

FORMATIVE ASSESSMENT TO TEACH MATH CONCEPTS IN HIGH SCHOOL CHEMISTRY

by

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of

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in

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DEDICATION

This paper is dedicated to my family who have supported my growth as an educator and professional. I am eternally grateful for my husband who has watched me from the student teaching days to the current position of being the department coordinator of our high school science department. I am grateful for my children who have taught me the value of being curious and to never stop learning. While I have been working on this project, they have supported me and encouraged me when I wanted to settle for close enough to finished and stop the progress. Finally, for all the obstacles that have happened over the last three years (Covid, forest fires, ice storms, and the loss of my grandmother), these have helped me to remember why I started the work for this degree to begin with.

ACKNOWLEDGEMENTS

It is important to acknowledge my students in this work. My students are the reason that I wanted to continue with my own education. It started with the Chemistry Certificate Program so that I would be a better chemistry teacher for them and has shifted to the MSSE degree so that I can be a better teacher leader for my entire team. My students are the purpose for the work that I have done. Their hard work inspires me and makes me want to do better for them each school year.

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ABSTRACT

Calculations relating to unit conversions in high school chemistry typically pose difficulty for students. The purpose of this study was to determine the impact of using consistent methods of formative assessment as daily check-ins to improve student success on this type of work as well as improve the overall score on the related college level unit exam. At the beginning of the unit students in the treatment group completed a pretest and survey to determine their skill level and comfort with unit conversions in chemistry. During the unit, these students completed a different type of formative assessment after each lesson to assist the instructor for how to prepare for the following lesson. After six lessons, students completed a posttest, survey, and college level unit exam. Students in the non-treatment group did not receive consistent formative assessment during the unit. From gathered data, students' comfort levels improved over the course of the study. Student achievement on the posttest was significantly greater than on the pretest and there was a noticeable increase in the overall percentage of students that earned a C or better on their college level unit exam. Where the non-treatment group had 70% of students score a C or better on the college exam, the treatment group percentage rose to a 76% of students earning a C or better on the same exam. This shows that intentional formative assessment does prove to be a useful tool to increase student performance on math-based topics in chemistry.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

I have been teaching for 13 years with an endorsement in science instruction for grades 5-12. My teaching experience has been at both middle school and high school levels. Currently I teach accelerated physical science, forensic science, and dual enrollment chemistry. My students are in grades, 9,11, and 12. The school I work at is Silverton High School in Silverton, Oregon. Silverton is a rural farming community located in Marion County Oregon, about 45 miles south of Portland, OR, with a population of 10,687 (worldpopulationreview.com, n.d.). Silverton High School is a part of Silver Falls School District which is composed of nine K-8 schools, two K-5 schools, and one middle school which all feed into a single high school with a student population of approximately 1200, composed of students in grades 9-12 (Oregon.gov/ode, n.d.).

Each student is required to take three years of science in our school consisting of one year of physical science, one year biology, and one year of elective credits. Many students choose to take four years of science and add a science elective during their senior year. Our elective options consist of three different AP courses, two dual-enrollment college credit courses and a handful of general electives. The course that I will be focusing on for my research project is a dual-enrollment chemistry course that offers students four credits hours in the State University system. Students may take the chemistry course after successfully completing their physical science and biology series and have taken or are currently enrolled in the proper math prerequisite of Algebra 2. Typically, there are 60-80 students enrolled in this class who are

juniors or seniors. Topics of study in this course include unit conversions, atomic theory, basics of compounds/molecules, evaluation of quantities in chemistry, solutions, and gas laws.

I have been teaching chemistry for a total of five years. The current school year is the first regular school year I have had while teaching this course. The learning curve has been great each year as I have had to learn new strategies for teaching the same curriculum in an online format as well as an in-person format. During these ever-changing times, one thing I have recognized as a consistent difficulty for students is the struggle to process and solve problems that involve unit conversions. While students learn math strategies from seventh grade on, they have difficulty recognizing and applying the same strategies for problem solving when it comes to work in their science courses, specifically in chemistry. The difficulties that I hope to address in this study include unit conversions for the metric system, gram/mole unit conversions, and how to write and solve word problems.

Focus Question

The focus question of this study was, To what extent can the implementation of consistent formative assessment increase student learning of math concepts in high school chemistry?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Formative Assessment

Classroom assessment can take many forms such as diagnostic, summative, and formative. Each type of assessment has a different purpose and is typically used at specific times during instruction as a snapshot of where each student is at with their comprehension of the content throughout the course. Diagnostic assessment can be used to identify student strengths and weaknesses in relationship to their knowledge and skills (Fan, 2021). Using a diagnostic assessment is a helpful way for teachers to get baseline information about their students and help assist in preparing units of study. This assessment will typically occur at the beginning of a unit. Summative assessment can provide teachers with numerical data that measures the achievements of students at the end of a unit (Taras, 2005).

Formative assessment is slightly different than diagnostic and summative assessment as it serves to provide feedback to both instructors and students as they progress in their learning. Formative assessment is described as a process of collecting evidence to show students' thinking and learning and to inform instructional practices, as well as a tool to provide feedback to students (Keeley, 2016). Instructors can use formative assessment to help students learn from mistakes as well as used towards developing the next step of instruction. Students can use formative assessment to start conversations with their peers or instructors about their current understanding of content. The use of formative assessment can be a way to help lower-level students work towards understanding without the penalty of poor grades that they may be

accustomed to experiencing on more high stakes assessments. While participating in formative assessment, students can learn to monitor their own learning and they can also have a better understanding of the purpose behind the assessment and how it can be used as a tool to improve their understanding of a given topic (Boston, 2002). For students, formative assessment can aide in achievement by increasing their motivation, helping students in developing an awareness of their learning, and improve the effectiveness of their overall learning (Weurlander et al., 2012). The value of formative assessment for teachers and students is clear and the use of formative assessment can enhance science instruction.

Using Formative Assessment in Science Classrooms

Formative assessment in the science classroom is an assessment strategy that can be useful when combined with proper feedback. Formative assessment classroom techniques (FACTs) are useful tools used to gather student ideas by integrating assessment and instruction. FACTs can be specifically selected to elicit prior knowledge, increase exploration and discovery, improve concept and skill development or transfer, and provide a platform for self-assessment and reflection. Teachers can be intentional when selecting FACTs to meet the expected learning outcomes (Keeley, 2016). Specific FACTs that are effective in demonstrating student comprehension include: K-W-L (know, want to know, learned) Charts, Frayer Model, True or False Statements, Card Mapping, Concept Maps, Check Lists, and Exit Cards (Ganajova et al., 2021). Using these FACTs has been shown to increase student achievement on future summative assessments for low-level cognitive skills as well as higher order analysis questions where students are expected to quantify data or results (Babincakova et al., 2020). The amount of new vocabulary used in science courses can be substantial. Therefore, it is critical to select FACTs

that will improve student use of content terminology and their ability to perform well on application style questions. Using FACTs with increased frequency has also been shown to improve inquiry and experimental design skills of science students (Ganajova et al., 2021).

Each FACT above has a specific way in which it is used as a helpful resource for both teacher and student. K-W-L allows students to start thinking about a topic, share what they hope to find out, and share what they have learned about a topic. It can provide information at the beginning and end of a unit. The Frayer Model is a graphic organizer that can be used to activate students' prior knowledge and help them to start communicating what they already know about a topic. It is best used at the beginning of a unit. Justified True or False statements can be used anywhere in a unit. They allow for a learner to choose True or False for a statement and then they can explain why they chose the way they did. It is a tool that is valuable for students to collaborate on and provides them an opportunity to argue about their ideas and opinions using science knowledge. Card Sorts and Concept Maps have a similar use in that they are ways to illicit student misconceptions associated with a concept or idea in science. Students can organize terms and definitions into groups that make sense, or they can create a map that links different terms/phrases together. These strategies are good at the beginning, middle or end of a unit. Exit tickets are one of the strategies that can be used daily to assess where students are. They can involve a quick check in where students can give an immediate response to a simple question or even just comment on how they are doing with material (Keeley, 2016). Each of the FACTs described are relevant in a science classroom and the use of them can be valuable for both teacher and student.

Teacher Perceptions of Using Formative Assessment

Instructors have different perceptions of assessment that can affect the likelihood of implementing formative assessment in their classes. It has been found that factors that may contribute to the use of formative assessment include years of service, subject area, and previous teacher training in preparing assessment. Science teachers are more likely to use formative assessment than other areas such as math or English, because in science the teachers tend to have more control over assessments as they are not standardized and predetermined. Teachers that have been through formative assessment training are more likely to use the various assessment types as they can easily embed them in their current instruction. New or younger teachers are likely to use formative assessments as well because they are not set in their assessment practices (Alotaibi, 2019). While teachers recognize the value of using formative assessment, research suggests a lack of teacher confidence in student self-reflection as an accurate way to measure comprehension. However, as students get older, teachers are more likely to use formative assessment as they recognize the positive aspects of students learning by being unsuccessful in classroom assessment. Therefore, in older students, self-reflection is more valuable (Sach, 2012).

CHAPTER THREE

METHODOLOGY

Demographics

I teach 9th-12th grade physical science, forensics, and chemistry at a high school in rural Silver Falls School District in Oregon. Students in my course are part of a dual-enrollment chemistry course in partnership with Willamette Promise and Western Oregon University. Students who are enrolled in this course can receive four college credits that can be transferred as general science electives. The current enrollment for this course is 32 students divided into two periods, one of 13 and the other of 19. Comparisons will be made as to the success of these 32 students compared to a group of students from the past school year that did not receive the treatment. Data from this previous class includes 66 students that completed the same summative exam for Unit 1 offered through Willamette Promise. Typical students in this course are concurrently or previously enrolled in other honors or AP courses. Students are expected to have taken Algebra 2 or the equivalent as a prerequisite to enrolling in the course. The research methodology for this project received an exception by Montana State University's Institutional Review Board and compliance for work with human subjects was maintained (Appendix A).

The goal of this study was to find strategies to help students be successful with problem solving in their chemistry course, specifically by using formative assessment. My goal was that by increasing formative assessment use during the unit, students would perform better on their end of the unit summative assessment for quantitative calculations in chemistry. Prior to the

study formative assessment was sporadic and often overlooked to inform instruction in my classes.

Treatment

The unit that students worked on during this study was the third unit that was taught during the term, in this study it is referred to as Unit One as that is the unit it is named for Western Oregon University. Students had completed two exams prior to this exam and had basic preparedness as to the format of exam they would be take. The unit one exam is the first where the students were expected to perform dimensional analysis style calculations that were skills based and required application of mathematics. All other exams have been strictly content/knowledge based.

For this study, two groups of students were involved. The treatment group followed typical instruction plan with the addition of daily formative assessment strategies used to drive the following day's lesson plan. The non-treatment group followed typical instruction plan with no daily formative assessment. Non-treatment students received instruction for Unit One prior to this school year and prior to the implementation of consistent formative assessment. Survey data was generated by comparing student attitudes toward their preparedness for problems solving in science classes at the beginning, middle, and end of the unit. In addition, students completed a pre/posttest as well as a summative assessment.

Data Collection Instruments

Students' attitudes were documented in the Chemistry Problem Solving Confidence Survey (Appendix B). This Likert-style survey asked various questions regarding student

confidence levels for several types of calculation procedures in chemistry (Appendix B).

Students were asked to rate their confidence on a scale of 1-5 where 1 = strongly disagree, 2= disagree, 3= neutral, 4= agree, 5= strongly agree. The confidence survey was completed at the beginning of the first lesson, middle of the unit after the third lesson, and end of the unit after the sixth lesson. The data for this survey was analyzed using a paired t-test that shows comparison overall for each question asked at survey times of beginning, middle, and end of the unit of study.

Students were given a pretest, Unit 1: Measurement in Chemistry (pretest), at the beginning of the unit as a part of Lesson One (Appendix C). The pretest had a selection of questions that were similar though not identical to the summative exam they took for college credit. The distribution of questions was related to significant figures, dimensional analysis, unit conversions, density, and scientific notation. Students were administered this same assessment as a primary posttest following six lessons delivered over three weeks of instruction (Appendix C). The pre and post assessment were analyzed for each student using a paired t-test that compares the student results from the pretest to the post test. Normalized gains were evaluated for the pre and posttest as well. The normalized gain was calculated to determine differences in student knowledge. Normalized gains of less than 0.3 were considered low, gains 0.3 to 0.7 were considered a medium gain and normalized gains greater than 0.7 were considered high (Hake, 1998).

Following the coordinated posttest written by me, students sat for the summative assessment, Exam 1: Measurement, given for college credit through Willamette Promise and Western Oregon University (Appendix D). This summative exam requires students to complete

multiple calculations based on significant figures, dimensional analysis, unit conversions, density, and scientific notation. To receive college credit students are expected to earn a 70 percent on this exam. To make comparisons, data was compared from the nontreatment group of students, who took the exam in the 2021-22 school year and the treatment group of students from the current school year. Overall score on the exam was analyzed using an independent-measures t test.

In addition to the above-described analysis, Unit 1 Pre-assessment/Unit 1 Post-assessment and Unit 1 Measurement summative exam were analyzed using paired t-test and normalized gains for the Unit 1 Pre/Post assessment. The Unit 1 Measurement summative exam was analyzed using an independent sample t-test due to the difference of test subjects ($n=66$ vs $n=36$). Box and whisker plots with the standard deviation were used to graphically show student gains through the unit of study.

During the unit, students in the treatment group completed daily formative assessment to gauge their understanding of the instructional material delivered. These formative assessments included a muddiest point exit ticket, a concept map for problem solving, card-sort, Frayer Model survey, density KWL (what do you know, what do you want to know, what did you learn), and a justified true/false questionnaire (Appendix E). At the end of each lesson, a selected formative assessment was delivered to students in the treatment group. The data gathered from the formative assessment was used to develop instruction strategies for the next lesson. Students in non-treatment group did not receive the formative assessment and proceeded through the unit instruction without explicit check-ins. Qualitative analysis of formative assessment was completed after each lesson. To analyze the data, common responses were categorized as points

to address on the next days' lesson. Data was organized by tallying common responses for each formative assessment delivered (Appendix F).

Both treatment and non-treatment groups received the same practice problems throughout the unit and spent time discussing problem solving strategies. This allowed all students the opportunity to practice the same type of problems that had the potential to appear on their final summative exam. All students also completed lab activities that involved calculations and skills of measurement in chemistry (Table 1).

Table 1. Data Triangulation Matrix.

Research Question	Data Method 1	Data Method 2	Data Method 3	Data Method 4
Does using formative assessment as a strategy to drive instruction, improve overall student success on summative exam of calculations in chemistry?	Likert style survey: Chemistry Problem Solving Confidence Survey	Pre and Post Test: Unit 1: Measurement in Chemistry (PRE-TEST)	Formative Assessments: <ul style="list-style-type: none"> ● Muddiest point exit ticket ● Concept map for problem solving ● Card-sort ● Frayer model survey ● Always, Sometimes, Never ● Justified True/False questionnaire 	Summative Assessment: Unit 1 Exam: Measurement

CHAPTER FOUR

DATA ANALYSIS

Results Unit One: Measurement in Chemistry Pre/Post Assessment

The Unit One Measurement in Chemistry Pre and Post assessments were administered to students in the treatment group. The assessments were administered at the beginning and end of the unit. The total point value of the assessment was out of 26 points. For the pretest, the mean of the assessment was determined to be 9.4 points out of 26 with a range of 0 to 26 points ($n=34$). There was a standard deviation for the pretest of 4.86. The posttest mean was determined to be 20.4 out of 26 with a range of 8 to 18 points. There was a standard deviation for the posttest of 4.72. Box chart analysis shows that there was no overlap of the standard deviation error bars indicating that the results were significant, and the null hypothesis was rejected and that the treatment was effective in improving student scores on the assessment (Figure 1).

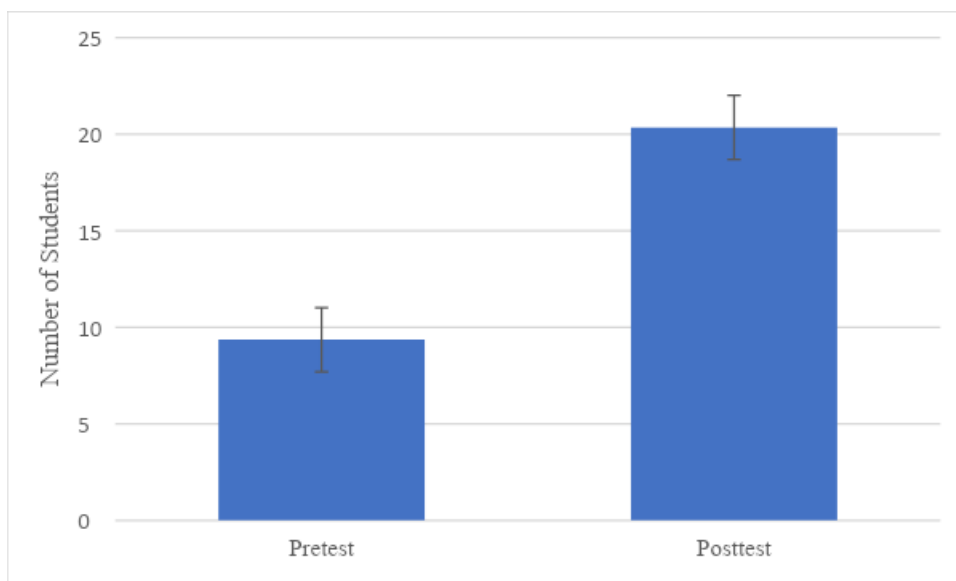


Figure 1. Pretest and Posttest Means with Standard Error Bars for treatment group, ($n=34$).

Further analysis was done on the results from the Unit 1 pre and posttest data using normalized gains (Hake, 1998). A double bar graph shows data for each student in the treatment group. The side-by-side view allows one to look at each student of the study ($n=34$) to help identify gains made due to the treatment of formative assessment. From this graph it can be seen that all students had gains from their pretest results, with the exception of student one that earned the same score for each assessment. For normalized gains to be significant, they must be over 0.7, twenty of the students in this study had gains that were significant (Hake, 1998) (Figure 2).

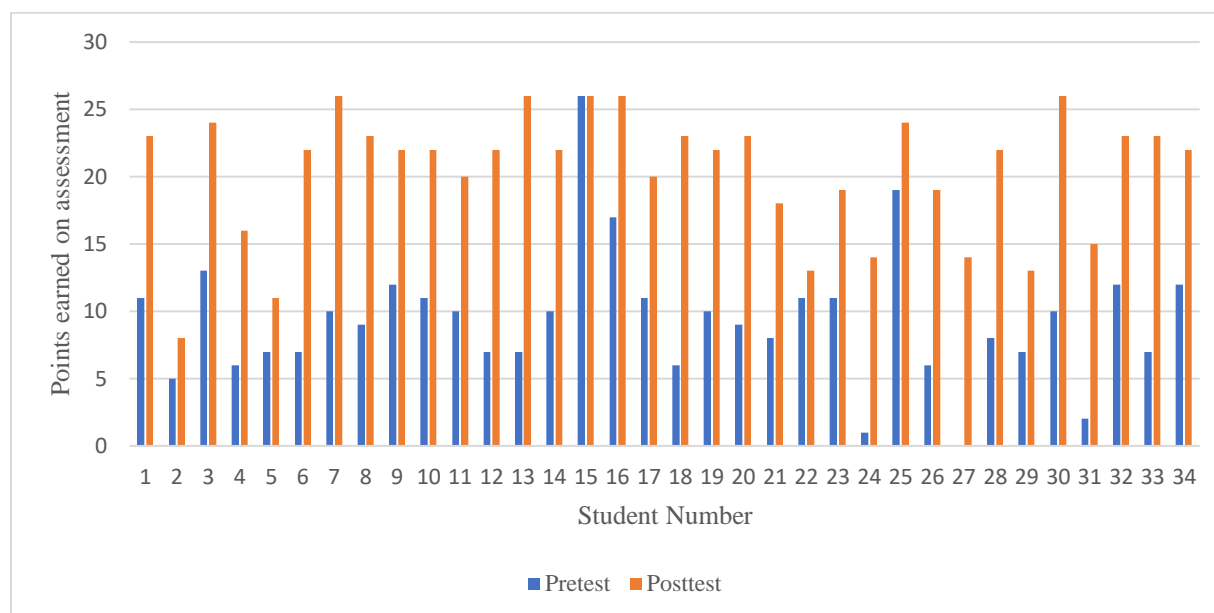


Figure 2. A bar graph comparison of Pre and Posttest data for each student in treatment group where left column is pretest data and right column is posttest data for each numbered student in the study, ($n=34$).

Using this quantitative data, normalized gains were determined for each student in the treatment group and a mean was calculated. The normalized analysis of the Unit One Measurement in Chemistry Pre/Posttest shows a gain of 0.68, considered a medium gain. For individual analysis, normalized gains of less than .3 were low, 0.3-0.7 were medium, and gains

of over 0.7 were high (Hake, 1998). Calculating the range of normalized gains for this data set, it was determined that 11.76% of students fit in the low range, 29.41% fit in the medium range, and 58.82% of students were in the high range for learning gains in this unit (Figure 3).

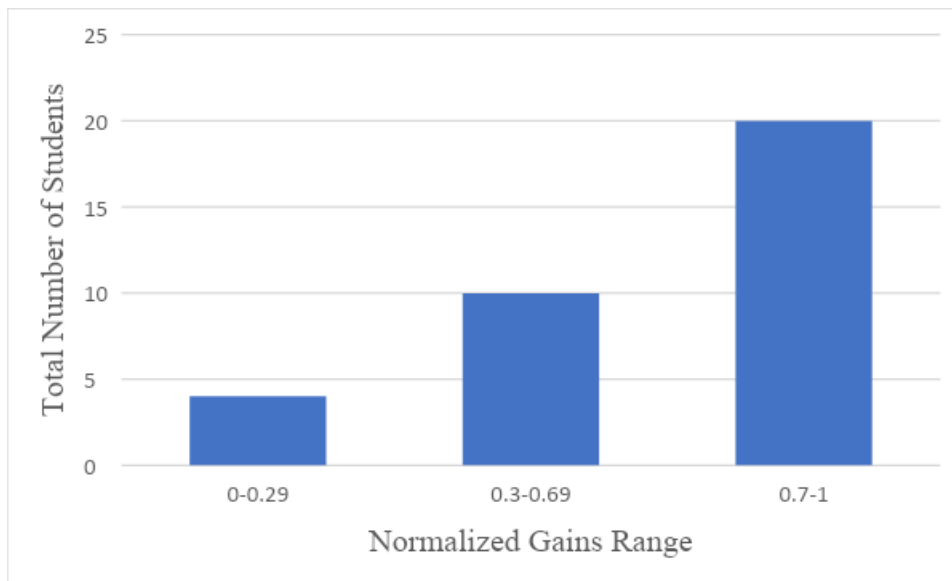


Figure 3. Normalized gains range count for students in treatment group, ($n=34$). *Note.* 0-0.29 low gain, 0.3-0.69 medium gain, 0.7-1 high gain.

Further confirmation to reject the null hypothesis, were the results of the paired t-test done on this data set. These results demonstrate the positive impact of formative assessment on student test scores. The goal was that the paired t-test would show 95% differences between pretest and posttest for the null hypothesis to be rejected meaning there is no difference between test scores. A p-value of less than 0.05 would signify that there is a significant difference between test scores. For this test, the p-value was determined to be significantly less than .05, because this is so much lower than 5%, it can be said that the null hypothesis was rejected.

Results for Chemistry Problem Solving Confidences Survey

At the beginning of the unit of study students completed a Likert style survey titled Chemistry Problem Solving Confidences Survey ($n=34$). This survey asked questions about their ability to study and solve a variety of problems in chemistry. Results for student responses for question 9 of this survey showed very low confidence with only 20% or less of students stating that they would strongly agree in their abilities in specific types of problem solving relating to dimensional analysis and basic problems involving quantities in chemistry (Figure 4). For question 10, students had the highest agreement on recognizing the importance of the unit as well as the fact that they had the resources to be successful.

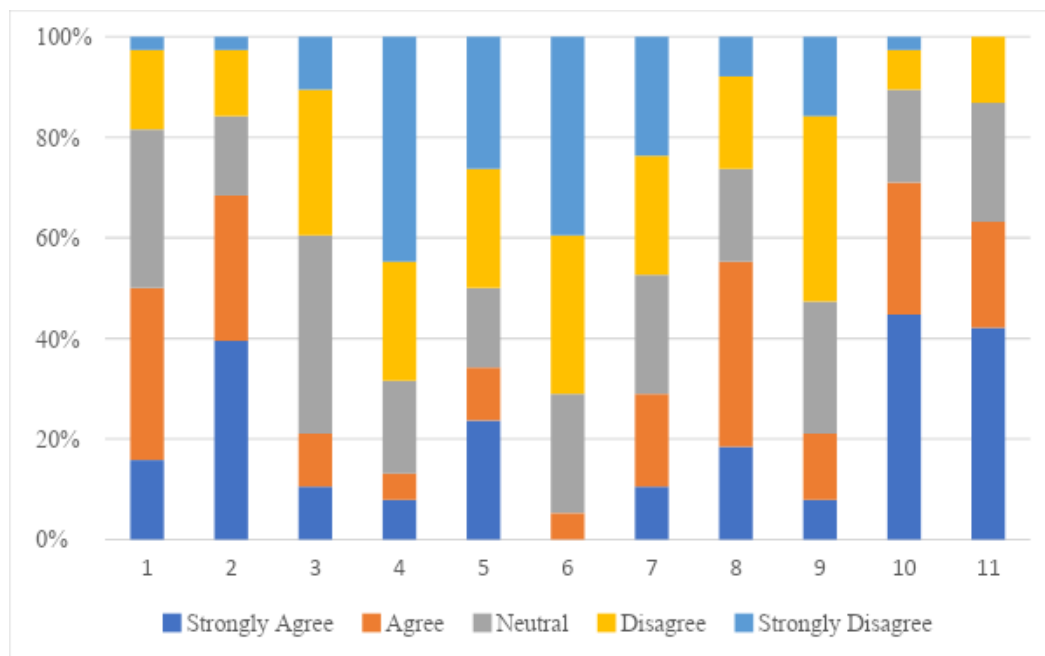


Figure 4. A stacked bar graph showing student confidence levels for problem solving in chemistry, taken at the beginning of the unit ($n=34$). *Note.* 1=My study habits are sufficient to help me perform well in class. 2=I complete my homework on time for chemistry class. 3=I can convert measurements of a quantity from one unit to another. 4=I can report my answers using correct significant figures. 5= I can use scientific notation to represent large and small numbers. 6= I can analyze a problem and solve it using the factor-label method. 7= I can define density and solve problems where density is involved. 8= I recognize there are different units of measurement in science and know when to use the correct units when making measurements. 9= I am confident in my ability to solve quantitative problems in chemistry. 10= It is important for me to be able to solve quantitative problems in chemistry. 11= I have the resources to be successful solving quantitative problems in chemistry.

At the end of the unit students again completed the Chemistry Problem solving Confidences Survey. Based on the results of the survey, 30% or more of students would say that they strongly agreed with their confidence in the ability to solve quantitative problems in chemistry class. What is even more clear is how few students selected strongly disagree in their ability to solve content specific problems, questions 3-8, which directly related to specific types of calculations (Figure 5).

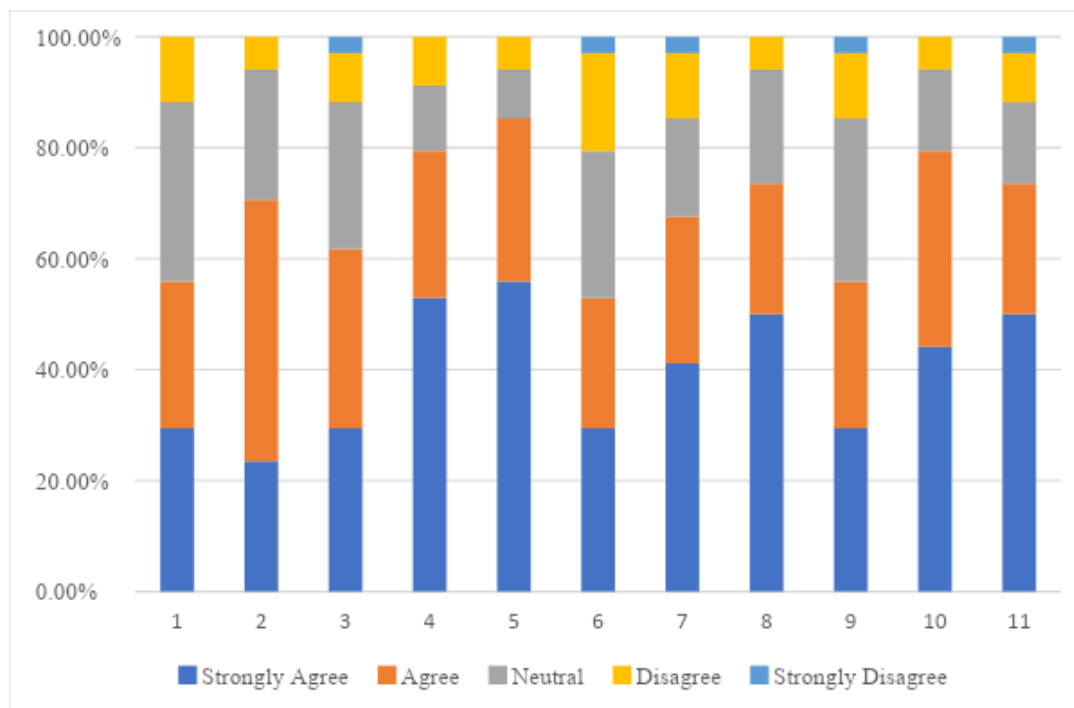


Figure 5. A stacked bar graph showing the final chemistry problem solving confidence survey results, taken at the end of the unit of study ($n=34$). *Note.* 1=My study habits are sufficient to help me perform well in class. 2=I complete my homework on time for chemistry class. 3=I can convert measurements of a quantity from one unit to another. 4=I can report my answers using correct significant figures. 5= I can use scientific notation to represent large and small numbers. 6= I can analyze a problem and solve it using the factor-label method. 7= I can define density and solve problems where density is involved. 8= I recognize there are different units of measurement in science and know when to use the correct units when making measurements. 9= I am confident in my ability to solve quantitative problems in chemistry. 10= It is important for me to be able to solve quantitative problems in chemistry. 11= I have the resources to be successful solving quantitative problems in chemistry.

In this survey students were asked to respond to their confidence level in their ability to solve quantitative problems in chemistry. Analysis of this prompt at the beginning of the unit shows 7.89% of students strongly agree, 13.16% of students agree, 26.32% were neutral with 52.63% of students either disagreeing or strongly disagreeing with that statement. Analysis of this same prompt at the end of the unit showed 29.41% of students strongly agree, 23.53% of students agree, 26.47% were neutral with only 20.59% of students either disagreeing or strongly

disagreeing with that statement in question 9. There was a large shift in the confidence level of the students from the beginning to the end of this unit (Figure 6).

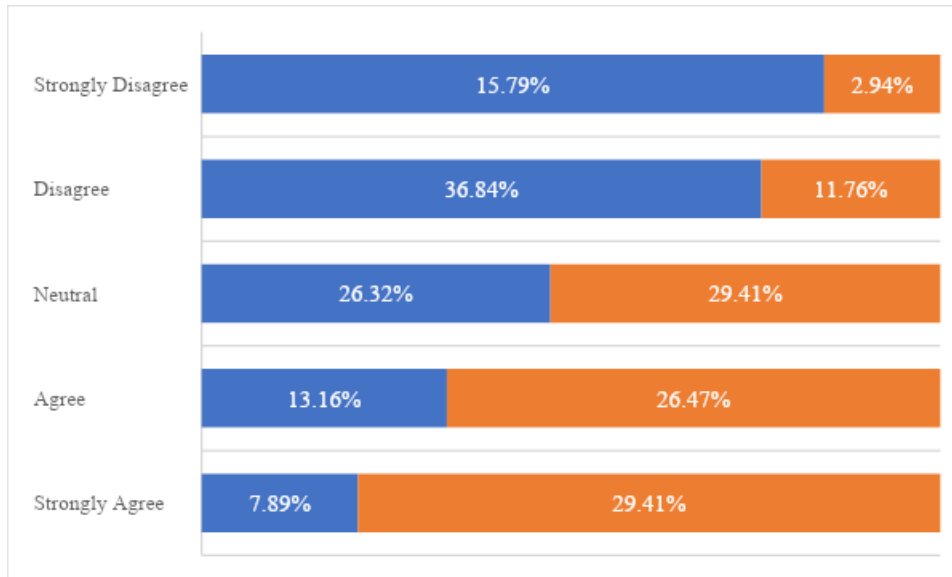


Figure 6. A stacked bar graph showing the confidence level of students at the beginning, left side (blue) and end, right side (orange) of the unit of study, ($n=34$).

Results of Unit One Exam: Measurement

Part of this study was intended to study the effects of formative assessment on the overall outcome for students on the college level unit exam. The nontreatment group was a sample of students ($n=66$) and the treatment group was a sample of students where ($n=38$). It was determined that the mean of the nontreatment Unit 1 exam was 30.26 out of 40 points possible with a range of 26. For the treatment group, the mean on the Unit 1 exam was 29.72 out of 40 points possible with a range of 23. After running an independent samples t-test, the p value was calculated at 0.69 which would reject the hypothesis that intentional formative assessment can improve student test scores on a college level exam. In addition, due to the overlapping standard

deviation bars on the bar graph, there is no change for the treatment group over the nontreatment group (Figure 7).

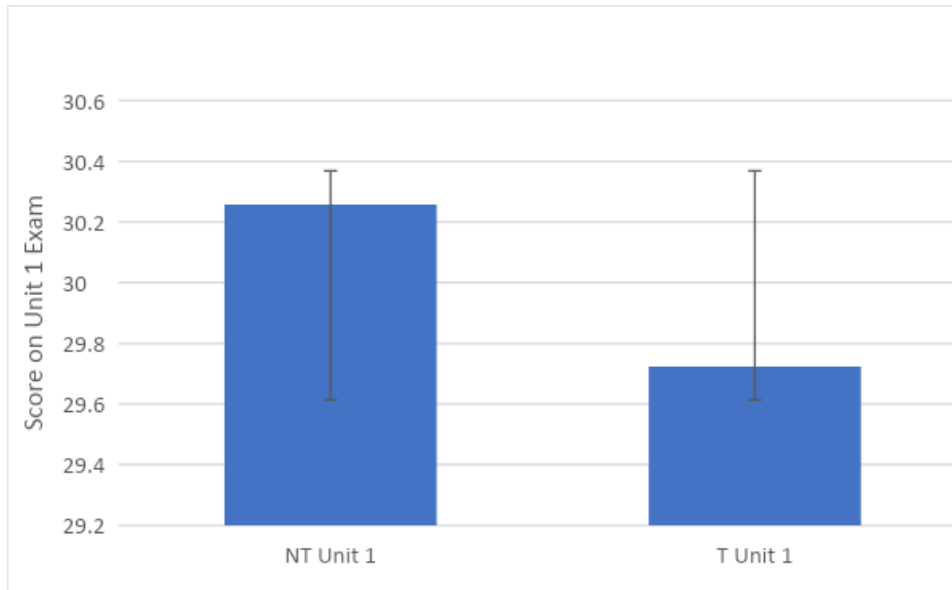


Figure 7. Bar graph showing standard deviation of nontreatment ($n=38$) vs treatment groups ($n=66$) and the Unit 1: Measurement Exam.

Further breakdown of data was done to evaluate the percentage of students scoring the different percentages on the exams. A basic count was done to determine the number of students that scored in the following ranges: 90-100%, 80-89%, 70-79%, 60-69%, and 0-59% (Figure 8). The most noticeable change was for the middle group, those earning a 70-79%. Students in this middle group with no formative assessments used, had 17% earning a 70-79%. The treatment group had 34% earn a 70-79% for this exam.

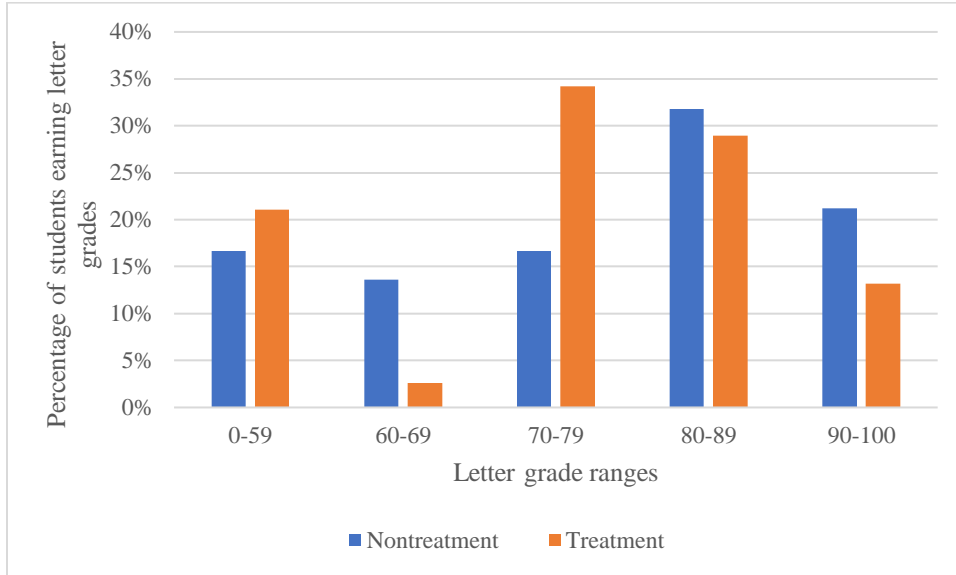


Figure 8. Bar graph showing the treatment and nontreatment comparison of letter grades for Unit 1: Measurement Exam, ($n=38$, $n=66$).

In addition to looking at the percentage of students earning each letter grade, the number of students earning a C or better (70-100%) on this Unit 1 Measurement Exam was determined. It was found that with the nontreatment group, 46 out of 66 (or 69.7%) of students earned a C or better on the exam. For the treatment group, this number was 29 out of 38 (or 76.3%) of students earning a C or better on the exam (Figure 9). While the treatment of formative assessment was not successful in an overall improvement of student scores on the exam, it can be noted that the number of students in the 60-69% range did decrease and the 70-79% group did increase. More students scored a C or better after treatment.

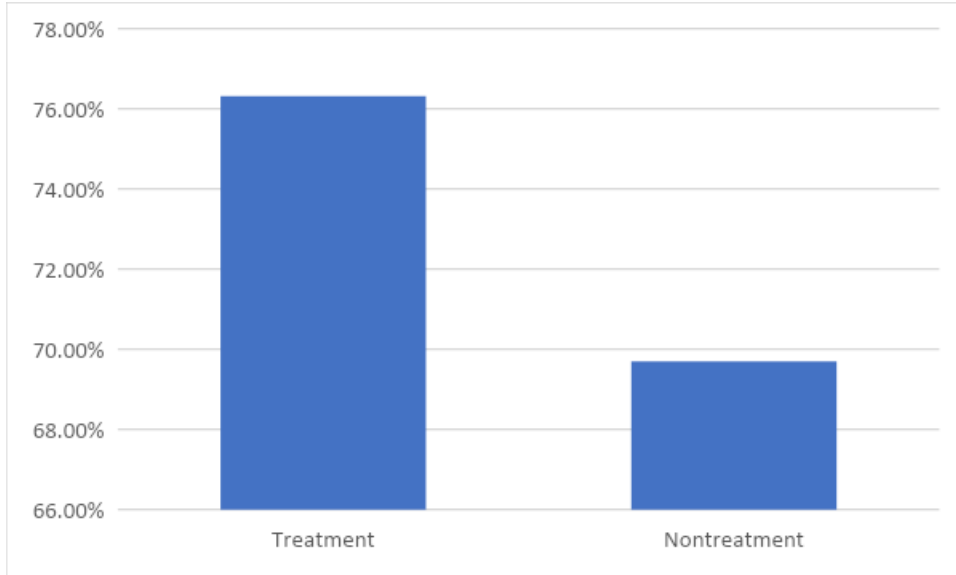


Figure 9. Bar graph showing the difference in Unit 1 Measurement Exam scores of C or better, ($n=38, n=66$).

CHAPTER FIVE

CLAIMS, EVIDENCE, REASONING

Claims From the Study

This action research paper was designed to determine to what extent the implementation of consistent formative assessment can increase student learning of math concepts in high school chemistry. Within this focus question three claims were determined as follows:

- (1) Student achievement of math concepts increased with the use of formative assessment,
- (2) Student confidence in their ability to solve problems in chemistry improved
- (3) Students earning a C or better on the college level Unit 1 Measurement Exam increased after using intentional formative assessment.

Evidence of the increase of student achievement on the solving of math problems in chemistry can be shown in the data collected from the pretest and post test administered during this study. The mean for the pretest was 9.35 out of 26 and the mean on the posttest was 20.35 out of 26. The range of the of the pretest was higher than the range on the posttest (26 vs 18). In addition, 58.82% of students had normalized gains over 0.7, this was 20 out of the 34 students that took both the pre and posttest. Students responded positively to the formative assessments which were delivered as exit tickets. When asked if they appreciated this method, many responded positively and said it was helpful in giving them different ways to look at the topics we were studying.

Using data from the Confidence in Problem Solving survey, it was determined that overall student confidence levels increased through the unit. At the beginning of the unit 21.5% of students agreed that they were able to successfully solve chemistry problems that were math

based whereas 52.6% of students were not confident. After six lessons that ended with formative assessments and modifications to lesson plans, these numbers flipped. At the end of the unit 52.8% of students felt favorable about their ability to solve chemistry problems that were math based whereas 20.6% of students were not confident. This improvement in student confidence did allow them to complete the Unit 1 Measurement Exam with a positive mindset and a calm demeanor. One student commented, "I feel so ready for this exam." While another stated, "That wasn't as bad as I thought it would be." These positive statements help demonstrate the ease they felt with the exam.

Finally, while the data did not suggest a significant improvement overall with student achievement on the summative college level unit exam, it was noted that the middle range of scores did improve. In the nontreatment group of students, approximately 70% of students earned a C or better on the exam. After implementation of a formative assessment plan, approximately 76% of students earned a C or better on the summative exam. While it was determined that the treatment did not positively affect the improvement of the mean score for the exam, data did show an increase of the students that earned the C or better and were able to continue to move forward towards earning college credit for the class.

Value of the Study and Consideration for Future Research

The value of this study was significant as it showed the importance of using formative assessment as a daily check-in and as an effective tool to improve student achievement on math concepts in chemistry as well as it increased student confidence when solving problems in class. Survey data showed a variance in the student confidence for solving several types of chemistry calculations, but their overall confidence did improve which is valuable. A lack of improvement

on overall summative test scores was disappointing however, an increase in the percentage of students that earned a C letter grade or better was good news.

When considering future research, it would be valuable to determine strategies that would improve overall test scores for students on the summative assessment. The summative assessment at the college level is one that is set and does not change from year to year. It is easy to look at different strategies that can improve the scores for this assessment. Perhaps changing the types of practice problems that students complete in preparation for the exam would be a research question that could be addressed. In addition, it would be interesting to look at the timing of the exam, delivered at the beginning of the year vs mid-year, on the effect of the test scores on the summative exam. It can be noted that the title of the exam is Unit 1. This would lead one to believe the exam is intended to be delivered at the beginning of the year. For this study it was delivered mid-year instead. These are all potential research questions to look at.

Impact of Action Research on the Author

This research allowed me to take a closer look at how I use formative assessment in my classroom. I consistently check in with students to see how they are doing with content. These check-ins involve quizzes, homework, and lab work with calculations. Giving feedback is something that I enjoy doing with this type of work. Students appreciate the feedback and consistently want to fix their mistakes on assignments. During a conversation with one student, she said, “I feel like the questions at the end of class helped me know if I was on target with my learning.” The formative strategies used in this unit were a wonderful way to get feedback on the lessons taught in the unit and the fact that they were not worth points was an effective way to get students to answer the questions honestly without having them copy from each other. The feedback was genuine and unique for each student. I found it easy to address misconceptions in

consecutive lessons based on student feedback. It allowed us to progress through the unit with students all on the same page.

One of my regrets in this study would be choosing a research question that had me use a small student sample group. I wanted to research how to improve student success on a difficult topic in chemistry but unfortunately, my classes were small this year. I could have selected a different topic and had a larger sample size if I would have selected a different course as a test population. As educators we are always evaluating and reflecting on our practice. I know that I will continue to search for better ways to improve student success with the topic of math in chemistry. I get feedback from students and am always working towards best practices.

The most impactful part of this project is taking a deep look at data and what it means. Having students do better overall was my goal but when looking deep into the data one can easily start to identify the outliers. Questions I have been asking myself as this process concludes are: how can I help the high achieving students be more engaged and how can I help the low achieving students improve? There are still so many variables to consider when teaching, such as covid, student home life, homework participation, and general study skills. The task to improve student achievement is heavy and a responsibility each teacher carries.

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APPENDICES

APPENDIX A

IRB DOCUMENT

Hello Bay, Clarissa,

Your protocol was reviewed by the IRB and has been approved.

PI: Bay, Clarissa

Approval Date: 11/30/2022

Title: Formative assessment to teach math concepts in high school chemistry

Protocol #: 2022-464-EXEMPT

Review Type: Exempt Review

Expiration Date: 11/30/2027

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

APPENDIX B

CHEMISTRY CONFIDENCE PROBLEM SOLVING SURVEY

Chemistry Problem Solving Confidence Survey (Delivered as a Google Form)

Complete this form to the best of your ability. Your level of confidence will help me in designing instructional tools to help you be successful. Each question is based on a scale of 1-5. (1= Strongly Disagree, 2= Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree)

1. My study habits are sufficient to help me perform well in class.
2. I complete my homework on time for chemistry class.
3. I can convert measurements of a quantity from one unit to another.
4. I can report my answers using correct significant figures.
5. I can use scientific notation to represent large and small numbers.
6. I can analyze a problem and solve it using the factor-label method.
7. I can define density and solve problems where density is involved.
8. I recognize there are different units of measurement in science and know when to use the correct units when making measurements.
9. I am confident in my ability to solve quantitative problems in chemistry.
10. It is important for me to be able to solve quantitative problems in chemistry.
11. I have the resources to be successful solving quantitative problems in chemistry.

APPENDIX C

UNIT ONE: MEASUREMENT IN CHEMISTRY PRE/POST TEST

Name: _____

Period: _____

Unit 1: Measurement in Chemistry (PRE-TEST)

Target 1: Units of the Metric System

List the correct base metric unit for the following:

Mass: _____

Length: _____

Volume: _____

Temperature: _____

Fill in the Blanks: 1.5 L = _____ mL = _____ kL

Target 2: Significant Figures

Give the correct number of significant figures in the following problems:

a. 65,670 cm _____

c. 725.6 mL _____

b. 0.00045 g _____

d. 1.00007 g/mol _____

Target 3: Prefixes of Measurement and Scientific NotationPlace the following units of measurement in order from **greatest** to **least**.

Milliliter, Kiloliter, Nanoliter, Deciliter,

Centiliter, Picoliter, Microliter, Liter

Correctly write the following value in *scientific notation*:

3,678, 982 m _____

0.0004578 L _____

Correctly write the following values in *expanded form*:1.674568 * 10⁶m _____2.3456 *10⁻⁴ mL _____

Target 4: Factor Label Method

If a solution has 1.4×10^4 g of mercury per 100 mL, how many milligrams is this per 100 mL?

Target 5: Density Calculations

Density = _____ / _____

A piece of copper that measures 9.0 cm by 5.0 cm by 4.0 cm has a mass of 180.0 grams.

What is the density of the copper? (volume = $L \times W \times H$)

APPENDIX D

EXAM 1 MEASUREMENT



Student-centered. Future-focused.

Students Name _____

Do Not Return Exam to Students
Exam 1: Measurement (40 points)

- (2 pts) A log of wood is chopped up with an axe into smaller pieces of wood.
 - Physical Property
 - Chemical Property
- (2 pts) Hydrogen peroxide dental strips will make your teeth whiter.
 - Physical Property
 - Chemical Property
- (2 pts) Give the number of significant figures in each of the following measurements:
 - 0.0560 m _____
 - 6,200 kg _____
 - 77 pennies _____
 - 7.075×10^{-5} s _____
- (1 pts) Show how to round off 6.65 g to two significant figures: _____

5. (2 pts) Fill in the blanks: $6.24 \text{ L} = \underline{\hspace{2cm}} \text{ ml} = \underline{\hspace{2cm}} \text{ cm}^3$

6. (2 pts) Which experiment to the right is precise but not accurate?

a. Experiment I

b. Experiment II

c. Experiment III

d. Experiment IV



Exp. I



Exp. II



Exp. III



Exp. IV

7. (2 pts) Put the following numbers into scientific notation form using the correct number of significant figures:

a. $0.00007300 \text{ g} =$

b. $12,030,000 \text{ L} =$

8. Metric to metric conversions. Use scientific notation where appropriate.

a) (2 pts) If a sample weighs 47.2 mg , what is this in grams?

b) (2 pts) A solution has $1.4 \times 10^4 \text{ pg}$ of uranium per 100 mL , how many kilograms is this per 100 mL ? Use scientific notation to both solve and express your answer.

c) (2 pts) If an automobile airbag inflates in 47.6×10^3 ns, what is the time in milliseconds (ms)?

d) (2 pts) If the radius of a silicon atom is 3.26×10^{-5} cm, what is the radius in μm ?

e) (2 pts) Convert 72°C to Fahrenheit.

9. Complete the following calculations using significant figures. (4 pts)

a) $12.5849 + 2.4 =$

b) $432.5 - 24.3984 =$

c) $246 \times 1.5 =$

d) $974.59/14.2 =$

10. (4 pts) A piece of wood that measures 3.0 cm by 6.0 cm by 4.0 cm has a mass of 80.0 grams.

a. What is the density of the wood? (volume = $L \times W \times H$)

b. Would the piece of wood float in water?

11. (3) I threw a plastic ball in the pool for my dog to fetch. The mass of the ball was 125 grams. What must the volume be to have a density of 0.500 g/mL.

APPENDIX E

FORMATIVE ASSESSMENT STRATEGIES

Muddiest Point Exit Ticket



What is a Question you have about Unit Conversions?

Students, write your response!

Pear Deck Interactive Slide
Do not remove this bar

The slide features a blue background with a white text box on the left containing the question. On the right, there is a cartoon illustration of a person with long brown hair, wearing a white shirt and brown pants, standing with their hand to their chin in a thinking pose. At the bottom left, there is a small green pear icon with a speech bubble. At the bottom right, there is a dark grey bar with white text.

Frayer Model

Operational Definition	Characteristics
Examples	Non-Examples

Unit Conversions

Always-Sometimes-Never

1. Units can be converted. <input type="checkbox"/> Always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never	Justify your answer:
2. Zeros are significant digits. <input type="checkbox"/> Always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never	Justify your answer.
3. Density can be calculated for a solution. <input type="checkbox"/> Always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never	Justify your answer.
4. Factor Label Method is a helpful tool to do chemistry calculations. <input type="checkbox"/> Always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never	Justify your answer.
5. Accuracy is important in chemistry. <input type="checkbox"/> Always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never	Justify your answer.
6. Precision is something that can be measured. <input type="checkbox"/> Always <input type="checkbox"/> Sometimes <input type="checkbox"/> Never	Justify your answer.

♥ 2019 Template from *Science Formative Assessment- 50 More Practical Strategies for Linking Assessment, Instruction, and Learning* (Page Keeley)
www.uncoveringstudentideas.org

APPENDIX F

FORMATIVE ASSESSMENT STUDENT FEEDBACK

Table 2. Formative Assessment Student Feedback

Formative Assessment Used	Student Feedback	Teacher Response
1 Muddiest Point Exit Ticket	Prefixes, what is on the top/bottom, how do we know where to start	Review prefixes, acronym, fraction review
2 Frayer Model: Unit Conversions	Change between units, good non examples of equalities	Good, continue on with lesson
3 Always, Sometimes, Never	Sometimes sig figs are important	Review this
4 Justified True and false	Meters to micrometers	Review prefixes and exponents
5 Odd One Out	Majority of correct responses	Continue on with next lesson