FORMATIVE ASSESSMENT EFFECT ON FRESHMEN HONORS SCIENCE STUDENTS

by

Stewart Preston Brody

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DEDICATION

I am dedicating this classroom research project to my family. They have been my best supporters during this process. A special dedication goes to my parents. Although they are not here to read my paper, I know they are smiling upon it.

ACKNOWLEDGEMENT

To all my peers I have worked with online and in person to successfully write and present my Capstone Project, I say thank you. To the students that have participated in the research for this project, I say thank you. To all my professors at Montana State University that have tirelessly aided my effort, I say thank you.

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ABSTRACT

High achieving high school freshmen are self-reliant to a fault. They do not communicate very well with their teachers. Methods of evaluation designed to open up lines of communication between the student and teacher were used during this research. These methods were different from standard high stakes exams or finals. This action research project studied the effects of formative assessments on the communication between student and teacher, student positivity, and student collaboration. Data collected indicated that communication levels between student and teacher were more open and at a higher level than previously observed. This led to higher achievement by the student because of a more relaxed and motivated class room environment. The students' collaboration skills were elevated via communication and positivity but the acceptance for continued collaboration waned in some students.

INTRODUCTION AND BACKGROUND

Teachers have long delivered lessons for students to learn and thus show mastery of standards set by schools, school districts, and both the state and federal departments of education. The purpose of those standards was to ensure mastery of a broad spectrum of concepts and skills that would ultimately culminate in success on high-stakes exams. Research has shown that when teachers use formative assessments and aid the students with detailed and sensible feedback, the students' educational accomplishments were superior. Students who were provided impactful feedback were enlightened to the purpose of formative assessments and became more self-reflective and self-reliant about their personal learning processes and education. Analyses and early studies have supported that using formative assessments had a large impact on students' achievements (Black & Wiliam, 1998).

Students placed into advanced or honors classes as freshmen typically wanted to show their teachers that they belonged in those high rigor classes. These students were traditionally quiet, respectful, and very hard working. Unfortunately, these students were also poor self-advocates, especially when they did not comprehend the concept being taught. Instead of asking a teacher for help or clarification, the students would gather in small groups physically or electronically to try to learn from one another. The idea of talking to a teacher about their lack of understanding in this high rigor class was a fearful one. The research was implemented and coincided with the start of a new semester and the topic of chemistry in the honors physical science curriculum.

The use of formative assessments on a regular basis should enable the teacher and student to work together to create an effective environment to achieve conceptual and skill-based mastery. The accomplishment of this would only come about if the student and teacher were effective communicators. Lines of communication should be open and constant with each side being exposed to suggestion and correction. They should be able to exchange information easily and readily. The information exchanged back and forth would help identify how and where a teacher needed to be a better educator as well as allow the student to know where they needed to improve their learning.

Teachers do not have absolute control over students' learning. Many teachers, including myself, have tried to motivate students to take control of their own education. The students' involvement and investment into their learning must be improved for students to achieve at a higher rate. Formative assessments have had positive effects on students' achievement in the past.

The high school where the classroom research project was conducted was Branson High School in Branson, Missouri. In the 2016-17 school year Branson High School had 1350 students enrolled. The demographics of the student body were: Asian 1.9%, Black 1.9%, Hispanic 10.3%, Native American 1.4%, Multi-Race 3.2%, Pacific Islander 0.3%, and Caucasian 80.9%. Students with free/reduced lunches was 50.3 %. The average classroom has a student teacher ratio of 17:1 (Missouri DESE, 2018).

The research was administered on a ninth grade honors physical science class. The class consisted of 28 students where 16 were female and 12 were male. The class consisted of two Hispanic students, one African-American student, and twenty five

Caucasian students. One student had modifications to their assignment's due dates because of a learning disability and two were in the school's gifted program. The curriculum covered for this study was an introduction to chemistry. Lessons centered around the atom, subatomic particles, atomic number, mass number, isotopes, allotropes, and atomic weight. Past classes with dynamics similar to this have been full of students with a high motivation to learn, high self-esteem, and high achievement. These students would often keep to themselves or work in small groups of friends. Their communication levels were low due to embarrassment at being incorrect or needing help. In my past experience, students thought they couldn't approach a teacher for help because they saw this as a weakness in their own character as a successful student. Students also thought that working collaboratively with a teacher might slow them down. To address these issues, the usage of formative assessments would have a positive effect on students' motivation to communicate, self-esteem, and achievement.

My experience with my classes this year led to the creation of my focus question: What are the effects of formative assessment on student/teacher communications? Additionally, the following sub-questions were addressed:

1. What are the effects of formative assessments on student positivity?
2. What are the effects of formative assessments on student collaboration?

CONCEPTUAL FRAMEWORK

Assessment is probably the most important thing we can do to help our students learn (Brown & Knight, 1994). A powerful tool used in today's classroom is the formative assessment. A formative assessment is diagnostic as it seeks to uncover both strengths and weaknesses in students' work (Freeman & Lewis, 1998). The simplest definition of formative assessment is that of an assessment which gives a student feedback that allows the student to improve their learning skills and allows a teacher to improve teacher practice. The purpose of a formative assessment is to provide teachers and students with feedback. The teachers can use the feedback to revise their classroom practices, and the students can use the feedback to monitor their own learning (Bell & Cowie, 2001). An example would be One-Minute Papers. One-minute papers are usually done at the end of the class. Students can work individually or in groups here. They must answer a brief question in writing. Typical questions posed by a teacher centers around the main point of the lesson, the most surprising concept of a lesson, questions not answered by the lessons instruction, the most confusing area of the concept taught, or a student's conjecture about a future question from the concept that might appear on a test. An innovative formative assessment strategy like this can take failure out of the classroom. Without formative assessments, the first indication that a student doesn't grasp the material is when they fail a quiz or a test (Beatty, 2009).

A well-designed formative assessment can have an impact on learning with gains of learning among the largest ever reported for educational interventions (Black & William, 1998). Providing chances for formative feedback via formative assessment may be the most advantageous process a teacher can provide for their students (Hounsell, McCune, Hounsell, & Litjens, 2008). Use of formative assessments and its goals as a classroom tool can lower the stress level of everyone involved and at the same time improve the classroom environment.

Formative feedback between the student and teacher focuses on the needs of the student and aligns the student's talents to be of better use immediately and in the future. Formative assessments may lead to more open and clearer lines of communication between the student and the teacher. The culmination of these three possibilities can lead to higher achievement by the student (Black & William, 1998).

The goal of formative assessment is a dedication to dialogue between teacher and student which allows the learner to grow. Teacher-student communication is vital. It is needed to understand each other through every step of learning to gain knowledge of each other and the concepts at hand (Beatty, 2009). Without communication from the teacher about an assignment, the student may not have the tools to satisfy the expectations placed on the assignment. Without communication from the student to the teacher, the teacher may not realize the misunderstandings of the students about the expectations of the assignment. Without communication after an assignment is finished, both the teacher and student will lose an opportunity to achieve a higher understanding of the concept taught. Students who participated in enhanced formative assessments became more self-critical and analytical, were helped in being more objective about their own work, and deemed it as a helpful learning process (Davies, 2003). Growth like Davies describes will be stunted if dialogue isn't used for the betterment of both the student and teacher when using a formative assessment.

The strictest definitions of formative assessment and its process varies widely. It is accurate to say that all forms of assessment can provide vital information, both formative functions and summative functions, to the teacher and student (Black & William, 1998). It is not enough for a teacher to merely assign work to students, grade said work, and provide comments on the work for students to learn. Students have to be able to judge their own quality of work and be able to control what they are doing while they are doing their work (Sadler, 1989). Therefore successful formative assessments might follow a pattern. The first part involves a teacher assisting students to have a true conception of what is expected for assignments. That is, explaining what counts as quality work (Nichol & Macfarlane, 2006).

Communication of assignment expectations is the first goal of a formative assessment. A teacher needs the most current and detailed information about students in order to start the learning process. This information should include but not be limited to prior knowledge, learning ability, and communication ability. This emphasis will be a significant function within assignments (Coffey, Hammer, Levin, & Grant, 2009). Insights through this process created by both the teacher and student can be utilized to create a better dialogue. When this information is processed, the teacher can facilitate learning because the student will understand an assignment's expectations. Knowledge is not passively transferred. It needs to be actively attained through environment and personal experience (Hori, 2011). Teacher communication of expectations with examples of quality work can facilitate this need. The teacher analyzes students during assignments, assessments and through a finished product in order to assess whether predetermined expectations were met or not. A successful learning environment utilizes continuous, detailed feedback from the teacher for the student to be guided by (Beatty & Gerace, 2009). A determination of success or future success can come at this time. Either determination of success needs to be communicated to the student.

Feedback is a review of students' work, constructed by the teacher to aid the analyzing and synthesizing of learning by the student. Feedback's goal is to improve future student performance (Rudolph, Simon, Raemer, & Eppich, 2008). The feedback must be clear to students and delivered when appropriate for students to improve. It should be written in a manner that the students can clearly digest its meaning and then implement into their own knowledge base (Nichol & Macfarlane, 2006). Proper feedback is essentially an attempt to extend and nurture a student's potential while improving an educator's teaching methods. This strategy can increase student learning but more importantly it can increase the student's self-reflection process. Self-reflection is central to a student trying to acclimate new information for further learning (Sadler, 1989).

Though formative assessments can be simplistic and easy to implement, a qualitative and beneficial feedback process is usually intricate and ornate when examined. Feedback elucidates the criteria and expected standards of a good student performance. Good feedback should show an understanding before, during, and after an assignment has been given.

Students often complain that they did not know what a teacher expected for an assignment. This is an initial phase of feedback from a student which a teacher can interpret. The teacher watches a student perform and critiques an assignment giving immediate or timely feedback for the student to take in (Freeman & Lewis, 1998). Through their initial portion of feedback, a teacher using formative assessments will recognize if the student had knowledge of the goal or standard being aimed for. The student will be initially advised by the teacher in a manner that is beneficial to the student (Bell & Cowie, 2001). Performance of a student who has little knowledge of the anticipated objectives will fall short of the performance levels desired. Initial feedback can close this performance gap.

Formative assessment is ideally separate from the rigors of grades. It should be given frequently and have lower risks than that of a grade. According to Rudolph (2008), this is another phase of feedback from a teacher. Feedback from the teacher to the student should be used to improve the current performance of the student. Formative assessment uses feedback as an evaluation of student performance midcourse for corrections (Scriven, 1967). Good feedback at this point provides chances to close the gap concerning current and preferred performance levels. At this point, feedback from the students aids the teacher to enhance their craft for future assignments and classes.

Feedback, from the teacher to the student, after an assignment is concluded is another phase to consider. Good feedback can help students evaluate what they thought, felt and did during the assignment to improve performance on future assignments. The purpose of this feedback, according to Beatty (2009), is to make students more aware of what is going on in the classroom and to make wiser choices about their learning. Feedback in this form may close the gap for an individual student’s work or the gap between lower achieving students and higher achieving students.

Each formative assessment needs independent closure. For this purpose a process called closing the loop needs to be in place for the assessment to work most effectively. Closing the loop refers to a process where revisions are made on the basis of qualitative and quantitative data gathered via formative assessment. It is a necessary and continuous dialogue between teacher and student. Closing the loop's intention is for a student and teacher to work together to adjust or adapt the student's learning process. Closing the loop is not necessarily a re-teaching of curriculum. It is a dialogue that aids the student to improve their understanding of the current concept and to help both the student and teacher to communicate more efficiently. Student analysis of closing the loop indicates it helps the student for future work. This analysis gives students a realization that their self-evaluation of their own work was too generous. Students felt the process gave themselves more personal reflection about their work (Davies, 2003). This closing the loop process puts the student at the center of learning and the focal point of the feedback process.

Direction and feedback given to students are the key measures of an effective teaching environment (Hounsell, McCune, Hounsell & Litjens, 2008). Well-designed formative assessments with good feedback and a constructive closing the loop can be tools in this environment. Formative assessments can help students become more self-critical and analytical about their work raising student learning and achievement higher. Formative assessments can help the teacher become a better teacher. The proper use of formative assessments can raise learning, rigor, and achievement to even higher levels. Formative assessments can open both the student and the teacher each to more dialogue between one another creating better communication for all. This can focus learning and achievement directly on the student.

Students whose relationships with teachers are characterized by emotional warmth, opportunity for independent decision-making, and instruction that is responsive to their learning needs develop a positive school identity and invest more in learning (Hughes, Luo, Kwok & Loyd, 2008). A classroom environment with such an arrangement could facilitate these characteristics. A classroom mastery goal structure which may achieve these is characterized by instructional practices that emphasize effort and improvement over correct answers, the development of competencies, and the student's intrinsic motivation. A student's relationship with the teacher may serve as a source of stress regulation, allowing the student to direct their energy toward engagement with tasks, peers, and teachers in the classroom (Hughes, 2012). Considerable evidence suggests that elementary and secondary students show the most positive motivation and learning patterns when their classroom settings emphasize mastery, understanding, and improving skills and knowledge (Meece, Anderman, & Anderman, 2006).

Recently, student engagement has been built around the hopeful goal of enhancing all students' abilities to learn how to learn or to become lifelong learners in a knowledge-based society (Gilbert, 2007). Student engagement has become both a strategic process for learning and an accountability outcome unto itself (Parsons & Taylor, 2011). The task of measuring engagement is a difficult because its definition for a teacher, an administrator, or an institution are varied from others. Literature does not agree upon a definition of what student engagement might be. Several types of engagement are noted – academic, cognitive, intellectual, institutional, emotional, behavioral, social, and psychological to name a few. These differences beg a number of questions. Must a learner function in all arenas of engagement for successful learning to take place? For example, some researchers studied students' need to "belong" to achieve high grades and graduate. But, must students belong to be academically successful; or, must they simply behave? Are high-achieving students who work but do not participate in extracurricular school events disengaged learners? (Harris, 2008). However it is defined, student engagement ultimately includes a clear and constant communication between student and teacher.

Undoubtedly, educators hope students are successful learners when they enter the classroom or that the students will become successful learners inside the teacher's classroom. Effective teaching is characterized by thoughtfully designing learning tasks with features such as a task requiring and instilling deep thinking, immersing students in disciplinary inquiry, connecting to the world outside the classroom, having intellectual rigor, and involving substantive conversation (Willms, Friesen, & Milton, 2009). Students today are intensely social and interactive learners. Those surveyed by Willms, Friesen, and Milton stated that they want to interact with people both within and beyond the classroom and school environment. Students want stronger relationships with teachers, with each other, and with their communities. They want their teachers to know them as people and how they learn. They want their teachers to take into account what they understand and what they misunderstand, and to use this knowledge as a starting place to guide their continued learning. Students want their teachers to establish learning environments that build interdependent relationships and that promote and create a strong culture of learning. Today's learners want to connect and communicate constantly and want an environment to support these connections (Willms & Flanagan, 2007).

METHODOLOGY

In my past experience, honors students' quietly accepted the lesson taught, worked independently and hard on their assignment, and then asked friends outside of class how to work or finish an assignment. These students were intelligent and motivated to succeed in the classroom but they felt they did not need the help of the teacher in order to do so. In my opinion, these freshmen were embarrassed to ask questions aloud in front of their peers. They felt they should know the particulars of each lesson just by writing notes or listening to lectures. Their past high-achieving success in a classroom led them to believe they did not need extra help understanding concepts. Any sign of weakness on their part would have proved to the teacher that the student did not belong in a high rigor environment. The study looked to open communication lines utilizing formative assessments and their feedback. The research methodology for this study received an exemption status from Montana State University's Institutional Review Board and a compliance for working with human subjects was maintained (Appendix A).

Content for this study consisted of introductory chemistry concepts. These concepts were centered on the atom. By the end of this chemistry unit, students were expected to be able to describe the structure of atoms, including the masses, electrical charges, and locations of protons, neutrons, and electrons. The students should be able to identify that protons determine an element's identity and with the use the periodic table identify differences between atoms of different elements. Students calculated the atomic number and mass number of individual atoms. Students created atom models using a Bohr template. Models informed students about the charges of each subatomic particle and the different characteristics individual atoms could have. They researched atoms by means of a virtual atom creator using the PhET website. Students utilized this free website using science simulations for teaching STEM topics, including physics, chemistry, and biology, from the University of Colorado Boulder (PhET, 2017). Students created atoms based on the number of protons, neutrons, and electrons listed. Students built and identified the atom. As students built a random atom, they discovered which subatomic particle determines the identity of the atom. Along with these assignments and concepts, isotopes and allotropes were discussed and identified.

The Capstone Project was initiated with a Student Attitude Survey that was implemented pre-treatment to evaluate several aspects of the students' mindset (Appendix B). This survey was a Likert survey where each student's response related to an attitude and was assessed or measured from a series of statements about situations, in terms of the extent in which they agree or disagree with them (N=27). Students were surveyed using a rating scale developed to measure their attitudes directly corresponding to the class in terms of the extent to which they agree with them, and so tapping into the cognitive and affective components of attitudes (Likert, 1932). The students could respond to each statement by marking their attitude as Strongly Disagree, Disagree, Agree, or Strongly Agree. Each response corresponded to the numbers 1, 2, 3, and 4 respectively for quantitative analysis. Data from questions where the student's attitude was measured against the negative of a question had attitudes reversed to fit the criteria and parameters set in the survey. The survey's questions were categorized into four themes and evaluated for a median response value, standard deviation, t-tested for significance, and placed into a histogram to further enhance the meaning of the students' collective attitudes. The categories were student positivity, working collaboratively, working alone, and communications. The survey posed six statements to measure student positivity. These statements attempted to find the students' collective attitudes towards science in their life, science as a class, and school in general. Four statements were implemented to assess student attitude towards working collaboratively with other students and with the teacher. Four statements were used to collect student perspectives on working alone. Three statements were utilized to gather the students' position on student/teacher communications. The Student Attitude Survey was again implemented post-treatment. The pre-treatment survey was on paper whereas the post-treatment survey was implemented via the internet. Pre-treatment and post-treatment survey data collected were analyzed using a t- test to calculate any significance in the students' responses and to determine any gains in positivity, working collaboratively, or communications.

Students who volunteered for this study took the Chemistry I Exam summative assessment both pre-treatment and post-treatment (Appendix C). The exam assessed the students' prior knowledge of atomic structure, atomic charge, subatomic particles, mass number, atomic number, isotopes and allotropes. The test consisted of 30 multiple choice questions that served as a standard for content mastery when utilized for a post-treatment test. Through the learning of the introductory chemistry's content taught, the students progression was analyzed for normalized gains in knowledge. Pre-test scores had no bearing on student's overall grade because each student earned only participation points for taking the assessment. The pre-test was again used as a section of the unit's final summative assessment and therefore used as a high stake tool each student's grade. The post-test was analyzed for normalized gains against the pre-test.

A daily journal was kept by the teacher about the students' attitudes, questions, and communications with the teacher (Appendix D). The attitudes were judged by the teacher through observation when lecturing and mentoring students via body language and dialogue. Questions asked by the students were recorded by the teacher. Notes were recorded as to the depth of questions and the occurrence of questions. Communications were summarized and recorded as to what was being said or written between student and teacher when using formative assessments. This included misconception probes described as a short, simple questionnaire given to students at the start of a course, or before the introduction of a new unit, lesson or topic (Appendix E). This probe was designed to uncover students' pre-conceptions. Minute papers tested how students were gaining knowledge, or not (Appendix F). The instructor ended class by asking students to write a brief response to the following questions: "What was the most important thing you learned during this class?" or "What important question remains unanswered?" Qualitative data were analyzed for commonality of responses among students or commonality of questions concerning content. The depth of questions and responses were noted on student papers. Teacher responses were to individuals unless a commonality of question was detected. Then a whole class discussion or small group discussion was led by the teacher to answer the common question.

Interviews were conducted pre-treatment and post-treatment to learn qualitative data about the students' attitudes towards communication between students and teachers, the motivation of the students in the science classroom and the values the students have about the class itself (Appendix G). This data was to supplement the analyzed data from Even though the participation was voluntary, students were chosen that had differing success within the study. Students were also chosen because of a change in attitude or no change. The teacher attempted to have interviews with as varied a group of individual students as possible but still wanted the students to be able to communicate freely and openly when interviewed. Students were interviewed individually in the classroom while the rest of the students were working loudly so to give the students' answers anonymity. Student answers from the interviews were analyzed for theme and similarity.

A triangulation matrix was utilized to better understand the qualitative data collected by matching questions with appropriate quantitative data (Table 1). It was implemented to validate any data found and to correspond any truths as reliable from the study. The matrix utilized multiple independent sources in the forms of the Student Attitude Survey for both pre- and post-treatment measuring student feelings and behaviors, teacher observations of student activities and communications written daily in a journal, post-treatment interviews of the students, and content assessment both pre- and post-treatment to measure the mastery of content.

Table 1.
Triangulation Matrix of Student/Teacher Communication

Research Question	Source #1	Source #2	Source #3	Source #4
1. Did the use of formative assessments improve student communication, teacher communication, and student/teacher communication?	Pre- and Post-Treatment Student Attitude Survey	Pre- and Post-Treatment Term 1 Chemistry Exam	Teacher Observation	Post-Treatment Interviews
2. Did the use of formative assessments improve student positivity toward science and school?	Pre- and Post-Treatment Student Attitude Survey	Pre- and Post-Treatment Term 1 Chemistry Exam	Teacher Observation	Post-Treatment Interviews
3. Did the use of formative assessments improve the collaborative nature of the students?	Pre- and Post-Treatment Student Attitude Survey	Pre- and Post-Treatment Term 1 Chemistry Exam	Teacher Observation	Post-Treatment Interviews

DATA ANALYSIS

The results of the Student Attitude Pre-Survey of student positivity towards science and school indicated that students' mean response was a 3.06 out of a possible four, which was positive towards agreeing with each statement with a standard deviation of 0.87. Eighty-two percent of the responses were agreeing or strongly agreeing that science and school are a positive for the students (Figure 1). Conversely, eighteen percent dissented by disagreeing or strongly disagreeing that science and school are positive.

Students surveyed were more positive for the individual statements "…science is important to life… and …I enjoy hearing the ideas of my peers in science class." Each statement had an average response of 3.25.

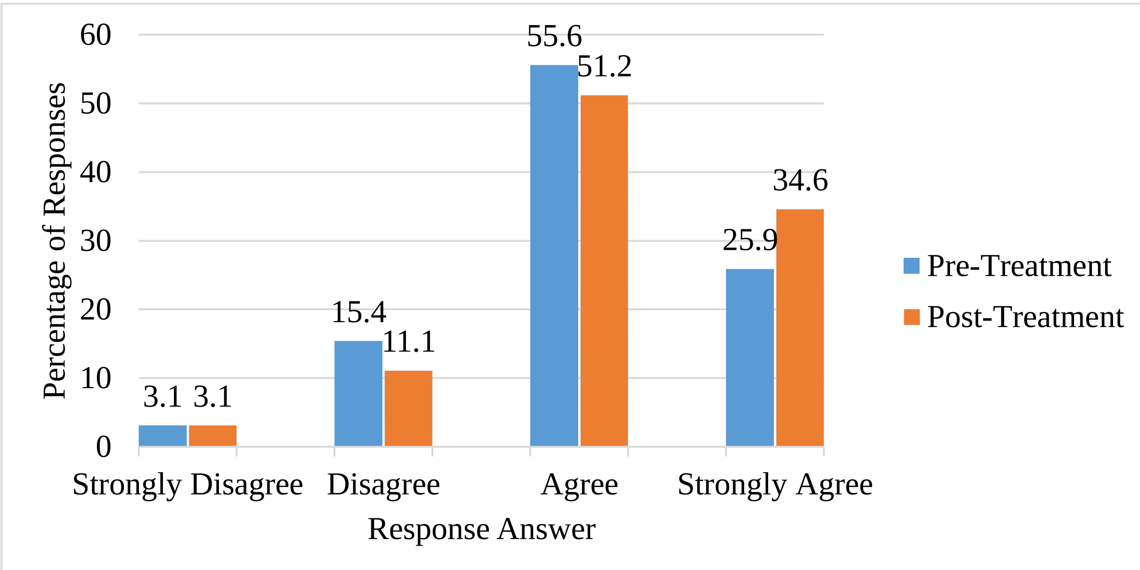

Figure 1. Student positivity towards science, science class, and school, (*N*=27).

Post-treatment results of the Student Attitude Survey indicated that positivity had increased by 5.3%. "Strongly agree" student responses increased by 33.3%, agree student responses decreased by 7.8%, disagree responses decreased by 28%, and strongly disagree responses had no change. This data had a median answer of 3.81 and a standard deviation of 0.40. Evaluation of a t-test calculation concluded no significance at the 95% confidence level.

The Attitude Survey employed four statements to measure students' perspective toward working collaboratively. These statements posed situations in the science classroom such as participating in discussions or going to the board to share answers with their peers. The average attitude for these statements was between disagreeing and agreeing at 2.40 with a standard deviation of 1.38 (Figure 2). The percentage of students dissenting to working collaboratively was 53% while in favor of working collaboratively was 47%. The standard deviation was large at 1.38 and the responses of the students were varied.

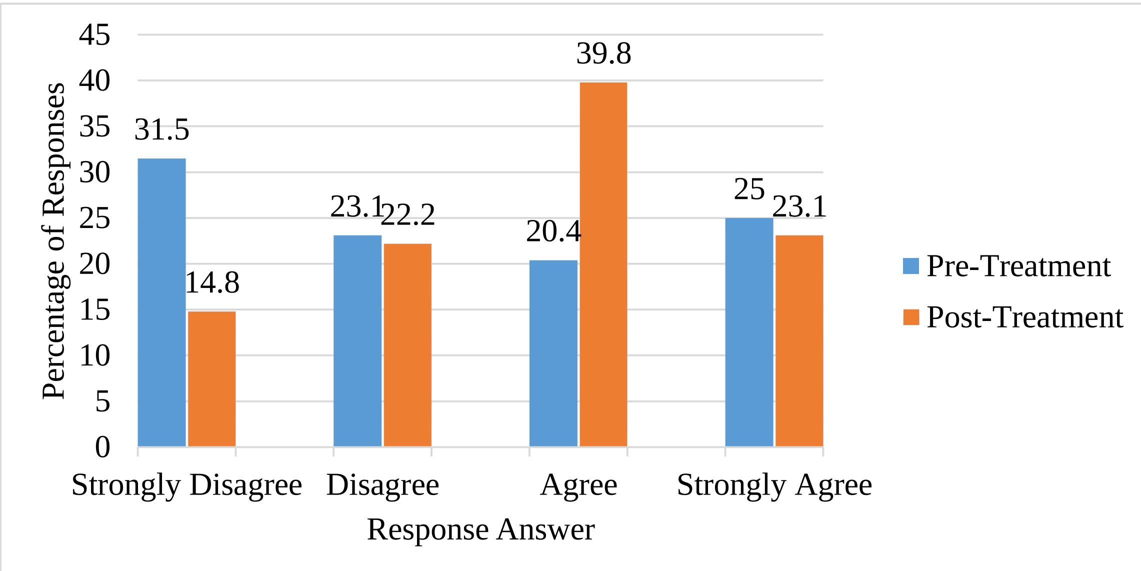

Figure 2. Student attitude toward working collaboratively, (*N*=27).

Post-treatment responses shifted to a more agreeing response. The average response to working collaboratively rose to 2.71 with a standard deviation of 0.98. Strongly disagree response dropped by 52.9% while the agree responses rose by 95.5%. Evaluation of a t-test calculation concluded significance at the 95% confidence level.

The survey utilized four statements the students responded to on the subject of working individually. These statements covered situations about working alone instead of in a group. The mean for these responses was 2.67 with a standard deviation of 1.04

(Figure 3). Fifty percent of the students' responses agreed or strongly agreed that they preferred working alone. The highest agreement that the students felt in this set of statements asked if they received good grades on science tests and quizzes. The statement had a mean of 2.75 and a standard deviation of 0.87.

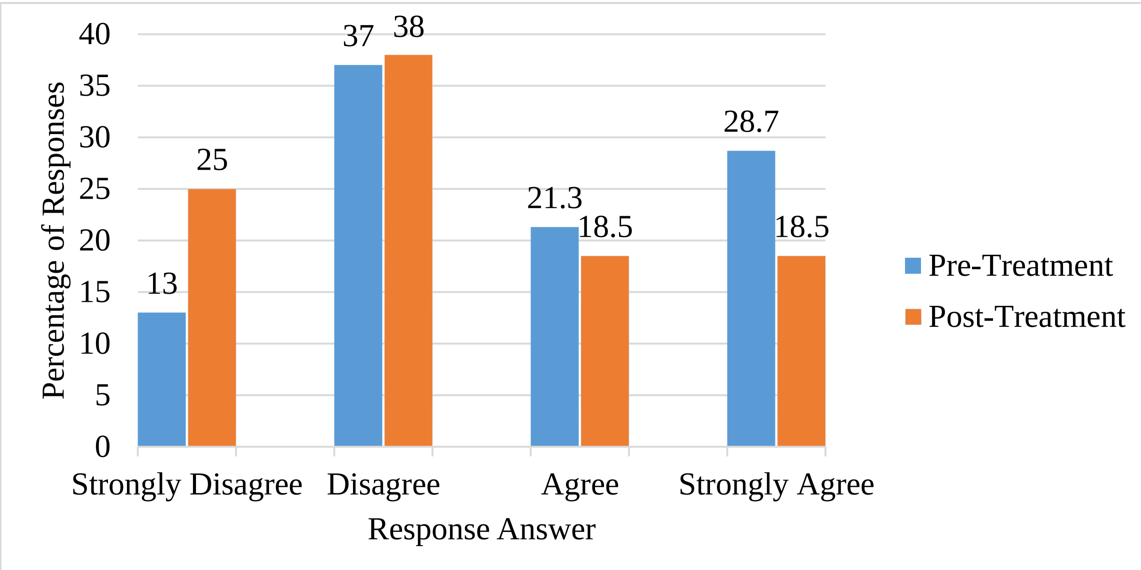

Figure 3. Students' attitude toward working privately, (*N*=27).

Post-treatment shifted away from working privately. Less than one third of the students responded to agreeing with working alone. Student responses of strongly agree decreased by 54.8%. Responses of strongly disagree rose by 92.9%. The average response was 2.17 with a standard deviation of 0.93 over this population of questions. Evaluation of a t-test calculation concluded significance at the 95% confidence level.

The survey employed three statements to measure the students' attitudes toward communicating with the teacher. The statements included words like dialogue and feedback with a teacher making science easier or better to understand. The mean of the students' responses to these statements was 3.56 with a standard deviation of 0.56 as seen in the Communications histogram (Figure 4). 100% of the students' responses agreed or strongly agreed that communications with a teacher were a positive. Statement (25), having the highest mean and lowest standard deviation, was a statement about enjoying notes from a teacher.

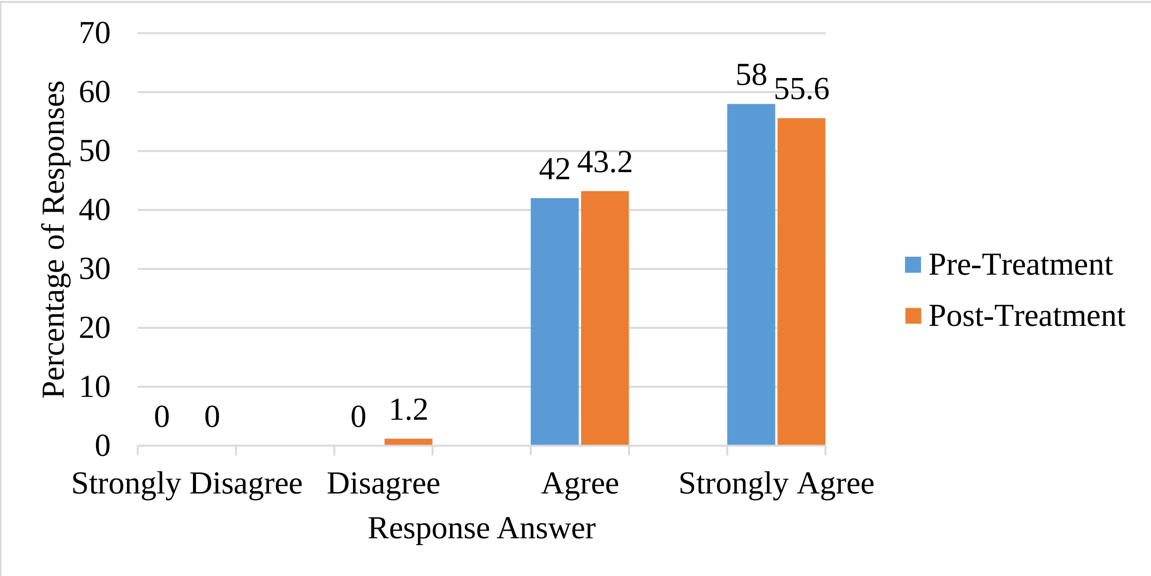

Figure 4. Student attitude towards student/teacher communication, (*N*=27).

The post-treatment survey responses were similar. Student responses were 98.8% positive towards communicating with the teacher. The average response value was 3.54 with a standard deviation of 0.54. One student did however disagree with the statement that dialogue with the teacher can make science easier to understand. Evaluation of a t-test calculation concluded no significance at the 95% confidence level (Appendix H).

Student prior knowledge of pre-treatment content had a median score of 40%. The high score was 73.3% and the low score was 16.7% (Figure 5). Just more than 11% of the students had a score of 60% or higher. Post-treatment content scores had a median of 93.3%. Students that scored more than 95% on the post-treatment portion was 40.7%. Calculation of normalized gain was 0.88.

A third tool utilized was pre-treatment and post-treatment student interviews given by the teacher. According to these students, pre-treatment communication about science was mainly with classmates or family. Post-treatment was mainly with the teacher. Pre-treatment communications skills with the teacher averaged a two out of five, where one is the best. Post-treatment averaged one and a half. The circumstances around the students' last communication for pre-treatment was for tests. Post-treatment circumstances were for homework or in class assignments. All interviewed students felt that better communication with the teacher would raise their current grade both pre- and post-treatment. Students felt their grade would be around 93% before treatment and 96% after treatment. Half of the students' proudest moments in science pre-treatment came before entering this class. Five of the six students' proudest moment came during treatment. More students preferred close supervision after treatment then before treatment. Their final thought for information they wanted to tell the teacher was to keep teaching in style the treatment created.

Classroom Assessment Technique (CAT) assessments in the form of minute papers captured a nearly 90% student understanding of the focus for the days lesson and its overall them. The misconception probe proved less unanimous at its onset. Forty-five percent of the students thought air was in between molecules of water. One student commented that "…air has to be between molecules. Something has to take up that space except electrons." Through small group discussion and a class discussion, it was decided by the students that if air was between water molecules, the air would bubble up and out of the water. Students immediately tested this theory with a glass of water and a plastic pipette. Air forced out of the pipette into the water bubbled out of the liquid. One student after this mini-experiment stated that nothing was proved. The student went on to say that until we can see a clear image of all an atoms subatomic particles, that we do not have 100% assurance that nothing is between molecules.

INTERPRETATION AND CONCLUSION

A comparison of the data collected from the pre- and post-treatment student surveys revealed three facets of the research: an increase in the students' positivity, an increase in student/teacher communication, and an ambivalence towards collaboration.

Student responses were overwhelmingly in agreement with the statements posed to them about their attitudes towards science and the science classroom. They agreed and strongly agreed that science was important in life, that they liked science, that they liked school, and that they were interested in science. Perhaps more importantly, the students felt less anxious in the science classroom after treatment. Although the t-test proved insignificance with the positivity responses, student responses for a more positive class and classroom grew.

Student pre-treatment responses to communication suggested they thought it was important. They agreed teachers listened to them, that a student/teacher dialogue could make science easier to understand, and that feedback from a teacher was a good thing. Post-treatment responses only reinforced this attitude. The t-test calculated no significant change in the students' attitude.

Students were more in agreement with working collaboratively after treatment then before treatment. This shift in attitude showed a 40% higher response to working collaboratively and a 31% lesser response to working alone.

The content assessment results marked a vast improvement by the students. The average score from pre- to post-treatment climbed 133% from 12 to 28. The first quartile rose 177% from 9 to 25. The third quartile rose 97% from 14.75 to 29. Only three students passed the pre-test but all of them passed the post-test. The students had their pre-test score held from them until after the post-test. Their candor in discussing what they missed originally and after treatment was refreshing. The students' incorrect answers were studied for any consistency in an effort to see if the teacher had overlooked content but none were found. Not only did the students perform at a higher level, they also finished their tests an average of 14 minutes faster. Students were able to finish their test more quickly, more confidently, and with fewer errors. Normalized gains were 0.89. This could be accounted for by the desire and ability of the students to learn and retain knowledge.

Student interviews were classified into two sections. The first half of the interview inquired about science classroom communications. Student responses shifted from communicating primarily through a friend or classmate to communicating more with the teacher. One student stated they asked questions about science class with their friends before the treatment. Now they ask the teacher first about class content. Students' self-rated communications skills went to a higher level. Student responses to their last communication with their science teacher changed from tests, which are weighted as 70% of their grade, to the assignments at hand (lab activities, homework, worksheets). One student stated "…if I'm going to get a good grade, I need to talk to you (teacher) more."

The students felt "good" during pre-treatment about their grade getting better with more student/teacher communication. After treatment, the students felt even stronger about this. "My A was so much easier to earn when I talked with my teacher." They went on to predict a grade of 93% before treatment and a grade of 96% after treatment. The last ten questions of the interview were an attempt to find student motivation. Their responses to their proudest moment went from past accomplishments to very recent within the timeframe of the treatment. Their initiative to correct mistakes rose. "You gave us the opportunity to correct our mistakes. I like that." All students stated they were more likely to correct something or someone after treatment. Five of the six students were less nervous or uncomfortable about having a teacher use closer supervision of their work. "When you work with us, it's like you're part of the team." Each student stated they did what they could to make their work correct by asking the teacher for further instruction, clues, or tutoring.

The teacher's daily journal included notes about which students asked questions, asked for help, gave further feedback to the teacher on assignments, or participated in discussions and formative assessments. In the beginning of the treatment, journal entries included only a few students that communicated with the teacher. Most of the students were steadfast in their attempt to do it all on their own or with a friend.

Within the first week of treatment, they started to get more involved in the process of feedback on formative assessments such as exit slips or minute papers at the end of class. The discussions started getting longer, broader in content, and with more student involvement. As the treatment came to a close, all students were involved in the feedback in one form or another. Some may not have enjoyed the treatment but when asked one-on-one with the teacher as a review, 100% of the students exclaimed they liked this style of teaching.

VALUE

If any form of feedback is good, then this was a great first attempt at action research. These very typical honors students came out of their shells and communicated via written notes on assignments, emails, asking questions, giving answers, and collaboration with other students. It was through their commitment to earn a better grade that they excelled at a higher level than they normally would have through their old style of learning.

The pre-treatment content test gave me a clear understanding of what prior knowledge students held. The tests' results channeled my teaching content to use teaching time more efficiently. I covered what they already knew more quickly and used that knowledge as a starting point to introduce new content. I used this concept each day as we moved through the entire unit.

Formative assessments, such as the water molecule misconception probe and minute papers, were more work for me but resulted in additional and deeper communication between student and teacher. The students that were hesitant to verbalize questions early in the treatment were directed to write them down for the teacher to read. Near the end of treatment, many students were more comfortable asking questions aloud. I received fewer written notes for me to answer. Students felt that talking with their peers collaboratively or with me allowed for a quicker turn around disseminating misconceptions or misinformation. This quickening made for faster resolutions to problems or concepts that were covered too fast for some students.

Although the students' survey responses indicated they agreed more with collaborative work than individual work, many spoke of getting tired of working at the same pace as others. Some students wanted to work ahead or to be challenged more intellectually. I gladly covered content outside of the unit at the end of a few classes. I assigned optional homework that I would only formatively grade. Students that worked these extra problems were some of the highest scoring students on the post-treatment content exam and some of the highest motivated to learn in the class.

This action research allowed me as a teacher to hear more students, more often as we jointly raised our communication levels in the science classroom. This higher level of communication resulted in more satisfied students. They were more satisfied in their preparedness for daily work, discussions, quizzes, and tests. Student satisfaction led directly to a more comfortable atmosphere in the classroom. The students were more relaxed about asking and answering questions posed by themselves or posed by the teacher. The students were more focused on learning because they knew that their questions about what they were learning would be answered. Their ability to communicate freely accelerated their recall to prior knowledge which led to higher scores and deeper understanding of the content taught.

A few comments from students during a discussion session after the treatment sums up what the students felt. "Even though the pace of the class seemed faster, learning about the atom with formative assessments was more fun than I had imagined it would be." Students felt they were "pushed harder" to learn. They said formative assessments made the information presented in class easier to retain. They liked this style of teaching better than any they had experienced before. They wanted me to "…teach with this style…" for the rest of the year.

The future of my teaching career will have formative assessments incorporated into all units of curriculum. The initiation of these assessments will be more up front work for me and I accept this. If the results of using formative assessment in the future come close to what I found in the research, then the work is worth it.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY RESEARCH EXEMPTION

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

MONTANA STATE UNIVERSITY

960 Technology Blvd. Room 127
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cherylj@montana.edu

Chair: Mark Quinn
406-994-4707
mquinn@montana.edu
Administrator:
Cheryl Johnson
406-994-4706
cherylj@montana.edu

MEMORANDUM

TO: Stewart Brody and John Graves

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

DATE: November 14, 2017

RE: *"The Effect of Formative Assessments Upon the Achievement of Student Learning Objectives in the Physical Science Classroom" [SB111417-EX]*

The above research, described in your submission of November 14, 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

CHEMITRY I EXAM

Chemistry I Exam

Multiple Choice
Identify the choice that best completes the statement or answers the question.

1. Atoms have no electric charge because they:
   a. have an equal number of charged and non-charged particles.
   b. have neutrons in their nuclei.
   c. have an equal number of electrons and protons.
   d. have an equal number of neutrons and protons.

2. A subatomic particle that has a negative charge is called a(n):

a.	molecule.	c.	element.
b.	electron.	d.	compound.

3. Which of the following statements is not true?
   a. Protons have a positive charge.
   b. A nucleus has a positive charge.
   c. Neutrons have no charge.
   d. Neutrons have a negative charge.

4. What is an atom's nucleus made of?

a.	protons and neutrons	c.	only neutrons
b.	only protons	d.	anodes

5. The charge of a neutral atom is:

a.	positive.	c.	negative.
b.	zero.	d.	unbalanced.

6. An iron atom has an atomic mass of 56. Its atomic number is 26. How many neutrons does the iron atom have?

a.	30	c.	26
b.	56	d.	82

7. How much effect do high percent abundance isotopes have on the average atomic mass of an element?

a.	less than low percentage isotopes	c.	same as low percentage isotopes
b.	no effect on atomic mass	d.	more than low percentage isotopes

8. An element's atomic number is equal to its number of:

a.	protons.	c.	valence electrons
b.	neutrons.	d.	protons and neutrons.

9. Two different isotopes of an element have different:

a.	numbers of neutrons.	c.	atomic numbers.
b.	numbers of protons.	d.	numbers of electrons.

10. What is the mass number of an element that has 19 protons, 19 electrons, and 20 neutrons?

a.	19	c.	39

b. 20 d. 58

11. Which statement about the atom's nucleus is correct?
    a. The nucleus is made of protons and neutrons and has a negative charge.
    b. The nucleus is made of protons and neutrons and has a positive charge.
    c. The nucleus is made of electrons and has a positive charge.
    d. The nucleus is made of electrons and has a negative charge.
12. Oxygen's atomic number is 8. This means that an oxygen atom has:
    a. eight neutrons in its nucleus.
    b. a total of eight protons and neutrons.
    c. eight protons in its nucleus.
    d. a total of eight neutrons and electrons.
13. Which statement about an element's average atomic mass is correct?
    a. It is determined by counting the number of isotopes in a sample of the element.
    b. It is equal to one-twelfth the mass of the most common isotope.
    c. It is a weighted average, so common isotopes have a greater effect than uncommon ones.
    d. It is based on an isotope's charge, so negatively charged isotopes have a greater effect than positive ones.
14. An atom's mass number equals the number of:
    a. protons plus the number of electrons.
    b. protons plus the number of neutrons.
    c. protons.
    d. neutrons.
15. An allotrope of carbon that is hard and is often used in jewelry is ____.
    a. diamond c. quartz
    b. graphite d. silicon
16. A Ca^{2+} ion differs from a Ca0 atom in that the Ca^{2+} ion has:
    a. more electrons c. fewer protons
    b. more protons d. fewer electrons
17. How many electrons does an element have with a mass number of 36?
    a. 36 c. 72
    b. 18 d. unknown
18. The nucleus of an atom consists of 7 protons and 6 neutrons. The name of this element is:
    a. carbon c. neon
    b. nitrogen d. aluminum

19. Atoms of $_{16}O$, $_{17}O$, and $_{18}O$ have the same number of:
    a. protons, but a different number of electrons
    b. electrons, but a different number of protons

c. protons, but a different number of neutrons
d. neutrons, but a different number of protons

20. All atoms of an element have the same:
a. number of neutrons c. atomic number
b. atomic mass d. mass number

21. The atomic number is always equal to the total number of:
a. neutrons in the nucleus
b. protons in the nucleus
c. neutrons plus protons in the atom
d. protons plus electrons in the atom

22. How many protons are in the nucleus of an atom of beryllium?
a. 2 c. 9
b. 4 d. 5

23. Which subatomic particle is negative?
a. proton c. electron
b. neutron d. nucleus

24. Which of the following particles has the least mass?
a. neutron c. electron
b. proton d. hydrogen nucleus

25. A sample of element X contains 90% X-35 atoms, 8.0% X-37 atoms, and 2.0% X-38 atoms. The average atomic mass will be closest to which value?
a. 35 c. 37
b. 36 d. 38

26. What is the total number of electrons in an Mg^{+2} ion?
a. 10 c. 2
b. 24 d. 12

27. The atomic mass of an element is defined as the weighted average mass of that element's:
a. naturally occurring isotopes
b. least abundant isotope
c. radioactive isotopes
d. most abundant isotope

28. Compared to the entire atom, the nucleus of the atom is:
a. smaller and contains most of the atom's mass
b. smaller and contains little of the atom's mass
c. larger and contains most of the atom's mass
d. larger and contains little of the atom's mass

29. What is the most likely nuclear charge in an atom of boron?
a. +11 c. +5
b. +6 d. +12

30. Which symbols represent atoms that are isotopes?

a. C-14 and N-14 b. I-131 and I-131

c. O-16 and O-18 d. Rn-222 and Ra-222

APPENDIX C

STUDENT ATTITUDE SURVEY

STUDENT ATTITUDE SURVEY
SUMMARY OF ITEMS AND ORDER

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

Please circle the appropriate responses based on the key below:

1 Strongly Disagree	2 Disagree	3 Agree	4Strongly Agree

1. I think science is important in life.	1	2	3	4
2. In middle school, my science teachers listened carefully to what I had to say.	1	2	3	4
3. I learn more about science working on my own.	1	2	3	4
4. I do not like to speak in public.	1	2	3	4
5. I prefer working alone rather than in groups when doing science.	1	2	3	4
6. I get anxious in school.	1	2	3	4
7. In middle school, I learned more from talking to my friends then from listening to my teacher.	1	2	3	4
8. Dialogue with my teacher can make science easier to understand.	1	2	3	4
9. Cell phones are an important technology in my life.	1	2	3	4
10. I like my own space outside school the majority of the time.	1	2	3	4
11. I enjoy being part of large groups outside school.	1	2	3	4
12. I do not participate in many group activities outside school.	1	2	3	4
13. I do not like school.	1	2	3	4
14. I like science.	1	2	3	4
15. I feel confident in my abilities to solve science problems.	1	2	3	4
16. In the past, I have not enjoyed science class.	1	2	3	4
17. I receive good grades on science tests and quizzes.	1	2	3	4
18. When I see a science problem, I am nervous.	1	2	3	4
19. I am not eager to participate in discussions that involve science.	1	2	3	4
20. I enjoy working in groups better than alone in science class.	1	2	3	4
21. I like to go to the board or share my answers with peers in science class.	1	2	3	4
22. I enjoy hearing the ideas of my peers in science class.	1	2	3	4
23. Science interests me.	1	2	3	4
24. I sometimes feel nervous talking out-loud in front of my classmates.	1	2	3	4
25. I enjoy notes from my science teacher about my work.	1	2	3	4
26. Feedback from my teacher has helped me to better understand science concepts.	1	2	3	4
27. I am not comfortable talking about my misconceptions in science class.	1	2	3	4

APPENDIX D

TEACHER'S DAILY JOURNAL

12/08/17 BRANSON HIGH BAHS-1718

12:07

Weeks of: 12/04/2017 and 12/11/2017

Page 2

BRANSON HIGH

HONORS PHYSICAL SCI H401205

BRODY, STEWART P 346 6

Board day 2/7

PT * 2/8

Review Day / Discuss

Quiz

Lab Behv

1/8/2018 1/15/2018

	Tue	Wed	Thu	Fri		Mon	Tue	Wed	Thu	Fri
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						*	*	*	✓	
			1	*						
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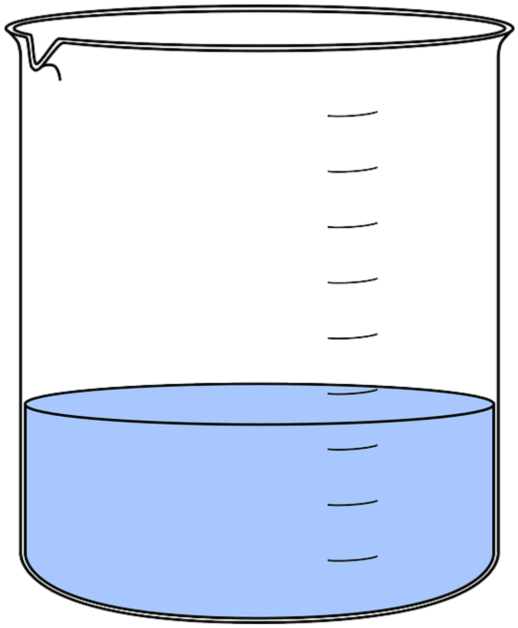
			11	*				*	✓	
				*	*	*		*	✓ *	
	*	*		*	*	*	*	*	✓	
				*	*	***				

* I like the notes on the rubric.
* Ask about 2 H or 2 C on WS - Intro to Isotopes without explaining
* Shrodinger Cay
* Ions?
* Connection to news paper isotopes
* Lab directions
* Calculate avg atomic mass
* why avg atomic mass is not whole
* man made elements whole #
* Valence

APPENDIX E

MISCONCEPTION PROBE

A single molecule of water has a chemical formula of H_2O.



In a beaker partially full of pure water, what is in between the individual molecules of water inside the beaker?

APPENDIX F

ONE-MINUTE PAPER

Example 1.

Summarize what you did today in class. Make sure you name the central concept, central topic, or central focus of today's lessons. If you have any questions, please write them down and I will answer them.

Example 2.

In concise, well-planned sentences, please answer the three questions below:
1. What are the two [three, four, five] most significant [central, useful, meaningful, surprising, disturbing] things you have learned during this session?

2. What question(s) remain uppermost in your mind?

3. Is there anything you did not understand?

APPENDIX G

STUDENT INTERVIEW QUESTIONS

STUDENT INTERVIEW QUESTIONS

Read to the student(s): **Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.**

The first five questions are about communication in the classroom. Please answer each question honestly and thoroughly.

1. Who do you communicate (talk, text, email, notes, etc.) with most often during any given week about your science class work?
2. Rate your communications skills with your science teacher with a score from one to five. One means you communicate very often or very clearly. Five means your never communicate or you don't understand each other.
3. Describe the circumstances surrounding your last communication with your science teacher?
4. Do you feel that better communication with your science teacher about science would raise your current grade?
5. What would your current science grade be if you had a better dialogue and communication with your science teacher?

MOTIVATION AND VALUES

A lot of seemingly random questions are actually attempts to learn more about what motivates you. Your response would ideally address this directly even if the question wasn't explicit about it.

6. Tell me about your proudest science class moment.

7. Describe a time when you saw some problem in the science class room and took the initiative to correct it rather than waiting for someone else to do it.
8. Tell me about a time when you worked under close teacher supervision or extremely loose teacher supervision. How did you handle that?
9. Give me an example of a time you were able to be creative with your science school work. What was exciting or difficult about it?
10. Tell me about a time you were dissatisfied in your work. What could have been done to make it better?
11. Is there anything else you want to tell me?