EDUCATIONAL SHIFTS IN PARADIGMS:

TRADITIONAL VERSUS PERFORMANCE BASED ASSESSMENTS

IN A STUDENT-CENTERED CLASSROOM

by

Erica May Bertrand

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 2024

DEDICATION

I dedicate my Capstone to my husband of 18 years, Rick Bertrand. I cannot thank you enough for all your support the past three years while I was obtaining my Master's in Science Education.

I also dedicate my Capstone to Walter Woolbaugh, my professor for all but one of my education classes and advisor. You pushed me to reach my full potential through some trying times when life threw me curve balls.

Lastly, I dedicate my Capstone to all 88 of my Advanced Chemistry students from spring of 2022 thru fall of 2023. Without their cooperation and input this would never have been possible.

ACKNOWLEDGEMENTS

Jack Loynd, the current AP Stats teacher, and principal when I first started teaching, agreed to assist me in making my project statistical sound. He has given me access to his AP College Board site, identified Chapter 7 as the one that discusses t-tests, and allowed me to audit his class for the duration of that Chapter in February of 2023. That was crucial to the success of analyzing my data as I am comparing student's scores on traditional versus performance assessments using matched paired t-tests. He also reviewed my analysis since he has written sections of textbooks.

In addition, Amanda Mattson agreed to be my MSSE Science Reader after completing Thermodynamics, Kinetics, and Equilibrium and Atoms First Primer for AP/IB Chemistry. As we both are Chemistry teachers, her knowledge and perspective of the content is an invaluable resource. Her insight had the ability to shape and strengthen my Capstone project as she offered a different perspective to proposed treatment and tools used to assess it.

.

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

ABSTRACT

As School Administrative Unit #9 shifts to competency-based education the way students are assessed is also evolving. At Kennett High School students' scores on traditional versus performance assessments were compared in a high school chemistry classroom. Students worked at their own pace and acquired knowledge of Chemistry concepts through a variety of modalities: pre-recorded instruction, simulations, POGILs, experimentation, and practice in a student-centered classroom. For Module 2: The Mole and Chemical Reactions and Module 3: Acid and Bases, students were assessed using a traditional multiple choice and free response assessment. For both modules students were also given a real-world application performance assessment where an investigation was conducted to gather data for analysis. For module 2 students had to find the empirical formula of an unknown substance A_xB_y using the masses obtained before and after heating. For module 3, students performed an acid-base titration to obtain data to determine the molarity of acetic acid using 1M sodium hydroxide. Self-confidence surveys were administered throughout the unit and interviews were conducted after both assessments for each module. The self-confidence survey for module 2 revealed their confidence in calculating the empirical formula using the percent and mass of each element increased from before the quiz to before the assessment. The self-confidence survey for module 3 revealed their confidence increased in the following areas from before the quiz to before the assessment: writing a complete chemical equation for an acid/base reaction, writing a net ionic equation for a weak acid and strong base, and using a chemical equation to solve acid/base titration problems to solve for the molarity of the other substance when given the molarity and volume of one and the volume of the other. However, for performing an acid/base titration the results were the same for all but one student whose confidence decreases from before the quiz to before the assessment. A matched pair t-test was performed to analyze traditional versus performance assessments scores. For Module 2 the results were not significant, however in Module 3 students scored significantly better on the traditional assessment.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

This study was conducted at Kennett High School, located in the School Administration Unit #9 (SAU #9). In 2017 the decision was made to transition to Competency Based Education (CBE). CBE is very similar to Standards Based Education (SBE) as SBE is defined as the following: "Grades should communicate students' current levels of learning based on standards, homework should serve as ungraded practice, and students should have multiple opportunities to demonstrate their learning (Townsley, 2020, p 8). However, CBE goes more in depth to include students having an active role in their learning, differentiated instruction, working at your own pace, measurable common goals, equal opportunities for all learners (Hess, 2020), and anytime, anyplace learning.

The decision to move to CBE led to me transition to a student-centered classroom and the motivating factor was the lack of student engagement in the traditional teacher-centered classroom. While I was lecturing at the front of the classroom, I witnessed students on their phones, doodling, zoning out, etc. When I would ask if they had any questions, they were afraid to because they thought they would be perceived as stupid even though I told them, if they have a question, it is likely that someone else does as well. This model does not promote students mastering concepts, so I began to embrace the educational shifts that my district wanted to initiate. In a student-centered classroom, students need to take an active role in their learning by being motivated and able to manage what they are doing, achieving proficiency in the material, and become lifelong learners. These skills will be necessary for higher education and in the workplace. This model has taught my students who they are as a learner, to embrace mastering a concept before moving on, and time management; Students have encouraged me to present this model to the faculty at my high school, so more teachers transition to this style of teaching.

To become a student-centered classroom the creation of an organized Google Classroom was vital as lectures, activities, and practice are sequentially ordered and allowed students to their own pace. As students completed each section of the module, they were able to check their answers and then move on to the next assignment. Throughout the unit, students' understanding of the content is assessed using exit slips and formative assessment quizzes. Because of the shift in paradigm to a CBE curriculum based on investigative problem solving, the way students are assessed needs to change as well. Instead of the traditional multiple choice and short answer summative assessment, students' knowledge is demonstrated through performance assessments such as experiments, modeling, projects, and other means. The purpose of this study is to examine if there is a correlation between a student-centered classroom and achievement levels on traditional versus performance summative assessments. Through the statistical analysis of both types of assessments, it will be determined whether there is a difference on how students perform on traditional versus performance assessments.

Focus Questions

Action Research Question (ARQ): How does having a student-centered classroom affect student achievement on traditional or performance summative assessments?

- **Sub Question #1 (SQ1):** How will immediate feedback impact student's confidence in the material?

- **Sub Question #2 (SQ2):** What effect will it have on a student's risk taking and problem-solving capabilities?
- **Sub Question #3 (SQ3):** How will the aspects of my student-centered classroom evolve based on the feedback that students provide?
- **Sub Question #4 (SQ4):** How do performance assessments in a student-centered classroom impact my teaching practice?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Student engagement in the traditional teacher-centered classroom has been on the decline for many years. “Mainstream public education is frequently characterized as emphasizing efficiency, monolithic teaching practices, a narrow curricula devoid of meaning to the real lives of students, and other correlates of widespread student disengagement” (Shernoff, 2014, p. 166). While educators are lecturing at the front of the classroom, they witness their students on their phones, doodling, zoning out, etc. This model does not promote mastery of learning concepts as they are afraid to ask questions because they believe they would be perceived as stupid even though if they have a question, it is likely that someone else does as well. This has driven many educational reforms that transition the focus from teacher-centered to student-centered classroom.

The first step in transitioning the classroom to become more student centered is Understanding by Design (UBD). The process is considered backwards design because the first step is to determine the end results (Wiggins, 2005). Since New Hampshire adopted the Next Generation Science Standards (NGSS) in November of 2016, the Kennett High School Science Department used them as a basis to create performance expectations for each course (New Hampshire Department of Education, 2016). The performance expectations for Chemistry students are expected to learn about the structure and properties of matter including the subatomic particles that make up an atom, the properties of atoms that contribute to how the periodic table is organized, and how atoms interact with one another. The first expectation is the basis for the next one, chemical reactions as those previous concepts allow students to predict the outcome of atoms interacting and mass is conserved while this occurs (High School Physical Science, 2017). Assessments are then created based on them to evaluate the students' level of understanding of the concepts.

The UBD's end goals drove the creation of the scaffolded learning materials such as lectures, activities, and practice to support them. For my Advanced Chemistry course, these were available in Google Classroom and created the basis of a student-centered classroom to allow anytime, anyplace learning. The previous components, UBD, student-centered classroom, and any time, any place learning, are ideas that segue into my district's initiative to move to competency-based education (CBE). "Competency-based education is a system designed for equitable student achievement to ensure all learners master academic knowledge, develop the expertise to apply it to real-world problems and build the skills to be lifelong learners for future success" (Sturgis, 2018, p 15). In this style of education, students need to take an active role in their learning by being motivated and able to manage what they are doing, achieving mastery of the material, and become lifelong learners. This can be done with changes in pedagogy that includes basing the starting point of the curriculum on a student's academic, social, and emotional needs, using DI where student receive feedback to identify their strengths and weaknesses, and having them apply knowledge versus just general recall. Pedagogy also needs to have a supporting structure that has consistent and clearly defined expectations with constant communication, so students know where they are at in their learning and what they have been successful at. Until mastery is achieved, the student cannot move on to the next concept (Sturgis, 2018).

Since what students need to be successful beyond secondary education has changed, the move to CBE also incorporates 21st century skills. "Students need to be able to find, evaluate, synthesize, and use knowledge in new contexts, frame and solve nonroutine problems, and produce research findings and solutions. It also requires students to acquire well-developed thinking, problem-solving, design, and communication skills" (Darling-Hammond, 2014, pp. 1-2). Instead of just knowing the content, educators need to show them the process of learning so that they can apply it to other situations that arise. This is because new information is being produced at an astonishing rate of double the amount each year (Darling-Hammond, 2014). Therefore, how students can synthesize and apply the information has moved to the forefront of skills necessary to be successful in the workplace.

Because of the shift in paradigm to a CBE curriculum using 21st century skills are based on investigative problem solving, the way students are assessed is changing as well. Assessment reform in the United States has come about for three main reasons: a better understanding of how students learn, changes in curriculum, and assessing more than basic recall. This can be achieved by transitioning from a traditional teacher driven classroom model to a more student centered one. Students are encouraged to work in groups and problem solve using hands-on activities through project-based learning (Shavelson, 1991). This method of learning lends itself to these types of assessments as they have them apply their knowledge to real world situations and allow them to demonstrate higher order thinking skills in writing and verbally. Their knowledge can be shown through experiments, modeling, projects, and other means (Wiggins, 2005).

The changes above require alternative assessments and there are five major guidelines for creating them. "They need to capture students' scientific understanding, reasoning, and problem solving, as well as permit novel, creative responses" (Shavelson, 1991, p 348). Students need to be able to work with the materials so they can explore cause and effect when changing variables. Since time and money are big factors in creating these assessments, technology should be utilized as a means of administering them as well. They need to be able to assess both what a student knows and what misconceptions they may have. Shavelson (1991) suggests that for this to occur the curriculum needs to change to support these types of assessments (Shavelson, 1991) which was done when I incorporated UBDs and DI into my classroom.

CHAPTER THREE

METHODOLOGY

Demographics

My Advanced Chemistry students, an overall motivated group of individuals, participated voluntarily in this study which began the fall of 2022 and concluded in January of 2024. There were 88 participants with varying class sizes which ranged from 13-22 students. The socio-economic status of the student population varies based on the percentage of free and reduced lunch students. Prior to COVID the state average was 19.76-22.37% for 2017-2020 while the students who attend KHS ranged from 24.12-28.1, 4-6% higher for the three school year values were compared (SAU #9 Report Cards 2019). A COVID free lunch waiver was in place from March 2020-June 2022 so there is no data for that time frame. There is only a 3% difference for the 22-23 school year with the state being 24% while KHS is 27% (SAU #9 Fall Report Card 2023).

Treatment

The treatment was a performance assessment where they conducted an experiment and applied their knowledge to solve the problem that they were presented with. All students were administered the treatment to make the study more statistically sound and their scores on those were compared to their scores on traditional paper assessments.

Traditional multiple choice, short answer, and free response essays are the how students are assessed in Module 1: Measurement, Structure, and Function. These types of assessments do not truly indicate what a student knows as there are test taking strategies for multiple choice questions, the wording of a question may be at fault, or students might have given up writing as their hand has begun to cramp. Since this is the method that students are most familiar with, this was the comparison for my action research project. Students were first presented Module 1: Measurement, Structure, and Function which was not included as it was foundational content and therefore did not lend itself to being assessed through a performance assessment. In addition, it allowed students time to acclimate to my student-centered classroom. During that module, parental consent forms (Appendix A) were sent home the beginning of October to my 22 Advanced Chemistry students that were in my class for the 2022 fall semester. In March 2023, they were sent home to the 18 Advanced Chemistry students that I had for the 2023 spring semester. The last group of forms was sent home in September 2023 to 14 Advanced Chemistry students, however only 13 students completed the course as one student chose to finish the school year using a virtual academy.

Activities that support the desired outcomes were created, and this is where differentiated instruction comes into play (Wiggins, 2005). Differentiated instruction (DI) takes into consideration the individual learner rather than lumping students into a one size fits all model. This model considers that everyone in the class has different prior knowledge, ways of learning, work ethic, interests, etc. and incorporates that into how they design their lessons (Ghazi, 2022,). Research also shows that “students strive and thrive when teachers challenge the pedagogy of indifference and create classrooms where instructional practices assist students to think hard (high cognitive), get actively involved (high operative) and connect emotionally (high affective) with content and classroom practices” (de Silva Joyce, 2018, p 49). Therefore, within a module, my students are exposed to a variety of lessons and activities that include but are not limited to pre-recorded instruction, inquiry-based activities, and guided practice. Students work at the lab stations with a partner of their choice with the caveat that this could change if they are ineffective. Working in groups has a higher level of engagement than teacher led instruction and students can effectively work on problems together as they possess the skills necessary for this type of interaction (MacQuarrie, 2012). Within my classroom students may be working on different topics and units at the same time. According to Miller, students gain a deeper understanding of content from a student-centered classroom versus a traditional one. Some of the major advantages of this type of classroom are that the teacher has a greater amount of interaction with students while they collaborate with each other to explore the topics presented to them, it incorporates their interests, and can be individualized based on where a student is at in their learning (Miller, 2020).

Initially I assessed their knowledge of empirical formula for Module 2: The Mole and Chemical Reactions by administering a word problem of similar difficulty as my treatment. Then students performed, The Empirical Formula of an Unknown (Appendix B). They heated a compound that contained elements A and B and during this process, B was released as a gas leaving just A remaining in the crucible. Using the data collected and a reference chart for their specific unknown, students calculated the empirical formula for the compound that they were given. Depending on how diligent students were performing the experiment portion, this was completed in an 80-minute block but no longer than a block plus an additional 30 minutes of the following class.

In Module 3: Acids and Bases, students solved a word problem where they wrote a complete equation for an acid-base neutralization reaction and used that information to determine the molarity of the acid or base. Students then performed an acid-base titration, the Percentage of Acetic Acid in Vinegar (Appendix C) to determine the quantity of vinegar aka acetic acid and sodium hydroxide required to reach the end point of the titration. They completed three trials so they could refine their technique and had multiple data points to analyze. Using the information obtained, they wrote a complete equation for the reaction, determined the molarity of vinegar, and deemed whether it was safe for human consumption. The titration to collect data was completed in an 80-minute block followed by 30-60 minutes of the next class for the assessment portion to process and analyze their data.

Modules Within my Student-Centered Classroom

Module 2: The Mole and Chemical Reactions took 26-30 class periods depending on class size and individual student's pacing and included the following concepts: grams, moles, and atoms conversions, percent composition, empirical and molecular formulas, balancing equations, types of reactions, and stoichiometry. The content was introduced using POGILs (Process Oriented Guided Inquiry Learning) for Relative Mass and the Mole and Types of Chemical Reactions. For the other concepts, I have created prerecorded lectures that include the vocabulary, step by step procedures to solve the variety of problems they will encounter, followed by modeling how to identify the key pieces of information in the questions and how to use it to solve the problems. While all of this is occurring, students can pause and ask me questions as they arise. Students then complete traditional practice problem worksheets such as Empirical and Molecular Formula Practice (Appendix D) while receiving constant feedback to foster them growing their self-confidence. Depending on the topic covered, an experiment may introduce or support a topic. For example, the Buy Gum experiment (Appendix E) is done right after the percent composition video notes as a quick, engaging activity to help them work on hypothesis writing, data collection and analysis, while seeing a real application of this topic. On the other hand, The Stoichiometry of Aluminum and Copper (II) Chloride (Appendix F) is performed after grasping the content because they calculate how much copper (II) chloride is needed for a complete reaction given preset amount of aluminum. Throughout the unit, there are formative assessments like Module 2 Quiz 2 (Appendix G) to gauge student's understanding of the content using entrance and exit slips as well as traditional paper and pencil quizzes. At the end of the unit, their knowledge is assessed using both traditional multiple choice and free response test along with a performance assessment.

Module 3: Acids and Bases ran about 17-19 class periods depending on class size and the individual student's pacing and included the following concepts: molarity, strong versus weak acids and bases, the properties of them, writing net ionic equations, conjugative acid/base pairs, and titrations. The content was introduced using POGILs (Process Oriented Guided Inquiry Learning) for Molarity, Acids and Bases, and Strong vs Weak Acids. Prerecorded lectures and Acid Base Neutralization Titration practice problems (Appendix H) were again utilized teaching content. Students performed The Properties of Acids and Bases experiment to examine their conductivity, effect on indicators, the pH scale, reactivity with metals, and ability to neutralize one another. This module also included two simulations: Collisions, an interactive game (Appendix I) and a Titration Screen Experiment. Collisions to help students visualize how acids and bases behave and connect their strength to their dissociation rate. The Titration Screen Experiment: The Contaminated Stream exposes students to a real-life application of titration and to introduce how an acid base titration is performed. Again, formative assessments were administered throughout the unit and both a traditional and performance assessment were given at the end of it.

Instrumentation

The Self-Confidence Survey (SCS) (Appendices J and K) occurred at the beginning of the module, after pre-determined check points, and at the end of the unit. At the beginning of the unit, it established a baseline, with many of students selecting the confidence level of none as they have not been exposed to this material before. The SCS was given again to gauge what their confidence level was before each formative assessment. Finally, students completed the SCS a final time for that module right before the traditional and performance assessments. Each individual's growth throughout the unit was analyzed as well as examining the class as a whole to determine trends and outliers.

Problem solving (SQ3) was determined using formative and summative assessments. Formative assessment quizzes were given twice per unit and since they are more formal, they gave better insight to where they are at in their learning and provided quantitative data (ARQ, SQ1, and SQ2). The final piece was the summative assessments where I compared their performance on traditional vs summative which also supported the main action research question.

The interviews at the end of a unit were small groups with a cross section of students that participated in these as they require a great deal of time. To get a varied population of students, interviews were conducted with students who have completed the unit at varying points: first, middle, and last. Twenty students or 24% of the population in groups of two to three were interviewed based on lab groups, willingness to participate, and where they were at within the module. This offered students' perception of their pacing for the unit, what modalities worked for them, and their level of proficiency in the content. They were recorded and notes were taken during the initial interviews so I could examine if there were common themes that emerged on the varying aspects of the modules. The questions (Appendix L) helped me to determine what components of the student-centered classroom best prepared them for the assessments, the focus of my main action research question.

The instrumentation was reviewed by my peers and my professor, Walter Woolbaugh, during MSSE 505 Foundations of Action Research in Science Education, and also triangulation using several instruments, and this helped to establish validity. In addition, my fellow science department colleagues, Kate Sargent and Scott Lajoie, who have taught Chemistry examined the breakdown of topics within each module and verified that concepts presented were not too narrow and were key components of the curriculum. Once that occurred, the IRB application was completed and approved as Protocol #: 2022-331-EXEMPT with an expiration date of 10/14/2027 (Appendix M).

Research Matrix

Action Research Question (ARQ): How will the varying components that make up a student-centered classroom affect student achievement on traditional or performance summative assessments?

- **Sub Question #1 (SQ1):** How will immediate feedback impact student's confidence in the material?
- **Sub Question #2 (SQ2):** What effect will it have on a student's risk taking and problem-solving capabilities?
- **Sub Question #3 (SQ3):** How will my student-centered classroom evolve based on the feedback that students provide?
- **Sub Question #4 (SQ4):** How do performance assessments in a student-centered classroom impact my teaching practice?

Table 1: Data Collection Methods to Answer Research Questions

	Self-Confidence Survey- Qualitative	Observations- Qualitative	Interviews- Qualitative	Summative Assessments- Quantitative
ARQ	X	X	X	X
SQ1		X	X	X
SQ2	X	X	X	
SQ3	X	X	X	X
SQ4		X		X

CHAPTER FOUR

DATA ANALYSIS

Results

How will immediate feedback impact student's confidence in the material and what effect will it have on a student's risk taking and problem-solving capabilities was evaluated using the self-confidence survey and student interviews? Unfortunately, even with constant reminders to take the survey, many students failed to complete it both before the Module 2 Quiz 2 and Module 2 Assessment (Figure 1). For calculating the empirical formula using the percent of each element before the quiz, the following were the confidence levels for seven students: three low, two medium, and two high. This number greatly shifted before the assessment to one medium and six high. For calculating the empirical formula using the mass of each element before the quiz, there were four low, one medium, and two high. For both types of calculations students' confidence vastly improved to one medium and six high before the assessment. When comparing individual scores using percents, three students' confidence rose two levels from low to high and one student's rose one level from medium to high. The remaining three maintained the same level, one at medium, and the other two high. When comparing individual scores calculating empirical formula using masses, three students' confidence rose two levels from low to high and one student's from low to medium. The remaining two maintained the same high level. When students were interviewed they admitted during a general review that they have a hard time paying attention, teachers only review the most commonly wrong questions, and they are embarrassed to ask questions in front of their peers. "If you go over it as a class, you can't focus on the things you specifically don't understand. Hence, the increase in confidence is attributed to the individual conferences students had with me after their quizzes. Students loved the personalize review sessions because I "made them redo the problems so they understand what they did wrong" and they were "more comfortable being able to bring up their own questions because you are not doing it in front of the class which is embarrassing."

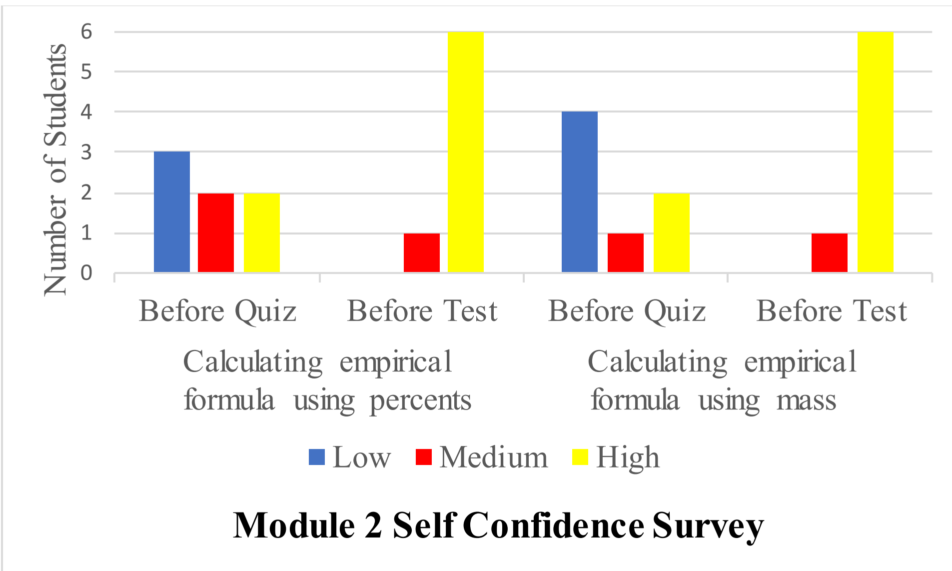


Figure 1. Module 2 self-confidence survey before quiz and test, (*N*=7).

Fewer students completed both the Module 3 Quiz and Module 3 Assessment survey (Figure 2). For creating a complete chemical equation for acid base reactions before the quiz, the following were the confidence levels for four students: two low, one medium, and one high. This number shifted before the assessment to three medium and one high. For creating a net ionic equation between a weak acid and a strong base before the quiz, there were three medium, and one high. Again, this number shifted before the assessment to one medium and three high. For using a chemical equation to solve acid/base titration problems to solve for the molarity of the other substance when given the molarity and volume of one and the volume of the other, students went from one of each confidence level, none, low, medium, and high to three mediums and one high. Lastly, the ability to perform an acid/base titration went from one none and three mediums to one none, one low, and two mediums. When comparing individual scores for complete equations, two rose from low to high and two maintained their level of medium or high. Net ionic equation individual's scores two rose from medium to high while the other two remained unchanged at medium and high. Using three given variables for titration problems, scores went from none to high, low to medium, one maintained medium, and the last one went from high to medium. For the final aspect of performing an acid base titration, three maintained their level, one none and two medium while the final one dropped from medium to low (Figure 2). Unfortunately this assessment occurred at the end of the semester and I was unable to interview students because two of the classes began second semester and the other four concluded their school year.

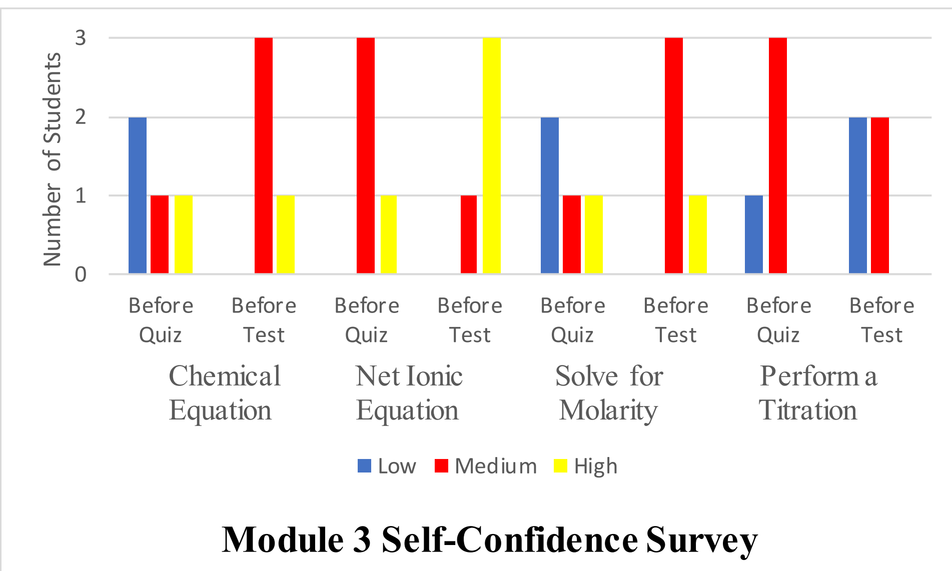


Figure 2. Module 3 self-confidence survey before quiz and test, (*N*=4).

When comparing the self-confidence survey results from module 2 and 3 the difference in continuity of the curriculum is a major factor that contributed to students' confidence levels. During Module 2 there were shorter more frequent breaks such as Veteran's Day and a 5-day Thanksgiving break for fall semester or teacher workshop days and weather-related time off for spring semester. Students were able to quickly refresh their memory from where they left off and able to retain the content more so during Module 2 versus Module 3. That was not the case for Module 3 which was broken up for either December or April vacation week depending on the semester in which students had 9 days off. This lapse in time made it harder for students to pick up where they left off. Therefore, that is attributed to students maintaining their confidence levels on specific topics within Module 3 versus making progress.

After analyzing students' self-confidence surveys, major patterns were identified from the interviews that were conducted. The first question was what advantages or benefits does a student-centered classroom offer? A major advantage was being able to work at your own pace with the ability to spend more time on a concept, if necessary, as it "helps us focus on the specific things we are struggling with." Students are also able to get more one on one time with the teacher so they can get immediate feedback. This also helps students speak up when they are struggling with a concept unlike a traditional lecture setting as some would say "I don't like asking questions in front of the class, I find that very embarrassing." There is a sense of feeling less stressed and pressured because "when there is a day that you really want to grind you can do like ten assignments and then if you are not feeling so good, you can hang back." Students can utilize class time more efficiently as well because "if we finish work early, we can continue to be productive, instead of having a bunch of dead time or not doing anything." All these components allow students to become more self-reliant and self-regulated as there is a "level of independence, the teacher is not holding your hand through the whole thing" and "you learn how to figure out your own work ethic." Students having ownership of their learning in a student-centered classroom helps boost their confidence and in turn increases their risk taking and problem-solving capabilities.

To gain more insight into the benefits of a student-centered model, students were asked how does this differ from your other classes? The twenty students who were interviewed unanimously agreed that I "work with them more than most teachers." Students also work in groups and are able to help one another and if they can't figure it out collectively, they have the ability "to ask questions whenever they need help." The last and most important theme that emerged was related to self-confidence and problem solving was the strict due dates that other classes have. Students are "forced to take a quiz even if you are not ready for it and it completely destroys your confidence." Allowing students to work together and to take assessments when they are ready plays a significant role in their risk taking and problem-solving capabilities and their confidence levels with the content.

How will the varying components that make up a student-centered classroom affect student achievement on traditional or performance summative assessments were statistically analyzed. Histograms of Module 2's scores on the traditional and performance-based assessments are shown in Figure 3 on the left side and right side respectively. As the figure shows, both distributions are severely skewed to the left. On average, students performed better on the traditional assessment (median = 92.5) than the performance assessment (median = 87.5). There is slightly more variability in the traditional scores with a range of 65 and an interquartile range of 16 compared with the performance scores with a range of 55 and interquartile range of 15. There were four negative outliers in the distribution of traditional scores and two negative outliers in the distribution of performance scores. The main factor that contributed to the variability in the assessment results is due to how the questions were presented for finding the empirical formula. For the traditional assessment students were presented with questions that were similar in wording to those they practiced all unit. In those types of problems students were given the masses or percents of an element and used those to convert to moles to find the empirical formula. In contrast, the performance assessment had students calculating the masses for substances A and B using data they collected during a lab experiment. Those masses were used along with a chart that contained the “Periodic Table Masses” for specific numbered unknowns to convert to moles to find the empirical formula of an unknown substance with formula A_xB_y. Additionally, there were students who did not use the appropriate numbers of significant figures when reporting their answers for the number of moles which caused some calculation errors on the performance assessment. The degree of difficulty for the performance assessment was higher than the traditional assessment which contributed to students doing better on the traditional assessment. Students questioned whether traditional assessments truly measure what they know because “I get good grades as there is too much logic and test taking skill that have ore to do with the fact that they are a multiple-choice test than the actual content and that kind of wrecks them.”

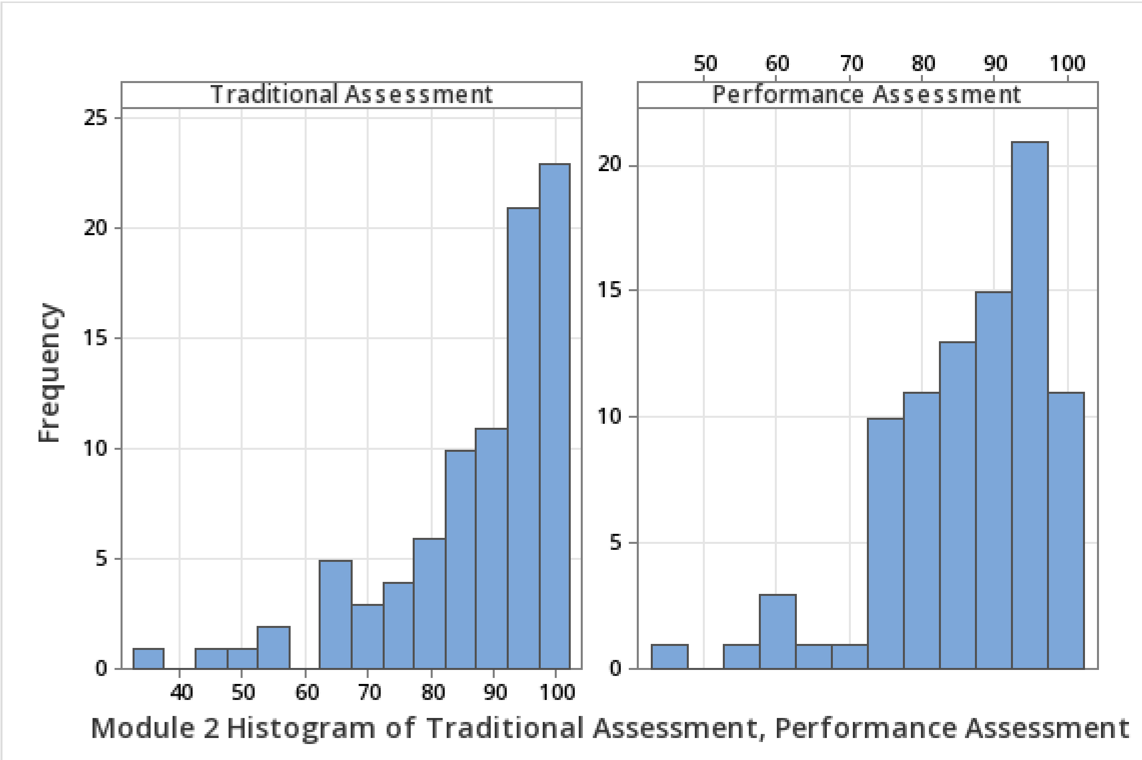


Figure 3. Module 2 traditional versus performance assessment scores, (*N*=88).

The mean difference was calculated by taking the traditional assessment scores and subtracting the performance assessments scores and a box plot was created (Figure 4). The box plot is approximately symmetrical even though the original distributions are skewed. This suggests that students with low scores on the traditional tended to be the same students with the low scores on the performance assessment.

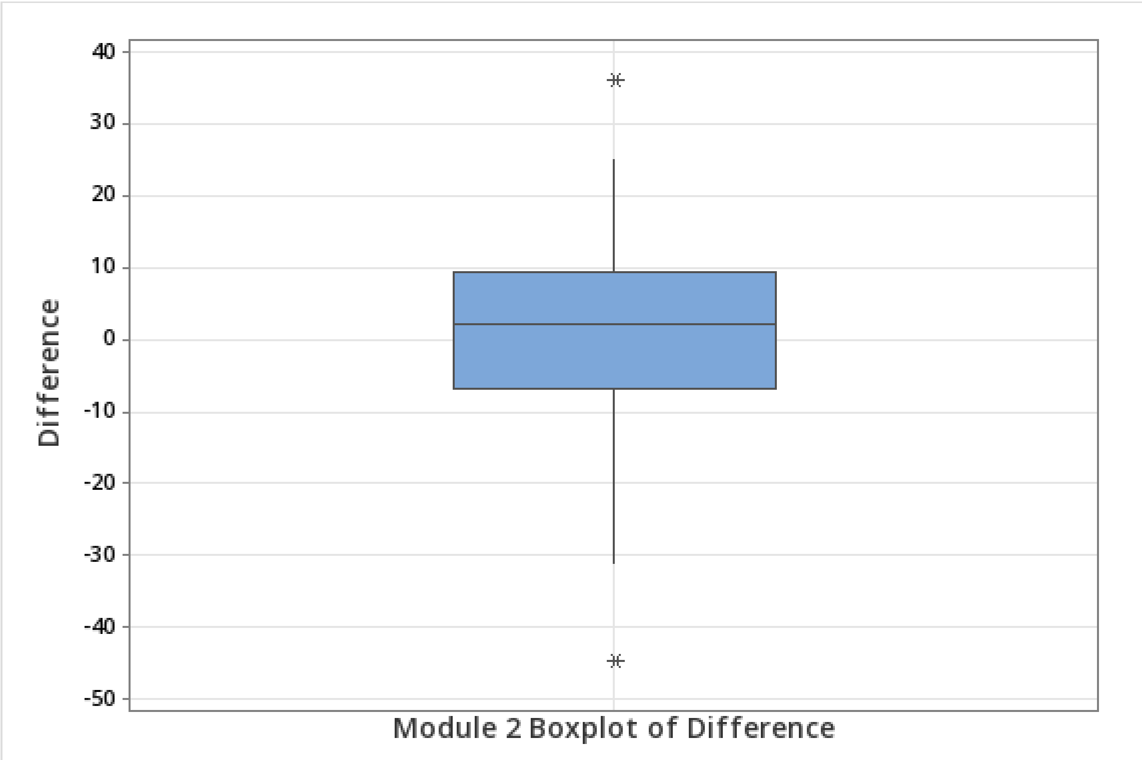


Figure 4. Module 2 boxplot of the mean differences between traditional and performance assessment, (*N*=88).

The null hypothesis was that there was no difference between the assessment scores H_o: $u_d = 0$ (traditional – performance), and the alternative hypothesis that the traditional assessment scores would be greater than the performance assessment scores, $H_a = u_d > 0$. A matched pairs t-test on the mean difference revealed that the p-value (0.1932) is greater than alpha (0.05), and I fail to reject the null hypothesis. There is not convincing evidence that traditional test scores were higher than performance assessment for Module 2. The mean difference between scores on the traditional and performance assessment is not statistically significant at alpha = 0.05.

Histograms of Module 3's scores on the traditional and performance-based assessments are shown on the left side and right side of the figure below. As the figure shows, both distributions are severely skewed to the left. On average, students performed better on the traditional assessment (median = 94) than the performance assessment (median = 90). There is slightly more variability in the traditional scores with a range of 81 versus the performance scores with a range of 77 but both distributions have the same interquartile range of 13. There were six negative outliers in the distribution of traditional scores and two negative outliers in the distribution of performance scores. Again, the variability of assessment scores can be attributed to a difference in how the questions were presented in the assessments. However, unlike Module 2 there was an even greater difference in the degree of difficulty between the traditional versus performance assessment. The traditional assessment contained questions that were similar in wording to those they practiced all unit. Students were given enough information to be able to solve for one variable of an acid base titration whether it be volume, molarity, or mass in grams. For the performance assessment students had to calculate the volume of acid and base used for each of the three trials and then use that information along with the molarity of sodium hydroxide to find the molarity of acetic acid in vinegar. The degree of difficulty for the performance assessment was higher than the traditional assessment which contributed to students performing better on the traditional assessment.

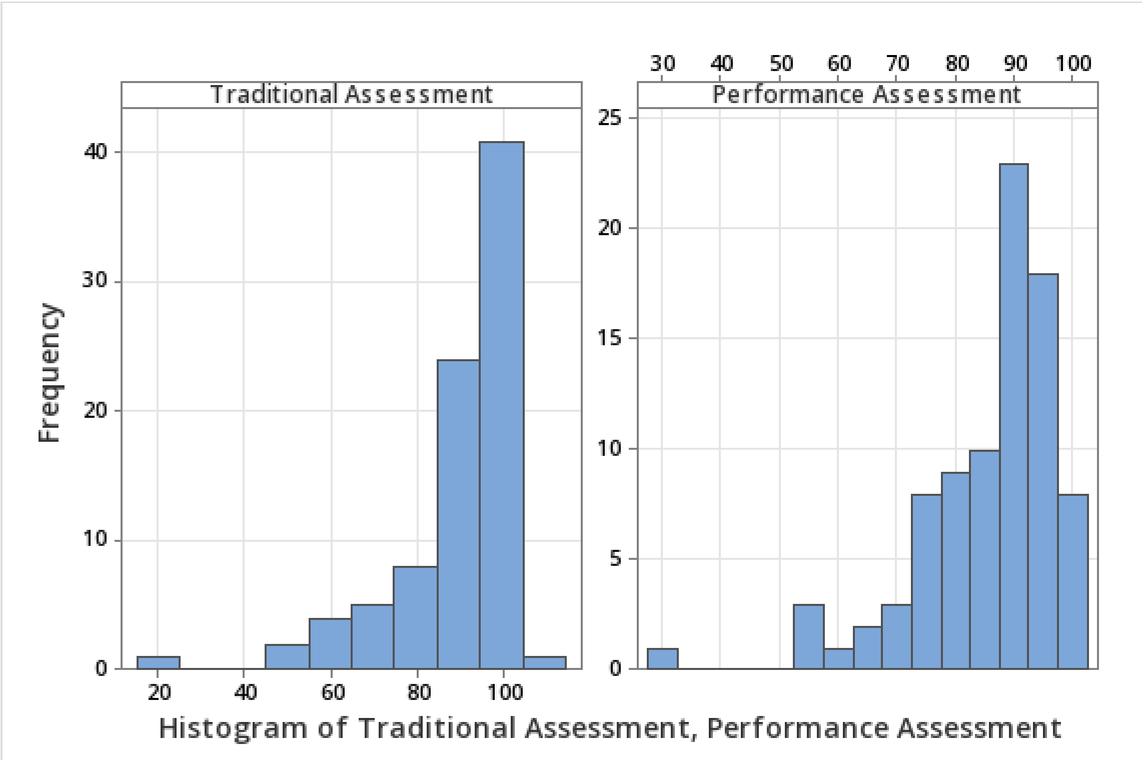


Figure 5. Module 3 traditional versus performance assessment scores, (*N*=86).

Again, the mean difference was calculated by taking the traditional assessment scores and subtracting the performance assessments scores and a box plot was created (Figure 6). The box plot is approximately symmetrical even though the original distributions are skewed. This suggests that students with low scores on the traditional tended to be the same students with the low scores on the performance assessment. However, the results of the matched paired t-test contradict that students performed similarly on both assessments meaning that students with low scores on the traditional were not to be the same students with the low scores on the performance assessment.

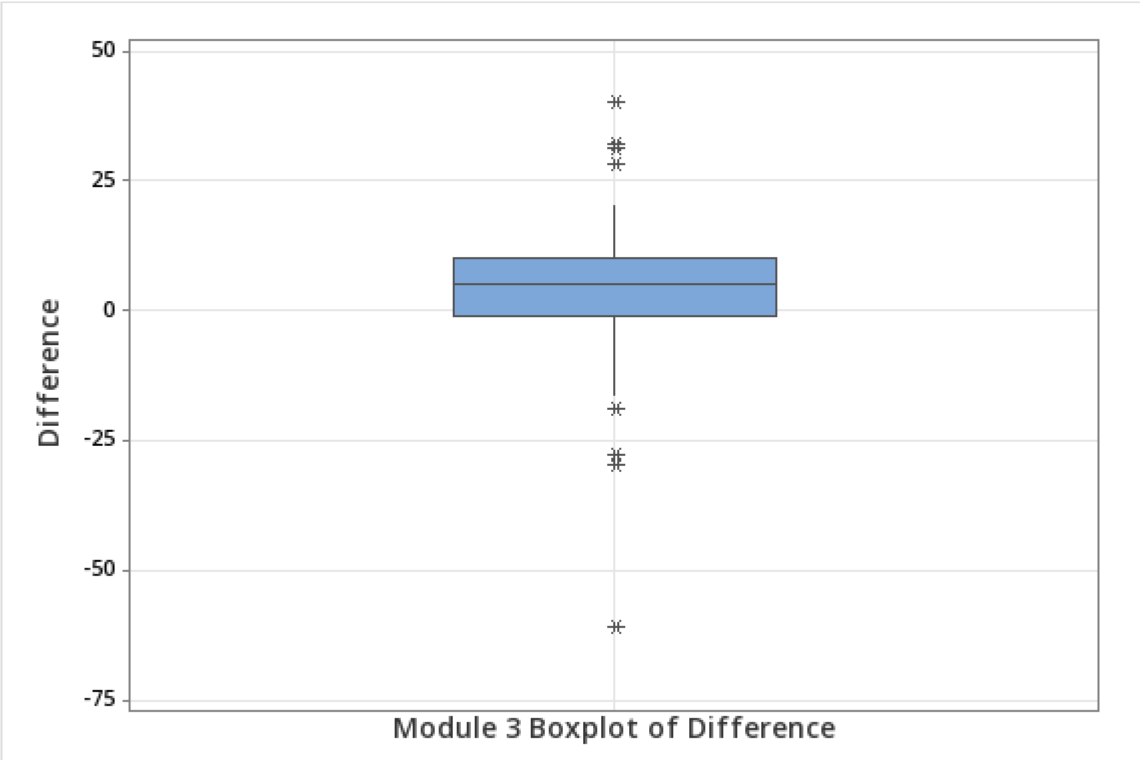


Figure 6. Module 2 boxplot of the mean differences between traditional and performance assessment, (*N*=86).

The null hypothesis was that there was no difference between the assessment scores, H_o: u_d= 0 and the alternative hypothesis that the traditional assessment scores would be greater than the performance assessment scores. H_a : $u_d > 0$. A t-test was performed on the mean difference and because the p-value (0.010) is less than alpha (0.5), I would reject the null hypothesis. There is convincing evidence that traditional test scores were higher than performance assessment. The traditional assessment contained questions in a similar format to the practice problems. However, the performance assessment's questions had students analyzing their data from the titration which made the degree of difficulty for the assessment higher than the traditional one.

How will my student-centered classroom evolve based on the feedback that students provide was determined by asking students which teaching strategies students found to be effective or ineffective after quarter 1 (Figure 7). Seventy-five percent of students expressed that simulations were ineffective as they were not as structured as other activities, were not engaging, not easy to navigate, and because we did not do a lot of them. Students said, "they could be confusing" and "sometimes could be really helpful, but other times would be such a pain to try to figure out." Fifty percent of students thought labs were effective because they are hands on and visual learners. Sixty-two and half percent of students stated that POGILs and videos were effective because the POGILs introduced the concepts and that helped make the notes easier to take because they had been introduced to the vocabulary already. The videos themselves made note taking easier because students could pause to write information down and ask me questions when they were confused. The notes also helped when students need to study and review for their assessments. Sixty-eight and three-quarter percent of students valued the effectiveness of the repetition of practice problems to help drive home the knowledge of the content. "These (videos and practice) were effective because of repetition and the help that it provided. Also just gave the reassurance I need(ed)." Last, the most effective teaching strategy with 81.25% was conferencing since students could ask their individual questions in a one-on-one setting versus in front of the whole class. For many the last three strategies, videos, practice problems, and conferencing were the perfect trifecta of learning the material. "The videos taught me how to do the stuff, practice problems were how I learned how to do the stuff, and conferencing helped me understand anything I was unsure about."

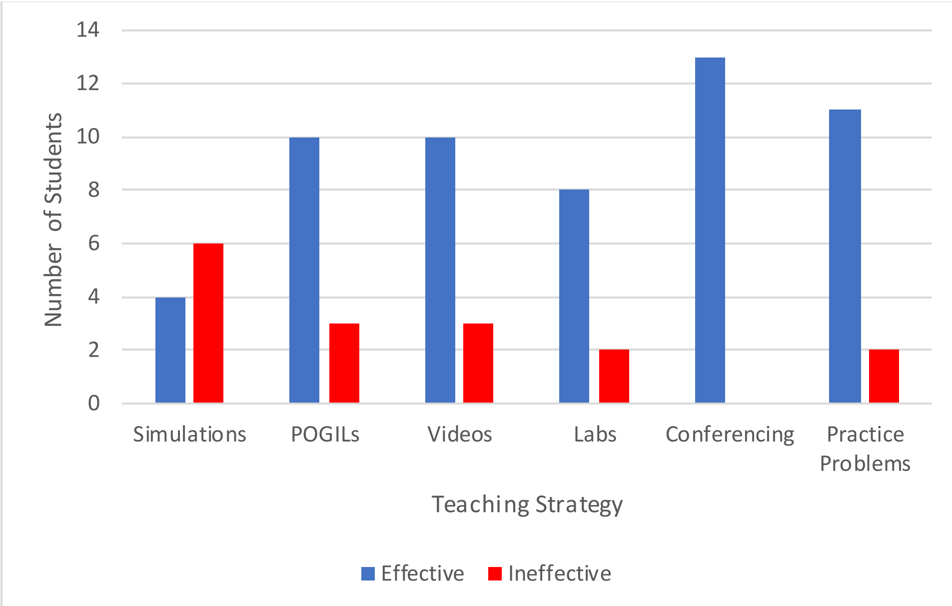


Figure 7. Quarter 1 effectiveness of teaching strategies, (*N*=16).

How will my student-centered classroom evolve based on the feedback that students provide was assessed again after by asking students which teaching strategies students found to be effective or ineffective after quarter 2 (Figure 8). The value for simulations did not change over time and remained at 75% ineffective. Labs dropped from 50% to 25% of students thinking labs were effective. Students divulged that “they were never really a physical learner, and never sure what to make out of the results of the lab” and “for some reason in my brain I cannot connect labs and practice problems.” POGILs dropped as well from 62.5% to 20% of students believing they were effective but hard because students were just thrown into a topic, they had to work through something that they did not understand and seemed tedious. “It’s not that I didn’t learn from POGILS they were just the hardest because it was semi-new material. I think it was a great way to introduce topics, but I didn’t really do most of my learning with them.” Videos has a slight increase from 62.5% to 65% and could be caused by the increase of participants from 16 to

20. Practice problems fell from 68.75% to 60% and a possible cause may be because two students failed the course by the end of the semester. Last, the most effective teaching strategy of conferencing dropped from 81.25% to 70% as it became more difficult to meet with every student when they went into panic mode at the end of the semester when their grade was not what they were hoping for.

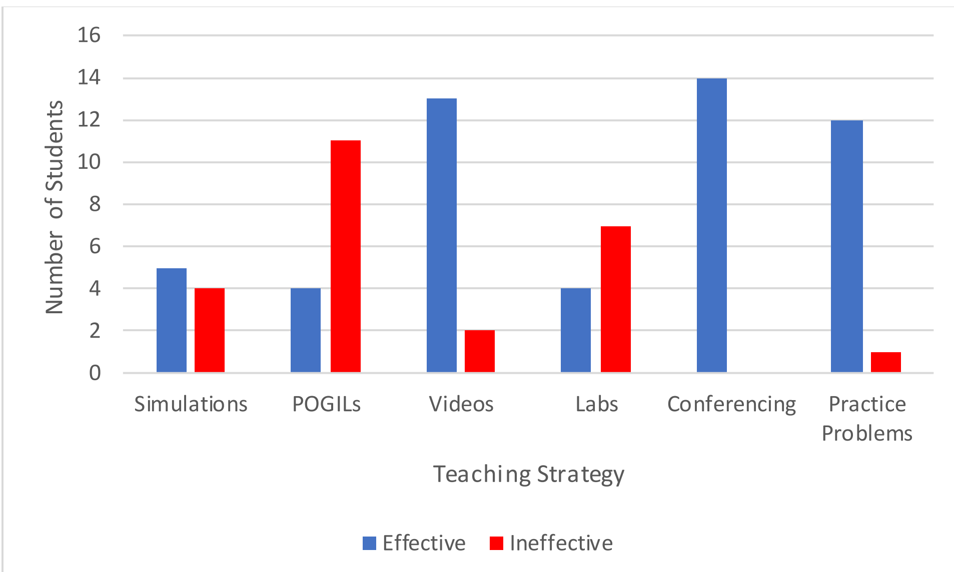


Figure 8. Quarter 2 effectiveness of teaching strategies, (*N*=20).

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

How will immediate feedback impact a student's confidence in the material (SQ1) was evaluated and students' self-confidence grew throughout the units of study because of my ability to circulate throughout the classroom and conference with students individually in my student-centered classroom (Figures 1 and 2). This allowed me to overhear students' conversations and inject and offer help when they were struggling or had a misconception. If a student has a question while I am working with another, I create my famous cue to answer their questions in the order they have been asked. While students are waiting, they confer with each other at their lab stations. More often than not their question is answered before I get to them and their ability to solve the problems on their own also contributed to their confidence in the material increasing. This allows me to work with more students as I just have to verify that their reasoning is solid. By creating a safe space for them to work through their struggles, they gain confidence in their own abilities to synthesize information and problem solve on their own (SQ2). In addition, after each quiz students met with me to conference one on one to review their mistakes. Each question is analyzed to determine if there are common threads among their incorrect answer. Students correct their mistakes and have told me this is one of the most beneficial ways they have ever learned how to improve their knowledge of the content. For example, when calculating empirical formula students who do not report the number of moles to the correct number of significant figures may end having to multiply their answers to get a whole number for the quantity of each element instead of obtaining one initially. Another example is not understanding what goes into a net ionic equation for a strong acid or base. In this instance, students put the whole formula in for an acid or base instead of just the H^+ for an acid or OH^- for the base. Lastly, there are pockets of students who also do not understand that a weak acid still donates an H^+ or that a weak base accepts that H^+ and a variety of errors are involving net ionic equations that involve weak acids and bases. By working with my students one on one to understand their misconception and other aspects of this style of classroom, I have created a safe, trusting, and caring environment for me and my students.

The comfort level students have because of my student-centered classroom allows students to give me open and honest feedback based on their perception of the curriculum (SQ3). This feedback allows me to modify the activities based on not only what I observe but what they feel they have gained from it. During the course of this study, students who took the course spring of 2022 expressed that the Collisions: Acid and Base Simulation Levels 8-16 were time consuming and repetitious with minimal knowledge gained so that component was eliminated from the course. POGIls are another activity that have had mixed reviews because breaking down modules and analyzing them is difficult. They are used to introduce new concepts and it makes students uncomfortable when they do not know the answer. However, this activity has not been eliminated as the knowledge students demonstrate on their exit slips and subsequent activities shows that they have merit. Students having a voice in their learning creates unbelievable relationships that prompted them to ask me to offer AP Chemistry!

Being a student-centered classroom led me to want to determine if there was a correlation between a student's grade on a traditional versus performance assessment (ARQ). For module 2, after performing a matched pair t-tests it was determined that there was no statistical difference between traditional and performance assessments as the p value was significantly greater than alpha, $0.1932 > 0.05$. The questions pertaining to empirical formula on both assessments were compared and found to be of similar difficulty. Both assessments are valid tools for evaluating students' knowledge using multiple choice, word problems, and real world application and remained as part of the Advanced Chemistry curriculum.

Again, being a student-centered classroom led me to want to determine if there was a correlation between a student's grade on a traditional versus performance assessment (ARQ). For module 3 there was a statistical difference between traditional and performance assessments as the p value was less than alpha, $0.010 < 0.05$. The questions were compared, and it was determined that the degree of difficulty of the questions were harder on the performance assessment. The traditional assessment contained similar style word problems that students had been practicing throughout the unit. The information was clearly presented and it was used to solve for a given variable such as molarity or the volume of the acid or base. However, the performance assessment had them analyzing data that included calculating the volume of both the acid and base for the three-individual trials, using it coupled with the molarity of the $NaOH$ to determine the molarity of the acetic acid, and then calculating how many grams of acetic acid were present. There is a great amount of synthesizing of data along the way versus the clear cut and dry problems that exist within the unit. Therefore, the limited exposure to data analysis may be the cause of the discrepancy between students' assessment grades.

Value of the Study and Consideration for Future Research

After finding students performed significantly better on the traditional assessment for Module 3, it was determined that there needs to be some reworking of the practice problems. This is how performance assessments in my student-centered classroom impact my teaching process (SQ4). Students were exposed to a cookie cutter style of word problem where the information was provided to solve for a given variable. The performance assessment had them synthesizing and analyzing three trials of data that was an unfamiliar format. This will be implemented for the current semester and the success of this modification will be a side note when I present my Capstone project this July. One of the first changes to the curriculum included determining the volume of the acid and/or base used during an experiment by reading images of burettes before and after the equivalence point was determined. Next, data tables with various trials were incorporated into practice problems to determine the amount of acid and base used in each trial. Finally, the data from each trial was used to determine the molarity of each individual trial so students were able to process data from the performance assessment with greater confidence as they have been exposed to problems with similar set ups.

Exposing students to data analysis in order to better prepare them for the performance assessment raised the question of whether or not this was teaching to the test. Problems that students will encounter in life are many a times one and done. Therefore, should students be exposed to how to break down a variety of problems that are presented to them? This skill in turn will allow them to become better problem solvers when data is presented in different circumstances that are not cut and dry like a memorized style of problem.

When analyzing test scores, this made me reflect on two students that did not pass Advanced Chemistry in the Spring of 2023. Each one had their own set of circumstances that led them to not be successful. One student really struggled with being able to focus in class and completing assignments in a timely manner even though they had the mental capability, they just lacked the work ethic and self-regulation skills required. Now I know some students initially struggle with working at their own pace but many learn the valuable lesson of how to manage the balance between working and socializing with peers. Why was this not evident to this student when they were working with successful peers at their lab station? What additional strategies could have been employed to prevent this from happening?

The other student had work ethic and put in the effort but was definitely misplaced based on their ability levels. This coupled with their lack of self-confidence caused a vicious cycle of self-doubt in knowing the material even after demonstrating they had the knowledge necessary to complete the task at hand. In order to earn credit for Chemistry, this student ended up completing the requirements for College Prep Chemistry instead utilizing a one on one tutor after school. That led me to wonder what strategies can be implemented in the future to increase student's ability to believe in oneself? Do they require additional or increased daily feedback to reinforce that they are understanding the concepts they are learning? If so, what would be the ideal class size that this could occur in? Also, is there a way to teach multiple levels within a classroom to when students are misplaced? These are all questions that I plan on presenting to my professional learning community.

Impact of Action Research on the Author

Developing, running, and modifying a student-centered classroom takes a great deal of time and energy. The results of this study have proven the impact that this model has on the growth and development of my students in their ability to problem solve and increase their confidence level. The self-confidence survey is now incorporated into my curriculum as a way to indicate the areas that students need additional assistance in and others they are confident in to modify the curriculum on an individual basis. Moving forward self-confidence surveys will be created for my College Prep Chemistry class based on the curriculum for that course and any additional courses that I teach in the future.

In addition, the outcomes of comparing the traditional and performance assessments further supports the role that professional learning communities provide when implementing new assessments and assessment styles into the curriculum. When new assessments are created, the analysis of questions for their validity is mandatory as it helps to identify what is at fault. Were the scaffolded activities lacking an aspect of knowledge that led to students being unsuccessful on a question? Was the question itself worded poorly? Did students have a misconception about a concept? All of these can be answered through interviewing students to obtain their perspective of the curriculum and conferencing with them one on one after formative and summative assessments to identify where the problems arose from. The analysis of the Module 3 performance assessment provided evidence that students need practice on breaking down experimental data. Therefore, practice problems are in the process of being created to help students extrapolate and organize their data so they can make sense of it. The practice of analyzing results was very impactful on my perception of test results and their meaning and will continue to be a regular part of my teaching practice. And as a result of this, assessments will continue to be modified based on my findings.

Students' voices within the classroom are a valuable tool! They help you understand who they are as a learner and where they are in their learning. Curriculum modifications will continue to be made based on their feedback of what resources were effective along with my observations of the active learning that occurred. Analyzing assessments as a whole and individually identifies where the sources of errors arouse from and will continue to determine changes that need to be made to accurately assess student's knowledge. Since all of these components combined helped to create an amazing learning environment for both teacher and student where everyone feels heard and appreciated, I will continue to integrate other components like choice and extended learning opportunities to strengthen it even more.

REFERENCES CITED

Darling-Hammond. (2014). *Next Generation Assessment: Moving Beyond the Bubble Test to Support 21st Century Learning.* (1st ed.). John Wiley & Sons, Incorporated.

de Silva Joyce, H., & Feez, S. (2018). *Multimodality Across Classrooms Learning about and Through Different Modalities.* Routledge. https://doi.org/10.4324/9780203701072

Ghazi M Ghaith, & Ghada M Awada. (2022). Scaffolding Understanding of Scholarly Educational Research Through Teacher/Student Conferencing and Differentiated Instruction. *Teaching and Learning Inquiry, 10*, 1-18.

Hess, K. J., Colby, R., & Joseph, D. (2020). *Deeper Competency-Based learning: Making Equitable, Student-Centered, Sustainable Shifts* (1st ed.). Corwin.

High School Physical Science. (2017). https://www.nextgenscience.org/sites/default/files/HSTopic.pdf

MacQuarrie, S., Howe, C., & Boyle, J. (2012). Exploring the characteristics of small groups within science and English secondary classrooms. *Cambridge Journal of Education*, *42*(4), 527–546. https://doi.org/10.1080/0305764X.2012.733345.

Miller, J. (2020). *The Student-centered Classroom: Transforming Your Teaching and Grading Practices*.

The New Hampshire State Board of Education adopts new academic standards for science. Department of Education. (2016, November 9). Retrieved April 3, 2022, from https://www.education.nh.gov/news/new-hampshire-state-board-education-adopts-new-academic-standards-science#:~:text=The%20NH%20Science%20Teachers%20Association,4th%2C%208th%20and%2011th%20grades.

Shavelson, R., Baxter, G., & Pine, J. (1991). Performance Assessment in Science. *Applied Measurement in Education, 4*(4), 347-362.

Shernoff, Tonks, S. M., & Anderson, B. (2014). The Impact of the Learning Environment on Student Engagement in High School Classrooms. *Teachers College Record (1970)*, *116*(13), 166–177. https://doi.org/10.1177/016146811411601315

Sturgis, Chris and Katherine Casey (2018). *Quality Principles for Competency-Based Education.*

Townsley, M., & Wear, N. L. (2020). *Making Grades Matter: Standards-Based Grading in a Secondary PLC at Work*. Solution Tree Press.

Wiggins, G., & McTighe, J. (2005). *Understanding by Design*.

APPENDICES

APPENDIX A

PARENTAL CONSENT FORM

PARENTAL CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH AT MONTANA STATE UNIVERSITY

Title: Educational Shifts in Paradigms: Traditional versus Performance Based Assessments

Sau #9 made the decision to transition to Competency Based Education (CBE) in 2017 and is the basis for me transitioning from a traditional classroom into a student-centered one. Your student's Chemistry experience at KHS involves them working at their own pace to learn the selected Next Generation Science Standards using Google Classroom. There are a variety of activities that incorporate multiple modalities such as Process-Oriented Guided Inquiry Learning (POGILs), pre-recorded instruction, lab experiments, and guided practice to meet the varying learning styles of each individual student. As they progress through the modules, their knowledge is gauged using formative assessments that include but are not limited to entrance and exit slips, quizzes, and student conferencing. This allows constant feedback throughout the learning process so that students can gain mastery of the content. Their knowledge is then measured through traditional and performance-based assessments at the end of the modules.

Your Advanced Chemistry student is being asked to participate in a research study to examine if there is a correlation between a student-centered classroom and achievement on traditional versus performance summative assessments using the action research question and set of sub questions below. Through the statistical analysis of both types of assessments, it will be determined whether there is a difference on how students perform on traditional versus performance assessments.

How will the varying components that make up a student-centered classroom affect student achievement on traditional or performance summative assessments?

- How will immediate feedback impact a student's confidence in the material?
- What effects will this have on student mindset: mastery vs completion?
- What effect will it have on a student's risk taking and problem-solving capabilities?

Participation is voluntary. If you agree to allow your student to participate, they will be asked to complete surveys that help them identify where they are at in their learning and to be interviewed so I can understand their perception is of a student-centered classroom, traditional, and performance-based assessments. Examples of the surveys and interview questions are provided on the back of this consent form. Participation is voluntary and they can choose to not answer any questions they do not want to answer and/or they can stop at any time. Participation or non-participation will not affect the student's grade or class standing and there are no unforeseen risks.

In addition, your student's name will not be used, and their identity will be confidential. When I am analyzing the information, they will be identified as student 1, 2, 3, etc. and this information will be used to improve their educational experience in my classroom.

Please feel free to contact me with any questions or concerns you may have at
e_bertrand@sau9.org
Sincerely,

Erica Bertrand
KHS Chemistry Teacher

"AUTHORIZATION: I have read the above and understand the discomforts, inconveniences and risk of this study. I, ___________________________________ *(name of parent or guardian),* related to the subject as ____ (*relationship*), agree to the participation of ____ (*name of subject*) in this research. I understand that the subject or I may later refuse participation in this research and that the subject, through his/her own action or mine, may withdraw from the research study at any time. I have received a copy of this consent form for my own records.

Parent or Guardian Signature: __________________________________ Date: _________

Student's Signature: ____ Date: _________

Investigator: ____ Date: _________

APPENDIX B

EMPIRICAL FORMULAS OF AN UNKNOWN PERFORMANCE ASSESSMENT

Empirical Formulas of an Unknown Performance Assessment

Each lab group will be given an unknown binary compound to analyze. The general formula of each group's compound will be A_xB_y. Heating any of the compounds will cause them to decompose according to the following equation:

$$A_xB_y \rightarrow x\,A_{(s)} + y\,B_{(g)}$$

- Since ``B'' is released as a gas, strong heating will leave only the ``A'' of the unknown in the crucible.
- Each lab group will be told their unknown number once they have completed collecting the necessary data.
- The gram atomic masses of ``A'' and ``B'' can be determined from the reference sheet that will be provided with the post lab questions.

Safety and Environmental Concerns:

- ____
- ____

  ____
- ____

  ____

CAUTION:

____

____

____

____

Materials:

CEM Crucible   CEM Disk   Unknown Compound   Screen   Ring Stand with O-Ring
Bunsen Burner   Crucible Tongs   Electronic Balance

Procedure:

1. Prepare a data table to include the following information. Make sure to include a title and put units in the headers, NOT on each measurement. This can be done on the back of this paper or on a separate sheet of paper.

   unknown number
   mass of crucible and cover
   mass of crucible, cover and your unknown A_xB_y
   mass of your unknown
   mass of crucible, cover and the ``A" in your unknown 1st time
   mass of crucible, cover and the ``A" in your unknown 2nd time

2. Place a CEM Crucible with the CEM Disk on the screen over a Bunsen burner and heat for about 2 minutes. This burns off any oxidizable impurities.
3. Carefully remove the crucible with crucible tongs and allow them to cool on the lab table.
4. Measure the mass of the crucible and cover to the nearest 0.01 g. Record the mass.
5. Add about 3 grams of the unknown to the CEM crucible, replace the disk, and measure the mass to the nearest 0.01 g. Record the mass.
6. Begin heating slowly. Increase the heat until you have heated the crucible strongly for about 10 minutes. You are driving off all the ``B" in your unknown in this step.
7. Remove the crucible from the screen, let it cool on the lab table, and measure the mass of the crucible and contents (now just the ``A" in your unknown). Record.
8. Reheat with a hot flame for a couple of minutes, cool, and measure the mass again. If the mass is different than the mass measured in step 6, repeat until the mass remains constant.

Empirical Formulas of an Unknown Performance Assessment

Unknown number ________

Calculations-Show all work to receive full credit!!

1. What is the mass of “A” in your unknown?

2. What is the mass of “B” in your unknown?

3. Using the masses for “A” and “B” from questions 1 and 2, your unknown number, and the reference sheet provided determine the empirical formula of your unknown.

Empirical Formula of an Unknown Reference Sheet

The Gram Atomic Masses of ``A" and ``B"

Unknown Number	Gram Atomic Mass of ``A"	Gram Atomic Mass of ``B"
1	107	55.5
2	195	11.2
3	238	61.8
4	104	18.0
5	126	65.4
6	112	4.84
7	141	48.8
8	154	13.3
9	219	12.6
10	73.0	25.2
11	84.0	9.68
12	119	82.4
13	224	19.4
14	255	29.4

APPENDIX C

PERCENTAGE OF ACETIC ACID IN VINEGAR PERFORMANCE ASSESSMENT

Percentage of Acetic Acid in Vinegar Performance Assessment

Background:

When sweet apple cider is fermented, the product is either an alcohol called apple jack, or an acid called vinegar. If fermentation takes place without oxygen, alcohol and carbon dioxide are produced. But if oxygen is present in the fermentation process, acetic acid and carbon dioxide are produced. Most commercial vinegars have a mass percentage of acetic acid between 4.0% and 5.5%. The white vinegar you will use in this experiment is not produced by fermentation; it is obtained by the dilution of 100% acetic acid.
The percentage of acetic acid in a sample of vinegar may be found by titrating the sample against a standard basic solution. By determining the volume of sodium hydroxide solution of known molarity necessary to neutralize a measured quantity of vinegar, the molarity of the vinegar can be calculated. The molarity can be converted to the percentage CH_3COOH in vinegar.

Safety:

Wear goggles and apron!
Do not touch any chemicals. If you get a chemical on your skin or clothing, wash the chemical off at the sink while calling to your teacher.

Materials:

125 mL Erlenmeyer flask	two burets	buret clamp
100 mL Beakers, 3	phenolphthalein indicator	ring stand
250 mL Beaker	1.0 M NaOH standard solution	white vinegar

Procedure:

1. Label one clean, dry 100 mL beaker *Vinegar* and the other *NaOH*. You should have one buret for *Acid* and one for *Base*.
3. Transfer approximately 80 mL of vinegar and approximately 80 mL of NaOH to the appropriately labeled beakers.
4. Pour approximately 5 mL of vinegar from the beaker into the appropriately labeled acid buret. Rinse the walls of the buret thoroughly with the vinegar. Allow the vinegar to drain through the stopcock into the 250 mL beaker for waste. Rinse the buret two more times in this way, using a new 5 mL portion of vinegar each time. Collect all rinses in the waste beaker.
5. Fill the buret with vinegar above the zero mark. Withdraw enough vinegar to remove the air from the tip of the buret and bring the liquid level into the graduated region of the buret.
6. Repeat steps 4 and 5 with the NaOH solution and the appropriately labeled *Base* buret.
7. Record the initial readings of both burets, estimating the volumes to the nearest 0.01 mL.
8. Allow about 10 mL of vinegar to flow into a clean flask. Add about 10 mL of distilled water to the flask to increase the volume. This procedure will make it easier to determine the color change when the end point is reached. Add one or two drops of phenolphthalein solution to serve as an indicator.
9. Titrate the vinegar with the standard solution of NaOH. Continually swirl the flask. Stop frequently to wash down the sides of the flask with distilled water from your wash bottle. Add the sodium hydroxide drop by drop near the end of the titration until the last drop keeps the

solution a pink color that remains after swirling. A white sheet of paper under the flask may make it easier to detect the color change.

10. Add successive quantities of both solutions, drop by drop, going back and forth from pink to colorless until the end point is clearly established. This point is indicated by the slightest suggestion of pink coloration in the flask. Record in your data table the final buret readings of both solutions to the nearest 0.01 mL.
11. Discard the liquid in the flask by flushing it down the sink with water. Rinse the flask thoroughly with distilled water and repeat the titration two more times.
12. Clean all apparatus and your lab station. Wash your hands thoroughly before you leave the lab and after all work is finished.

Vinegar and Sodium Hydroxide Titration Data

Trial Number	Initial NaOH reading (mL)	Final NaOH reading (mL)	Initial vinegar reading (mL)	Final vinegar reading (mL)
1				
2				
3				

Acetic Acid in Vinegar Performance Assessment

Calculations: All work must be shown for calculations in order to receive full credit.

1. Calculate the volumes of vinegar, CH_3COOH, and sodium hydroxide, 1M NaOH used for each of the three trials.

Trial Number	Volume of 1M NaOH (mL)	Volume of Vinegar (mL)
1		
2		
3		

2. Write the **complete equation** for the reaction between acetic acid (weak), CH_3COOH, and sodium hydroxide (strong), 1M NaOH.

3. Write the **net ionic equation** for the reaction between acetic acid (weak), CH_3COOH, and sodium hydroxide (strong), 1M NaOH.

4. Calculate the molarity of acetic acid in vinegar for all three trials.

Trial 1

Trial 2

Trial 3

5. Calculate the average molarity for your vinegar.

6. Using the average molarity, determine the mass of acetic acid in 1L of vinegar. (formula mass = 60.052g)

Bonus-Assume that the density of vinegar is very close to 1.00 g/mL. Calculate the percentage of acetic acid in your vinegar sample.

Questions: Answer the following in complete sentences.

1. Why is it important for a company manufacturing vinegar to regularly check the molarity of its product?

____

____

____

____

2. What was the purpose of the phenolphthalein? Could you have titrated the vinegar sample without phenolphthalein?

____

____

____

____

APPENDIX D

ADVANCED CHEM EMPIRICAL AND MOLECULAR FORMULA PRACTICE

Advanced Chem Empirical and Molecular Formulas

A. Calculate the Empirical Formulas for problems 1-6 and 8. Ignore the bolded statements until you take notes on Molecular Formula
B. After taking notes on Molecular Formula, go back and calculate it for problems 4-8.

1. A compound is made up of C, Cl, and O atoms. It has 12.13% of C and 70.91% of Cl by mass. What is its empirical formula? (What do all percent add up to equal? Use that to find the percent of O.)

2. Analysis of a 10.150 g of a compound known to contain only phosphorus and oxygen indicates a phosphorus content of 4.433 g. What is the empirical formula of this compound? **Remember you can not round if it is NOT close to a whole number!**

3. Analysis of 20.0 g of a compound containing only calcium and bromine indicates that 4.00 g of calcium are present. What is the empirical formula of the compound formed?

4. A compound is analyzed and found to contain 68.54% carbon, 8.63% hydrogen, and 22.83% oxygen. **The molecular weight of the compound is known to be 140 g/mol**. What is the empirical formula and **the molecular formula**?

5. A compound is found to contain 33.3% calcium, 40.0% oxygen, and 26.7% sulfur. **Its formula weight is 120 g/mol**. What is the empirical and **molecular formula** for the compound?

6. Benzene contains only carbon and hydrogen and is 7.74% hydrogen by mass. **The molar mass of benzene is 78.1 g/mol**. Determine the empirical and **molecular formulas** of benzene.

7. **The compound in problem #2 is found to have a molar mass of 283.89 g/mol. What is the compound's molecular formula?**

8. A compound containing only nitrogen and oxygen is 30.4% nitrogen by mass; **the molar mass of the compound if 92 g/mol**. What are the empirical and **molecular formulas** of the compound?

APPENDIX E

BUY GUM LAB

Buy Gum Lab

Purpose: To calculate the percent of sweetener in gum.

Hypothesis:

Which gum do you think has more sweetener, sugar or sugarless? If, then , because format

____

____

____

Procedure:

1. Mass piece of gum in wrapper.
2. Chew gum for 3 minutes.
3. While chewing gum mass the wrapper.
4. Mass chewed gum in wrapper.
5. Determine the amount of sweetener dissolved.
6. Calculate percent of sweetener in gum.
7. Repeat with sugarless gum.
8. Calculate percent sweetener- $\frac{\text{mass of sweetener}}{\text{mass of unchewed gum}} \times 100$

Data:

Sugared Gum Data

Mass un-chewed gum and wrapper (g)	Mass of Wrapper (g)	Mass of un-chewed gum (g)	Mass chewed gum and wrapper (g)	Mass of chewed gum (g)	Mass of sweetener (g)	Percent sweetener

Sugarless Gum Data

Mass un-chewed gum and wrapper (g)	Mass of Wrapper (g)	Mass of un-chewed gum (g)	Mass chewed gum and wrapper (g)	Mass of chewed gum (g)	Mass of sweetener (g)	Percent sweetener

Questions:

1. What assumptions are you making about the difference in mass before and after chewing?

____

____

____

2. Compare the difference between the two gums' percent mass of sweetener.

____

____

____

3. How many moles of aspartame were dissolved? $C_{14}H_{18}N_2O_5$

4. How many moles of sugar were dissolved? $C_{12}H_{22}O_{11}$

APPENDIX F

THE STOICHIOMETRY OF ALUMINUM AND COPPER (II) CHLORIDE

M2-33. Stoichiometry of Aluminum and Copper (II) Chloride Lab

Purpose: To calculate the quantity of copper (II) chloride necessary to completely react with 0.65 g of aluminum. The reaction will then be observed and the actual amount of copper produced will be compared to the theoretical quantity predicted through a stoichiometric calculations.

Materials

Aluminum Foil	Copper (II) Chloride	Balance	150 mL Beaker
Stirring Rod	Distilled Water	Drying Oven	

Safety

- Follow appropriate laboratory safety rules for working with chemicals and an open flame.
- Dispose of solids in the waste container
- Liquid wastes should be rinsed down the drain with plenty of running water.

Aluminum and copper (II) chloride react to form iron (II) chloride and copper. Using approximately 25 mL of water and 0.65 grams of aluminum, you will react aluminum with copper (II) chloride in a 150 mL beaker.

Before doing this activity

1. Write a complete and balanced equation for the reaction described above.

2. Calculate the amount of copper (II) chloride needed to react with aluminum.

3. Calculate the amount in grams of copper metal that should theoretically be produced from 0.65 grams of aluminum.

4. Create a data table to record the measurements you will be taking during this experiment.

These calculations and your data table must be presented to your instructor prior to beginning this activity.

Procedure

1. Mass empty, clean, dry 150mL beaker.
2. Dissolve calculated amount of Copper (II) Chloride in 25mL of distilled water in a 150mL beaker.
3. Add 0.65 grams of aluminum.
4. Observe reaction and record observations.
5. Decant solution of aluminum chloride. Rinse with distilled water and decant twice.
6. Heat in drying overnight.
7. Mass beaker and product.

Observations:

____

____

____

<u>Post Lab Calculations</u>

Answer the following questions showing all mathematical equations or in a complete sentence.

1. Calculate the percent yield of copper produced.

   $$\text{Percent yield} = \frac{\text{actual amount of copper produced in the lab}}{\text{calculated amount of copper (from stoichiometry)}} \times 100$$

2. Are 100% theoretical yields a realistic expectation in chemistry? Use evidence from the lab to support your answer.

   ____

   ____

   ____

   ____

   ____

3. What are the signs of a chemical reaction occurring? Describe using specific details you observed during the experiment.

   ____

   ____

   ____

4. What type of reaction is this? ____

APPENDIX G

ADVANCED CHEMISTRY MODULE 2 QUIZ 2

Advanced Chemistry Module 2 Quiz 2

1. What is the percent composition of magnesium hydroxide by mass? (3 pts)

2. A sample of a compound contains 86.4% F and 13.6% C. Find the empirical formula. (3pts)

3. A compound is made of 6.83 g carbon and 1.43 g hydrogen. Its molar mass is 58 g/mol. Find the empirical and molecular formula of the compound. (4 pts)

4. Balance the following equations. For question C write and then balance the equation. (1 pt ea)

a) $KClO_3$ (s) → KCl (s) + O_2 (g)

b) $Al(NO_3)_3$ (aq) + H_2SO_4 (aq) → $Al_2(SO_4)_3$ (aq) + HNO_3 (aq)

c) sodium metal combines with chlorine gas to form crystalline sodium chloride

5. Name the type of reaction for the above equation. (1 pt ea)

a) ___________________________________

b) ___________________________________

c) ___________________________________

APPENDIX H

ADV CHEM ACID BASE NEUTRALIZATION TITRATION PROBLEMS

Adv Chem Acid Base Neutralization Titration Problems

Solve the following neutralization titration problems showing all work and make sure to include the following:

- the complete balanced equation
- the mole to mole relationship between the acid and the base
- all calculations using $M = \frac{moles}{L}$

1. What volume of 0.250 M KOH is required to react completely with 25.00 mL of 0.200 M HCl?

2. A 25.00 mL sample of hydrochloric acid requires 24.16 mL of 0.106 M sodium hydroxide for complete neutralization. What is the molarity of the original hydrochloric acid solution?

3. A 50.00 mL sample of aqueous $Ca(OH)_2$ requires 34.66 mL of 0.0980 M nitric acid, HNO_3, for complete neutralization. What is the molarity of the original calcium hydroxide solution?

4. What volume of 0.250 M HNO_3 is required to titrate (neutralize) a solution 0.200g of KOH?

5. What is the molarity of an aqueous solution of barium hydroxide, $Ba(OH)_2$, if 45.00 mL are required to react with 12.35 mL of 0.1500 M hydrochloric acid, HCl, in order to reach the equivalence point?

6. A sample is known to contain only potassium hydroxide and an inert, nonreactive substance. If 29.80 mL of a 0.2513 M solution of perchloric acid, $HClO_4$, reacts completely with the potassium, KOH, in the sample, how many grams of KOH reacted?

7. A sample of solid strontium hydroxide is mixed with water at 30°C and allowed to stand. A 100.0 mL sample of the solution is titrated with 59.4 mL of a 0.0400 M solution of hydroiodic acid, HI. What is the concentration of the strontium hydroxide solution?

APPENDIX I

COLLISIONS: ACIDS & BASES EXPLORE ACID STRENGTH

Collisions: Acids & Bases Explore Acid Strength

DIRECTIONS: Complete the following activity as an introduction to today's topic: Acid Strength

1. Log into Collisions and enter the Acids & Bases game.
2. Play through Level 1 - 6. During play, complete the questions.

This should take approximately 20 minutes to complete are signing up for my Collisions Classroom

Level 1

1. HF is an acid. What is the behavior of an acid?

2. What happens to hydrogen's only electron?

3. What does hydrogen become?

4. Is HF a strong or weak acid?

5. What is the dissociation rate of 0.1 M HF?

Level 2

6. What is the behavior of a base?

7. What is created when a base accepts a proton (H^+)?

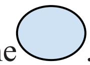
Level 3

8. Is HI a strong or weak acid?

9. What is the dissociation rate of 0.1 M HI?

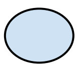
10. What is a neutralization reaction?

Level 4
11. Is HBr a strong or weak acid?

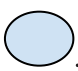
12. Click the . What is the dissociation rate?

Level 5
13. What does it mean to be amphoteric?

14. Is water a strong or weak acid?

15. Click the . What is the dissociation rate?

Level 6
16. Is HCl a strong or weak acid?

17. Click the . What is the dissociation rate?

ANALYSIS:
1. Complete the table below using your findings from above.
2. Using the information from the table, describe the relationship between acid strength and dissociation rate?

Acid	**Strong or Weak Acid?**	**Dissociation**
HF		
HI		
HBr		
H_2O		
HCl		

APPENDIX J

SELF-CONFIDENCE SURVEY IN MODULE 2: THE MOLE

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

Self-Confidence Survey in Module 2: The Mole

The purpose of this survey is to determine how confident you are with the following topics in the mole unit. Indicate your level of ability to complete the following types of problems. This will be administered throughout the unit so you may not have encountered some at this time.

Kinds of Problems	*Self-Confidence in Your Ability to Do Them*			
Elements				
1. Convert between grams and moles	None	Low	Medium	High
2. Convert between moles and atoms	None	Low	Medium	High
3. Convert between grams and atoms	None	Low	Medium	High
Compounds				
4. Convert between grams and moles	None	Low	Medium	High
5. Convert between moles and molecules	None	Low	Medium	High
6. Convert between grams and molecules	None	Low	Medium	High
Calculate Percent Composition				
7. When given the percent of each element	None	Low	Medium	High
8. When given the mass of each element	None	Low	Medium	High
9. When given the mass of the compound	None	Low	Medium	High
Empirical Formula				
10. Calculate the empirical formula when given the percent of each element	None	Low	Medium	High
11. Calculate the empirical formula when given the mass of each element	None	Low	Medium	High
Molecular Formula				
12. Calculate the molecular formula using the empirical formula	None	Low	Medium	High
Chemical Equations				
13. Balance a chemical equation	None	Low	Medium	High
14. Write a chemical equation from a word equation	None	Low	Medium	High
15. Identify the type of chemical reaction	None	Low	Medium	High
Stoichiometry				
16. Perform mole to mole stoichiometric calculations	None	Low	Medium	High
17. Perform mole to gram or gram to mole stoichiometric calculations	None	Low	Medium	High
18. Perform gram to gram stoichiometric calculations	None	Low	Medium	High

APPENDIX K

SELF-CONFIDENCE SURVEY IN MODULE 3: ACIDS AND BASES

Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

Self-Confidence Survey in Module 3: Acids and Bases
The purpose of this survey is to determine how confident you are with the following topics in the acid/base unit. Indicate your level of ability to complete the following types of problems. This will be administered throughout the unit so you may not have encountered some at this time.

Kinds of Problems	*Self-Confidence in Your Ability to Do Them*			
Molarity				
1. Calculate moles when given the molarity and liters.	None	Low	Medium	High
2. Calculate liters when given the molarity and moles	None	Low	Medium	High
3. Calculate molarity when given the moles and liters	None	Low	Medium	High
Characteristic Properties				
4. Identify whether it is an acid or base when given characteristic properties	None	Low	Medium	High
Chemical Equations				
5. Create a complete chemical equation for an acid/base reaction	None	Low	Medium	High
Create a net ionic equation for				
6. For a strong acid and strong base	None	Low	Medium	High
7. For a strong acid and weak base	None	Low	Medium	High
8. For a weak acid and strong base	None	Low	Medium	High
9. Identify the conjugate acid/base pairs	None	Low	Medium	High
Use a chemical equation to solve acid/base titration problems to solve for the molarity of the other substance when				
10. Given the molarity and volume of one and the volume of the other	None	Low	Medium	High
11. Given the grams of one and the volume of the other	None	Low	Medium	High
Use a chemical equation to solve acid/base titration problems to solve for the grams of the other substance when				
12. Given the molarity and volume of one and the volume of the other	None	Low	Medium	High
13. Given the grams of one and the volume of the other	None	Low	Medium	High
14. Perform an acid/base titration	None	Low	Medium	High

APPENDIX L

INTERVIEW QUESTIONS

Interview Questions

1. What types of activities: simulations, POGILs, video tutorials, practice problems, labs, etc. helped you to comprehend material and why (ARQ)? Can you give me an example?
2. If you were able to incorporate any aspects of student-centered learning into your other classes, what would they be and why (ARQ)? Have you ever done anything like this in earlier classes? If so, what was it like?
3. When you work at your own pace what are the advantages (SQ2)? Can you give me an example?
4. When you work at your own pace what are the disadvantages (SQ2)? Can you give me an example?
5. How did the formative assessment quizzes prepare you for the summative assessment (ARQ)? What information did they provide you with?
6. What impact did student conferences have on your understanding of the content (SQ1)?
7. Are there any concepts that are still unclear for you? If so, what?
8. After both assessments have been given, I asked what type of assessment do you prefer and why (ARQ)?

APPENDIX M

IRB EXEMEPTION

IRB Exemption

Hello Erica,

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

PI: Erica Bertrand

Approval Date: 10/14/2022

Title: Educational Shifts in Paradigms: Traditional Versus Performance Based Assessments

Protocol #: 2022-331-EXEMPT

Review Type: Exemption

Expiration Date: 10/14/2027 All looks good.