

INVESTIGATING THE IMPACT OF FORMATIVE ASSESSMENTS ON STUDENT
ENGAGEMENT IN A SECONDARY SCIENCE CLASSROOM

by

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ABSTRACT

The purpose of this research project was to investigate the impact of formative assessments on student engagement, motivation, self-efficacy and overall learning in a chemistry classroom. A variety of surveys, questionnaires and exit slips were used to measure student feelings and attitudes about formative assessments throughout the treatment period. The overall result of the research project demonstrated that students increased their overall level of engagement, self-efficacy and learning of chemistry concepts through the use of varied formative assessments and continuous feedback.

INTRODUCTION AND BACKGROUND

The Burlington-Edison School District is located in a rural agricultural community in Burlington, Washington with an enrollment of approximately 3,700 students in grades K-12. Over the past 13 years, I have taught a variety of different science courses at Burlington-Edison High School (B-EHS) including Chemistry, Honors Chemistry and Human Anatomy and Physiology. There are approximately 1,050 students enrolled at B-EHS in grades 9-12, of which 58.6% of students are White, 34.0% are Hispanic/Latino, 2.5% are Asian, 0.9% are American Indian/Alaskan Native and 0.9% are Black/African American. Thirty-nine percent of the student body receive free or reduced lunch services, 13.6% receive special education services, 10.9% are classified as Transitional Bilingual and 3.0% are classified as migrant.

The chemistry courses that I selected for this classroom research project consisted of students in grades 10-12 earning a physical science credit for their Washington State graduation requirements in science. Chemistry is considered an elective science course to earn credit for graduation requirements, in which most students elect to take this course during their sophomore or junior year. Students enrolled in this class are expected to have a strong background in physical science concepts from 7th and 8th grade, as well as basic algebra skills. Over the years, I have found that students that enroll in chemistry come from varied backgrounds of scientific knowledge and mathematical reasoning. These differences can lead to varying levels of motivation and engagement both in the classroom setting and with regards to time spent learning concepts outside of the

classroom, which may ultimately impact how students learn and measure their own success in school.

One of the main aspects of this classroom research project is to understand what motivates students to learn and how varying levels of motivation may impact engagement in the classroom. Over the years, I have learned that the factors that motivate or keep students engaged in the classroom varies considerably from student to student.

Individual students develop their own beliefs of the purpose of school, what motivates them in the classroom, and what is considered to be a true measurement of their success.

The central goal of this classroom research project was to observe how the implementation of formative assessments may impact a given student's self-determined view of motivation and self-efficacy as it relates to their overall engagement and conceptual understanding in the classroom. I wanted to learn how to use a student's self-determined view of motivation to help support their active participation in the learning process and to encourage engagement in the classroom. If I can understand how to help my students remain engaged and motivated while they are in my classroom through the use of formative assessments, then I will be able to help them make stronger connections to scientific content and become more successful learners now and in the future.

My overall concern about increasing student engagement and motivation in my classroom has led me to my current overarching action research question:

- How will the use of formative assessments in the science classroom improve overall student engagement?

Additionally, I wanted to explore the following sub questions:

- How will the use of formative assessments be used to increase student self-efficacy in the science classroom?
- How will the use of formative assessments be used to increase student motivation in the science classroom?
- How will the use of formative assessments improve student learning?
- How will the use of formative assessments help me to inform my instructional practices to increase student learning?

CONCEPTUAL FRAMEWORK

The general purpose of using assessments is to measure whether students have learned a given set of concepts, to measure current levels of achievement, and to assign points and grades to establish a variety of different motivational factors for students. In the most traditional sense, an assessment is a test or a quiz to be used in conjunction with the end of a conceptual unit or a learning period, which leads teachers to only measure what students may have learned after the learning has been completed (Lee & Abell, 2007). However, classroom assessments can also be considered as all activities undertaken by teachers—and by students in assessing themselves—to provide information to be used as feedback to modify teaching and learning activities. Such assessments become formative when the evidence is used to adapt the teaching to meet the needs of students (Black & William, 1998). Effective teachers that use formative assessments during instruction can identify specific student misunderstandings, provide feedback to students to help them correct their errors, and identify and implement instructional correctives (Cauley & McMillan, 2009).

Implementation of formative assessments in the classroom can often be linked to the level of engagement, motivation and self-efficacy for students. However, in many situations assessments are often created within a system of collected values to only measure content standards and what teachers, departments, schools and districts have decided is worth learning (Nolen, 2011). In many schools and school districts, this is how assessments have been developed and administered for decades. To support an equal system for student learning, all educators need to communicate learning targets clearly and use assessments and assessment data to make decisions about who has learned and what to do next (Nolen, 2011). In many cases, assessment data is not used to drive instruction or to make large-scale instructional change. Instead, the data is simply used to determine a letter grade for a report card without a reflective analysis process being utilized with it. The function of assessments and feedback within the classroom needs to be embedded in the larger social structures in which teachers do their work (Nolen, 2011). If teachers can effectively utilize assessment data to inform instructional practices, then assessments are truly a formative measure and can have significant impacts on student learning and engagement.

Formative assessments are often used as instruments to impact student learning by potentially increasing student motivation within the classroom. Teachers are the purveyors of conceptual information and students are the receivers of the learning process. However, some students do not realize the importance of their role in the classroom and the overall learning experience. Information that is provided through formative assessments can be a valuable tool for both students and the teacher if a

connection is made regarding what is being learned and what is truly important. If students believe that learning is important, they will exert a greater effort (Stiggins, 2005).

A goal for any classroom teacher should be to utilize assessments in a more flexible and formative manner, where student learning is measured throughout the learning process, rather than only at the end of learning. Assessments *of* learning traditionally take place only after the learning is supposed to have occurred to determine if it actually happened (Stiggins, Arter, Chappuis, & Chappuis, 2006). Assessments *for* learning happen while learning is still taking place and is conducted in such a manner that teaching and learning are used to diagnose student needs, provide feedback and help students to be the most successful (Stiggins et al., 2006).

An important aspect of implementing formative assessments in the classroom is to attempt varied and continuous assessment to check for student understanding during the actual process of learning. When continuous formative assessments are implemented, both the students and teachers are better able to identify how best to proceed through the next lesson or within the next unit (Crumrine & Demers, 2007). It is also important to understand that when teachers implement formative assessments, they need to be flexible within the instructional process because if an assessment uncovers that students do not understand a particular concept, it may be necessary to reteach that concept (Crumrine & Demers, 2007).

Creating a classroom environment that embraces formative assessments as a part of the learning process can be a challenging paradigm shift for even the most veteran

teachers. However, there are a few key strategies that can help any teacher embrace the idea of using formative assessments to assess *for* student learning. One strategy is to establish clear learning targets and benchmarks for both students and the teacher which will help to establish a culture of learning (Cauley & McMillan, 2009). This will provide students with a strong foundation to understand what they are learning, why they are learning, and to self-assess (Stiggins, 2005). It has also been noted that providing clear expectations enables students to set realistic and attainable goals for themselves (Cauley & McMillan, 2009). When teachers help students establish clear and attainable learning goals, it becomes much easier to develop and monitor student improvement over time as it relates to overall scientific understanding and engagement in the classroom. When a student understands the learning target, then it follows that they may have increased motivation to meet the learning target because they understand what goal they are working toward.

Helping students develop and monitor their own learning goals can also help to increase their overall level of self-efficacy. Self-efficacy is the belief that an individual has about his or her ability to perform on a given task. High self-efficacy is measured when students feel that they are successful about attempting a given task based on their level of effort (Cauley & McMillan, 2009). Establishing clear learning targets, helping students create their own learning goals and encouraging students to increase their own views of their self-efficacy in a learning environment using formative assessments is a powerful tool for ensuring success of all students.

Teachers can help students increase their level of motivation in the classroom by providing purposeful and timely feedback on formative assessments. Feedback to students through formative assessments can influence how students attribute their successes (Cauley & McMillan, 2009). The function of assessments and feedback in the classroom system is relevant when examining the relationship to student engagement (Nolen, 2011). Nolan (2011) refers to a series of studies where:

...feedback has been shown to support motivation and achievement if it provides specific information about the work related to standards and learning progressions, suggests strategies for improvement and is focused on learning and improvement rather than grades or social comparison (p. 319).

Providing feedback should be a key part of the learning process where there is continuous and reciprocal feedback from student to teacher and teacher to student. However, the type and quality of feedback alone may not be the only requirement needed to ensure change in student behavior. This is evident when teacher feedback on formative assessments is clear and specific yet does not have the desired effect on student engagement and learning (Sadler, 1989).

In today's classrooms, it is important for educators to help students embrace the learning process, rather than focusing only on earning points or achieving a letter grade. O'Conner (2002) states that there is often too much emphasis placed on grades and this can have detrimental effects on student achievement, motivation and self-concept. Teacher feedback can be used to increase students' intrinsic motivation when the feedback is designed to support student learning. Additionally, student progress will only be enhanced by formative assessments if they are able to use feedback effectively and

recognize specific achievable steps where they may need to improve or develop their thinking and skills (Evans, Zeun, & Stainer, 2014).

A significant benefit of formative assessments is that students commonly attribute their successes to their own individual effort, which is highly effective for increasing student motivation because it places students in control of their own learning (Cauley & McMillan, 2009). Students who believe that their success in a learning environment is due primarily to their own effort and ability tend to have a stronger motivation and staying power to complete challenging work (Cauley & McMillan, 2009). A key factor to increasing student motivation and engagement is to provide feedback that students can use to improve their understanding of concepts to ensure that they have an opportunity to act on that feedback (Nolen, 2011). The ultimate goal for any teacher should be to create a learning environment where students take control of their own learning and become intrinsically motivated to be resilient, persevere and to be successful in life beyond the classroom. If teachers can maintain this type of assessment structure within their classrooms, the level of student motivation and engagement should increase as student self-efficacy increases.

Increasing overall student motivation through the use of formative assessments also incorporates the process of self-assessment in order for students to continually assess their own learning. Unfortunately, with most traditional forms of assessment students only receive feedback from the teacher for the purpose of summative assessments and establishing points for a grade. Within this traditional assessment system, students do not play an active role in the evaluation and analysis of the assessment. An inherent design

of formative assessments should be that students are encouraged to self-assess their own learning where they can monitor and evaluate the nature of their thinking in order to improve their overall understanding (McMillan & Hearn, 2008).

According to Cauley and McMillan (2009), formative self-assessment is a three-step process: students judge their own work (self-monitor), identify discrepancies between current and desired performance (self-evaluation), and identify and implement further learning activities to enhance their understanding. Students need to be provided with opportunities to evaluate their own work, compare their answers to correct answers and then determine the next steps for their learning. If time is dedicated to teaching students how to self-assess, they will gradually assume more responsibility for their own learning and evaluating their ability to achieve a specific learning target and what steps might be needed for continuous improvement (Cauley & McMillan, 2009).

Increasing student engagement and motivation in the classroom is essential to increase overall student learning of content. If teachers can implement varied strategies that include providing clear learning targets, opportunities of self-reflection and continuous positive feedback using formative assessments, students are likely to increase their overall motivation to become engaged and active participants in the learning process. Although it is understood that teachers must give summative assessments to measure overall student understanding and to provide grades within a traditional educational system, teachers also need to provide students with opportunities to demonstrate their learning through alternative methods. From this process, teachers can design lessons that confront alternative conceptions, help students adopt new ways of

thinking that are consistent with a scientific worldview (Hutner & Sampson, 2015).

When students begin to take responsibility for their own learning, they will be able to become active participants in the classroom to the point where they are motivated to learn and are willing to take intellectual risks to learn more about the scientific world beyond the classroom.

METHODOLOGY

This classroom research project was designed to determine if the implementation of formative assessments can improve student engagement, motivation, self-efficacy and overall learning in a high school chemistry classroom. The schedule at B-EHS is an alternating 4-period block schedule, where students have four classes on one day and four classes on the next day. Due to this schedule, students are in the chemistry classroom typically two days during one week and three days during the following week. Each class period is 90 minutes long, except for the occasional schedule change when class periods are shortened to 60-80 minutes.

The instruction and data collection instruments used for this classroom research project were implemented over a two-month period between February and March 2018 while students learned about chemical reactions including key concepts such as balancing chemical equations, stoichiometry and limiting reagents. The concepts for this classroom research project were selected due to the challenging nature of the content and lack of student background knowledge from previous science courses, as well as incorporating a small level of review from previous units earlier in the year. Due to the level of difficulty of the concepts, students were asked to complete a variety of different formative

assessments, as well as feedback forms to provide details about their conceptual understanding and the impact that formative assessments might have on the variables and questions of this research project.

Permission to conduct this classroom research project was established in accordance with commonly accepted educational practices as granted by the building principal. In accordance with Burlington-Edison School District policy, a letter asking for informed consent from a parent or guardian was sent home with each student at the beginning of the research period. To uphold this school district policy, student data represented within this classroom research project pertains only to students who submitted the informed consent letter. Additionally, the research methodology for this classroom research project received an exemption by Montana State University's Institutional Review Board, in which compliance for working with human subjects was maintained (Appendix A).

Students selected for this classroom research project were from two different chemistry courses (class periods), with a total sample size of 55 students ($N=55$). Of these students, 31 (56.4%) are male and 24 (43.6%) are female. The demographics of these classes consist of students coming from middle-class to working-class families, from racial backgrounds including 56.3 % White, 29.1% Hispanic/Latino, 9.1% Asian/Pacific Islander, and 5.5% African-American. Four (7.3%) students receive special education services such as a Section 504 plan or an Individualized Educational Plan (IEP), three (5.5%) students are Limited English Proficient and receive English Language (EL) services, and eight (14.5%) students are designated as gifted/talented.

To establish baseline data for engagement, motivation, self-efficacy and overall learning, students completed the How I Learn Best questionnaire (Appendix B). Student responses were measured on a five-point Likert-type scale including the following options: strongly agree, agree, neither agree or disagree, disagree and strongly disagree. The survey was administered on paper to all students and the results were inputted into an electronic spreadsheet. The same questionnaire was also administered at the end of treatment period to measure whether student feelings regarding how they learn best in chemistry may have changed during the treatment period after the implementation of various formative assessments.

In addition to the How I Learn Best questionnaire, students also completed a Student Engagement Survey (Appendix C) at the beginning of the treatment period in which they answered a series of survey questions to establish a relative baseline of their overall feelings and attitudes towards engagement in school based on questions in two categories—motivation and self-efficacy. Students did not know which questions or statements were related to each indicator at the time of the survey to keep student responses as reliable as possible. Student responses were measured on a five-point Likert-type scale including the following options: always, often, sometimes, seldom or never. The survey was administered on paper to all students and the results were inputted into an electronic spreadsheet. This survey was also administered at the end of the treatment period to measure whether student attitudes and beliefs regarding their level of engagement and self-efficacy may have changed after the implementation of formative assessments.

At the end of the research treatment period, students filled out the End of Treatment Summary questionnaire (Appendix D) that asked how each formative assessment and/or instructional intervention may have impacted them based on four major criteria—overall learning, engagement, self-efficacy and future success. Students were asked to rank their overall feelings using a Likert-type scale (strongly agree, agree, neither agree or disagree, disagree and strongly disagree) to specify how a given formative assessment or instructional method may have changed their attitudes towards each criterion. In addition, students were asked to include one task or assignment that helped improve their overall feelings of a particular indicator. Results from this questionnaire were documented into an electronic spreadsheet for further analysis.

To determine the overall impact of formative assessments on student engagement, motivation and overall learning throughout the treatment period, a variety of different formative assessments, including checkpoint quizzes, misconception probes, entrance slips and exit slips and guided practice packets were administered after the presentation of brand new concepts or to review key chemistry concepts. The purpose of these formative assessments was to allow students opportunities to demonstrate their understanding during the process of learning, as well as to provide feedback to the teacher about any potential misconceptions or conceptual misunderstanding.

For the treatment, checkpoint quizzes were administered at times where students were asked to demonstrate their conceptual understanding using mathematical reasoning or algebraic concepts (Appendix E). At the completion of each checkpoint quiz, students self-assessed their own work to measure their current level of progress towards the

learning target(s) and to generate questions about what concepts they were still having difficulty in understanding. After completing the self-assessment, students filled out a feedback form to provide information about their level of confidence of the concept, to identify any point of confusion, and to determine if the checkpoint had any impact on student learning (Appendix F). Results from each checkpoint quiz feedback form were inputted into an electronic spreadsheet to measure how student feelings and attitudes changed over time.

A misconception probe was used during the treatment period to measure current student understanding and any potential misconceptions prior to learning about chemical reactions and stoichiometry (Appendix G). The results of the misconception probe provided a way to gauge the level of understanding of a key chemistry concept prior to learning the underlying reasons and to help adjust any instruction of the concept. The misconception probe that was used for this research project consisted of a YouTube video demonstrating the concept of the Law of Conservation of Mass and a multiple-choice question for students to select and explain their response. Results of the misconception probe were recorded into an electronic spreadsheet for further analysis.

Entrance and exit slips were also used during the treatment to provide students opportunity to reflect upon their learning of concepts presented during a given class period. Entrance slips were used when it appeared that students were having a difficult time either understanding a given concept or making connections between concepts (Appendix H). Exit slips were administered at the end of almost every class period during the research project to collect feedback from students about their current level of

understanding of a given concept and to provide information about how best to modify any instructional methods for the next class period (Appendix I). On each exit slip, students were asked to rank their feelings about their current level of understanding of a given concept using a five-point Likert-type scale, provide a reason for their ranking and to provide an explanation of anything that might still be a point of confusion. Information from each entrance and exit slips were recorded into an electronic spreadsheet and were analyzed daily to look for patterns or trends to inform any instructional practices during the next class period.

At the end of a formative assessment or formative classroom activity, students completed a Post-Task Questionnaire survey (Appendix J) to provide information about their attitudes and beliefs towards motivation and engagement as it related to a specific assessment or activity. The Post-Task Questionnaire asked students to rank their feelings about a specific formative assessment immediately after completing the assessment using the following five-point Likert-type scale including the following options: strongly agree, agree, neither agree or disagree, disagree and strongly disagree. The results of the Post-Task Questionnaire were used to determine how student attitudes towards specific formative assessments may have helped with their overall learning of key chemistry concepts.

Classroom observations were used during this classroom research project to develop a better understanding of student motivation and engagement during classroom activities and formative assessments. Due to time constraints within the school schedule, each classroom observation was conducted in approximately a five to ten-minute period

using the Student Engagement On-task Log (Appendix K). Observers were selected based on their availability during the same class periods as the chemistry courses that were a part of this classroom research project. Observers were asked to look for the following student engagement indicators: positive body language, consistent focus, verbal participation, confidence, involvement, and overall engagement. To determine the how many students were considered engaged in a given activity, observers compared the total number of students at the time of the observation to the number of students matching the specified description for each student engagement indicator. The total number of students engaged versus not engaged for a given activity were documented and entered into an electronic spreadsheet.

Throughout the entire classroom research project, general observational notes were recorded into an electronic observational journal to document the day-to-day observations about how students remained engaged during and to document any interesting findings. The same student engagement indicators from the Student Engagement On-Task Log were used as a guide to record specific student behaviors as they related to engagement and motivation in the classroom. Information from the Student Engagement On-Task Log was used in conjunction with other instruments to look for common themes and patterns

To ensure reliability and validity of the data collection instruments, I utilized a combination of peer review with several colleagues and several modified instruments that were used in either in other classroom research projects or different versions of motivation/engagement surveys found online. For the Student Engagement Survey and

the How I Learn Best Questionnaire, I used a combination of the Student Engagement, Motivation and Beliefs Survey (Road Map Project, 2011), the Motivation and Engagement Scale—High School (Martin, 2013) and the COLDEX Motivation Questionnaire (COLDEX, 2005). These surveys/questionnaires were used as a guided to develop some statements for the instruments used in this classroom research project.

To ensure that the data collection instruments used during this classroom research project were calibrated and would provide reliable results, I implemented a pre-research treatment period (November 2017-January 2018) where I was able to create, use and modify some of the same formative assessments that were used in the actual treatment period. I discovered during the pre-treatment period that some of the questions or Likert-type scales did not return the type of data that I was hoping to collect. Modifications made during this period led to more consistent and reliable data during the actual treatment period. Table 1 shows the connection of the research questions to the various data collection instruments that were used within this classroom research project.

Table 1
Action Research Questions and Data Collection Instruments

RESEARCH QUESTIONS	DATA COLLETION INSTRUMENTS								
	Student Engagement Survey	How I Learn Best Questionnaire	End of Treatment Summary Questionnaire	Checkpoint Quizzes	Formative Assessment Feedback Forms	Entrance and Exit Slips	Classroom Observations	Misconception Probe	Teacher Observation Journal
How will the use of formative assessments in the science classroom improve overall student engagement?	✓	✓	✓	✓	✓	✓	✓	✓	✓
How will the use of formative assessments be used in increase student self-efficacy in the science classroom?	✓	✓	✓	✓	✓	✓	✓	✓	✓
How will the use of formative assessments be used in increase student motivation in the science classroom?	✓	✓	✓	✓	✓	✓	✓	✓	✓
How will the use of formative assessments improve student learning?		✓	✓	✓	✓	✓		✓	
How will the use of formative assessments help me to inform my instructional practices to increase student learning?	✓	✓	✓	✓	✓	✓	✓	✓	

DATA AND ANALYSIS

To determine the impact of formative assessments on student engagement and motivation in the science classroom, data from the various instruments used throughout this classroom research project were analyzed to look for trends and patterns that may show an impact on student attitudes towards these variables. Results from the Student Engagement Survey, How I Learn Best Questionnaire, Post-Task questionnaires, End of Treatment Summary questionnaire, exit slips and classroom observations were examined to see if the use of formative assessments had a significant impact on student attitudes and feelings about their level of engagement and motivation during the research project.

The Student Engagement Survey was designed to have students analyze their own beliefs and attitudes towards their engagement in the science classroom based on two categories of questions—motivation and self-efficacy. Based on the initial results of the Student Engagement Survey, students had fairly positive feelings about their level of motivation and self-efficacy in the science classroom and school in general at the beginning of the treatment period. However, when analyzing the results of the questionnaire given at the end of the treatment period, student beliefs about their own motivation and self-efficacy improved.

At the beginning of the treatment period ($n=52$), 44.2% of students stated that they Always work on assignments for class because they know those assignments will help them understand the concepts better (Figure 1). At the end of the treatment period ($n=48$), 50.0% of students stated Always for the same indicator of motivation. Along the same lines, 44.2% of students stated that they Always or Often review their notes or other resources after class to gain a better understanding of key concepts ($n=52$), while at the end of the study 50.0% of students made this same claim ($n=48$). Although there was a small change in student attitudes towards motivation during the treatment period, it can be inferred that the intentional use of formative assessments and other resources may have helped students become more motivated to learn about a given concept.

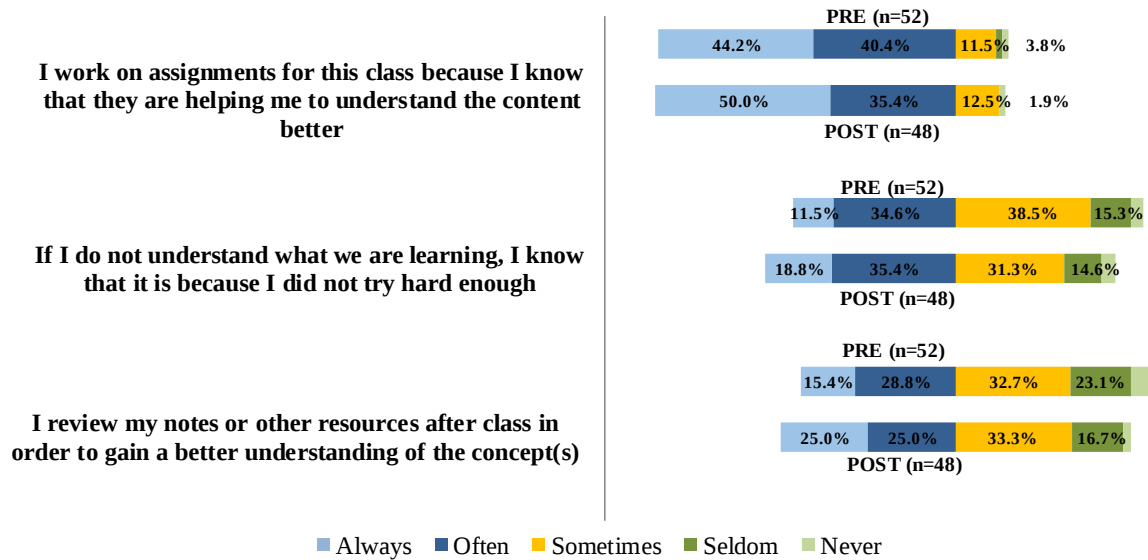


Figure 1. Student attitudes about motivation—Student Engagement Survey.

Student attitudes and beliefs about their own self-efficacy also appeared to have changed positively during the treatment period (Figure 2). At the beginning of the treatment period ($n=52$), 38.5% of students responded with Always and 27.1% responded with Often to the indicator “I believe that I can earn the best grade possible in this class because of my effort” on the Student Engagement Survey. At the end of the treatment period ($n=48$), the number of students that selected Always for this indicator increased by 9.4%, the number of students that selected Seldom decreased by 1.3% and the number of students that selected sometimes increased by 1.3%.

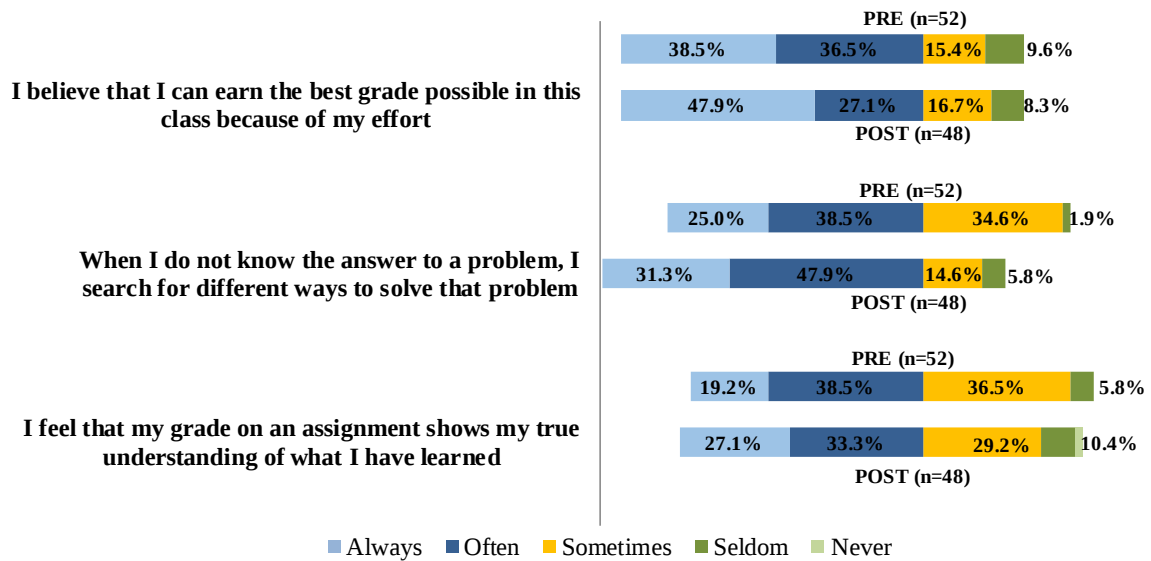


Figure 2. Student attitudes about self-efficacy—Student Engagement Survey.

Another indicator of self-efficacy that improved dramatically during the treatment period was “When I do not know the answer to a problem, I search for different ways to solve that problem (Figure 2). At the beginning of the treatment ($n=52$), there was a large percentage of students that stated Sometimes (34.6%) and Seldom (1.9%). The number of students that selected the same responses at the end of the treatment ($n=48$) decreased for Sometimes (14.6%) and increased for Seldom (5.8%). The overall positive responses from the beginning of the treatment improved from 25.0% to 31.3% for Always and 38.5% to 47.9% for Often. The overall net change in positive student attitudes regarding this indicator of self-efficacy increased by 15.7% during the treatment period. A possible explanation of this large increase in students with positive attitudes towards self-efficacy could be due to the use of continuous and varied formative assessments that were in some cases designed based directly on feedback received from students through feedback forms, exit slips and informal conversations.

An essential component of this classroom research project was to determine how formative assessments may have impacted both student engagement and overall learning. The How I Learn Best questionnaire was one instrument used to measure student attitudes towards how feedback may have impacted their learning of chemistry concepts (Figure 3). Based on this questionnaire, student attitudes towards receiving feedback on daily assignments or assessments to improve understanding increased significantly during the treatment period. Thirty-two-point three percent of students at the beginning of the study ($n=52$) responded that they Strongly Agree increased to 47.9% of students making the same response at the end of the study ($n=48$). This increase of 15.6% of students from the beginning of the treatment period could be attributed to the fact that there was a more intentional focus regarding gathering and utilizing feedback directly from students. Students appeared to be more engaged in the learning process when they were completing a variety of different formative assessments.

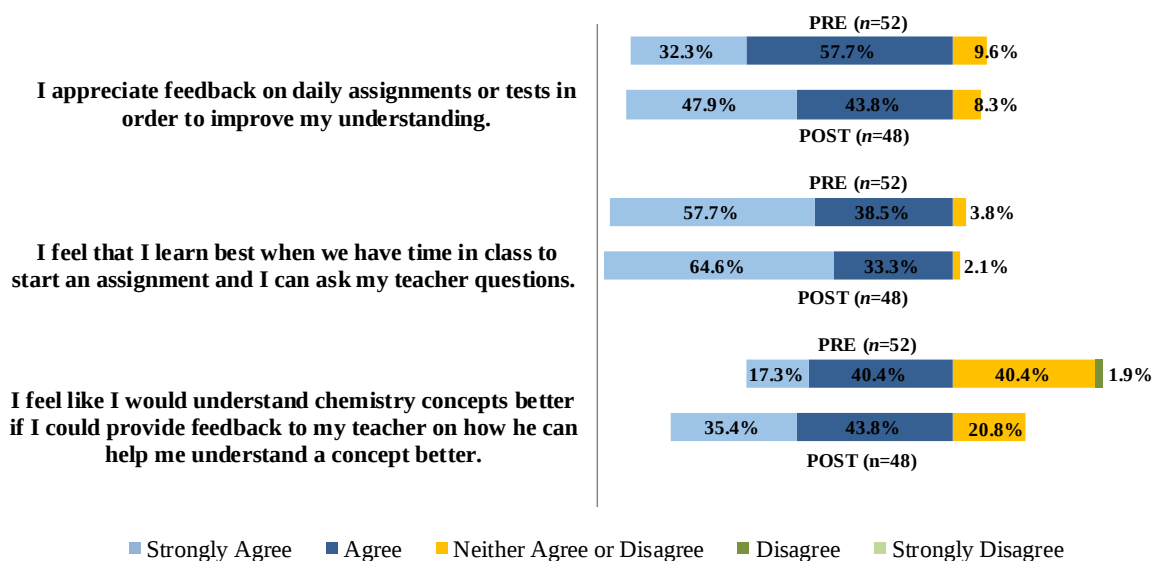


Figure 3. Student attitudes about feedback—How I Learn Best Questionnaire.

To measure student thoughts and attitudes regarding formative assessments, an emphasis was placed on providing more opportunities for students to complete formative assessments in class and to provide immediate feedback to the teacher. Based on the results of the How I Learn Best questionnaire, there was a small change in student attitudes regarding having class time to begin an assignment and to be able to ask the teacher questions, changing from 57.7% of students responding with Strongly Agree at the beginning of the study to 64.6% at the end of the study (Figure 3). In addition, the number of students that responded with Strongly Agree or Agree about their feelings towards providing feedback to the teacher to help with conceptual understanding increased from 57.7% to 79.2%. This positive change in student attitudes regarding receiving and giving feedback and its impact on conceptual understanding could be attributed to the intentional use of feedback strategies like feedback forms and exit slips that were used throughout the treatment period.

Measuring the potential impact of feedback was also collected on the End of Treatment Summary questionnaire, where students were asked their attitudes about the impact of receiving feedback directly from the teacher based on four categories—overall learning, engagement, self-efficacy and future success (Figure 4). Based on the results of this questionnaire, receiving feedback directly from the teacher had the biggest impact on student beliefs with overall learning and future success. Ninety-one-point one percent of students claimed that they agreed or strongly agreed that receiving feedback directly from the teacher impacted their overall learning, while 93.3% made the same responses for the impact on their future success. One student that selected Strongly Agree commented,

“When I receive direct feedback from the teacher, it helps me understand what I got wrong and why.” An interesting result was with student feelings about the impact of receiving feedback had on their engagement in class, where 80.0% of students stated that they agreed or strongly agreed, and 20.0% neither agreed or disagreed. When looking at student responses for this category, most students felt that the actual formative assessments had the most impact on their engagement rather than receiving feedback from the teacher.

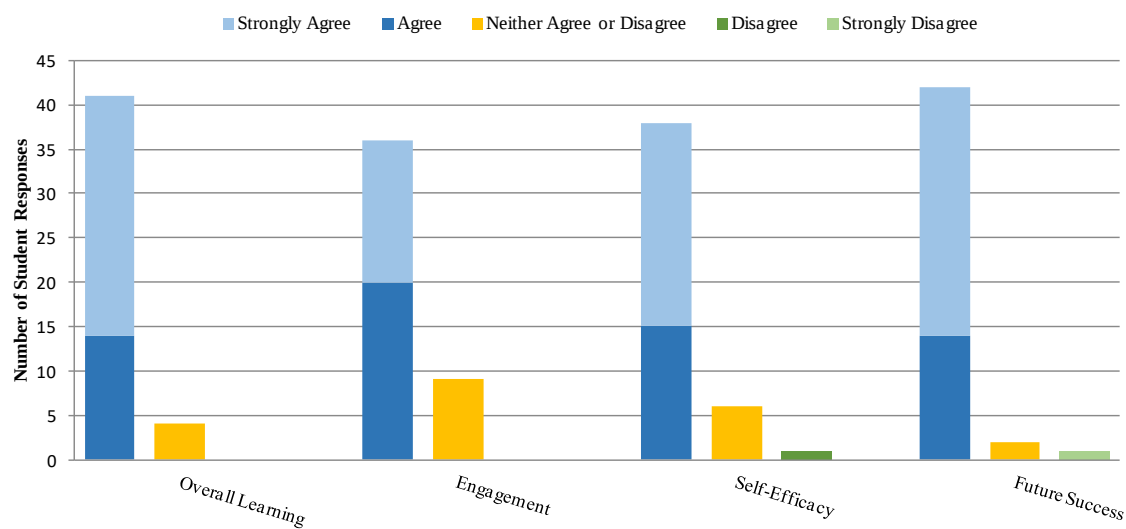


Figure 4. Student attitudes about feedback—End of Treatment Summary, ($n=45$).

Exit slips were one of the most impactful methods of collecting student feedback throughout the classroom research project. Exit slips were administered at the end of almost every class period to measure student feelings and attitudes about key chemistry concepts during the process of learning. Students were asked to rank their feelings of current understanding of concepts learned during a given class period, as well as provide statements about what they felt confident about and any points of confusion. Student

feelings of conceptual understanding collected at the beginning and the end of two mini conceptual units are represented in Figure 5.

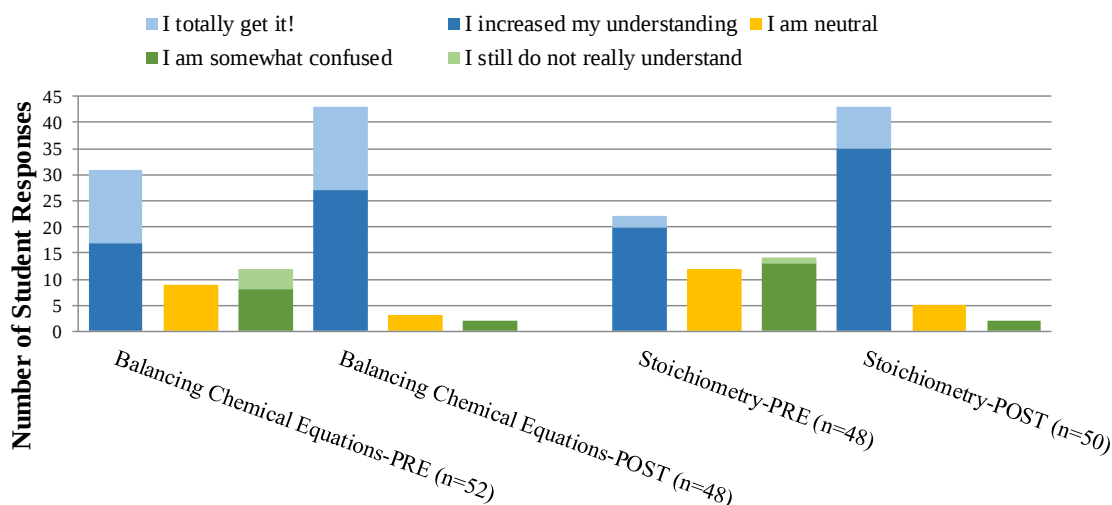


Figure 5. Student attitudes of conceptual understanding from exit slips.

Based on student responses from exit slips at the beginning of learning how to balance chemical equations, 59.6% of students responded as either “I totally get it!” or “I increased my understanding” of the concept, while 23.1% of students responded negatively as either “I am somewhat confused” or “I still do not really understand”. At the end of the mini unit on balancing chemical equations two class periods later, the number of students that increased their understanding increased by 23.1% to a total of 82.7% and the total number of students that were confused or did not understand the concept dropped by 19.3% to a total of 3.8%.

A similar result occurred when students were learning about stoichiometry. Upon first learning about stoichiometry, the total number of students with positive feelings of their conceptual understand was fairly low, with 20 of 48 (41.7%) of students commenting that they increased their understanding and only 2 of 48 (4.2%) of students

stated that they “totally get it”. Most students commented that they were neutral (25.0%) or that they were somewhat confused (27.1%). One student commented on their exit slip, “I do not understand a lot, but I kind of know what I need to do.” Another student commented, “I get it, but I think I will understand it a little more with practice.” These comments summarize many student responses after first learning how to complete stoichiometry problems when there was a lot of confusion and only a little bit of true conceptual understanding.

After the completion of three class periods and lessons about stoichiometry, another exit slip was administered to determine if there was any change in student feelings about stoichiometry. There was a significant change in positive student feelings at the end of learning about stoichiometry, with a 40.2% increase in the number of students responding with “I totally get it” or “I increased my understanding”. In addition, the total number of students that selected “I am neutral” or “I am somewhat confused” dropped 38.1% to a total of two students. One possible reason for this positive change in student attitude could be due to the implementation of the guided practice formative assessments (Appendix L). The exit slip on the last day of learning about stoichiometry asked students how the activity (guided practice on stoichiometry) that class period helped with their understanding of stoichiometry and conversion tables. Of all the responses ($n=50$), 100% of student comments reflected the positive experience they had with the guided practice activity. At the beginning of learning about stoichiometry, one student ranked his understanding as a “2—I’m somewhat confused”, commenting “It has a lot of steps and converting between different types of units is a bit tricky.” This same

student ranked his understanding as a “4—I increased my understanding” three days later and commented that the guided practice for stoichiometry “...taught me how to properly use the conversion tables, which I was struggling with.”

To measure student engagement effectively, classroom observations were conducted to evaluate the actual level of student engagement during classroom activities. Classroom observations were conducted during all classroom activities regardless if they were considered formative assessments or activities (Figure 6).

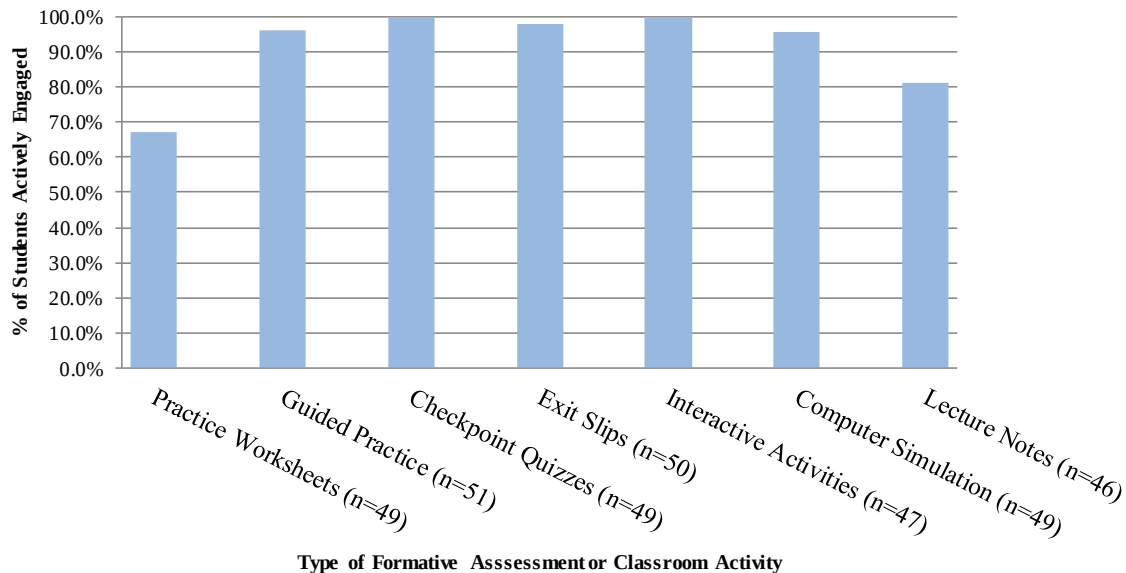


Figure 6. On-task log summary from classroom observations.

Based on the results of classroom observations, formative assessments appeared to have had a positive impact on student engagement (at the time of the observation), with checkpoint quizzes and interactive activities both showing that 100% student engagement. The guided practice had 96.1% and the computer simulation formative activity had 95.9% student engagement. The computer simulation activity consisted of an interactive simulation from the PHET website through the University of Colorado

Boulder, where students could work independently to gain a better understanding of how to balance chemical equations. Of all the formative assessments and activities that were used during this research project, the computer simulation seemed to have the most positive impact on student engagement during the implementation of the assessment due to the connection to technology. One student commented, “It helped me because now I know what to do and also I got more practice and it was fun.” Several students commented that they like the visual aspect of the simulation, including one student who stated, “The visual gave me another way of thinking about it, which helped a lot.” The lowest level of engagement demonstrated was during times where students were working on practice worksheets (67.3%) or completing lecture notes (81.4%). It should be noted that there were some variable levels of engagement during all activities due to the nature of the activity/formative assessment and the time in which the observations were made.

Student attitudes towards different types of formative assessments were measured to determine how the use of formative assessments may have impacted student learning using the Post-Task Questionnaire. For the indicator “I feel like this task helped me understand chemistry concepts better”, the guided practice, checkpoint quizzes and interactive activities had the most impact on student learning (Figure 7). The guided practice formative assessment had 44 of 48 (91.7%) students state that they Strongly Agree or Agree. The interactive activities had 42 of 43 (97.7%) of students respond with Strongly Agree or Agree and the computer simulation (Balancing Chemical Equations) had 38 of 43 (88.3%) of students responded with Strongly Agree or Agree.

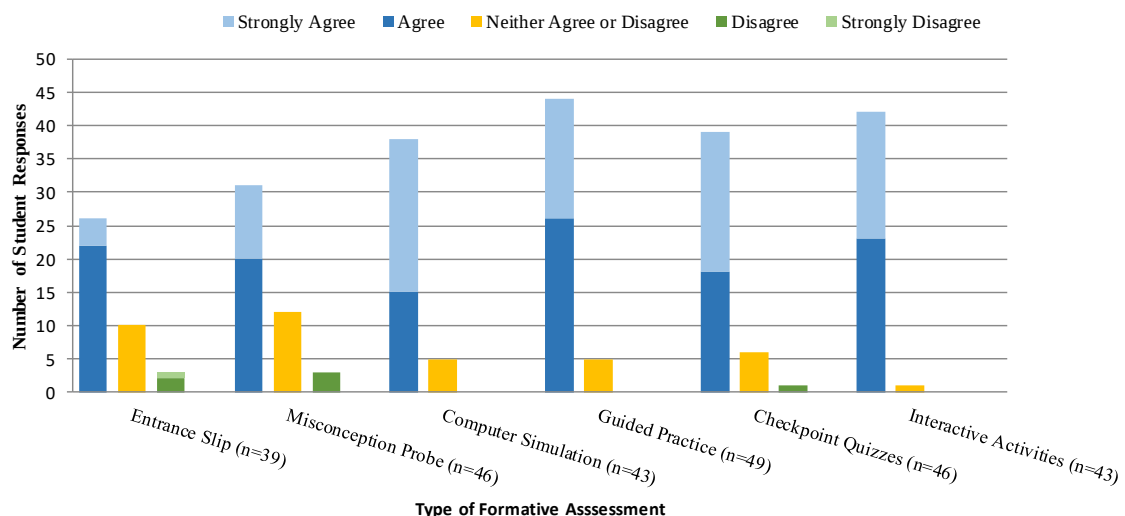


Figure 7. Post-task questionnaire— “I feel like this task helped me understand chemistry concepts better”.

An interesting result from this classroom research project was related to student attitudes towards entrance slips and misconception probes. With both of these formative assessments, students had a more indifferent attitude towards the impact on their conceptual understanding. For the Entrance Slips, 10 of 39 (25.6%) of students responded with Neither Agree or Disagree and 12 of 46 (26.1%) of students made the same response for the Misconception Probe. Both formative assessments also had the most responses of either Disagree or Strongly Disagree of all the different types of formative assessments. One possible explanation for these two formative assessments having more negative responses could be attributed to the fact that these assessments were used mostly for gathering feedback rather than helping with conceptual understanding. The other formative assessments were more connected to how students learned a given concept and they could see the results of their learning almost immediately.

The End of Treatment Summary questionnaire was administered at the end of the treatment period to collect student responses and feelings regarding how the use of different formative assessments may have impacted their engagement with learning chemistry, their overall belief about being successful in chemistry (self-efficacy) and how their overall learning may have improved. The guided practice, interactive activities, computer simulation and checkpoint quizzes had the most positive responses towards overall engagement in learning chemistry concepts (Figure 8).

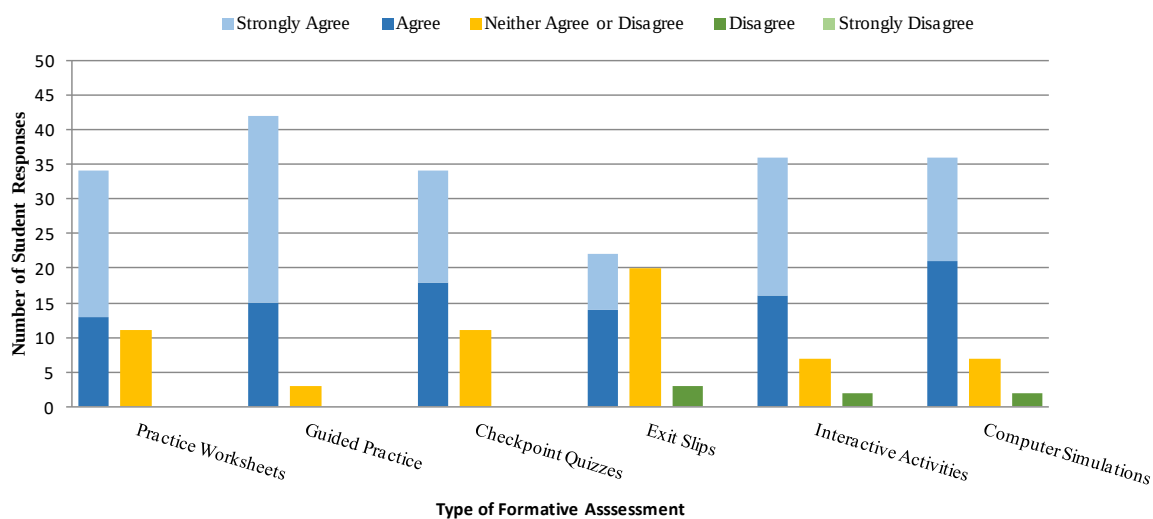


Figure 8. End of treatment survey—Engagement, ($n=45$).

The guided practice formative assessments seemed to be the most popular among students, with 42 of 45 (93.3%) students responding favorably with Strongly Agree or Agree. The least popular formative assessments seemed to be the practice worksheets (daily assignments) and the exit slips. Thirty-four of 45 students (75.5%) responded with Strongly Agree or Agree for the practice worksheets, while only 22 of 45 (48.9%) of students responded using the same indicators for exit slips. One student commented,

“Anything we did with practice worksheets or guided practice because I was interested in it and I was not scared to mess up because they were very forgiving.”

When students were asked to determine which type of formative assessment may have impacted their overall belief about being successful (self-efficacy) in chemistry during the treatment period, the guided practice, practice worksheets and checkpoint quizzes had the most impact (Figure 9). The guided practice formative assessment had the most positive responses, with 41 of 45 (91.1%) students selecting Strongly Agree or Agree. One student that selected Strongly Agree stated that the “Guided practice helped show me that if I do not understand something at first, it is not the end of the world.” The checkpoint quizzes were also very popular with student beliefs about being successful in chemistry, with 38 of 45 (84.4%) students selecting positive responses. One student stated that the checkpoint quizzes helped to improve their overall belief about being successful in chemistry because “...seeing that I did well on something makes me feel better about my performance.”

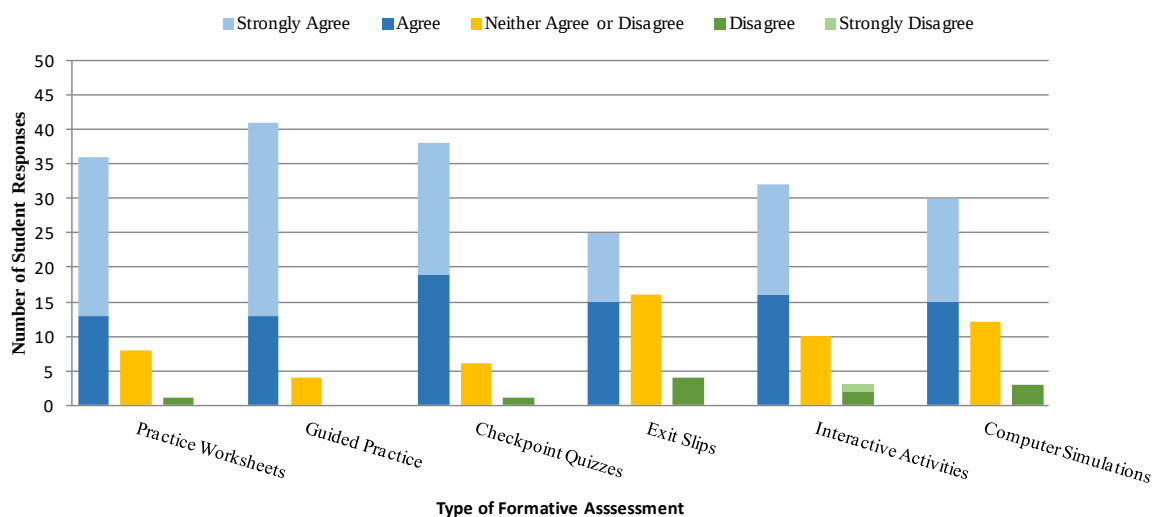


Figure 9. End of treatment survey—Self-efficacy, (n=45).

Student beliefs and attitudes towards the impact of formative assessments on their overall learning of key chemistry concepts were very favorable with most of the formative assessments (Figure 10). As with engagement and self-efficacy, student attitudes towards the guided practice, practice worksheets and checkpoint quizzes were all very positive. The guided practice formative assessment demonstrated the most impact, with 37 of 45 (82.2%) of students selecting Strongly Agree and 8 of 45 (17.8%) of students selecting Agree. This was the only formative assessment that students did not select any other response other than Strongly Agree or Agree. The practice worksheets and checkpoint quizzes were fairly similar to each other with 38 of 45 (84.4%) students selecting Strongly Agree or Agree for the practice worksheets and 39 of 45 (86.6%) students selecting the same responses for the checkpoint quizzes.

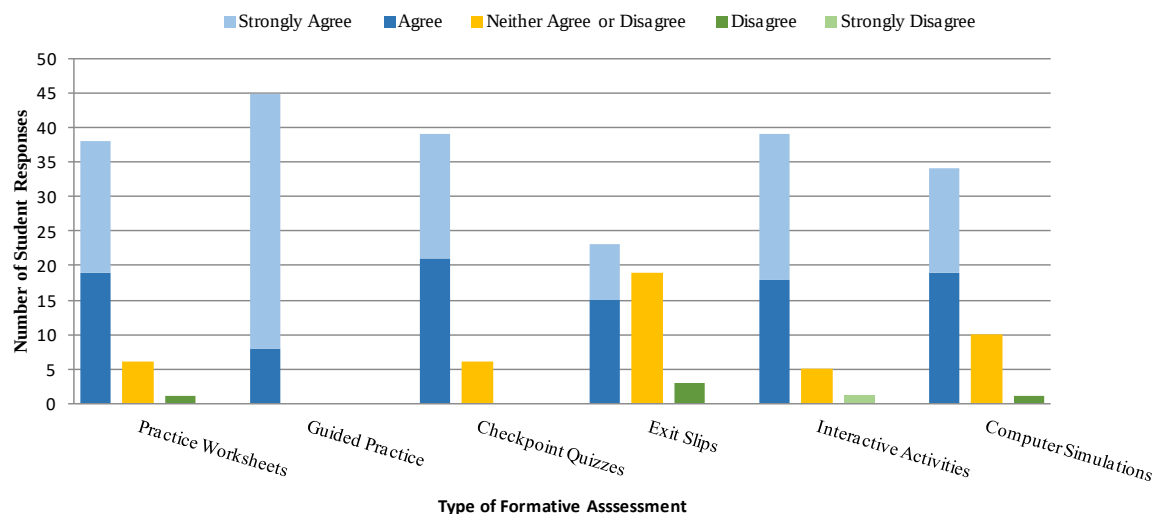


Figure 10. End of treatment survey —Overall learning, ($n=45$).

When analyzing student responses compared to the task or assignment that they felt helped to improve their overall learning of chemistry concepts, the guided practice formative assessments were by far the most popular with 22 of 45 (48.9%) stating that

this type of assessment helped them the most with their overall understanding of stoichiometry. One student commented that “The guided practices really helped, and I really like them. I would like to see more of these in the future!”

INTERPRETATION AND CONCLUSION

From the onset of this classroom research project, my main goal was to determine the impact that formative assessments might have on student engagement in the science classroom, as well as the impact on student motivation, self-efficacy and overall learning. From my previous experiences using formative assessments, I had a notion of how formative assessments might impact student learning. However, I did not truly realize the impact that assessing student learning during the process of actual learning could influence how students view their own beliefs of being successful in the chemistry classroom.

One key discovery that I made during this classroom research project was not only are formative assessments great instruments to measure student learning, but certain formative assessments are best used in certain learning situations. For example, I learned that the best time to use checkpoint quizzes was when students were learning more mathematical concepts that required demonstrating their understanding through showing their work rather than written responses. The feedback forms that were associated with these formative assessments were designed for students to self-assess their own work and then provide written feedback to the teacher. Checkpoint quizzes do not really work when the concepts are more abstract or require more critical thinking skills. Entrance slips/startup questions worked best to measure student learning either at the beginning or

the end of smaller conceptual units where students could provide feedback in a way that was more helpful for me to modify the learning targets for the next class period or how I might present new concepts. Guided practice formative assessments worked best when the concept was very procedural and could be presented in a very logical manner, rather than with concepts that required a written response. For example, these formative assessments worked best with the concepts of stoichiometry and limiting reagents because both concepts required building conversion tables, following a set path of conversions, and connecting answers from one question to the next question.

Based on data collected from the Student Engagement On-Task Log, it can be concluded that formative assessments do have an impact on overall student engagement in a chemistry classroom (Figure 6). However, there were a few variable aspects of these observations that need to be stated. For example, the time that a given observation was conducted could have impacted the total number of students that were engaged in a given activity. Since the observations only occurred in approximately five to ten minutes and at various times in a given class period, there could be some variability in the data since an observation may not have accurately represented how many students were or were not engaged at various times during the class period.

It should also be stated that the type of formative assessment clearly had an impact on overall student engagement. For example, formative assessments that were assigned a specific amount of time to complete showed a higher percentage of students engaged versus assessments that were more open-ended. Observations made when checkpoint quizzes and exit slips were administered to students with a pre-determined

amount of time to complete (i.e. 20 minutes of the class period remaining) showed that most, if not all students were actively engaged. For assessments or classroom activities that were permitted a more open timeline for completion or the time to complete these activities was not as structured demonstrated a lower percentage of students actively engaged. One exception to this is the guided practice formative assessment, where most students were observed as actively engaged during most of the class period. I feel that the guided practice formative assessments helped to engage students more during the learning experience because they were able to measure their level of success immediately while working on these assessments. One student commented that he liked the guided practice assessments because "...it instructed me step by step of how to get on the right track to solve each problem." Another student commented that they felt the guided practices helped him "...because I know how everything works after trying one. Plus, if needed, I can always look back at them to help me on other assignments."

With respect to the research sub question "How will the use of formative assessments improve student learning?", I feel that the use of formative assessments had a significant impact on student learning. Based on the results of the How I Learn Best questionnaire, there was a 15.6% increase of students who responded as Strongly Agree to the indicator regarding how receiving feedback on daily assignments or tests to improve their understanding (Figure 2). I believe that one of the reasons for this positive change in student attitudes can be linked to the use of student feedback to continually monitor and measure student learning throughout the treatment period. When provided opportunities to share thoughts or concerns, most students shared honest and thoughtful

feedback to provide me with the best information about how best to proceed during the next lesson.

One of the most beneficial formative assessments to measure the impact of student feedback were the checkpoint quizzes, where students were able to demonstrate their understanding of a given concept through self-assessment, providing feedback to the teacher and to receiving feedback back from the teacher all during the same class period or the next class period. It is important to note that measuring student learning for this research project was not necessarily using points or grades, but rather direct feedback from students. Measuring student learning from formative assessments was best measured using the five-point Likert-type scale on the feedback forms and the comments that students wrote regarding their current level of understanding. This measure of student learning can be best seen in Figure 5, where student learning for both balancing chemical equations and stoichiometry is measured at the beginning and end of learning these concepts. Analyzing how student attitudes changed over time provided the best measure of how a given formative assessment or activity helped students to learn the concepts better.

To measure the impact of formative assessments on helping to increase student self-efficacy, I utilized a combination of exit slips and informal conversations with students to determine how a given formative assessment might change a given student's belief of being successful in chemistry. The results from the Student Engagement Survey showed a positive change in student attitudes towards self-efficacy, with a 15.7% change in student attitudes from the beginning to the end of the treatment period (Figure 2). One

possible reason for this positive change in student attitudes could be due to students feeling like they had a vested interest in the learning process. The conceptual unit that was a part of this classroom research project can be very difficult for some students due to its complexity and overall connection to algebraic concepts, which can discourage some students from challenging themselves to be successful. To capture student thoughts during the moment of learning, open-ended questions on the exit slips asked students to share a “point of confusion” or how an activity or formative assessment may have helped their understanding that day. This feedback was then used as a conversation starter during the next class period where I was able to check in with individual students to address specific concerns or questions. These one-on-one conversations helped most students to not only increase their understanding of a given concept, but also helped me to modify and/or differentiate my lessons as needed based on direct feedback from students. With respect to self-efficacy, 38 of 45 (84.4%) of students either agreed or strongly agreed that getting individual help from the teacher will help them to be successful in chemistry based on responses on the End of Treatment Survey.

Observing and measuring student motivation using formative assessments was an important component of this classroom research project due to its direct connection to engagement, self-efficacy and overall learning. Throughout the treatment period, I discovered that measuring student motivation was rather challenging because it can be difficult to quantify what motivates a particular student. However, the Student Engagement Survey was used to gather information about indicators that students felt impacted their overall motivation in the classroom. As seen in Figure 1, student attitudes

regarding how they felt about working on assignments in class or how reviewing notes or other resources could help them understand concepts better increased from 44.2% ($n=52$) to 50.0% ($n=48$). Even though this was a small change in student attitudes towards their level of motivation, I feel that the use of varied formative assessments, feedback forms and informal conversations may have helped some students that did not have a high level of motivation see the importance of how remaining engaged in the learning process can have a positive impact on their understanding of chemistry concepts.

The last major aspect of this research project was to determine how the use of formative assessments could help me as the teacher to inform my instructional practices to increase student learning. I think that the most valuable aspect of this entire process was gathering feedback directly from students immediately after a given learning activity. I found this feedback to be invaluable as I was able to create new formative assessments to further student learning of chemistry concepts based directly on student comments and concerns. For example, the guided practice formative assessments were created based on direct feedback about the difficulties that students were having about learning how to complete a given conversion using stoichiometry (Appendix L). Student comments on exit slips like “I do not know where to put anything in the conversion table” or “How do I know when to use moles from the balanced equation” were essential in developing these formative assessments. I designed the guided practice formative assessments to provide opportunities for students to learn about the process with a lot of support structures in place, which were then slowly removed as students progressed further in the packet. After the completion of the first guided practice packet, student attitudes about

stoichiometry changed dramatically. One student commented that the guided practice “...taught me how to break down the steps to understand it better and is a really good reference sheet.” Another student commented, “It helped me understand it better because it would guide me through the steps”.

Overall, I feel that the use of formative assessments had a direct impact on my students’ overall level of engagement, motivation, self-efficacy and learning of chemistry concepts. I think that the use of varied formative assessments in correlation to collecting feedback about student feelings of conceptual understanding and beliefs of being successful were an important aspect of this classroom research study.

VALUE

One of my main goals as an educator is to create a learning environment where students feel safe to share their ideas by challenging themselves to learn new things and to remain engaged in the learning process. The results of this classroom research project really helped to support the idea that I can have a positive impact on student engagement and motivation in my classroom using formative assessments. I feel that the findings from this research project will have a great impact on my instructional practices moving forward as I look to increase the number and variety of formative assessments in my classroom to continue to positively impact student engagement and learning.

One major impact of this classroom research project was how my students responded to the implementation of formative assessments, as well as opportunities to be able to directly impact the learning process. Not only did students find the various types of formative assessments helpful, they also felt that the feedback that was generated from

these assessments supported their learning. Before this classroom research project, I never intentionally utilized student feedback to help impact both student learning and my own instructional practices. I had always believed in the importance of providing students with feedback on assignments and assessments for them to understand their learning of a given concept. However, the role of continuous and reciprocal feedback from my students through exit slips, formative assessment feedback forms and other activities truly had a positive impact on both how well my students were able to learn chemistry concepts as well as how I was able to modify my instructional practices to help my students be more successful.

Another impact of this classroom research project was learning how the use of formative assessments in the classroom can shift student attitudes about measuring their overall learning of a concept from one where students measured their learning based on points or a grade, to one where the emphasis of learning was attached to how student attitudes and feelings changed from one class period to the next. In today's world of education, there is an inherent emphasis placed on earning good grades and the connection to both overall learning and a belief of success. Throughout this action research process, I feel that I shifted one of my core educational philosophical practices to emphasize the importance of learning for the sake of learning, rather than learning to earn points or a letter grade. During the treatment period students still earned points on formative assessments or other assignments, however points were assigned based on the completion of the task rather than right or wrong answers. This philosophical shift was measured on the How I Learn Best questionnaire, where students were asked "I like

knowing daily assignments are graded based on how much I completed, rather than right or wrong answers.” At the beginning of the treatment period ($n=52$), 46.2% of students stated that they strongly agreed with this statement. At the end of the treatment period ($n=48$), 64.6% of students stated that they strongly agreed to this statement. Most students shifted their attitudes about earning grades on an assignment into the “strongly agree” category by the end of the treatment period.

From the onset of this classroom research project, I wanted to create a learning environment where students became active participants in the classroom and could have a positive impact on my instructional practice. The power that formative assessments have within the classroom is amazing to witness as students become actively engaged in the learning process, and in some cases become instructors for their peers as they can apply what they are learning to help classmates that may be struggling with a particular concept. Even though I have used formative assessments as a part of my lesson and unit plans since the beginning of my career 13 years ago, I feel that I now have a better understanding of the importance of implementing formative assessments and collecting feedback from my students to make impactful instructional decisions on a day-to-day basis. I also feel that the value of varied formative assessments and the impact that these activities can have on student engagement, motivation and overall learning in the science classroom cannot be overstated. I truly feel that this entire process has had a profound impact on my teaching career by changing the way I think about designing lessons and activities for my students to create new and exciting ways to learn about key scientific concepts.

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APPENDICES

APPENDIX A
MONTANA STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Ryan Wallace and Walt Woolbaugh

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

DATE: November 27, 2017

RE: "Investigating the Impact of Formative Assessments on student Engagement in a Secondary Science Classroom" [RW112717-EX]

The above research, described in your submission of November 21, 2017, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

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

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

APPENDIX B

HOW I LEARN BEST QUESTIONNAIRE

How I Learn Best Questionnaire

How often are the following statements true for you?

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
1) I feel that completing worksheet assignments help me to understand chemistry concepts better.	☐	☐	☐	☐	☐
2) I feel that I learn best when I know that I can retake a quiz/test.	☐	☐	☐	☐	☐
3) On tests, I feel that multiple choice questions are the best way for me to show my understanding.	☐	☐	☐	☐	☐
4) I feel like I would understand chemistry concepts better if I could provide feedback to my teacher on how he can help me understand a concept better.	☐	☐	☐	☐	☐
5) I like knowing daily assignments are graded based on how much I completed, rather than right or wrong answers.	☐	☐	☐	☐	☐
6) I like having smaller quizzes throughout a given unit so I can practice my understanding before a unit test.	☐	☐	☐	☐	☐
7) On quizzes/tests, I feel that calculation/short answer questions are the best way for me to show my understanding	☐	☐	☐	☐	☐

		Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree
8)	I feel that unit tests do not allow me to truly show my understanding about chemistry concepts.	☐	☐	☐	☐	☐
9)	I feel that I learn best when we take notes in class with PowerPoint.	☐	☐	☐	☐	☐
10)	I feel that I learn best when I am able to work in small groups so I can work with other people to solve problems.	☐	☐	☐	☐	☐
11)	I feel that I learn best when we have time in class to start an assignment and I can ask my teacher questions.	☐	☐	☐	☐	☐
12)	I feel like I learn better when my teacher provides me with feedback on assignments or quizzes/tests.	☐	☐	☐	☐	☐
13)	I feel that if I can ask questions directly to my teacher, I will understand what I am learning better.	☐	☐	☐	☐	☐
14)	I feel that if I have the opportunity to redo an assignment or test, I can demonstrate my understanding better.	☐	☐	☐	☐	☐
15)	I appreciate feedback on daily assignments or tests in order to improve my understanding	☐	☐	☐	☐	☐

APPENDIX C
STUDENT ENGAGEMENT SURVEY

Student Engagement Survey

How often are the following statements true for you?

	Always	Often	Sometimes	Seldom	Never
1) I ask questions in class when I am unsure of the answer.	☐	☐	☐	☐	☐
2) I work hard in this class even if I do not like what I am doing.	☐	☐	☐	☐	☐
3) I seek out solutions to a problem and explain them to others.	☐	☐	☐	☐	☐
4) When I do not know the answer, I seek alternative solutions to a problem.	☐	☐	☐	☐	☐
5) I accept that making mistakes is a part of the learning process.	☐	☐	☐	☐	☐
6) When I am absent from school, I am worried about keeping up with assignments that I missed.	☐	☐	☐	☐	☐
7) I feel that my grade on an assignment shows my true understanding of what I have learned.	☐	☐	☐	☐	☐
8) If I forget to do an assignment, I am OK with the grade that I earn.	☐	☐	☐	☐	☐
9) When I do not know the answer, I do not worry about finding the correct answer.	☐	☐	☐	☐	☐

How often are the following statements true for you?

	Always	Often	Sometimes	Seldom	Never
10) I know that if I study my notes/assignments, then I will be able to better learn the material in this course.	☐	☐	☐	☐	☐
11) When I take a test, I think about how poorly I am doing compared to other students.	☐	☐	☐	☐	☐
12) I believe that I can earn the best grade possible in this class because of my effort.	☐	☐	☐	☐	☐
13) In a class like this, I prefer to learn material that sparks my curiosity, even if it is difficult to learn.	☐	☐	☐	☐	☐
14) When I take tests, I think of the consequences of failing.	☐	☐	☐	☐	☐
15) I am confident that I can do well on assignments and tests in this class.	☐	☐	☐	☐	☐
16) If I don't understand what we are learning in class, it is not because I didn't try hard enough.	☐	☐	☐	☐	☐
17) Grades are the main motivating factor for me to do well in school.	☐	☐	☐	☐	☐

How often are the following statements true for you?

	Always	Often	Sometimes	Seldom	Never
18) When I earn a low grade on an assignment or test, I feel that I could have done better.	☐	☐	☐	☐	☐
19) During class time, I often miss important points because I am thinking of other things.	☐	☐	☐	☐	☐
20) Even if I have trouble learning the material in this class, I try to do the work on my own.	☐	☐	☐	☐	☐
21) I review my notes or other resources after class in order to gain a better understanding of the concept(s).	☐	☐	☐	☐	☐
22) If an assignment is difficult, I keep working at it until I can figure it out.	☐	☐	☐	☐	☐
23) When concepts get challenging, I either give up or only do the parts that I know.	☐	☐	☐	☐	☐
24) I only complete assignments when I know that it is helping me to earn a better grade.	☐	☐	☐	☐	☐
25) I work on assignments for this class because I know that they are helping me to understand the content better.	☐	☐	☐	☐	☐

APPENDIX D

END OF TREATMENT SUMMARY QUESTIONNAIRE

End of Treatment Questionnaire

Based on some of the activities/assignments/assessments that you have completed since the beginning of the semester (February and March—Chemical Reactions and Stoichiometry Unit), answer the follow statements/questions.

I feel that my <u>OVERALL LEARNING</u> about chemistry concepts has improved over the past two months by completing...					
<u>TASK/ACTIVITY</u>	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Lecture notes/in-class notes	☐	☐	☐	☐	☐
Practice worksheets (homework)	☐	☐	☐	☐	☐
Guided Practice worksheets	☐	☐	☐	☐	☐
Checkpoint Quizzes	☐	☐	☐	☐	☐
Exit Slips	☐	☐	☐	☐	☐
Interactive activities (like the “Who-Dunnit” activity)	☐	☐	☐	☐	☐
Computer activities/simulations (like the “Balancing Chemical Equations” Game)	☐	☐	☐	☐	☐
Having class time to work individually or in groups	☐	☐	☐	☐	☐
Getting individual help from the teacher	☐	☐	☐	☐	☐
Receiving feedback directly from the teacher	☐	☐	☐	☐	☐
Identify and explain one task/assignment that you feel has helped to improve your <u>overall learning</u> of chemistry concepts.					

I feel that my <u>ENGAGEMENT</u> about chemistry concepts both in and outside of class has improved over the past two months by completing...					
<u>TASK/ACTIVITY</u>	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Lecture notes/in-class notes	☐	☐	☐	☐	☐
Practice worksheets (homework)	☐	☐	☐	☐	☐
Guided Practice worksheets	☐	☐	☐	☐	☐
Checkpoint Quizzes	☐	☐	☐	☐	☐
Exit Slips	☐	☐	☐	☐	☐
Interactive activities (like the “Who-Dunnit” activity)	☐	☐	☐	☐	☐
Computer activities/simulations (like the “Balancing Chemical Equations” Game)	☐	☐	☐	☐	☐
Having class time to work individually or in groups	☐	☐	☐	☐	☐
Getting individual help from the teacher	☐	☐	☐	☐	☐
Receiving feedback directly from the teacher	☐	☐	☐	☐	☐
Identify and explain one task/assignment that you feel has helped to improve your <u>engagement</u> of learning chemistry concepts.					

I feel that my <u>OVERALL BELIEF ABOUT BEING SUCCESSFUL</u> in chemistry has improved over the past two months by completing...					
<u>TASK/ACTIVITY</u>	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Lecture notes/in-class notes	☐	☐	☐	☐	☐
Practice worksheets (homework)	☐	☐	☐	☐	☐
Guided Practice worksheets	☐	☐	☐	☐	☐
Checkpoint Quizzes	☐	☐	☐	☐	☐
Exit Slips	☐	☐	☐	☐	☐
Interactive activities (like the “Who-Dunnit” activity)	☐	☐	☐	☐	☐
Computer activities/simulations (like the “Balancing Chemical Equations” Game)	☐	☐	☐	☐	☐
Having class time to work individually or in groups	☐	☐	☐	☐	☐
Getting individual help from the teacher	☐	☐	☐	☐	☐
Receiving feedback directly from the teacher	☐	☐	☐	☐	☐
Identify and explain one task/assignment that you feel has helped to improve your <u>overall belief of being successful</u> in chemistry.					

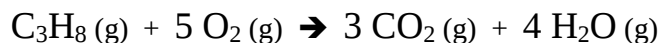
I feel that I will <u>CONTINUE TO BE SUCCESSFUL</u> in chemistry in the future because of...					
<u>TASK/ACTIVITY</u>	Strongly Disagree	Disagree	Neither Agree or Disagree	Agree	Strongly Agree
Lecture notes/in-class notes	☐	☐	☐	☐	☐
Practice worksheets (homework)	☐	☐	☐	☐	☐
Guided Practice worksheets	☐	☐	☐	☐	☐
Checkpoint Quizzes	☐	☐	☐	☐	☐
Exit Slips	☐	☐	☐	☐	☐
Interactive activities (like the “Who-Dunnit” activity)	☐	☐	☐	☐	☐
Computer activities/simulations (like the “Balancing Chemical Equations” Game)	☐	☐	☐	☐	☐
Having class time to work individually or in groups	☐	☐	☐	☐	☐
Getting individual help from the teacher	☐	☐	☐	☐	☐
Receiving feedback directly from the teacher	☐	☐	☐	☐	☐
Identify and explain one task/assignment that you feel will help you to continue to be successful in chemistry in the future.					

APPENDIX E
CHECKPOINT QUIZ EXAMPLE

Name: _____ Date: _____ Period: _____

Chapter 8-Checkpoint Quiz

Limiting Reagents 1



Use the balanced chemical equation above to answer the questions below...

If you start a reaction that involves **10.2 grams of C₃H₈** and **34.5 grams of oxygen gas (O₂)**...

1) **Which substance is the limiting reagent?**

				=
--	--	--	--	---

				=
--	--	--	--	---

Limiting Reagent: _____

2) How many **grams** of carbon dioxide (CO₂) will be produced in this reaction?

				= _____ g CO ₂
--	--	--	--	---------------------------

3) How much of the excess reagent (in grams) will be left unreacted?

Excess Reagent: _____ g

APPENDIX F

CHECKPOINT QUIZ FEEDBACK FORM

Checkpoint Quiz

Feedback Form

Question	Correct (all points)	Missed Points	Incorrect Process	Math error	Incorrect answer	Incorrect unit	Did not answer
1							
2							
3							

Reflection Questions:

- What is one thing that you totally feel confident about regarding the concept(s) on this Checkpoint Quiz? Why do you feel confident?
- Did you have any points of confusion with this concept? If so, what are they?
- Using the following scale, how would you rank your understanding of the concept(s)?
(circle only ONE choice)

1	2	3	4	5
I'm Really confused	I'm Somewhat confused	I'm Neutral	I increased my understanding	I totally get it!

Answer the following questions based on this Checkpoint Quiz activity using the following scale...**(circle only ONE choice)**

1	2	3	4	5
Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree

I feel that this Check for Understanding has helped me to understand the concept(s) that we are learning better.	1	2	3	4	5
I feel more confident about what I may have done wrong or missed after completing this Check for Understanding.	1	2	3	4	5
I feel more confident about answering similar questions on future assignments or tests.	1	2	3	4	5
I feel better about the concepts that were a part of this Chemistry Concept Check than before.	1	2	3	4	5

APPENDIX G
MISCONCEPTION PROBE

Name: _____ Date: _____ Period: _____

Misconception Probe

Understanding Chemical Reactions

You will complete this activity after watching a short video that demonstrates a basic chemical reaction with vinegar (acetic acid) and baking soda (sodium bicarbonate). You need to answer the questions below ON YOUR OWN.

- 1) After watching the video, select (circle) the statement below that BEST describes what you witnessed in the video...
 - A. The reason that the mass is different after the reaction than before the reaction is because some of the atoms were created in the chemical reaction.
 - B. The reason that the mass is different after the reaction than before the reaction is because some of the chemicals spilled out of the beaker during the reaction.
 - C. The reason that the mass is different after the reaction than before the reaction is because some of the atoms turned into a substance that is no longer in the beaker.
 - D. The reason that the mass is different after the reaction than before the reaction is because some of the atoms were destroyed in the chemical reaction.

- 2) State the **Law of Conservation of Mass** in your own words

- 3) Does this demonstration violate the Law of Conservation of Mass? Why or why not?

- 4) Provide a brief explanation why you think is the Law of Conservation of Mass important in chemistry?

APPENDIX H

ENTRANCE SLIP (STARTUP QUESTION)

Name: _____ Date: _____ Period: _____

Entrance Slip/Startup Question

A Reflection on Limiting Reagents

Take a moment to think about how your thinking/reasoning/understanding about **STOICHIOMETRY** has changed over the past few class periods.

What are <u>three</u> key ideas that I will remember?

What are <u>two</u> things that I am still struggling with?

What is <u>one</u> thing that I will help me prepare for the test?

Reflection Question:

Rank your feelings/understanding of stoichiometry based on...

- **When you first learned the concept...**

1	2	3	4	5
Really confused	Somewhat confused	Neutral	I kind of got it	I totally got it from Day 1!

- **Your feelings now...**

1	2	3	4	5
I'm Really confused	I'm still somewhat confused	I'm Neutral	I increased my understanding	I totally get it!

- Identify AND explain **one thing** that has really helped you understand **STOICHIOMETRY** better over the past few class periods?

APPENDIX I

EXIT SLIP—SAMPLE

Name: _____ Date: _____ Period: _____

Exit Slip—SAMPLE

- 1) Rank your feelings about **STOICHIOMETRY** as of TODAY...(CIRCLE ONE NUMBER)

1	2	3	4	5
I'm Really confused	I'm Somewhat confused	I'm Neutral	I increased my understanding	I totally get it!

- 2) Provide a brief explanation of your ranking above.
- 3) List and explain one “**point of confusion**” that you are having with **STOICHIOMETRY** after our lesson today?

APPENDIX J
POST-TASK QUESTIONNAIRE

Post-Task Questionnaire

Answer the following questions completing the task using the following scale...(circle only ONE choice)

	1	2	3	4	5
	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
I am satisfied with my performance on this task	1	2	3	4	5
I put a lot of effort into this task to demonstrate my understanding	1	2	3	4	5
I completed this task because I will receive a grade	1	2	3	4	5
I did not try very hard to do well on this task	1	2	3	4	5
I feel like this task helped me to understand chemistry concepts better	1	2	3	4	5
I prefer this kind of task because I feel like I learn better as compared to other types of tasks in the class	1	2	3	4	5
It is important to me that I do well on an task like this one	1	2	3	4	5
This type of task helps me to become a better learner	1	2	3	4	5
I still felt like I was not able to understand chemistry concepts any better after completing this task	1	2	3	4	5
I only tried hard on this task because it will potentially will have an impact on my grade	1	2	3	4	5
I would like to see other tasks like this one in the future	1	2	3	4	5

APPENDIX K
STUDENT ENGAGEMENT ON-TASK LOG

Student Engagement On-Task Log

Short Observation (5-10 minutes)

Each box below represents one student in the classroom. As you make your observations, spend no more than 10-20 seconds observing a given student. In one box, mark “E” for engaged or “NE” for not engaged. Continue observing as many students as possible during your observation period.

A student is considered to be “**engaged**” if they are participating in the classroom activity at the time (speaking, writing, listening, questioning, etc). You may also use the indicators on the back of this document to help you identify student engagement indicators.

A student is considered to be “**not engaged**” if they are doing anything beyond the scope of the given task.

At the conclusion of your observation, please return your form back to me.

TOTAL NUMBER OF STUDENTS: _____

D
o
o
r

Front Lab Table

W
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Additional Comments/Observations:

Indicators of Student Engagement

Positive Body Language—Students exhibit body posture that indicate that they are paying attention to the teacher and/or other students

Consistent Focus—All students are focused on the learning activity with minimum disruptions

Verbal Participation—Students express thoughtful ideas, reflective answers, and questions relevant or appropriate to learning

Student Confidence—Students exhibit confidence and can initiate and complete a task with limited coaching

Student Involvement—Students demonstrate a general interest in the activity and are on task

Overall Student Engagement—what is the general feeling of student engagement during the observation period

Questions to Help Guide Classroom Observations

- 1) During the lesson/activity, how do students interact with each other?
- 2) During the lesson/activity, how do students interact with the teacher?
- 3) What does the teacher do to keep students engaged during the lesson/activity?
- 4) What evidence can be seen that students are engaged in the lesson/activity?
- 5) What strategies could be used to increase student engagement during the lesson/activity?

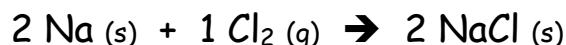
APPENDIX L
GUIDED PRACTICE—EXAMPLE

Name: _____ Date: _____ Period: _____

Guided Practice—Limiting Reagents 1

(Converting moles A → moles B)

1. Sodium chloride (NaCl) can be prepared by the reaction of sodium metal (Na) with chlorine gas (Cl₂).



In a lab experiment, you react 4.12 mol of sodium with 1.19 mol of chlorine. Using this information and the balanced chemical equation above, answer the following questions.

a. **WHAT IS THE LIMITING REAGENT?**

To determine the limiting reagent, you need to determine how much of each reactant you would need in order to run the reaction to completion (maximum amount of product). **TO DO THIS, YOU USE A CONVERSION TABLE AND STOICHIOMETRY FOR BOTH REACTANTS**

- i. Convert 4.12 mol Na to **moles Cl₂**.

Place the "given" here. Since you are starting with moles A, you only need to convert to moles B

4.12 mol Na		
	_____ mol Cl ₂	= _____ mol Cl ₂
	_____ mol Na	

Look at the balanced chemical equation...find the coefficient with Cl₂ and place it here.

Look at the balanced chemical equation...find the coefficient with Na and place it here.

If I **HAVE** (started with) 1.19 mol Cl₂, I will **NEED** _____ mol Cl₂

- ii. Convert 1.19 mol Cl₂ to **mol Na**.

1.19 mol Cl ₂		
	_____ mol Na	= _____ mol Na
	_____ mol Cl ₂	

If I **HAVE** (started with) 4.12 mol Na, I **NEED** _____ mol Na

Based on the answers to PART A...

- i. Which substance do you NEED more than what you HAVE (based on the original values in the problem)?

Na OR Cl₂

 (circle one)

- i. This substance is considered your LIMITING REAGENT...which is the substance that is going to determine how much of a given product you can produce

- ii. Which substance do you HAVE more than what you NEED (based on the original values in the problem)?

Na OR Cl₂

 (circle one)

- i. This substance is considered your EXCESS REAGENT...which is the substance that is going to determine how much of a given product you can produce

b. How many moles of sodium chloride (NaCl) will be produced?

- i. In order to do this, you need to start with the amount of limiting reagent that you HAVE (based on the original problem...not the amount that you determined in Step A)

Place the moles of the "limiting reagent" that you HAVE here*...

***NOTE**

This is NOT the amount of substance that you calculated in PART A. This value will ALWAYS be the amount of substance GIVEN IN THE PROBLEM

Look at the balanced chemical equation...find the coefficient with NaCl and place it here.

= _____ mol NaCl

Look at the balanced chemical equation...find the coefficient with the limiting reagent and place it here.

c. How much of the excess reagent will be unreacted?

- i. To do this, you need to find the amount of excess reagent that will be used in the reaction (SEE PART A).

i. Which substance is the excess reagent? **Na** or **Cl₂**

ii. How many moles of excess reagent did you calculate? _____ mol

iii. How many moles of excess reagent is there in the problem? _____ mol

- ii. Subtract the amount of excess reagent (from the problem) AND the amount of excess reagent used. Show this work here. This is the amount of excess reagent left over.

_____ mol - _____ mol = _____ mol
 ↑ ↑
 From problem... Calculated in
 PART A...

TOTAL AMOUNT OF
EXCESS REAGENT

2. Consider the following reaction:



In a chemical reaction, you react 3.22 moles of Al with 4.96 moles of HBr? Using this information and the balanced chemical equation above, answer the following questions.

a. **What is the limiting reactant?**

(Show BOTH conversion tables; mol Al $\rightarrow$ mol HBr AND mol HBr $\rightarrow$ mol Al)

3.22 mol Al	_____ mol HBr	= _____ mol HBr
	_____ mol Al	
4.96 mol HBr	_____ mol Al	= _____ mol Al
	_____ mol HBr	

Take a look at the conversion tables and answers that you just calculated above...

- I **HAVE** (started the reaction with) 3.22 mol Al...but I **NEED** _____ mol Al (ANSWER FROM PART A).
- I **HAVE** (started the reaction with) 4.96 mol HBr...but I **NEED** _____ mol HBr (ANSWER FROM PART A).

Based on the answers to the previous question, which substance do you **NEED** (based on your answers from PART A) **more** than what you **HAVE** (based on the original values in the problem)?

Al OR HBr

 (circle one)

b. **How many moles of H₂ gas will be produced?**

(Using the original AMOUNT OF LIMITING REAGENT (original amount in the problem...determine how many moles of hydrogen (H₂) gas will be produced.)

Place the moles of the "limiting reagent" that you HAVE here (from the original problem)...

Place the moles of hydrogen gas (H₂) from the balanced chemical equations here...

	_____ mol H ₂	= _____ mol H ₂

Place the moles of the "limiting reagent" from the balanced chemical equations here...

3. Consider the following reaction:



In a chemical reaction, you react 10.5 moles of methane (CH_4) with 14.0 moles of oxygen gas (O_2)?

a. What is the limiting reactant?

(Show BOTH conversion tables; mol $\text{CH}_4 \rightarrow$ mol O_2 AND mol $\text{O}_2 \rightarrow$ mol CH_4)

10.5 mol CH_4		=		mol O_2
14.0 mol O_2		=		mol CH_4

The limiting reagent in this reaction is... (substance ONLY...not amount in moles)

b. How many moles of H_2O will be produced?

(Using the original AMOUNT OF LIMITING REAGENT (original amount in the problem...determine how many moles of water (H_2O) gas will be produced.)

Place the moles of the "limiting reagent" that you HAVE here (from the original problem)...

Place the moles of hydrogen gas (H_2O) from the balanced chemical equations here...

c. How much of the excess reagent will be unreacted?

Place the moles of the "limiting reagent" from the balanced chemical equations here...

mol - mol = mol

From problem...

Calculated in
PART A...

TOTAL AMOUNT OF
EXCESS REAGENT