the unit (Appendix L).

Student interviews were conducted post-treatment, with relevant questions about their processes through the two units (Appendix M). A mix of 12 male and female students with varying levels of success were chosen to be interviewed from both groups, treatment and non-treatment (Table 1).

Table 1
Data Collection Strategies Matrix

Focus Question	Data Source	Data Source	Data Source
<i>Primary Question:</i> How does purposefully teaching science-related math concepts and skills at the beginning of each chemistry unit affect the academic achievement of chemistry students?	Pre- and Post-Formative Content Assessments	Formative Assessments (Quizzes), Common Assessment Techniques (CATs)	Teacher Journal
<i>Sub-Questions:</i> 1. How does teaching the necessary math concepts at the beginning of each unit affect students' general attitudes toward math and chemistry?	Teacher Journal	Pre- and Post-Treatment Student Math/Science Likert Survey	Student Interviews
2. How will the students' math proficiencies be affected by the extra math exposure?	Math Pre- and Post-Test	Pre- and Post-Formative Content Assessments	Student Interviews
3. How will front-loading the math concepts and practice affect the teacher's inspiration and enthusiasm for teaching the units?	Teacher Journal	Pre- and Post-Treatment Student Math/Science Likert Survey, CATs	Student Interviews

DATA AND ANALYSIS

Various test and survey results were compared between the treatment and non-treatment groups in two units, a Moles Unit and a Solutions Unit, to assess student achievement, confidence and attitude, ($N=104$). Pre-test scores for the Moles Unit were compared between the two groups. The treatment group scored an average of 30.3% compared to the non-treatment group's results of 28.5%. The post-test scores for the treatment group averaged 77.4% while the non-treatment group averaged 79.9% (Figure 2). A Welch's two-sample t-test was performed on the post-test results between the two groups and was found to be statistically insignificant with a p-value of 0.487 at 95% confidence.

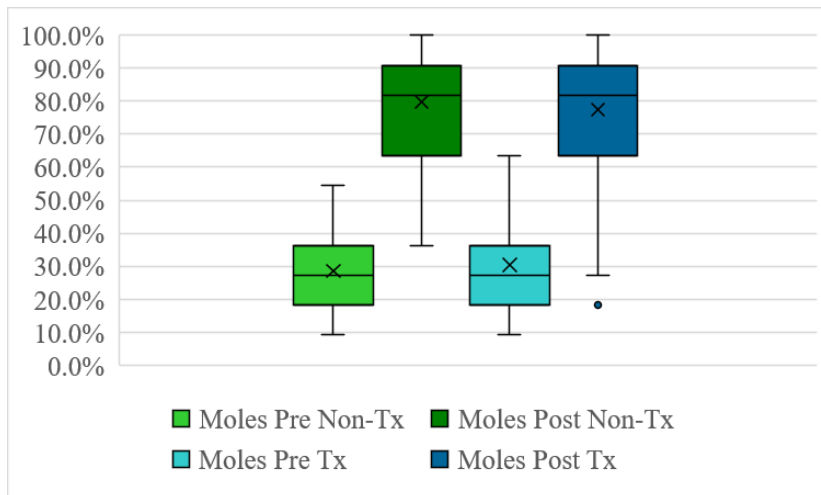


Figure 2. Moles unit pre- and post-test scores for treatment (Tx) and non-treatment (Non-Tx) groups, ($N=104$).

The Punctuated Lectures CAT for this unit was used twice, once at the beginning of the unit and again toward the final lesson. The initial results indicated that within both groups approximately 51.0% of the students were totally off task and just writing words and sentences without making any connections to the material. Their thoughts were on

everything from lunch to sports to a quiz in their next class. Thirty-three percent of the treatment group felt comfortable with the information and were focused in their notetaking, and 15.7% of the students confused but not asking questions. The non-treatment group had 41.2% of the students on task and confident and only 7.8% confused. The second time, the students were asked to assess their focus and listening skills later on in the unit lectures. The students in the treatment group were 60.0% on task, 8.0% confused and 32.0% not focused on the subject at hand (including 2.0% finding the information so easy that they lost focus). The results of the non-treatment group revealed 61.5% on task, 3.8% confused and 34.6% off-task due to either finding it too easy (7.7%) or other distractions (Figure 3). One student admitted to being bored and wanting to “jump right into the chemistry and worry about the math when it came.”

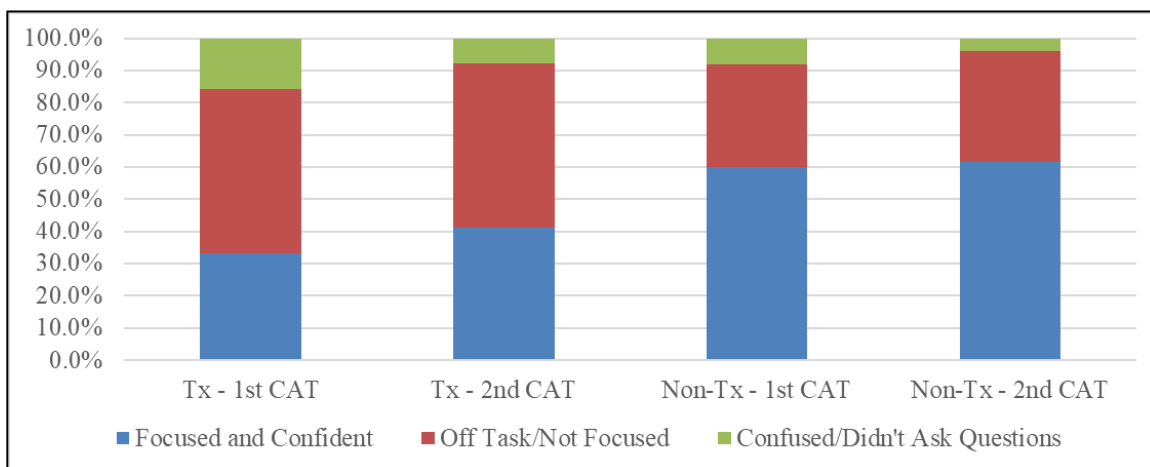


Figure 3. Punctuated lecture CAT results for treatment (Tx) and non-treatment groups (Non-Tx), (N=104).

The Moles Unit Quiz, which was used to assess understanding at the midpoint of the unit lessons, showed an average score of 73.2% for the treatment group while the non-treatment group averaged a 74.8%. During my class observations and journaling, I

noted that there were still many students in both groups not using dimensional analysis to help them convert units.

The treatment and non-treatment groups for the Solutions Unit were switched in an attempt to eliminate any variables between the two groups. Pre-test scores for the two groups were very similar with the treatment group scoring 71.6% and the non-treatment group scoring 70.1%. After a month of lessons and labs, the post-test average scores resulted in 86.0% for the treatment group and 82.6% for the non-treatment group (Figure 4). A Welch's t-test was used to determine the statistical significance of the post-test data between the two groups and found no statistical significance with a p-value of 0.2066 at 95% confidence level.

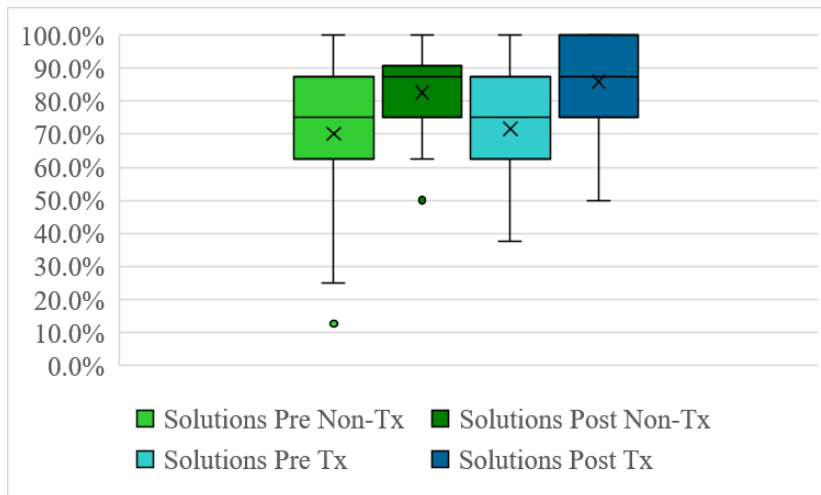


Figure 4. Solutions Unit pre- and post-test scores, ($N=104$).

The Solution Unit CAT, Documented Problem Solutions, consisted of two questions: an easy problem, followed by a more difficult one. Each correct answer had to be accompanied with a clear explanation of their process to be awarded points. The treatment group showed that 67.7% of the students could solve and explain both problems effectively, and 25.5% of them could only accurately solve and explain the first

problem. The non-treatment group was less successful with 47.1% correct for both problems and 37.3% for the first question only (Figure 5). The Solutions Quiz given in the middle of the unit as a formative assessment showed the treatment group had a 79.5% proficiency on the material at that time, compared to 76.9% for the non-treatment group.

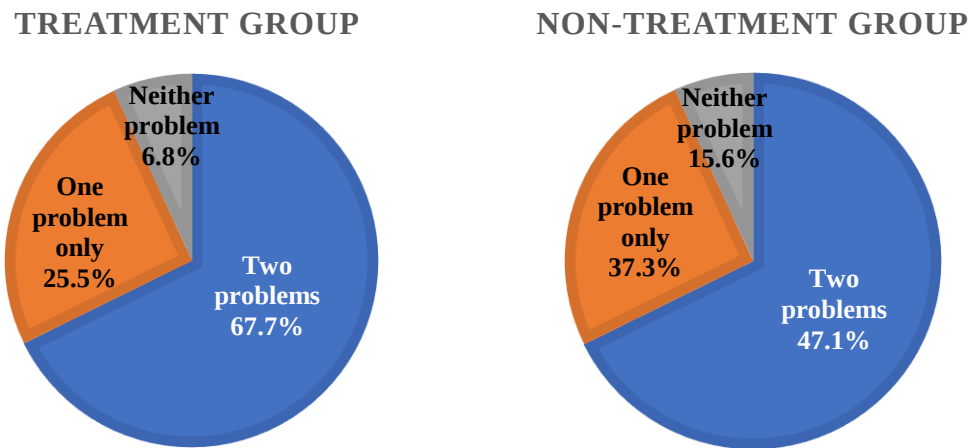


Figure 5. Documented Solutions CAT results for solving mathematical problems in Solutions Unit, ($N=101$).

The overall average of the five pre-math confidence questions for the non-treatment group was 2.92 which increased to 3.16 after the first unit. The pre-treatment average for the treatment group was 3.23 and after treatment decreased to 3.21 (Figure 5).

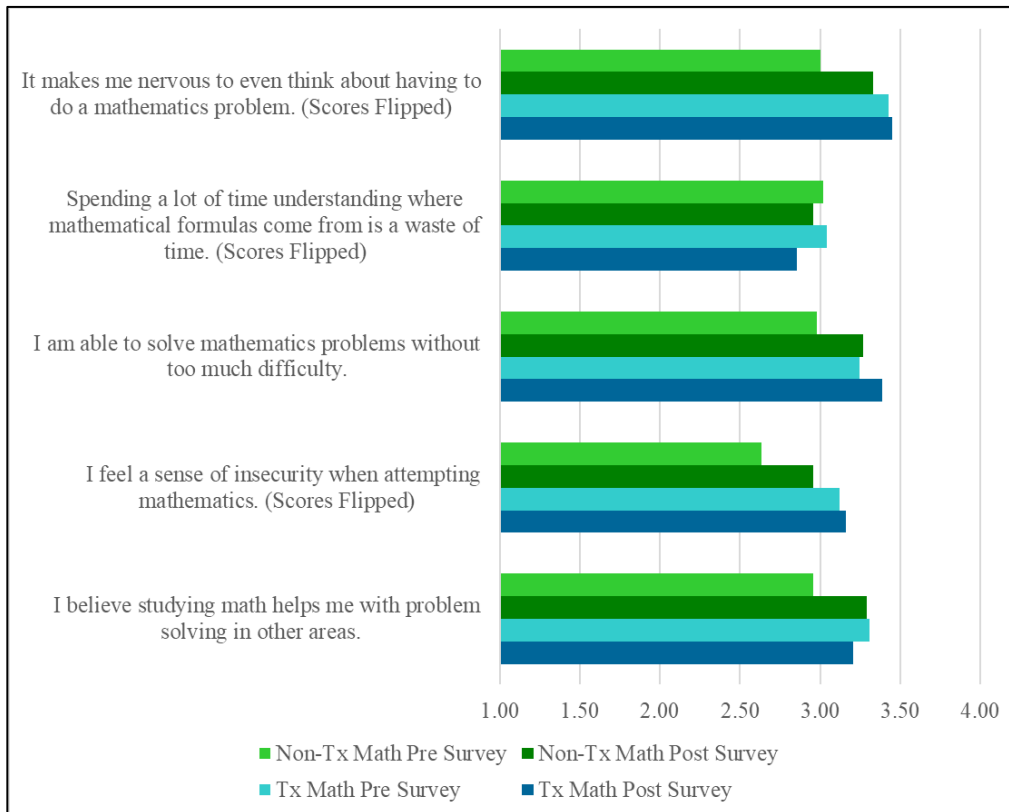


Figure 6. Math attitude and confidence results from survey for treatment (Tx) group and non-treatment (Non-Tx) group, ($N=104$).

A Wilcoxon Signed Rank Test result of $p = 0.43$ showed no statistical significance between the pre- or post-data means of the math categories between the treatment and non-treatment groups. A Welch's t-test was also used and again indicated no significant difference with a p value of 0.153. However, the pre-survey data averages between the two groups were analyzed with a Welch's t-test and was found to be significantly different with a p -value of 0.0196 at a 95% confidence level. All of the students that were interviewed agreed that working with the math in chemistry helped them with their mental math, "I don't just plug and chug like I used to. Now I take a second look at my answer and check significant figures too." One student felt that

learning the math first “definitely helped my grade in this class and helped me with the non-calculator part of the SAT exam.”

Both groups exhibited an overall increase in chemistry confidence and attitude after the first unit. The non-treatment group had an increase of 0.2, from 2.62 to 2.82. The treatment group showed an increase in attitude and confidence from 2.69 before treatment to 2.79 after the unit. No significance difference with the data sets between the treatment and non-treatment groups were found through a Wilcoxon Signed Rank test or a Welch’s t-test (Figure 6).

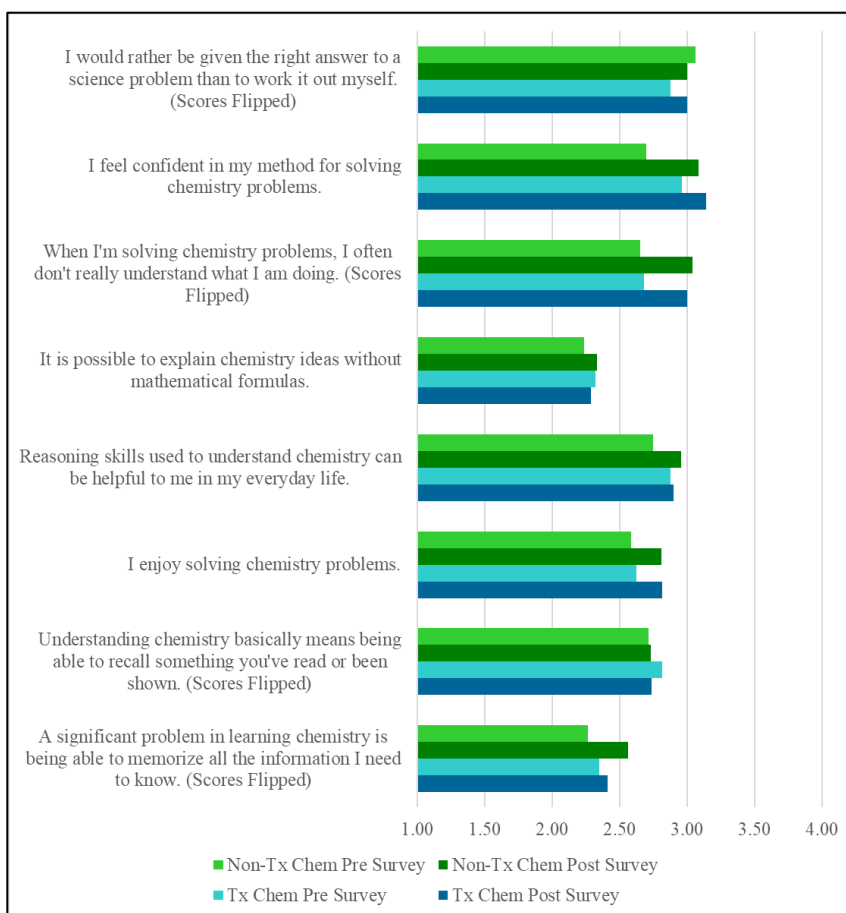


Figure 7. Chemistry attitude and confidence results from survey for treatment (Tx) and non-treatment (Non-Tx), (N=104).

The differences between chemistry with math confidences and attitudes pre- and post-survey results for the treatment and non-treatment groups were graphed and analyzed as well. The non-treatment group presented with a confidence and attitude level of a 3.01 that increased to 3.15 after working with the Moles Unit. The treatment group went from a 2.95 to a 3.01 (Figure 7).

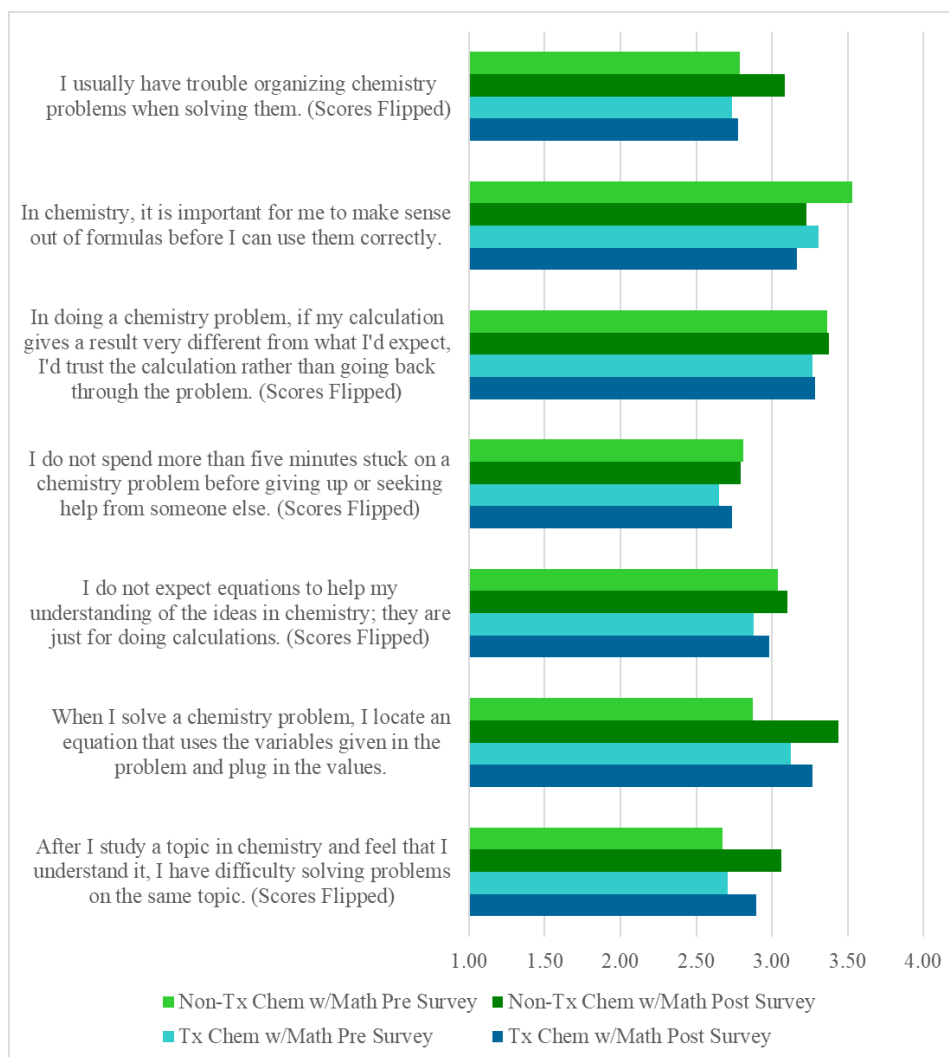


Figure 8. Chemistry with math attitude and confidence results from survey, (N=104).

Neither a Wilcoxon Signed-Rank Test nor a Welch's t-test analysis showed any statistical significance among the population means of the two groups. Ten out of the 12

students interviewed revealed that getting the math upfront did not make it easier to apply the math tools to chemistry content later in the unit. “I need to learn it all together so I can make the connections right there, otherwise I forget it with seven other classes.” Another student suggested putting the math practice into the daily warm-ups instead of all in two or three days, as she did not want to sit through two math classes in one day.

A general math assessment was given at the beginning of the spring semester to determine the math level differences between the two treatment groups (blocks one and two vs. blocks three and five). Blocks one and two scored an initial 60.5% and increased their scores to 76.6% after both units. Blocks three and five started out with a 62.7% and improved to 75.8% at the end of the observation period. A few students appreciated the pre-math assessments, “I liked the math tests that you gave us in the beginning because it gave me an idea of what math would be needed soon.” The math levels of the students varied among the two groups used in this project. The scores of each of the three different levels - geometry, Algebra II and advanced math were averaged for each unit (Table 2, Table 3). The students in the treatment group that were currently taking Algebra II scored a 73.1% compared to the non-treatment group who scored 76.5% in the Moles Unit. In the Solutions Unit, the treatment Algebra II students earned an 82.7% while their non-treatment counterparts scored an 82.3%. The geometry group score for blocks one and two was unreliable, due to only having one student at that math level versus blocks three and five containing five students currently taking geometry. The advanced math group scores in the Moles Unit pre- and post-tests for treatment and non-treatment differed by less than a one percent, and the Solutions Unit scores between

treatment and non-treatment presented with seven percentage points variation on the unit post-test.

Table 2
Moles Unit Pre- and Post-Test Score Averages Separated Into Student Math Levels

	Moles Unit Pre-test			Moles Unit Post-test		
	Geometry	Algebra II	Advanced	Geometry	Algebra II	Advanced
Blocks 1 and 2 (Non-treatment group)	27.3% (N=1)	25.2% (N=30)	34.3% (N=19)	72.7%	76.5%	85.6%
Blocks 3 and 5 (Treatment group)	23.6% (N=5)	28.4% (N=24)	33.5% (N=25)	52.7%	73.1%	86.5%

Note. (N=104).

Table 3
Solutions Unit Pre- and Post-Test Score Averages Separated Into Student Math Levels

		Solutions Unit Pre-test			Solutions Unit Post-test		
		Geometry	Algebra II	Advanced	Geometry	Algebra II	Advanced
Blocks 1 and 2 (Treatment group)		75.0% (N=1)	68.1% (N=30)	77.0% (N=19)	100.0%	82.7%	91.0%
Blocks 3 and 5 (Non-treatment group)		52.5% (N=5)	68.2% (N=24)	75.5% (N=25)	77.5%	82.3%	84.0%

Note. (N=104).

INTERPRETATION AND CONCLUSION

The main purpose of this study was to determine the effect on student success when the basic math skills used in a chemistry unit were taught at the very beginning of the unit. Post-test results of each unit showed no statistical significance between the means of the scores of the treatment and non-treatment groups. This does not mean that there was nothing to gain from this experience as there was much self-reflection on the teaching methods and student reactions.

After reflection on the Moles Unit pre- and post-test questions and the large gap between the pre- and post-test scores, I decided that the problems were too content-related and may not have fairly assessed the math lesson impact. In the future, I would use conversion problems with familiar units and not use the vocabulary of moles and the relationship that moles has to volume and molar mass. Historically, the students do poorly on the Moles Unit pre-assessment as the material is very foreign to them. The Punctuated Lecture CAT results of lack of focus through the unit may be an indication of why the treatment group averaged 2.5% lower than the non-treatment group. I adjusted the pre- and post-test questions for the Solutions Unit to ensure a more math-based evaluation, with less unit-specific content and vocabulary. This approach may have decreased the gap between the pre- and post-test scores for the Solutions Unit. The Documented Solutions CAT results showed a significant difference in scores. The treatment group scored 20% higher than the non-treatment group when solving two word problems. After this formative assessment, the non-treatment group received remedial instruction and practice on the concept and performed better on the summative quiz that followed. The pre-test averages between the two groups for the unit on solutions only differed by 1.5% but the post-test averages varied by 3.4%. This difference was not enough to warrant a statistical significance, however when compared to the post-test averages from the first unit, a trend began to appear. The non-treatment group in the Moles Unit became the treatment group in the Solutions Unit, which was blocks 1 and 2. Students in these blocks averaged 2.5% higher on Moles Test than the treatment group, or blocks 3 and 5. This suggests that Blocks 1 and 2 may be a stronger group of students

overall. That may be attributed to the fact that only one of the six geometry students were in that group. I did notice that as I worked with the geometry students more on basic skills and proper calculator usage, they seemed to need the most help and really worked hard to understand the calculations and connections. This may be due to the pressure they felt to succeed compared to their peers with higher math experience. As I walked around the class during partner work, I found the advanced math students were the ones more often helping other students with math and calculator difficulties. The advanced students also scored slightly higher on the survey in their math confidences and attitudes.

When I separated the pre- and post-test data from the math and both unit tests into three different math levels and compared their averages, the geometry students scored lower in all assessments compared to the other two math groups. The advanced math students scored the highest among all math levels in the treatment and non-treatment groups (Figure 8). This reinforces the common idea among high school and college level instructors that the more advanced the students are in math skills, the greater the success they will have in a chemistry class.

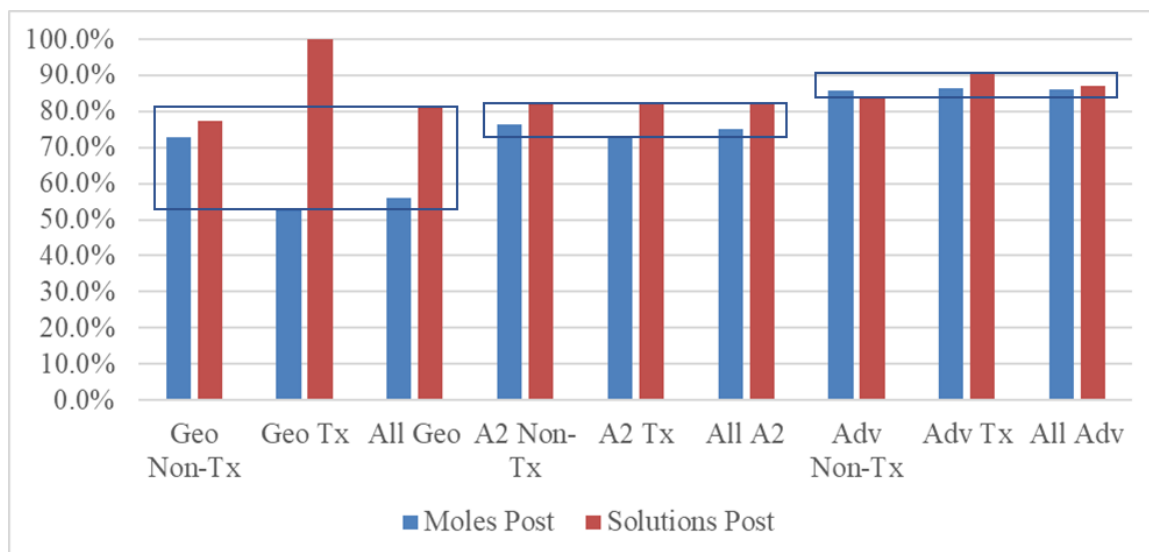


Figure 8. Post-test scores for the three math levels – geometry (Geo), Algebra II (A2) and advanced math (Adv), ($N=104$).

The second goal in this project was to determine if students' attitudes toward chemistry and math would be affected by reviewing the math basic skills before applying them to a concept or word problem within a unit. The survey results indicated a positive change or increase in most categories, but not a statistically significant difference between the treatment and non-treatment groups in any particular category. I noticed the students enthusiastically worked out the problems on the desktops with bright chalk markers. They were able to collaborate with a partner, check each other's work and ask for feedback easily. They asked to work with the markers and partners often after the lesson. Going into the Moles Unit, the treatment group revealed that they were more positive and confident in their math skills than the non-treatment group. After scoring slightly lower on the unit post-assessment than the non-treatment group, the treatment group had a smaller increase in confidence than the non-treatment group on the post-survey. Many of the students were reluctant to use the dimensional analysis method

during the unit yet later on in the semester, they admitted to using it more and more with greater understanding and confidence.

VALUE

I have seen chemistry students struggle with math year after year and I have brainstormed about how to review the math before students need it. I have observed that students in the honor course often shut down when they are not as successful as their peers. They feel they should be proficient in the math required, since they passed the prerequisite classes needed to enroll in the course. I was afraid to try a new method and upset the balance to the curriculum pacing guide set by our district. This capstone project gave me the confidence and the freedom to try this approach and the skills to analyze the results. It also encouraged me to look into the standards of our Geometry and Algebra II courses to see what is covered and what gaps may exist. The results also confirm the increased level of success in chemistry students that possess a strong understanding of mathematics.

I plan to continue incorporating more basic math lessons into the curriculum in warm-ups and mini-lessons within each unit to strengthen the weaker aspects of students' math skills. I feel this will have a bigger impact next year as I will be teaching General Chemistry classes that require lower math prerequisites than the honors level, but have the same math-related concepts, formulas and calculations. As a teacher and a life-long learner, I am looking forward to this challenge and finding more ways to improve math instruction and build confidence among my students when it comes to the marriage of chemistry and math.

REFERENCES CITED

- Angel, Stephen A., & LaLonde, Donna (1998, November). Science success strategies: An interdisciplinary course for improving science and mathematics education. *Journal of Chemistry Education*, 75(11), 1437
- Angelo, T.A., & Cross, K.P. (1993). *Classroom Assessment Techniques A Handbook for College Teachers*. San Francisco: Jossey-Bass.
- Barbera, J., Adams, W., Weiman, C., & Perkins, K. (2018). Modifying and Validating the Colorado Learning Attitudes about Science Survey for Use in Chemistry. *Journal of Chemical Education*, 85(10), 1435-1439.
- Bohning, James J. (1982). Remedial mathematics for the introductory chemistry course: The "CHEM. 99" concept. *Journal of Chemical Education*, 59(3), 207.
- Buchler, M. (2017, November). Erie High School Demographics. (C. Giammo, Interviewer).
- Cook, E., Kennedy, E., & McGuire, S. (2013). Effect of Teaching Metacognitive Learning Strategies on Performance in General Chemistry Courses. *Journal of Chemical Education*, 90(8), 961-967.
- Donovan, W.J., & Wheland, E.R. (2009). Comparisons of success and retention in a general chemistry course before and after the adoption of a mathematics prerequisite. *School Science and Mathematics*, 109(7), 371+.
- Genyea, J. (1983). Improving students' problem solving skills: a methodical approach for a preparatory chemistry course. *Journal of Chemical Education*, 60(6), 478.
- Hoban, R.A., Finlayson, O.E., & Nolan, B.C. (2013). Transfer in chemistry: a study of students' abilities in transferring mathematical knowledge to chemistry. *International Journal of Mathematical Education in Science & Technology*, 44(1), 14-35.
- Lobato, J. (2006). Alternative Perspectives on the Transfer of Learning: History, Issues, and Challenges for Future Research. *Journal of the Learning Sciences*, 15 (4), 431-449.
- NGSS Lead States. (2013). *Nest Generation Science Standards: For States, By States*. Washington, DC: National Academies Press.
- Ngu, B.H., Yeung, A.S., & Phan, H.P. (2015). Constructing a coherent problem model to facilitate algebra problem solving in a chemistry context. *International Journal of Mathematical Education in Science and Technology*, 46(3), 388-403.

- Nokes-Malach, T.J., & Mestre, J.P. (2013). Toward a Model of Transfer as Sense-Making. *Educational Psychologist*, 48(3), 184-207.
- O'Connor, S. (2003). Connecting algebra & chemistry. *The Science Teacher*, 70(1), 38.
- Polancos, D.T. (2009). Is mathematics review giving an edge in learning high school chemistry concepts? *Liceo Journal of Higher Education Research*, 6(1), 112+.
- Potgieter, M., Harding, A. & Engelbrecht, J. (2008). Transfer of Algebraic and Graphical Thinking between Mathematics and Chemistry. *Journal of Research in Science Teaching*, 45(2), 197-218.
- Preininger, A. (2017). Embedded mathematics in chemistry: A case study of students' attitudes and mastery. *Journal of Science Education & Technology*, 26(1), 58-69.
- Suburban Stats (n.d.) Retrieved February 12, 2018, from <https://suburbanstats.org/population/Colorado/how-many-people-live-in-erie>
- Town of Erie Colorado (n.d.) Retrieved February 12, 2018, from <https://www.erieco.gov/ArchiveCenter/ViewFile/Item/2853>
- Wink, D.J., & Gislason, S.F. (2000). The MATCH Program: A Preparatory Chemistry and Intermediate Algebra Curriculum. *Journal of Chemical Education*, 77(8), 999.

APPENDICES

APPENDIX A
INSTITUTIONAL REVIEW BOARD APPROVAL



INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects

FWA 00000165

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MEMORANDUM

TO: Cheri Lynn Giammo and John Graves

FROM: Mark Quinn *Mark Quinn CJ*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 17, 2017

RE: "The Effect of Front-Loading Necessary Math Concepts and Computations at the Beginning of Chemistry Units on Student Achievement and Confidences" [CG111717-EX]

The above research, described in your submission of November 17, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

- X (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
- X (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
- _____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
- _____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
- _____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
- _____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

“MATH IN CHEMISTY” PRE- AND POST-TEST

Name _____ Blk _____

SPRING SEMESTER "Math in Chemistry" Pre-test and Post-test

This test is not for a graded score, it is to see how comfortable you are with the upcoming math in the future units. Remember your sig figs when working with measurements.

Solve the problems below to the best of your ability. Please show work wherever possible. You will not be allowed the use of a calculator on this front page. You may use one for the back page.

1. $(7 + 4)7 =$

2. $\frac{24}{6 \times 2} =$

3. $48/2^3 =$

4. $4^3/2^4 =$

5. $6(2/3) + 12 =$

6. $(2 + 3)^2 =$

7. Convert 35 degrees Celsius to Fahrenheit using the following formula: $^{\circ}\text{F} = (9/5)^{\circ}\text{C} + 32$.

Solve for x in the following:

8. $5x + 3 = 28$

10. $48/x = 6$

9. $(20 + x)/4 = 4$

11. $y = 12, z = 3$, solve for x:
 $6x + 2z = y/4$

Using the equation $AB = CDE$, solve for the missing variable:

12. $A = 6, B = 8, C = 3, E = 4$

13. $B = -3, C = 1/3, D = 4, E = 5$

14. If a formula reads $x = y(z)$ and the units for y are liters and the units for x are seconds, what are the units for z?

15. 4 stars = 3 rainbows. 2 rainbows = 3 clovers. 1 clover = 2 diamonds. How many stars are equal to 9 diamonds?
16. There are 24 hours in a day and 14 days in a fortnight. How many fortnights will have passed in 4800 hours?

You may use a calculator on these problems.

17. Convert 4.50×10^8 minutes to days.
18. How much would it cost a year to drink a Starbucks Carmel Latte (\$4.65) twice a week?
19. You have a twenty-dollar bill that has to be used for gas until payday. Gas is currently \$2.53 a gallon and your car averages an impressive 39.6 miles per gallon. If you drive to and from school and work (yes, seven days a week you go to school) for an average of 12.03 miles a day, how many weeks will you be able to drive on your twenty dollars?
20. Solve the following: $5 \times 10^4 (3 \times 10^2) =$
21. Solve the following: $8.6 \times 10^8 (2.2 \times 10^{-2}) =$
22. Solve the following: $\frac{2.3 \times 10^{-4}}{5.5 \times 10^9} =$
23. Solve the following: $\frac{8 \times 10^7}{2 \times 10^5} =$

APPENDIX C

ATTITUDES AND CONFIDENCES IN MATH AND CHEMISTRY SURVEY

ATTITUDES AND CONFIDENCES IN MATH AND CHEMISTRY SURVEY

*Below are a number of statements about math and chemistry. Please read each one and **mark the box** (not between the boxes) to indicate to what extent you agree or disagree with the statement.*

Participation is voluntary, and you can choose to not answer any question that you do not want to answer, and you may stop at any time.

Your participation or non-participation will not affect your grade or class standing.

Please mark your gender: _____ Male _____ Female Codename _____

	Strongly Agree	Agree	Disagree	Strongly Disagree
1. A significant problem in learning chemistry is being able to memorize all the information I need to know.				
2. It is useful for me to do lots and lots of problems when learning chemistry.				
3. After I study a topic in chemistry and feel that I understand it, I have difficulty solving problems on the same topic.				
4. I believe studying math helps me with problem solving in other areas.				
5. The easiest part of solving a chemistry problem is doing the algebra.				
6. When I solve a chemistry problem, I locate an equation that uses the variables given in the problem and plug in the values.				
7. I do not expect equations to help my understanding of the ideas in chemistry; they are just for doing calculations.				
8. I feel a sense of insecurity when attempting mathematics.				
9. Understanding chemistry basically means being able to recall something you've read or been shown.				
10. I do not spend more than five minutes stuck on a chemistry problem before giving up or seeking help from someone else.				

Please continue on the back →

	Strongly Agree	Agree	Disagree	Strongly Disagree
11. In doing a chemistry problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.				
12. I am able to solve mathematics problems without too much difficulty.				
13. In chemistry, it is important for me to make sense out of formulas before I can use them correctly.				
14. I enjoy solving chemistry problems.				
15. Reasoning skills used to understand chemistry can be helpful to me in my everyday life.				
16. Spending a lot of time understanding where mathematical formulas come from is a waste of time.				
17. I find carefully analyzing only a few problems in detail is a good way for me to learn chemistry.				
18. It is possible to explain chemistry ideas without mathematical formulas.				
19. When I'm solving chemistry problems, I often don't really understand what I am doing.				
20. I feel confident in my method for solving chemistry problems.				
21. I usually have trouble organizing chemistry problems when solving them.				
22. The easiest part of solving chemistry problems is finding the right equation.				
23. The easiest part of the solving a chemistry problem is identifying the necessary information needed for calculations.				
24. It makes me nervous to even think about having to do a mathematics problem.				
25. I would rather be given the right answer to a science problem than to work it out myself.				

Is there anything you want me to know about your feelings toward math and science?

APPENDIX D
MOLES UNIT PRE-TEST

Moles Unit Pre-test **Name** _____ **Date** _____ **Blk** _____

Using the data table, answer the following questions.

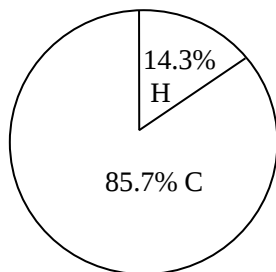
1. In the laboratory, a student makes the following measurements to determine the percent by mass of water in a sample of copper (II) sulfate pentahydrate.

Mass of $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ before heating	5.44 g
Mass of CuSO_4 after heating	3.68 g
Mass of water lost	
Percent of water lost from $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	

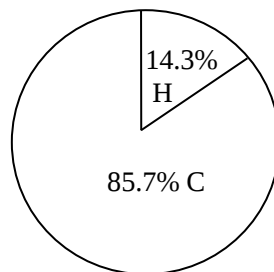
a & b) Calculate the mass of water lost and the percent of water lost **and add your answers to the table.**

c) The theoretical yield of water lost is 1.96 g. Use the mass you calculated as the actual yield to calculate the percent yield of this reaction. *Show work here:*

2. Use the graphs of cyclohexane and ethane below to answer the following questions.



Cyclohexane C_6H_{12}



Ethene C_2H_4

- a) What is the percent of carbon in 100 g of cyclohexane?
 b) Calculate the mass of hydrogen in 5.00 g of ethene.

- c) What is the empirical formula of these two compounds? _____
 d) Use the circle graphs to explain why percent composition alone is not sufficient to distinguish one compound from another.

- How many representative particles are in 338 g of aluminum?
- How many representative particles are in 2.55×10^{-2} mol potassium nitride?
- What is the volume of 4.07 mol O_2 at STP?
- Describe, in words, how to convert 8.00×10^6 cm into miles. You may use numbers in your description but do not solve. (These conversions may help: 1 mile = 5280 ft, 1 yard = 3 ft, 1 inch = 2.54 cm, 100 cm = 1 meter)

[illegible]

APPENDIX E

MAKING “CENTS” OF PERCENTAGES AND RATIOS ACTIVITY

Names _____ Blk _____ Date _____ Bag # _____

MAKING "CENTS" OF PERCENTAGES AND RATIOS

1. In your own words, how will you find the answers to questions #2-4?
2. What percent of your money is made up of pennies?
3. What percent of your money is made up of nickels?
4. What percent of your money is made up of quarters?

Find the mass of your bag of money. Record your mass here: _____ (where are those units?)

5. I'm going to exchange coin bags with you. You cannot see into this bag but I can tell you that the ratio of coins is the same in both bags. What does that mean to you and your activity partner?

Now find the mass of your new bag of coins. Can you infer what coins and how many are in the new bag? List them here:

6. If you had two compounds that contained the same ratio of elements within their formula, and you knew the formula for one of them, could you determine the formula for the other? How would you accomplish that?

APPENDIX F

MOLAR MASS AND REPRESENTATIVE PARTICLES QUIZ

Name _____ Blk _____ Date _____

Molar Mass and Representative Particles Quiz

*Determine the number of representative particles in each of the quantities below. Be sure to include **units** and correct **significant figures** as you are using measurements.*

- 1.) 2.0 moles of water
- 2.) 15 moles of atomic hydrogen
- 3.) 0.75 moles of NaCl
- 4.) 25 g of LiCl

Determine the mass (in grams) in each of the quantities below:

- 5.) 2.5 moles of sodium chloride
- 6.) 0.50 moles of H_2SO_4
- 7.) 0.25 moles of lithium hydroxide
- 8.) 3.2 moles of MgBr_2

BONUS: How many representative particles are in 444 g of iron (II) nitrate?

****How are those sig figs looking?**

APPENDIX G

MOLES UNIT POST-TEST

Name _____ Date _____ Blk _____

Chemistry Unit 5: Moles Test

Multiple Choice: Circle the best choice. Show your work to the side of each question with calculations.

1. A mole is a measurement of
 - A. the volume of a liquid.
 - B. the mass of an atom or molecule of a substance.
 - C. the number of atoms or molecules or formula units in a substance.
 - D. the weight of a substance.
2. One mole of carbon atoms
 - A. has a mass of 12.01 g.
 - B. has the same mass as one mole of nitrogen atoms.
 - C. has the same number of atoms as 1.00 g of O₂.
 - D. has 12 times Avogadro's number of carbon atoms.
3. One mole of solid aluminum, one mole of solid carbon, and one mole of solid silver:
 - A. have the same density
 - B. contain the same number of atoms
 - C. occupy the same volume
 - D. have the same molar mass
4. How many moles is 1.25×10^{25} atoms of Pb? *Show work:*
 - A. 20.8 mol
 - B. 0.208 mol
 - C. 7.525×10^{48} mol
 - D. 7.525 mol
5. Which of the following contains the same number of atoms as 12.01 g of carbon?
Show work:
 - A. 35.01 g Al
 - B. 64.20 g S
 - C. 9.01 g Be
 - D. 11.33 g H
6. How many moles is 5.00 g of H₂C₄O₂? *Show work:*
 - A. 0.831 mol
 - B. 0.0609 mol
 - C. 410 mol
 - D. 0.109 mol

7. Which of the following is **always** conserved in a chemical equation?
- A. mass
 - B. moles
 - C. molecules
 - D. volume
8. A sample of gas at 1 atm of pressure and 0°C is at
- A. a standard elevation
 - B. a high temperature
 - C. an unusual temperature and pressure
 - D. standard temperature and pressure
9. Krypton is used in flashlight bulbs. Find the number of moles in 0.800 L of krypton gas at STP. *Show work:*
- A. 4.82×10^{23} mol Kr
 - B. 17.92 mol Kr
 - C. 4.816 mol Kr
 - D. 0.0357 mol Kr
10. Magnesium chloride is used to de-ice roads. Calculate the number of grams in 1.20 mol of magnesium chloride. *Show work:*
- A. 114 g
 - B. 93.4 g
 - C. 58.6 g
 - D. 0.0126 g
11. A chemical reaction produces 1.76 g of O₂ gas. What volume in liters does this gas sample occupy at STP? *Show work:*
- A. 1.23 L
 - B. 1.26 L
 - C. 2.46 L
 - D. 2.51 L

Calculation Questions

Answer the following questions and show your work including units on your answer sheet.

12. How many moles are in 72.0 g krypton?
13. How many grams are in 10.0 mol of copper?

14. How many moles are in 1.20×10^{25} atoms of nitrogen gas?
15. How many representative particles are in 540 g of strontium?
16. How many representative particles are in 4.20×10^{-3} mol potassium sulfide?
17. What is the volume of 5.40 mol O_2 at STP?

Lab and Graph Questions

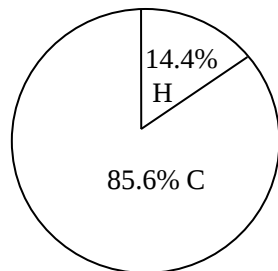
Using the data table, answer the following questions.

18. In the laboratory, a student makes the following measurements to determine the percent by mass of water in a sample of copper (II) sulfate pentahydrate.

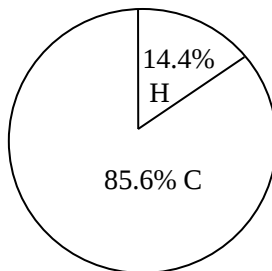
Mass of $CuSO_4 \cdot 5H_2O$ before heating	5.44 g
Mass of $CuSO_4$ after heating	3.50 g
Mass of water lost	
Percent of water lost from $CuSO_4 \cdot 5H_2O$	

- a) Calculate the mass of water lost and the percent of water lost **to complete the table.**
- b) The theoretical yield of water lost is 1.96 g. Use the mass you calculated as the actual yield to calculate the percent yield of this reaction. *Show work here:*

19. Use the graphs of cyclohexane and ethane below to answer the following questions.



Cyclohexane C₆H₁₂



Ethene C₂H₄

- What is the percent of carbon in 100 g of cyclohexane and ethene?
- Calculate the mass of hydrogen in 8.00 g of ethene.
- What is the empirical formula of these two compounds? _____
- Use the circle graphs to explain why percent composition alone is not sufficient to distinguish one compound from another.

Essay Questions (Worth 3 points each):

Write at **least four sentences** to answer the following questions:

20. Describe, **in words**, how to convert a substance from grams to representative particles.

21. Why is it useful for chemists to count atoms and molecules using moles?

BONUS (worth 2 pts) At STP, find the volume of 9.00×10^{21} molecules of nitrogen trihydride.

APPENDIX H
SOLUTIONS UNIT PRE-TEST

Solutions Unit Pretest Name _____ Blk _____ Math level _____

1. Floyd is an aspiring music artist. He has a record contract that pays him a base rate of \$200 a month and an additional \$12 for each album that he sells. Last month he earned a total of \$644. Write an equation to determine the number of albums Floyd sold last month. Now solve for the number of albums.
2. Grayson is planning a field day for the graduation picnic. He is dividing the students evenly into eight teams for the tug-of-war tournament. There will be nine students on each team. Which equation can you use to find the number of students (n) in the graduating class at his school?

A. $n + 8 = 9$	C. $n/8 = 9$
B. $n - 9 = 8$	D. $8n = 9$
3. Mitch's cat, Einstein, is missing! Mitch makes a bunch of flyers with Einstein's photo and description, and then asks some friends to help him post them around town. Mitch divides all the flyers evenly among six bags, one for each person. Each bag contains 12 flyers.
Which equation can you use to find the number of flyers Mitch makes?

A. $x/6 = 12$	C. $6x = 12$
B. $x + 6 = 12$	D. $x - 6 = 12$
4. What is the molarity of a solution that contains 2.5 moles of sodium nitrate (NaNO_3) in 3.0 liters of solution? ($M = \text{mol/L}$)

A. 0.20 M	C. 0.75 M
B. 0.45 M	D. 0.83 M
5. You mixed 16 g of NaCl in 750 g of water, what is the percent mass-mass (% m/m) of the solution?

A. 0.21 % m/m	C. 2.1 % m/m
B. 1.6 % m/m	D. 7.0 % m/m
6. You must prepare 500.0 mL of 0.75M NaBr, how many mL of a 2.5M NaBr solution should you use?

A. 150 mL	C. 300 mL
B. 200 mL	D. 500 mL

7. A solution is 8.0% v/v in ink. How many mL of ink are in 35 mL of the solution?
- | | | | |
|----|--------|----|--------|
| A. | 1.4 mL | C. | 5.6 mL |
| B. | 2.8 mL | D. | 8.0 mL |
8. Calculate the new molarity that results when 250. mL of water is added to 125 mL of 0.251 M HCl. ($M_1V_1 = M_2V_2$)

APPENDIX I
SOLUTIONS TEST

Honors Chemistry Unit 7 Solutions Test A

Formulas: $\frac{S_1}{P_1} = \frac{S_2}{P_2}$ M = mole solute/L solution % **m/m** = mass solute/mass soln

% **v/v** = volume solute/volume solution $M_1V_1 = M_2V_2$

Multiple choice: Answer in CAPITAL letters **on your answer sheet**. Show your work for calculations. (*Worth one pt each, work is worth an additional pt each #6-9*)

- For a given substance, which of the following will **NOT** influence how fast it dissolves?
 - temperature
 - amount of stirring
 - molar mass
 - size of the crystals
- The solubility of a substance is often expressed as the number of grams of solute per
 - 100 liters of solvent.
 - 1 cm³ of solvent.
 - 100 grams of solution.
 - 100 grams of solvent.
- The solubility of a solute in a solvent is affected by
 - temperature, stirring, and pressure.
 - only pressure.
 - only temperature.
 - temperature and pressure (if it's a gas).
- At a constant temperature and pressure, a saturated solution contains
 - the maximum amount of solvent
 - the maximum amount of solute
 - the minimum amount of solute per liter of solution
 - the minimum amount of solvent per gram of solute
- Upon adding sugar to a cup of tea you noticed that there is some sugar at the bottom of the cup. What can you do to dissolve that excess sugar?
 - Increase the temperature of the tea
 - Remove some tea
 - Cool down the mixture
 - Filter out the excess sugar
- What is the molarity of a solution that contains 2.5 moles of sodium nitrate (NaNO₃) in 3.0 liters of solution?
 - 0.20 M
 - 0.45 M
 - 0.75 M
 - 0.83 M
- You mixed 16 g of NaCl in 750 g of water, what is the percent mass-mass (% m/m) of the solution?
 - 0.21 % m/m
 - 1.6 % m/m
 - 2.1 % m/m
 - 7.0 % m/m

8. You must prepare 500.0 mL of 0.75M NaBr, how many mL of a 2.5M NaBr solution should you use?
- A. 150 mL
B. 200 mL
C. 300 mL
D. 500 mL
9. A solution is 8.0% v/v in ink. How many mL of ink would be present in 35 mL of the solution?
- A. 1.4 mL
B. 2.8 mL
C. 5.6 mL
D. 8.0 mL

Short Answer and Graphing:

Plot a graph of the solubility of potassium nitrate (KNO_3) vs. temperature on your answer sheet from the following data. Connect the points on your graph with a line and label the axes. **Don't forget a title.**

Temperature ($^{\circ}\text{C}$)	Solubility (mol/kg)
0	1.61
20	2.80
40	5.78
60	11.20
80	16.76
100	24.50

10. **Use your graph** to answer the following questions.
- A. What is the solubility of KNO_3 at 33°C **and** at 76°C .
B. As the temperature increases, what happens to the solubility of KNO_3 ?
C. When the solubility of KNO_3 is 17.6 mol/kg, what is the temperature?
D. When the solubility of KNO_3 is 4.24 mol/kg, what is the temperature?
E. What part of the graph indicates a saturated solution?

Precipitation Reactions Lab Questions

11. Complete this table on your answer sheet with the precipitates that will form from the reactions. Write the **names and formulas** of the **precipitates** only. Use the solubility rules to find the precipitates. If no reaction occurs or precipitate is formed, write "NR."

	AgNO ₃	CaCl ₂	BaSO ₄
Na ₂ CO ₃	X	X	X
LiOH	X	X	X
Pb(NO ₃) ₂	X	X	X

Table 11.3

Solubility Rules for Ionic Compounds

Compounds	Solubility
Salts of alkali metals and ammonia	Soluble
Nitrate salts and chlorate salts	Soluble
Sulfate salts, except compounds with Pb ²⁺ , Ag ⁺ , Hg ₂ ²⁺ , Ba ²⁺ , Sr ²⁺ , and Ca ²⁺	Soluble
Chloride salts, except compound with Ag ⁺ , Pb ²⁺ , and Hg ₂ ²⁺	Soluble
Carbonates, phosphates, chromates, sulfides, and hydroxides	Most are insoluble

12. Ashley has a 2.0 L of an 8.0M solution at her lab station. When she went to get other equipment, Derek removed 2.0 moles of the solute and added enough water to maintain the 2.0 L so she was none the wiser. However, she caught him and asked him how many moles he took. He confessed to taking the two moles. Write an equation to determine the initial number of moles in the solution. Solve for the new molarity of the solution.

13. Jack needs to perform a dilution experiment and needs a 6.0 *M* solution. He finds a bottle labeled “12 moles of HCl in this container”. He notices that the volume of the container is 2.5 L and it is full. Which equation would help him determine if this solution was an appropriate one?

- A. $2.5 = 12x$
- B. $x = 12(2.5)$
- C. $2.5x = 12$
- D. $12 = 2.5/x$

14. Emily is going to run a titration experiment and needs a precise number of moles in her acid concentration. She wants to use an acid she has on hand so she chooses a 12.0 *M* HCl acid. She only has equipment that will hold 50.0 mL. Which equation will determine the number of moles in her acid sample?

- A. $.050x = 12.0$
- B. $12.0x = 50.0$
- C. $12.0 = x/50.0$
- D. $x = 12 (.050)$

15. Calculate the new molarity that results when 250. mL of water is added to 125 mL of 0.250 *M* HCl.

APPENDIX J

BACK TO THE BASICS MATH ACTIVITY

Names _____ Blk ____ Date _____

Back to the Basics

Using the strategies we discussed in class, you and your partner solve the following word problems together. If you get stuck, move on to the next problem until you get your question answered. Be ready to explain how you solved # _____ to the class using your iPad or the document camera.

1. There are two numbers whose sum is 63. One number is twice the other. What are the numbers?
2. Sarah is six years older than Ethan. Six years ago, she was twice as old as he. How old are Sarah and Ethan now?
3. There are three consecutive even numbers such that twice the first is 20 more than the second. Find the numbers.
4. A mixture containing 6.0% hydrochloric acid is to be mixed with two liters of a mixture which is 15% hydrochloric acid in order to acquire a solution which is 12% hydrochloric acid. How much of the 6.0% solution should be used?
5. Think of a number. Double the number. Subtract six from the result and divide the answer by two. The quotient will be 20. What is the number?
6. M_1 multiplied by V_1 is equal to M_2 multiplied by V_2 ($M_1V_1 = M_2V_2$). If the value of M_2 is smaller than M_1 , mathematically speaking, what can you say about the value of V_2 compared to V_1 ?
7. Using the above formula, if $M_1 = 6.0$, $M_2 = 2.5$ and $V_2 = 500$, what would V_1 equal?

8. A service station checks Mr. Buchler's radiator and finds it contains only 30% antifreeze. If the radiator holds 5 liters and is full, how much must be drained off and replaced with pure antifreeze in order to bring it up to a required 50% antifreeze concentration?
9. The instructions on a can of powdered lemonade drink mix say to mix $\frac{1}{4}$ cup of the mix with 2 quarts of water. How much of the mix should be used with $1\frac{1}{2}$ gallons of water?
10. Find a number such that five more than one-half the number is three times the number.
11. A carpenter cuts a board into three pieces of equal length and then cuts off $\frac{1}{4}$ of one of the pieces. If the smallest piece of wood he has is one foot in length, what was the length of the original board?
12. Will has scores of 96, 86 and 78 on three tests. What much his average score on the next two tests be in order for him to have an average of at least 90?
13. Bags of chips are sold in groups of ten. If they cost \$2.90 a group, how much would 90 bags cost?
14. The Erie High School football team made 21 touchdowns and 14 field goals this season. They missed 8 field goals. A touchdown is worth 6 points and a field goal is 3 points. If they had made all of their field goals, how many points would they have totaled this year?
15. If you mix 400.0 mL of 20% NaCl with 400.0 ml of 50% NaCl, what would be the final concentration?

APPENDIX K
STATIONS FOR SOLUTIONS UNIT

Station 1

The 500 mL beaker in front of you contains 25% copper sulfate solution (notice the blue coloring). How could you produce 250 mL of a 10.0% solution?

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 2

Measure out 0.25 mole of NaCl on the scale. Now place it in the 400 mL beaker and add enough water to produce 3.0×10^2 mL of solution. What is your concentration in moles per liter of solution?

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 3

Place 25 mL of isopropyl alcohol in 250 mL of distilled water. What is the % concentration of alcohol in your newly made solution? (Remember that percent = part/whole $\times$ 100%)

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 4

Mass 28.3 g of NaNO_3 and place in a 500 mL beaker. Add distilled water up to 2.0×10^2 mL. What is the concentration of moles per liter of your solution?

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 5

The 400 mL beaker in front of you contains 30.0% copper sulfate solution (notice the blue coloring). How could you produce 200. mL of a 20.0% solution?

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 6

Measure out 0.10 mole of sodium carbonate on the scale. Now place it in the 100 mL beaker and add enough water to produce 1.0×10^2 mL of solution. What is your concentration in moles per liter of solution?

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 7

Place 60.0 mL of isopropyl alcohol in 200. mL of distilled water. What is the % concentration of alcohol in your newly made solution? (Remember that percent = part/whole $\times$ 100%)

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

Station 8

Mass 28.3 g of NaNO_3 and place in a 500 mL beaker. Add distilled water up to 2.0×10^2 mL. What is the concentration of moles per liter of your solution?

- Assess what info you have and what equation(s) would be suitable
- Calculate to get your answer
- Evaluate. Does your answer make sense? Why or why not?

APPENDIX L
SOLUTIONS QUIZ

Honors Chem Solutions Quiz A

Name _____ Blk _____

Answer on a separate sheet of blank notebook paper.

- 1) A 7.50% potassium chloride solution is prepared by dissolving enough of the salt to give 100.0 g of solution. What is the mass of **water** required?
- 2) What volume of 6.00 M hydrochloric acid contains 10.0 g HCl solute (36.46 g/mol)?
- 3) Concentrated hydrochloric acid is available commercially as a 12 M solution. What is the molarity of an HCl solution prepared by diluting 50.0 mL of concentrated acid with distilled water to give a total volume of 2.50 L?
- 4) How many liters of 4.0 M solution can be made using 125 grams of lithium bromide, LiBr?
- 5) A 50 L baby pool has a chlorine concentration of 0.200 M. If 20 L of water **evaporated** on a hot summer day, what is the final concentration of the pool?

Bonus: The elevation of Lake Havasu is 400 feet, and Lake Tahoe is 6200 feet. If the water temperatures are the same, which lake has a lower concentration of oxygen gas?

Honors Chem Solutions Quiz B

Name _____ Blk _____

Answer on a separate sheet of blank notebook paper.

- 1) A 12.50% potassium chloride solution is prepared by dissolving enough of the salt to give 100.0 g of solution. What is the mass of **water** required?
- 2) What volume of 8.00 M hydrochloric acid contains 10.0 g HCl solute (36.46 g/mol)?
- 3) Concentrated hydrochloric acid is available commercially as a 12 M solution. What is the molarity of an HCl solution prepared by diluting 60.0 mL of concentrated acid with distilled water to give a total volume of 2.50 L?
- 4) How many liters of 4.0 M solution can be made using 140 grams of lithium bromide, LiBr?
- 5) A 50 L baby pool has a chlorine concentration of 0.200 M. If 15 L of water **evaporated** on a hot summer day, what is the final concentration of the pool?

Bonus: The elevation of Lake Havasu is 400 feet, and Lake Tahoe is 6200 feet. If the water temperatures are the same, which lake has a higher concentration of oxygen gas?

APPENDIX M
STUDENT INTERVIEW QUESTIONS

POST-TREATMENT STUDENT INTERVIEW QUESTIONS

1. Do you feel the math lessons at the beginning of the unit were helpful in solving the word problems throughout that unit or was it more beneficial to see the math when we got to it within the lesson? Why?
2. What were some advantages to having the math taught upfront versus within the unit? Disadvantages?
3. Do you think your mental math skills and ballpark evaluations of an answer have improved due to the approaches taught at the beginning of the unit?
4. Do you think you could utilize the strategies taught in solving chemistry word problems in other types of problem-solving?
5. Is there anything else you would like me to know