THE EFFECTS OF METACOGNITION AND STANDARDS-BASED GRADING ON STUDENT ACHIEVEMENT AND PERCEPTION IN HIGH SCHOOL CHEMISTRY

by

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ABSTRACT

In this study, students in a first-year high school chemistry class were introduced to assignments designed to increase metacognition. Students were also assessed using standards-based grades rather than a traditional system to better align course content to enhance metacognitive abilities. Student pre- and post-surveys, teacher and student reflections, and student interviews were used to analyze treatment. Results suggest that the majority of students experienced increased understanding of expectations, greater control over grades, and a stronger focus on learning.

INTRODUCTION AND BACKGROUND

Highland High School is part of the Gilbert Public School District and is located in Gilbert, AZ. Gilbert, with a population of roughly 240,000, is primarily Caucasian-American (83.7%). The largest minority group in Gilbert is the Hispanic population, which accounts for 16% of the overall population (US Census, 2016). Total enrollment for grades 9-12 hovers around 3,000 students. The student population is primarily white, with around 25% of the student population being identified as a minority and 15% of these identifying as Hispanic. Highland is one of seven high schools in the district (US News, 2018). At the time of the study, students at Highland High School consistently performed better on statewide assessments than the average student in Gilbert Schools and higher than the state average. Additionally, the graduation rate for Highland High School was higher than the district and state average (Arizona Department of Education, 2015). Teachers at Highland High School participated in weekly professional learning communities (PLC) each Wednesday. In the 2018-2019 school year, the focus of these meetings was to create a healthy practice of data cycles within common class teams. Included in this process, new in the 2018-2019 school year, was the requirement for common formative assessments among PLC teams.

As teachers, regardless of grade level or science content, we belabor assessments. Whether we are creating our own assessments, completing state assessments, or working in professional learning teams to create common assessments, we work hard to create artifacts that authentically measure students' knowledge and that reflect the focus of our instruction. Unfortunately, all too regularly, I have heard students express frustrations

when receiving assignment grades that are lower than they anticipated. They receive their paper and exclaim, "I thought I knew this stuff!" Admittedly, when I first started teaching, I chose to accept the easy explanation: students had not properly studied for the assessment. They had either not spent enough time studying or had studied the wrong material. However, often some of my best students were experiencing this same frustration. They simply did not know what they did not know. Nor did they know what was expected of them, or perhaps, the depth of knowledge that would be required on the assessment.

Quite often, after a moment of reviewing their assessment, the question that naturally follows is, "Is there something I can do about this grade? Can I do corrections or retake the test?" Grade replacement policies are challenging, as they are often heavily disputed and vary among teachers. Some teachers believe the objective of their classes is for the students to learn the material. Whether it be in the first week or the last, the learning is what is important. Other teachers want their students to be able to meet deadlines of learning to model performance deadlines needed for professions later in life. Often both teachers with and those without strict and arduous policies argue that extended deadlines or multiple attempts are not staples practiced in corporate America, nor in college. Some use personal workloads and stress factors to help manage creating these policies. In my experience, the expectations around these practices and policies vary dramatically between classrooms within the same school building, creating confusion among students and contention among staff members. The dilemma is finding a policy that honors learning as the priority for the student, while still maintaining a

manageable workload for teachers and fostering a healthy respect for deadlines from students.

The combination of these two experiences, an apparent lack of student metacognition and frustration with test corrections, led to my proposed research. I wondered if there was a way to modify classroom policies to remove these frustrations, for teacher and student alike, from my classroom. Upon reflection, frustration with test corrections seemed to be linked with students' lack of metacognitive skills. Students thought that they had prepared for the test, but they had not. My objective was to actively instruct students to think about their learning and thinking as part of the learning process in preparation for an assessment. This assessment may be as formal as a test or as informal as a group discussion about the content. I felt compelled to investigate if students would better achieve if they were intentionally and routinely directed to contemplate their own levels of learning.

Secondly, I wanted to find a way to remove corrections and retakes as structures in my classroom. Corrections and retakes create more work for me as the teacher. While some argue that it creates a better system to encourage students to view learning as a true process, it creates more opportunities for academic dishonesty and inhibits feedback reaching students in a timely manner. It is difficult to defend how the new score or corrections should affect a student's original numerical score. Some teachers completely supplant the grade with the new scores; some teachers average the scores; some teachers award partial credit for corrections. I felt that standards-based grading (SBG) had the potential to alleviate these concerns while enhancing student learning and reducing

teacher stress. It intentionally creates a system where students are assessed on a topic more than once and their current score in the class is modeled off their continuous demonstration of mastery of that skill or knowledge. Additionally, SBG aims to increase the clarity of expectations between all stakeholders, including parents and students by clearly articulating the relationship between the learning expectations and scores received. This, in turn, has the potential to provide another structured opportunity for students to practice metacognition with guidance.

These experiences have led to the focus question of my research: Will active instruction of metacognitive strategies, coupled with standards-based grading policies, enhance student achievement in chemistry classes and modify student perceptions of these strategies and practices?

CONCEPTUAL FRAMEWORK

Being aware of one's thinking - or metacognition - is not a new field of interest. The term was first coined by Flavell in the 1970s and has only grown as an area of interest (Flavell, 1979). As educators, we are often encouraged to be reflective in our practice to better understand how to serve our students. More recent research shows that teaching our students how to become more aware and how to evaluate their own thinking may be the best practice for educators to share with their students in order to assure student success in learning (Chekwa, McFadden, Divine, & Dorius, 2015; Schraw & Dennison, 1994; Ohtani & Hisasaka, 2017). Additionally, research shows that "metacognition is separable from other cognitive restraints on learning such as aptitude and domain knowledge and cannot be predicted entirely, or even with a moderate degree of accuracy,

on their basis" (Schraw & Dennison, 1994, p.461). This means this factor of student success is not predictable based on normal measures of student aptitude. Further, research articulates that while some educators know that it is a crucial skill for students to develop, it is most frequently implicitly taught rather than explicitly: the delivery method chosen for most content area specific information (Michalsky, 2017; Veenman, 2017; White, 2017). Often, after an assessment, students identify that they thought they understood the material. It was not until after the test or quiz that they realized they did not understand the material as expected by their teacher. Instructing students in using metacognition strategies may help to mitigate this experience, as students will have the training to plan and evaluate their own learning.

Metacognition is often broken down into three subcategories: planning, monitoring and evaluating. Ideally, students should actively participate in each category of metacognition as these categories are thought to be cyclical in nature; one leading to another (Favrieri 2013; Zepeda & Richey, 2015). Consequently, instruction in each of the three areas of metacognition should be included in the explicit instruction planned by teachers.

It is well-documented that individuals tend to be overconfident regarding their achievements (Miller & Geraci, 2011). As mentioned before, students are often surprised by low scores on assessments. There is a disconnect somewhere between an individual's thoughts in the planning phase of the metacognitive cycle and the actual evaluation of his or her performance. It has also been documented that there is a higher correlation between accurate predictions of performance and overall performance. This means

individuals who can accurately predict their performance tend to perform better than those who are unable to accurately predict their performance (Everson & Tobias, 1998). Unfortunately, research also shows that overconfidence produces underachievement (Dunlosky & Rawson, 2011). If students are unable to accurately predict their performance, they are more likely to do poorly on the assessment.

Ideally, with training in the planning phase of metacognition, students should be able to accurately predict their performance on an assessment. Miller's (2011) research provides evidence that student prediction calibration increased when the students were provided with feedback regarding their predictions. Additionally, this effect was found to be more robust with lower performing students. One limitation highlighted in this study was that though students' predictive accuracy increased, little improvement was made to their actual performance. This could mean that, in most cases, their predictions became more accurate because they lowered them to match their performance. Therefore, increases in prediction accuracy did not lead to an increase in proficiency as measured by the assessment. However, it could be argued that with instruction, increased prediction accuracy may lead to a greater opportunity to modify strategies implemented in the monitoring phase of metacognition, which could create further effects to achievement scores.

Schofield (2012) also addressed that often students are unaware of what they know and what they do not know. This reality indicates that students are not participating in metacognition. Schofield argues that teaching content is not enough, but that teachers must also enable their students to utilize strategies for accurately processing information.

To do so, teachers must first understand what metacognition is and the important role it plays in teaching and learning (Jiang, 2016). One strategy to teach metacognition Schofield highlighted was reflective journaling. Students recorded a brief summary of what was learned each day and the skills associated with that learning. Students in this study also participated in self and peer evaluations against a rubric as part of their instruction in metacognition. One student quote highlighted that peer evaluations without concrete expectations for the assignment result in little growth for either participant. The quote articulated that the student had to be aware not only of what they are learning, but also how it will be evaluated. In other words, the students needed to know, explicitly from the teacher, what learning outcomes were expected. Another strategy towards developing metacognition were exam wrappers in a study conducted by Soicher and Gurung (2017). The study was conducted based on previous research showing an increase in metacognitive skills when exam wrappers were used. The study was conducted with community college psychology students. The exam wrappers asked students to reflect on their exam performance after it had been graded and returned. A variety of questions were included to ask the students to reflect on their performance. Students were asked about how long and what they did to prepare. They were asked how their performance aligned with what they predicted and with previous performances in the class. The study showed no significant difference between those students who used the wrappers and those that did not. The researchers found it important to recognize that the wrappers were only used in one class and previous research had indicated they were more impactful when used in more than one class.

One large area of deficiency within this field of study is viable, valid tools to measure a student's metacognitive processes. Within the field, there are two large categories of tools utilized: online methods and offline methods. An online method measures metacognition while a task is being completed, where offline methods measure independently of a task or after a task (Michalsky, 2017). Veenman (2017) argues that offline methodologies offer little valid data. Validity issues highlighted in the research include the idea of memory bias in the participants, the proclivity of the nature of questioning to modify student self-reporting, and the closed-answer format utilized in many surveys. Additionally, studies have shown that there is little correlation between the results of one tool of measurement when compared to another. Favrieri (2013) further argues that there is not an instrument that has been developed and validated for the study of metacognition in mathematics, which will be a heavy content focus of this study. Regrettably, the online alternatives provided by Veenman (2017) are not viable in the traditional high school classroom, with the exception of the thinking aloud method, which is not viable for large sample sizes. Schraw and Dennison also highlight the impracticality of online methods in normal practice (1994). Despite the issues cited with offline tools, or perhaps because of the lack of viable online methods, a study by Michalsky (2017) of over 200 teachers from nearly 400 schools in Israel found that the majority of strategies used were indeed, offline methods.

It then follows that for students to be successful learners, not only do they need to be aware of their own learning through metacognition, but the assessments used to measure their learning need to be equitable. If a classroom's assessment strategy is inextricably

linked to the metacognitive practices utilized by teacher and student, all will be working towards a common, well-communicated goal. Regardless of the depth of a student's metacognition, if classroom assessments are not aligned with instructional focus or are systematically biased, student success, as indicated by assessment scores, will be systematically limited. An assessment has two crucial components. It must accurately measure what a student has learned and have a viable means to convey that information back to the student who took the test. This means that not only does the content of an assessment need to be critically evaluated, but the way an assessment is scored and communicated to all stake holders must be considered as well.

Educators have recognized issues with traditional grading systems and scales for over a century (Guskey, 2015). Before modifications to a grading system can be made, the purpose of grades must first be identified. Guskey identifies six major motivations behind reporting grades: to communicate student progress to stakeholders, to provide feedback for students' self-evaluations, to separate and identify students for certain pathways, to provide motivation for students to learn, to evaluate the effectiveness of school programs, and to provide evidence of student irresponsibility or lack of effort. Regardless of what a school or individual's motivation behind reporting grades is, Guskey argues that the traditional percentage grade, one grade per content is unfair.

His first argument stems from the statistical validity of the percentage grade. Starch and Elliot (1912) conducted a study in which English teachers were given the same assignment to grade within their content. Scores ranged by over 30 percent, with 15 percent of the teachers assigning a failing grade and 12 percent assigning a grade of

above 90, which would typically be recognized as an A. After criticism, Starch and Elliot repeated the study (1913) with geometry papers and the range of score increased to more than 60 points in variation. This study was repeated again nearly 100 years later. Brimi (2011) provided 20 hours of training to the teachers in his study prior to allowing them to grade the study paper. After receiving grades back from 73 of the teachers he trained, there was still more than a 40 point difference in score. These studies show that across different teachers, even with training, the reliability of grades on the 100-point scale is extraordinarily low.

A potential solution that Guskey (2015) highlights is to reduce the number of categories represented in a grading scale to a more manageable number. State assessments typically have four categories of performance: below basic, basic, proficient and advanced. The number of classification errors dramatically decreases when students can only be classified into four categories. This means that it is far less likely for a student to be classified as below basic when he or she is actually basic than it is for a student to be misclassified as writing a paper scored at a 79 when it is actually an 80. He boldly claims that the increased precision of percentage grading is more imaginary than real.

Additionally, Guskey discusses the imbalance in a traditional grading scale between the numbers of ways to fail compared to the number of ways of passing. He also discusses the tremendous power a single zero can have on a student's grade when an average of all grades is taken. Guskey advocates that multiple grades should be given in

each class to represent what the student has actually learned based on the content required in the class (Guskey, 2011; Guskey, 2015).

Standards-based grading (SBG) is an alternative grading system growing in popularity. The structure of SBG addresses many of the issues previously identified in traditional grading systems (Iamarino, 2014). In the design of SBG, students are measured on their current comprehension of clearly defined objectives in the class (Tomlinson & McTighe, 2006). A student's grade is calculated as a result of a student's most recent performance, rather than as an average of the student's performances. This creates a long-term approach to student learning rather than a limited, short-sighted approach (Iamarino, 2014). Iamarino also articulates that because more than one grade is assigned per class, communication with students and parents regarding student progress is more clear and effective.

In their 2017 study, Toledo and Dubas combined elements of SBG with Marzano's taxonomy and Nilson's specification grading to focus on grading for proficiency and providing multiple attempts at mastery. They defined their course content into 20 learning objectives for their students and assessed with the categories of Marzano's taxonomy: retrieval, comprehension, analysis and knowledge. Overall, they found that more students passed the class using the modified system. With the new system, fewer students earned an A, but nearly double the number of students earned a B and there were fewer students earning Ds and Fs. In perception surveys, some students articulated that they felt the new system was confusing, but others also recognized that they felt the focus was more on the process of learning rather than guessing correct answers.

Not all SBG studies have yielded favorable results. In a study done in the Midwest with two rural high schools, results indicated no GPA change and a negative trend in ACT scores for those in the new SBG system versus traditional grades (Townsley & Varga, 2018). The high school utilizing SBG used two years to transition to the new system and provided a full year of teacher training with supporting time to collaborate. The article articulates that students often 'play the game' of school as one way to interpret the lack of shift in GPA. The rules of the game were changed by the school, so the students adjusted their approach in response. No data were reported regarding students' opinions or feelings regarding the change. It is also worth noting that it is unclear how long after the implementation of the SBG system the data were collected.

In closing, research has shown that the ability to think about and regulate one's own thinking processes is crucial to learning. It follows then, that educators at all levels should work to foster this ability in students. It has also been shown that explicit instruction is necessary; being transparent with students about the process is not enough. Students need to be actively taught how to plan, regulate and evaluate their own thoughts. For some, this requires a shift away from the belief that the focus must be solely on content. It follows then, that the way student thought is assessed must be critically evaluated. If a student has enhanced his/her metacognitive abilities, but is still being graded with archaic grading practices, the marks will not reflect the new understanding. Research continues to show that SBG is a more equitable, learning focused grading system. It aligns student and teacher metacognitive practices and places the focus on learning the material rather than meeting a deadline. It also eradicates the need for

complex and varied test corrections or score recapture programs in the classroom. These researched and reported benefits have led to the development of the classroom research study.

METHODOLOGY

This classroom research was modeled after the action research design. A pilot study was conducted in October of 2018 and the main study was conducted starting in December 2018 and concluded in April 2019. Students in five different chemistry classes participated in the study. Three classes were general chemistry and two were honors chemistry classes. Participating students were freshmen, sophomores, juniors, and seniors, with large majority being sophomores. Approximately 140 students participated in the study. All classes received treatment. Effects of the study were measured using pre- and post-treatment data, classroom observations using the first quarter as a baseline, and student interviews. The Institutional Review Board deemed this research exempt from review (Appendix A).

There were two primary changes to the students' classroom experiences. The first primary change was to increase explicit instruction in metacognitive practices. Students were exposed to a greater number of metacognitive strategies and tools throughout the course including, but not limited to, concept mapping, summarizing, using One Pager assignments, using Ready to Test (RTT) surveys (Appendix B), and guided reflections. Student work samples from assignments targeting metacognition are available in Appendix C. Treatment effect was measured pre-treatment and post-treatment through the Metacognition Survey, a Likert survey (Appendix D). Survey responses were ranked

agree (4), *sometimes agre*e (3), *sometimes disagree* (2), and *disagree* (1). These questions were created based on my reflections from classroom observations and were taken from the General Metacognitive Strategies Inventory (GMSI) (Favieri, 2013).

This information was analyzed using Wilcoxon Signed Rank for changes in individual questions. Data from general chemistry was also compared to data gathered from honors classes to see if the class level had an impact on treatment effect. Additionally, students were interviewed prior to the start of treatment and at the end of the study. Interview questions (Appendix E) were utilized to measure students' thoughts and perceptions that may not have been measured with the Metacognition survey and as a way to verify the validity of the survey questions.

The second primary change was the replacement of the traditional grading system with a SBG practice. Standards were established prior to the unit of study and were shared with the students at the beginning of the unit. An example of a set of standards for a unit is included in Appendix F. These unit standards were created to appear similar in nature to the RTTs the students had seen previously. Each graded item in the class was linked to one or more standard. As the unit progressed, students received scores based on the standard being assessed, rather than based on compliance or completion. Standards were scored from 0-4. Table 1offers general descriptions for each score. Students' scores on the standard were re-evaluated each time the standard was assessed. Each standard was assessed, at minimum, twice during class time. Unlimited reassessment opportunities were granted to students outside of class time. This means, contrary to most traditional grading system with correction opportunities, a student's score on a

standard could increase and decrease throughout a semester. This created an accurate portrayal of a student's understanding, by standard, in a class at any given time.

Table 1
Score Descriptions

4	Exceeding Expectations: Student went above and beyond the expectations for a question or could explain the standard to someone else. Often including a connection to another topic, strict observation of significant figures and units, analogies, etc.
3	Meeting Expectations: Student has demonstrated mastery of the standard, but may have made errors regarding other standards not being assessed.
2	Approaching: Student shows some understanding of the question asked, but is making significant errors or has not completely solved the problem.
1	Getting Started: Student has demonstrated some prerequisite knowledge, but has not demonstrated significant knowledge on the standard being assessed.
0	Assignment not submitted or submitted blank, or standard not observed.

Because of district regulations, a traditional letter grade needed to be reported at intermittent check points throughout the semester and for the final grade. Table 2 articulates the guidelines that were used to convert the scores on each standard to a traditional letter grade, and the corresponding numerical value. These were determined at a meeting with my Principal, and the Directors of Curriculum, Technology, and Assessment for the district. Additionally, due to district regulations, I was not able to access the SBG portion of my district's gradebook. This necessitated either calculating each students' grades by hand or creating a secondary gradebook. I chose to create an Excel spreadsheet (Appendix G) that would convert from SBG to traditional grades based on the guidelines in Table 2. Students overall grades were manually updated each Friday in the district's official gradebook program.

Table 2
Grade Conversion Guidelines

		No score lower than...	At least...
A	98%	3.0	⅓ standards at a 4
B	88%	2.0	⅓ standards at a 3
C	78%	2.0	
D	68%	1.0	⅓ standards at a 2

The effects of SBG were analyzed using the SBG Survey (Appendix I). This survey was issued at the beginning and end of the study. Survey responses were ranked *agree* (4), *sometimes agre*e (3), *sometimes disagree* (2), and *disagree* (1). Analysis of the SBG Survey results were analyzed similarly to those of the Metacognition Survey. A Wilcoxon Signed Rank test was utilized for individual questions. Again, data from all general chemistry classes were compared to those from honors classes to see if there was a more robust effect for either level of class. Lastly, interviews, classroom observations, and conversations were used to best understand how students were interpreting the change in grading system.

Quiz correction data from the first two quarters were compared to the third and part of fourth quarter data to evaluate the effects of SBG. The number of students participating in voluntary, outside-of-class-time quiz corrections, was compared to the number of students who benefited from SBG. An analysis of the reported benefits and restraints of each system for both teacher and student was completed. Some of this analysis came from the student interviews, while others came from classroom discussion, and teacher reflection. At the end of the study, all data was analyzed collectively to

better understand treatment effects as indicated in the Data Triangulation Matrix (Table 3).

Table 3
Data Triangulation Matrix

Focus Question	Data Tools Utilized		
Will active instruction of metacognitive strategies change my students' perception and use of those techniques?	Metacognition Survey	Student Interviews and classroom discussions	Ready to Test surveys
Will active instruction of metacognitive strategies change my students' achievement in chemistry?	Metacognition Survey	Student Interviews and classroom discussions	Ready to Test surveys
Will SBG enhance student achievement in chemistry?	Standards-Based Grading Survey	Student Interviews and classroom discussions	Classroom data on student grades
Will SBG change how students perceive and use grades in chemistry?	Standards-Based Grading Survey	Student Interviews and classroom discussions	Classroom data on student grades

DATA AND ANALYSIS

Data was collected from students prior to treatment in the form of two Likert surveys. These surveys were issued using Google forms. These surveys were used to determine students' current practices in metacognition and their general attitudes towards grades in their chemistry classes.

The Metacognition Survey (Appendix D) was issued to five first-year chemistry classes: two honors chemistry classes (N=60) and three general, on level classes (N=72) as part of a pilot study. The survey was designed to illustrate students' current metacognitive practices. Honors students completed the survey on, or near, November 1, 2018. Five of these honors students articulated, in the free response section, some sort of deficiency in their current study system. One was able to articulate that when a concept

was difficult, he only focuses on studying that concept, rather than reviewing other concepts. One was able to articulate that "I might need help studying, like not a tutor, but help getting on the right track towards better study habits and work ethic."

For the Metacognition Survey, the ideal response for each question was *Agree*. This would mean that students were always engaging in a variety of different metacognitive strategies. Honors student responses were summarized below in Figure 1. Based on initial results, honors students overall agreed most with "I am confident I can learn this content." My honors students disagreed most often with "I summarize what I've learned after I finish." In fact, this was the only prompt that more than 50% of students disagreed with in some fashion.

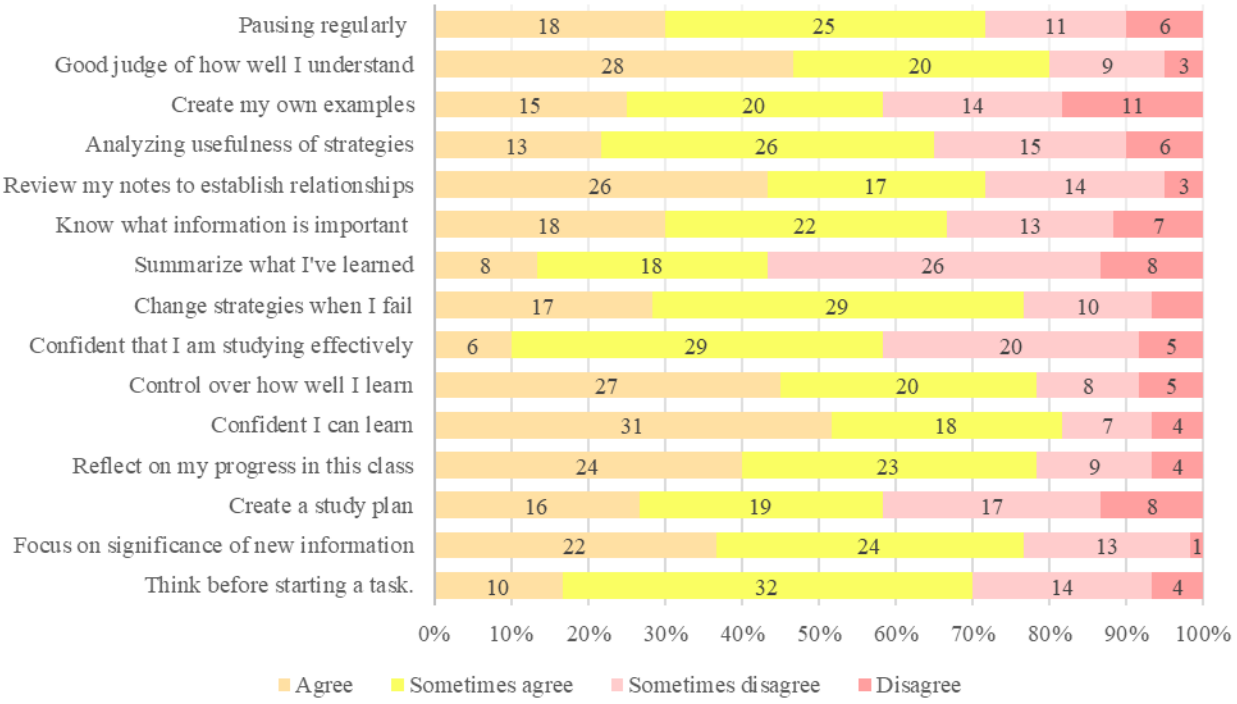


Figure 1. Metacognition Survey pre-treatment data from honors chemistry, (*N*=60).

After the question probing confidence, questions regarding making a study plan, confidence in study strategies and creating novel examples to make information more meaningful were equally ranked among students with 58% of students agreeing. This information identifies that although only five students explored their study strategies in the free response question, many more students identified they needed assistance with study strategies.

General student responses are summarized below in Figure 2. General students completed the survey on, or near, January 7, 2019. My general students, overall felt most confident with the statement "I have control over how well I learn." Similar to my honors students, they disagreed with "I summarize what I've learned after I finish." In the free response section, one student admitted that he had never even thought of some of the strategies listed on the survey. Another student identified that she often feels unsure about what material will be on the test and thus inefficiently uses her study time.

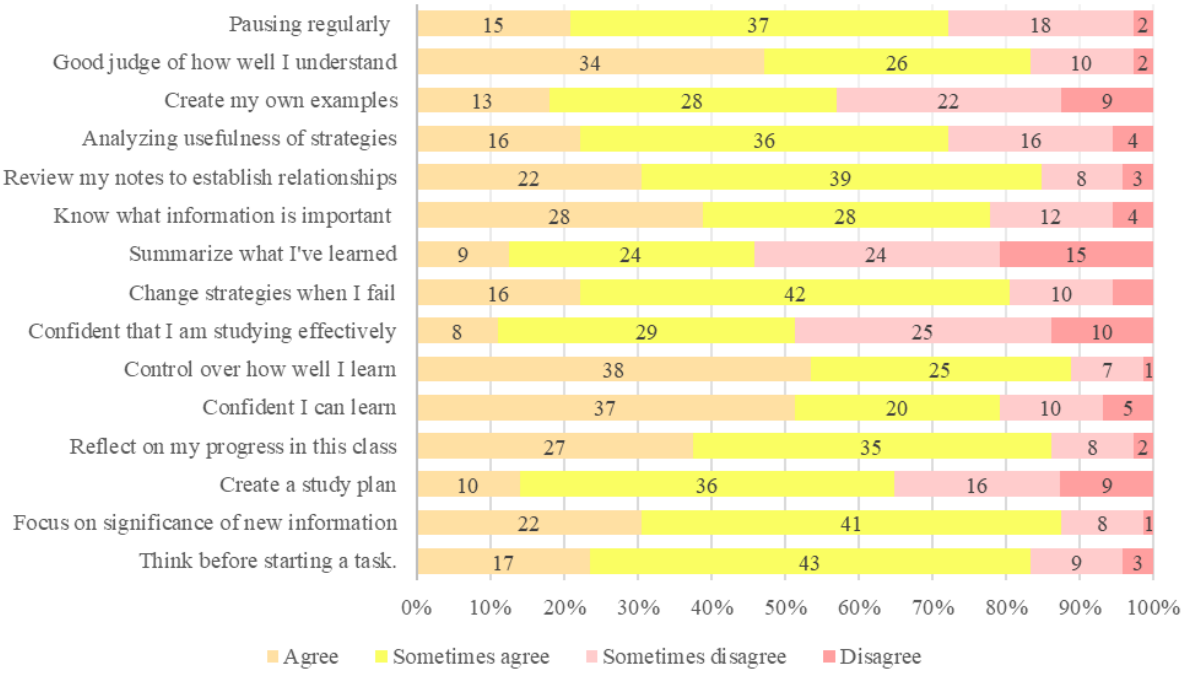


Figure 2. Metacognition Survey pre-treatment data from general chemistry, (*N*=72).

When comparing responses from general and honors students, the general shape of the responses recorded is largely similar. Questions 6 (I have control over how well I learn), 10 (I know what information is important to learn) and 11 (I review my notes to help me understand important relationships between topics) differ most dramatically between my honors and general students. My general students reported feeling greater degrees of control over how well they learn, knowing what kinds of information is important to learn, and that they review their notes to find meaningful connections between topics. Disaggregated data closely resembled overall distributions in aggregate data.

The second Likert survey that was issued was the Standards-Based Grading Survey (Appendix H). This survey was given to the two honors classes (*N*=60) and three general classes (*N*=76). All students completed this survey on, or near, October 31, 2018

in a pilot study. It should be noted, for questions 7 (I feel like my grade discourages my learning), 9 (I find quiz retakes frustrating), and 10 (I often feel like I learn the material after the test/quiz), *disagree*, was considered an ideal score, contrary to the rest of the survey. Largely, the distributions for the two levels were similar when disaggregated.

Disaggregated data, based on class level, may be found in Figures 3 and 4. Regardless of class, students deviated farthest from the ideal score when asked about learning the material after the assessment. This indicated that students often felt like content knowledge was solidified after a test or quiz was given. Additionally, regardless of level, question five and eight are the closest to ideal score, indicating that students believed their grades to be fair in their chemistry class and that quiz corrections were valued as a learning experience. There were two glaring inconsistencies between honors and general chemistry students' distributions: questions six and seven. Student responses indicated that general chemistry students did not feel encouraged by their grades and felt like their grade discouraged their learning more often than their honors level peers.

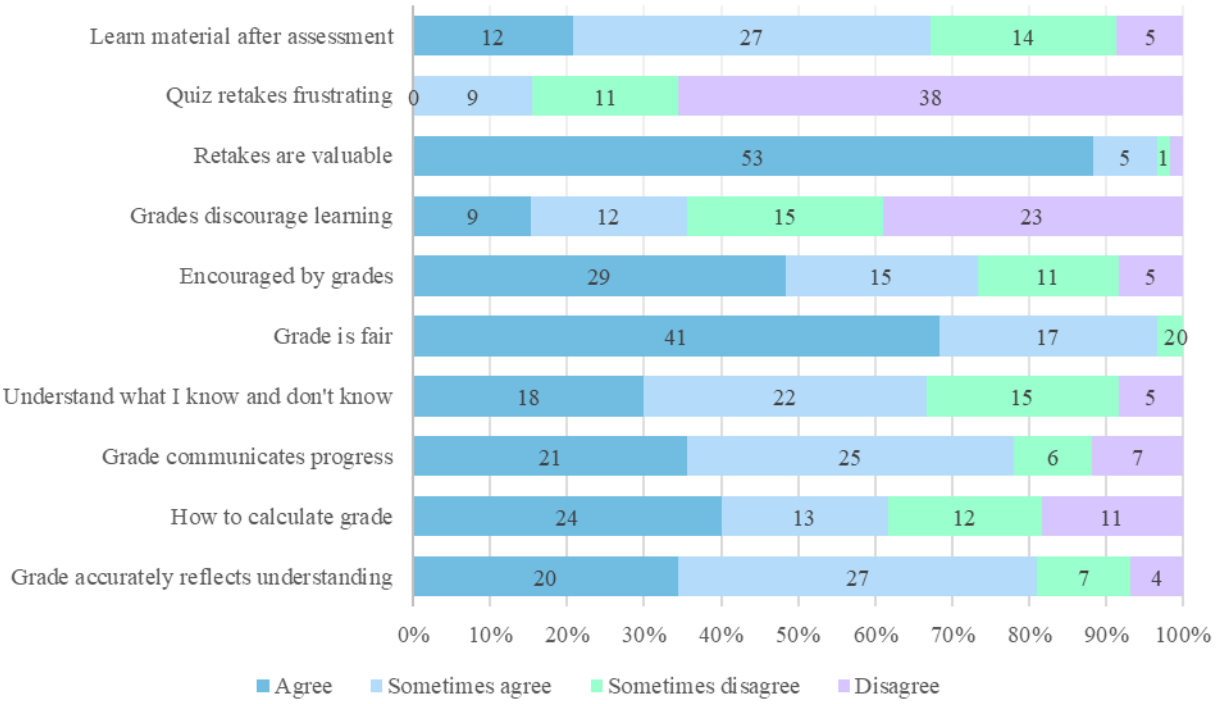


Figure 3. Standards-Based Grading Survey pre-treatment data from honors chemistry, (*N*=60).

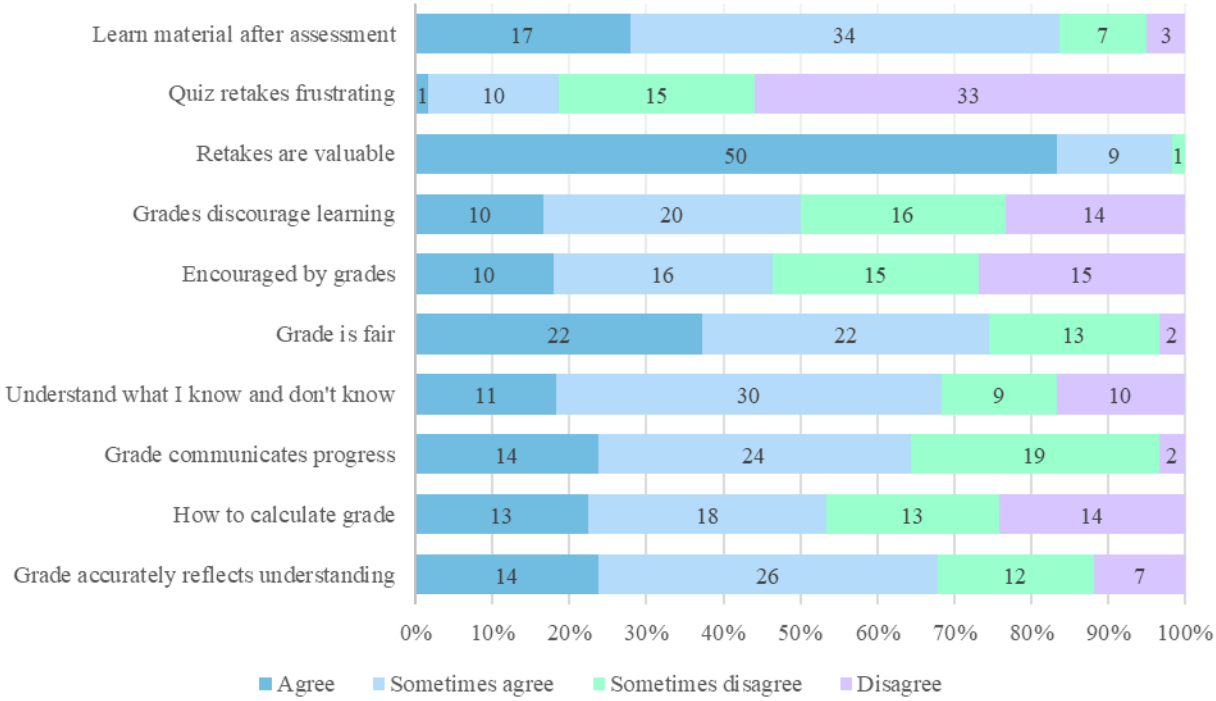


Figure 4. Standards-Based Grading Survey pre-treatment data from general chemistry, (*N*=76).

Post-treatment data was collected primarily in March and April. All post-surveys were conducted on Google Forms.

Post-treatment data was collected on, or near March 2, 2019 for the Metacognition Survey for all classes. It is worth noting that these samples represent the same classes, but sample sizes have changed due to course enrollment and conflicts with multiple spring field trips. The ideal response for each question on the Metacognition Post-Survey remained *agree*.

My honors students (Figure 5) disagreed most with questions 7, 9, and 13; that is, my students were not confident that they were studying correctly, they acknowledged that they did not create summaries of what they were learning and they did not create novel examples to make information more meaningful. My honors students reported feeling that they knew what information is important to learn, they reflected on their progress in the class, that they were a good judge of how well they know something, and that they had control over what they learn.

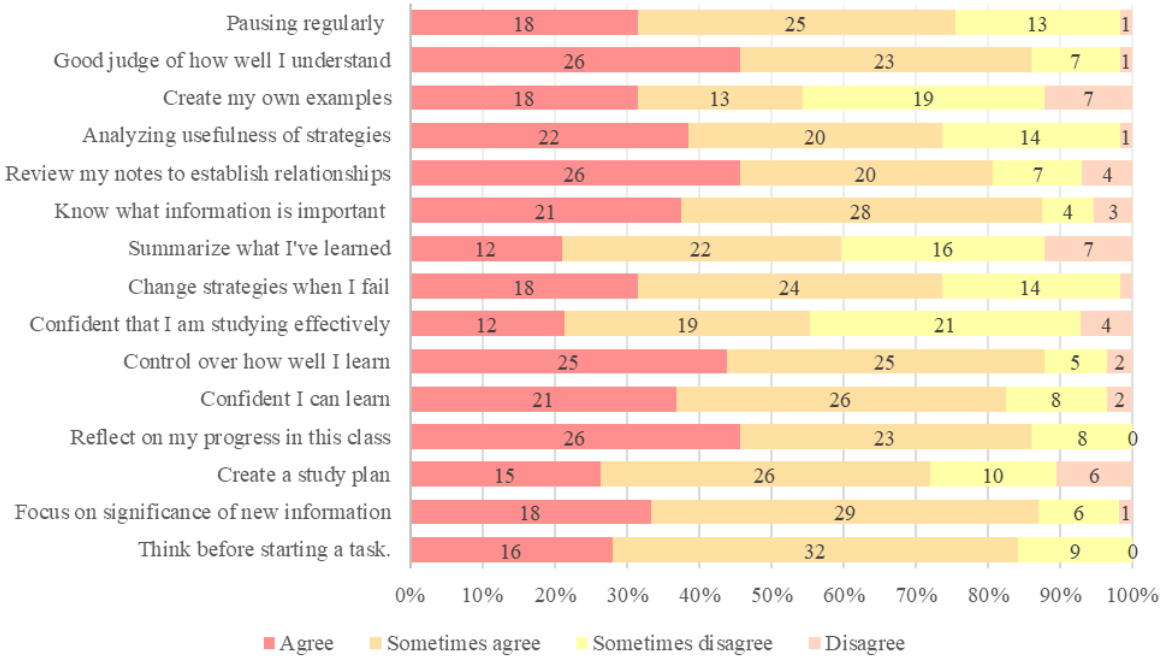


Figure 5. Metacognition Survey post-treatment data from honors chemistry, (*N*=57).

My general students (Figure 6) identified that they disagreed most with "I create a study plan before a test." They also aligned with my honors students in that they acknowledged that they did not create summaries of what they were learning and they did not create novel examples to make information more meaningful. Similar to my honors students, my general students believed they had control over how well they learn and that they also identified that they reflected on their progress in the class.

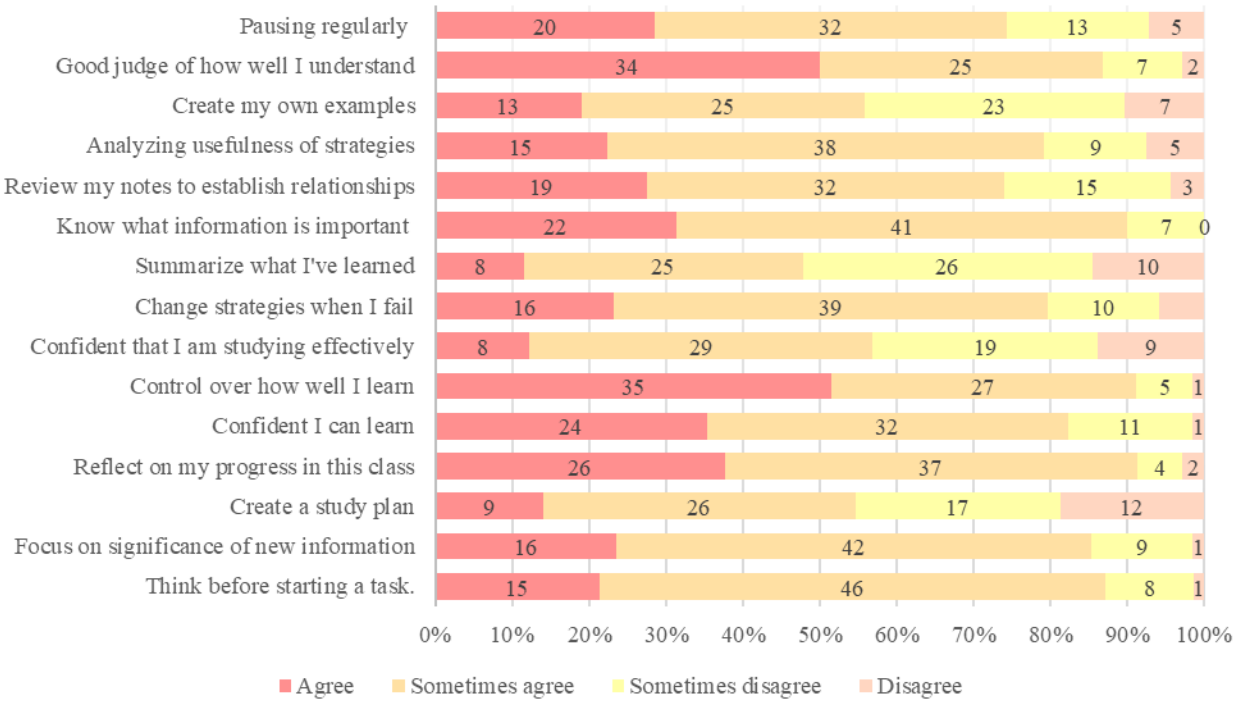


Figure 6. Metacognition Survey post-treatment data from general chemistry, (*N*=70).

Pre- and post-data for each survey were analyzed for changes. Mean scores were reviewed for each question for each survey. When reviewing the Metacognition Survey results, there was a decrease reported by my general students for creating a study plan before an assessment and in feeling confident that they can learn the material. My honors students saw substantial increases in their likelihood to think about what they need to learn before they start a task, reflecting on their progress, and summarizing what they have learned. The average score for my honors students for knowing what kind of information is important, and analyzing the usefulness of learning strategies increased dramatically.

In order to run Wilcoxon Signed Rank tests, samples were paired and any student who did not have both pre- and post-tests were removed from the sample. If a student

only skipped one or two questions, they remained in the sample for the questions they answered and were removed from the question samples for the unanswered questions. This analysis was done on the disaggregated data. Table 4 contains data for the honors classes and Table 5 contains data for the general classes.

As shown below, questions 1, 9, and 10 met statistical significance in the ideal direction. This means that there was a difference in the shape of the distribution of the data for my honors students regarding the following prompts: they knew what to study before a test, they spent time summarizing, and that they knew what kind of information they needed to learn.

Table 4
Honors Chemistry Metacognition Wilcoxon Signed Rank Tests

Question	P-value for two-sided test	Conclusion	P-value for appropriate one-sided test	Conclusion
1	0.020	Reject	0.010	Reject
2	0.545	Fail to reject	0.273	Fail to reject
3	0.399	Fail to reject	0.200	Fail to reject
4	0.177	Fail to reject	0.088	Fail to reject
5	0.235	Fail to reject	0.888	Fail to reject
6	0.441	Fail to reject	0.221	Fail to reject
7	0.586	Fail to reject	0.293	Fail to reject
8	0.745	Fail to reject	0.377	Fail to reject
9	0.030	Reject	0.015	Reject
10	0.027	Reject	0.014	Reject
11	0.628	Fail to reject	0.314	Fail to reject
12	0.050	Fail to reject	0.252	Fail to reject
13	0.376	Fail to reject	0.188	Fail to reject
14	0.501	Fail to reject	0.251	Fail to reject
15	0.430	Fail to reject	0.215	Fail to reject

Note. (*N*=54 for all questions except questions 7 and 10, where *N*=53 and question 2, where *N*=51).

Table 5
General Chemistry Metacognition Wilcoxon Signed Rank Tests

Question	P-value for two-sided test	Conclusion	P-value for appropriate one-sided test	Conclusion
1	0.875	Fail to reject	0.571	Fail to reject
2	0.479	Fail to reject	0.767	Fail to reject
3	0.312	Fail to reject	0.847	Fail to reject
4	0.687	Fail to reject	0.344	Fail to reject
5	0.211	Fail to reject	0.897	Fail to reject
6	0.592	Fail to reject	0.711	Fail to reject
7	0.703	Fail to reject	0.654	Fail to reject
8	0.656	Fail to reject	0.680	Fail to reject
9	0.846	Fail to reject	0.423	Fail to reject
10	0.510	Fail to reject	0.255	Fail to reject
11	0.096	Fail to reject	0.953	Fail to reject
12	0.722	Fail to reject	0.645	Fail to reject
13	0.931	Fail to reject	0.540	Fail to reject
14	0.898	Fail to reject	0.898	Fail to reject
15	0.925	Fail to reject	0.542	Fail to reject

Note. (N=64 for all questions except questions 2, 3, 4 and 12, where N=63 and question 6, where N=62).

As seen in Table 5, no questions in the Metacognition Survey showed a statistical difference from pre- to post-treatment for my general students.

Post-treatment data for the Standards-Based Grading Survey was collected on, or near March, 5, 2019. It is worthy to note that these samples represent the same classes, but sample sizes have changed due to course enrollment and conflicts with multiple spring field trips. Questions seven and nine ideal scores were still *disagree;* all other questions had an ideal score of *agree*.

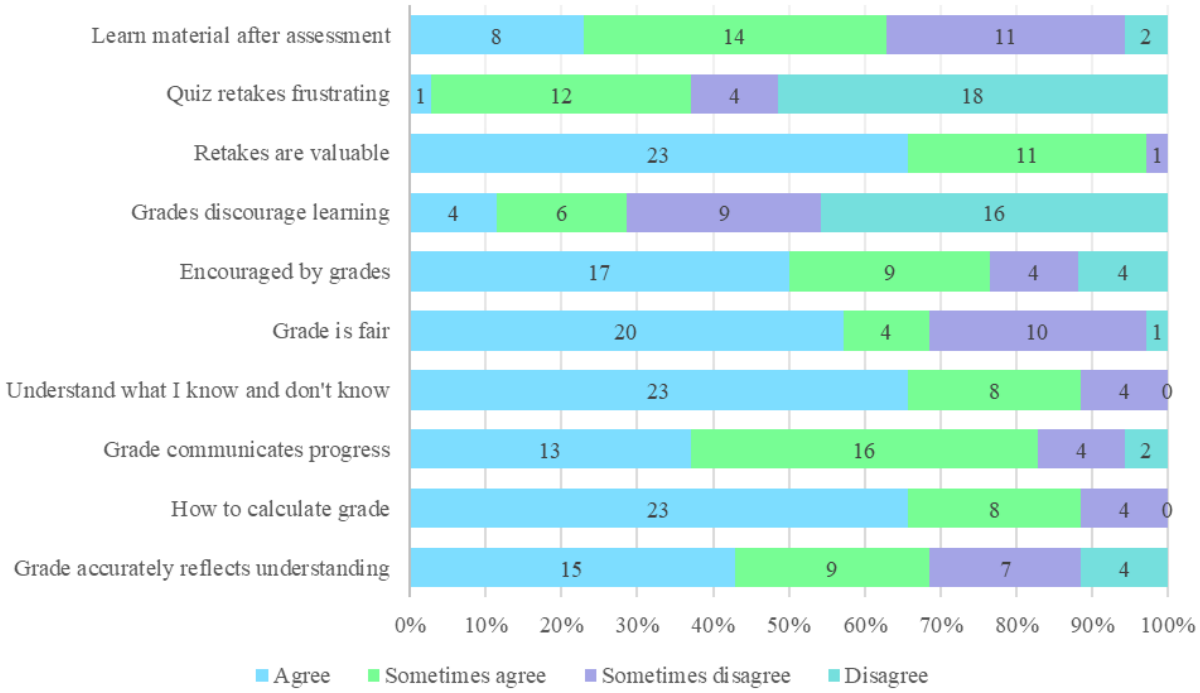


Figure 7. Standards-Based Grading Survey post-treatment data from honors chemistry, (*N*=35).

Data in Figure 7 indicates that my honors students, after treatment, agreed with the value of retakes, that their grades helped them understand what they knew and did not know about course content, and that they often learned material after the assessment. They disagreed most often that their grade in the class was fair, that their grade accurately reflected their understanding, and that they found quiz retakes frustrating.

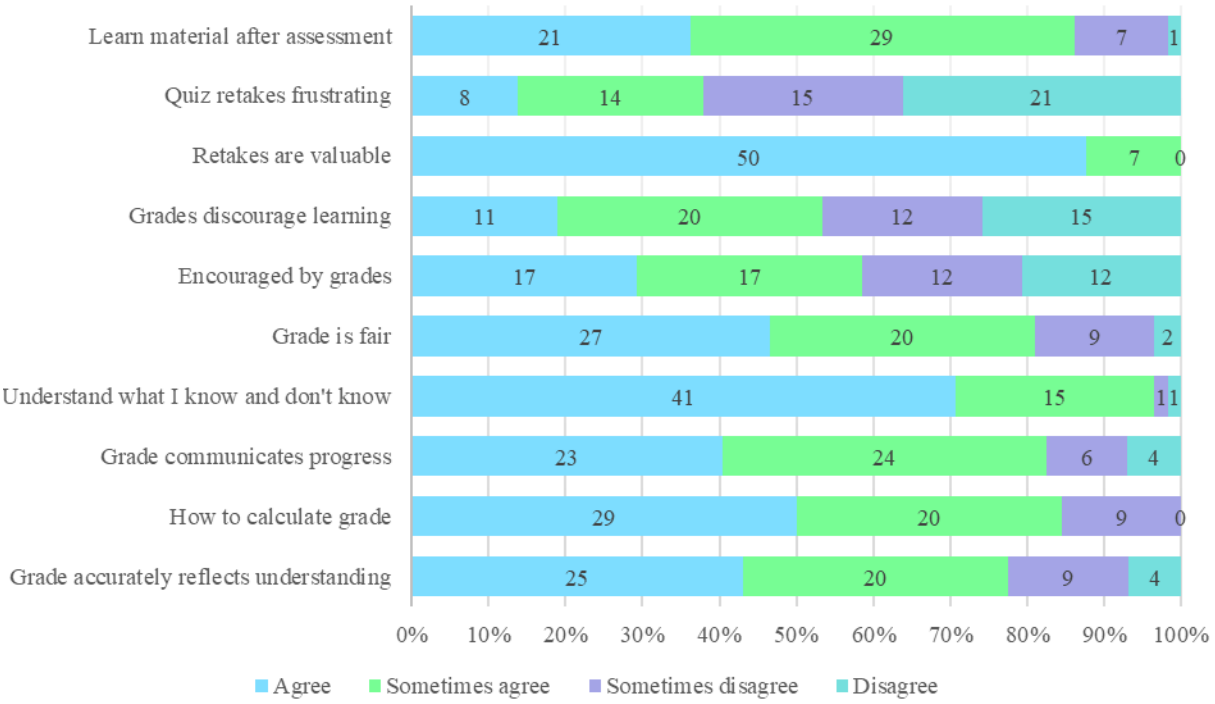


Figure 8. Standards-Based Grading Survey post-treatment data from general chemistry, (*N*=58).

Data from Figure 8 suggests, similar to my honors students, my general students most agreed that their grade helped them understand what they knew and did not know and they often felt like they learned material after the test. They reported agreeing least with finding their grades encouraging and that they found quiz retakes frustrating.

Regarding the Standards-Based Grading Survey, my general students reported a higher average by approximately 0.2 points for believing that their grade accurately reflected their understanding, SBG accurately communicated with stakeholders, and feeling like they learned the material after the test or quiz. An increased average by 0.4 points or higher was seen in understanding how to calculate their grades, their grades being helpful to understand what they knew and did not know and finding quiz retakes frustrating.

My honors students reported increased average scores of 0.5 or higher for understanding how to calculate their grade, believing that their grade helps them understand what they knew and did not know, and finding quiz retakes frustrating.

Aggregate data mirrored these trends with increased scores reported in how to calculate grades, belief that their grades helped them understand what they knew and did not know, finding quiz retakes frustrating, and learning information after the test.

In order to run Wilcoxon Signed Rank tests, samples were paired and any student who did not have both pre- and post-tests were removed from the sample. If a student only skipped one or two questions, they remained in the sample for the questions they answered and were removed from the samples for unanswered questions. This analysis was done on the disaggregated data. Table 6 contains data for the general classes and Table 7 contains data for the honors classes.

Table 6
General Chemistry SBG Wilcoxon Signed Rank Tests

Question Prompt	P-value for two-sided test	Conclusion	P-value for appropriate one sided test	Conclusion
1	0.020	Reject	0.010	Reject
2	0.003	Reject	0.001	Reject
3	0.173	Fail to reject	0.086	Fail to reject
4	$1.31x10^{-6}$	Reject	$6.535x10^{-7}$	Reject
5	1	Fail to reject	0.506	Fail to reject
6	0.163	Fail to reject	0.081	Fail to reject
7	0.992	Fail to reject	0.512	Fail to reject
8	0.227	Fail to reject	0.114	Fail to reject
9	0.161	Fail to reject	0.923	Fail to reject
10	0.129	Fail to reject	0.065	Fail to reject

Note. (*N*=49, for questions 1, 2, 4, 5, 7, and 10; *N*=48 for question 3, 6 and 8).

According to Table 6, only questions one, two, three and four had samples that were statistically different from one another according to the two-sided test. I then

continued and ran the appropriate one-sided test for all questions and found that only questions one, two, three and four showed a shift to the right, which was considered the ideal score.

Table 7
Honors Chemistry SBG Wilcoxon Signed Rank Tests

Question Prompt	P-value for two-sided test	Conclusion	P-value for appropriate one sided test	Conclusion
1	0.420	Fail to reject	0.803	Fail to reject
2	0.018	Reject	0.009	Reject
3	0.369	Fail to reject	0.185	Fail to reject
4	0.007	Reject	0.004	Reject
5	0.024	Reject	0.990	Fail to reject
6	0.819	Fail to reject	0.607	Fail to reject
7	0.579	Fail to reject	0.289	Fail to reject
8	0.013	Reject	0.995	Fail to reject
9	0.036	Reject	0.984	Fail to reject
10	0.547	Fail to Reject	0.274	Fail to reject

Note. (N=34 for all questions with the exception of question six, where N=33).

According to Table 7, only questions two, four, five, eight, and nine had samples that were statistically different from one another according to the two-sided test. I then continued and ran the appropriate one-sided test for all questions and found that only questions two and four showed a shift to the right, which was considered the ideal score. This means that the significance in questions five (believing grades in the class were fair), eight (quiz retakes are valuable) and nine (find quiz retakes frustrating) were not due to the ideal shift.

At the end of the semester, the number of reassessments completed by students were compared pre- and post-treatment. The number of reassessments increased over 10 fold in most classes and a larger variety of students were seen for reassessment.

At the end of the study, students were asked to answer five additional Likert style questions based on a variety of observations and reflections during the study in the Standards-Based Grading Follow-Up Survey (Appendix I). These questions were administered via Google Forms on the same days as the Standards-Based Grading Post Survey. Aggregate data for questions is listed below in Figures 9-13.

In all of the questions, at least 75% of the students identified as agreeing with the prompt, which identifies a positive aspect of SBG, in some fashion.

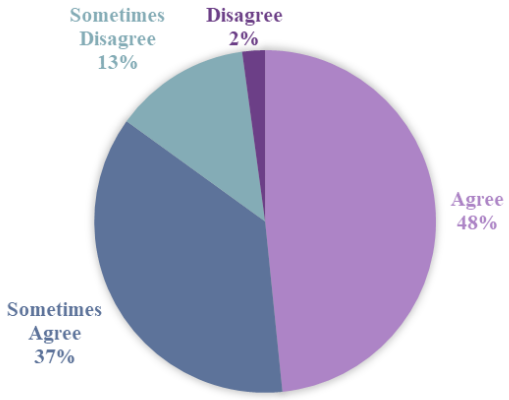


Figure 9. I feel like SBG encouraged/forced me to focus on my actual learning, (*N*=93).

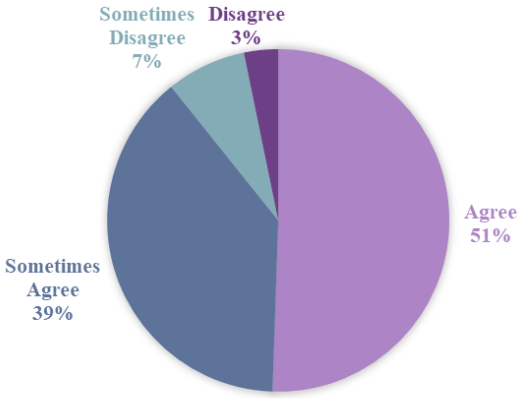


Figure 10. With SBG, I had a better understanding of what to expect on an assessment, (*N*=93).

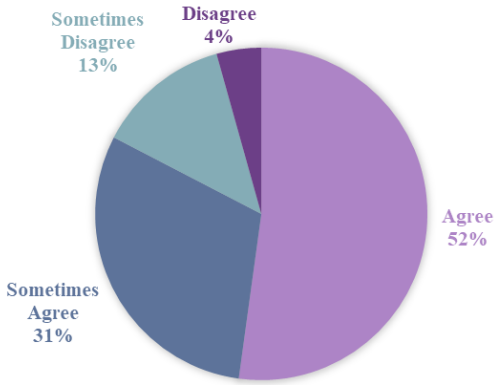


Figure 11. I took advantage of the 2 assessment opportunities provided in class, (*N*=92).

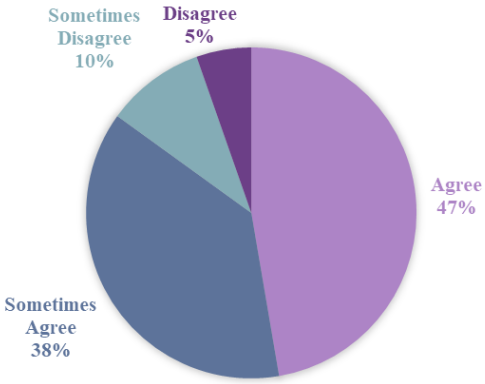


Figure 12. Knowing the standards helped me create a better study plan, (*N*=93).

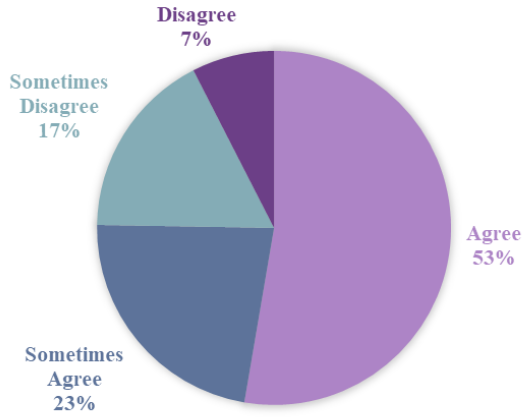


Figure 13. I feel like SBG provides me with more control over my final grade, (*N*=93).

Lastly, students were asked if they would want to see SBG again in the future. This data is shown below disaggregated in Figures 14 and 15. They were also provided an opportunity to explain their response, if they chose to do so. The most common

response to this prompt was that students believed a single “1” should not drop their grade to a D. Many students also commented that their preference for SBG was dependent on which type of class they were in. The majority of students thought it would be better suited in a math or science class. One student admitted that part of his/her struggle was that he/she had been on the traditional grade system so long, any change was difficult to understand, but he/she appreciated the new approach. This is a hesitation that I heard from a majority of students throughout the study.

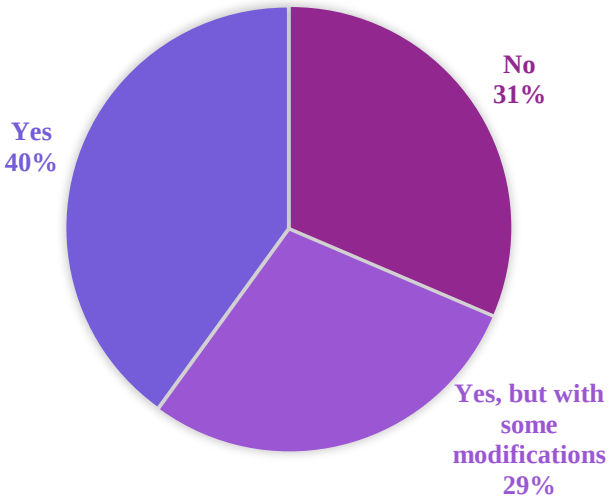


Figure 14. Honors: I would like SBG in more of my classes/future, (*N*=35).

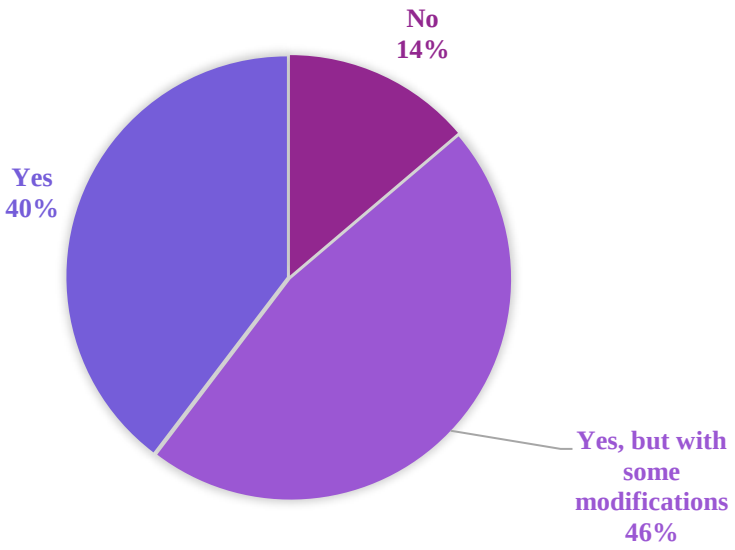


Figure 15. General: I would like SBG in more of my classes/future, (*N*=58).

INTERPRETATION AND CONCLUSION

Regardless of the grading system chosen in my classroom, my students reported feeling that they find quiz retakes helpful and that they felt like they often learned course content after the assessment. These two pieces of data seem congruous in my mind. Students may value quiz retakes *because* they often feel like they learn the material after the test. The retakes allow them an opportunity to demonstrate that they have bettered their understanding. Year after year, I hear feedback from some students that they wish we could slow down the pace of our class. With curriculum requirements and state testing, there is little that I can do to create change regarding the pacing of the class. That being said, I am curious how many students also felt like they learned the material after the second in-class assessment. The question prompts were unspecific. Students could have been considering the first or second assessment with the material when responding to the question. This confirms my belief that there needs to be some degree of flexibility in my classroom with regard to the timing of assessments. It is a classroom policy that

aligns with learning being the primary objective of my class rather than abiding by a stagnant pacing calendar.

My students, particularly my honors students, reported feeling that this grading system was less fair, but they admitted that they were better able to calculate their grade and reported stronger beliefs that their grade helped them understand what they knew and did not know when compared to the traditional grade system. At first, this seemed somewhat contradictory to me, but free response comments and wording in the questions have provided some more insight. The largest flaw in our version of SBG, according to my students was that a single score of a "1" changed their grade so dramatically. Most acknowledged that the effect was temporary and was completely in the hands of the students to change, but one student articulated that this still led to feelings of discouragement because that is not how 'normal' grades have worked. I also acknowledge that this created a different dynamic for my students who were athletes and had to meet more rigorous and frequent grade checks in order to participate. I was actually able to meet with a few coaches to discuss the implementation of policy and how to best mutually support one another.

I also heard many students comparing their scores from first semester to second semester. The course content was markedly different between the two semesters, with the second semester being more challenging for most students. Few students contemplated these kinds of factors in their reflection. Rather, many students laid the blame on the grading system. For some of my students, the change in grading system

became an excuse for lack of performance. What I intended as a means to enhance accountability, for a small number, became a loophole.

I am pleased that my students found it easier to calculate their grades and found their grades more useful as a tool to aid their learning. This means that grade became more meaningful as feedback for students rather than arbitrary letters or numbers in a gradebook. This may serve as an opportunity to empower them to approach their grades in other classes in a similar way or to advocate to better understand how to connect their grades to their learning.

The Wilcoxon Signed Rank test results provided an interesting big picture. Overall, my students statistically modified their responses from pre- to post-treatment, regarding thinking about what is important to learn before they study, analyzing the usefulness of the strategies they have chosen, knowing how to calculate their grades and that their grades helped acknowledge what they knew and what they did not know. These are impressive areas of growth for my students to be experiencing. These modifications to their experience have the potential to create gains well beyond my specific class for them. Additionally, I found it particularly interesting that summarizing, while it still remained one of the lowest scoring prompts, was shown to be statistically significant for my honors students. When I started analyzing my data without the non-parametric tests, I was really disappointed that there wasn't motion in this category as it is a skill required in many of the strategies used in our class. I was thrilled to see that the change was significant despite the score still remaining low.

I believe the six questions in the mini-survey provided the most direct feedback regarding the change in grading system. Regardless of the mixed results of the first two surveys and moments of contention in my classroom, the vast majority of my students experienced one, if not more, of the benefits built into the SBG system. I was also impressed with the caliber of feedback my students provided regarding modifications. Overall, their responses were maturely crafted and constructive showing they had been thinking about the changes and how it was impacting them in the class.

Figures 14 and 15 also, in a quantitative way, confirm what research prepared me to see. Research has shown that this shift in grading system often benefits lower performing students more than higher performing students. Based on whom I saw for reassessment and help, and these results, I can conclude that this was true for my study as well. General students that I had never seen for assistance in the first semester became dogged about increasing their understanding to increase their score. I had a number of general students who earned Cs and Ds in the first semester, working to achieve As and Bs in the second semester, regardless of the content being more challenging. Additionally, I had a number of students who dug themselves into a hole with their performance in my class in the second semester. In the last six weeks of the semester, many of those students were able to use the system to better their understanding and be rewarded for it. With my older systems of test corrections and quiz retakes these students would have missed out on the allowable time frame to demonstrate understanding.

Regarding my honors students' higher levels of dissatisfaction, I acknowledge that I removed a safety cushion when I removed compliance and completion grades from

our system. I can understand this causing unrest and general feelings of apprehension or mistrust. There are students who have been taught for years that compliance and completion are ways to make grades better. When we adopted SBG, learning was placed at the forefront again of things impacting their scores. Additionally, I was not removing exterior pressures like scholarships, household rules, or honor roll requirements. I made the 'game' more challenging for them. In the long run, I stand in my belief that learning how to learn will serve them better, I understand the stress it may have caused them in the moment. I also thought it was particularly interesting that my general students reported making plans before studying more frequently than my honors students. It could be that my general students were more familiar with this metacognitive skill than my honors students. If this is true, I could also see this serving as an advantage for my general students to adapt to the new grading system as it is a habit they have already worked to develop.

VALUE

The most distilled purpose of this research was to create a change in my classroom to better instruct my students. I wanted to work on a skill that would not only enhance their abilities to succeed in my classroom, but also to succeed wherever they choose to explore. While I feel that as a teacher, I gained tremendous insights and so did my students, this research also challenged my professional confidence and courage to the core. I am extremely fortunate to be working for and with likeminded individuals who value and create space for change to occur when it may create a better learning environment for our students.

I started my study optimistically. I was confident in the research that I had done and was confident that the choices I was making were in the best interest of my students. I had the support of both my colleagues and my administrators. I was confident the experience would be a positive one and lead to lasting positive insights. Throughout the study's time frame that optimism and confidence was challenged. I had a small percentage of parents very publically unhappy with my choice. I had student relationships that were negatively impacted because of the change. Thankfully, at the end of my study, my feelings of optimism and confidence have been restored. Because I started the project with the support of peers and supervisors and because of my diligence to create meaningful relationships with my students, I am confident that the choices I made were the correct ones.

I chose metacognition as a field of study because I saw it lacking in my classroom. At the very beginning of my study, I had one of my most consistent honors student's come to me and ask about a project we were working on. She was struggling to create a question that modeled a concept. I asked her if, when she was studying, she thought about what I would ask her on a test. She verbally guffawed and said 'No, I just read.' It was so plainly obvious to me that when she was interacting with our class content, despite being a diligent, intelligent student, her interactions were extremely shallow. I was honestly shocked. My students were physically interacting with their resources, but with little cognitive engagement. If this was a correct interpretation of the situation, then my students were not considering how to extend their learning to new situations that may appear on a comprehensive assessment. Their cognitive involvement

seemed to be limited to exactly what we had done in class: a very cookie-cutter approach. I knew being intentional about metacognition in my classroom would illuminate deficiencies. I was not prepared for how pervasive and how early on those deficiencies would become apparent.

When we first started practicing SBG, I had multiple students who were unable to see the connection between the standards on the RTT sheets, the questions on the tests, and the practice and learning we had done in class. Even when they were given time in class to pair class experiences with specific standards, they struggled to do so. Many of my students asked why I simply could not label the worksheets for them. My first reaction was the time it would take me to do so was time I could not quite find this semester. But later, after reflection, that practice *is* the metacognition I was working to help them develop. They were craving easy, ignoring, or perhaps ignorant of the fact that *doing* this process is what would develop their metacognitive skills. It was only after we spent the time to complete the pairing in class did students truly understand how SBG works and the benefits of working to understand the interconnectedness of what they were learning and what they were being assessed on.

I know that reflection is crucial for me to truly process all the data and experiences I have in a day of teaching. I wanted to create a time for my students to have the same experience with their learning. We determined that as often as possible, we were going to use Fridays to reflect on our progress. At first I started without much guidance for my students. I did not want to dictate what their reflection would look like. This was a mistake. They had shown me a need for instruction in metacognition; this

should have also indicated to me that they were not ready to reflect on their own. Our first reflections included things like “All good!” or “I don’t get it.” We eventually settled on a simple reflection, guided by our grades in the class (Appendix J). When I asked the students if they found this helpful, they almost unanimously responded that they did. When I asked if they wanted to continue the practice, most actually shouted “Yes!” When I asked why, if it was so helpful, they did not do it for their other classes, I was heralded by crickets. During one of our grade reflections early on, at the start of February, I had a general student say ‘I like this now! You know exactly what you need to work on!” I was encouraged. Later that same day, a second student rose his hand and said "I just want to say that I like this system more. It's much more reflective and I don't feel like I need to stress for a test because I know I can demonstrate learning later also.” A variety of students also articulated “Then how could someone fail!?” It was working. It was not working for everyone yet, but some students were seeing some of the tremendous benefits of metacognition and a grading system that worked hand in hand with it. At the end of the semester when I introduced the final exam project, many students, including some who have been very vocal about disliking SBG exclaimed “But we don’t have the standards first semester…” I was so pleased that they had internalized the value of these standards and were actively seeking them to help accomplish a larger task requiring synthesis. I heard one student put together that the RTTs were their best resource for the units we covered prior to SBG taking effect.

Generally speaking, I believe this systematic change was more beneficial for my lower-performing students. I saw students in the second semester coming in for help and

to work on standards who I had not seen at all invested in their performance first semester. They were able to clearly ask for help on standards and were better able to better prioritize where to focus to see the success they wanted to see. My honors students, my highest performing students, were overall my most disgruntled. At first, I was disappointed. I wanted them to embrace the challenge, or perhaps, more accurately, just be open to the experience. For many of them, it exposed some of their academic weaknesses. They 'played the game' with the traditional grading system quite well. When the game changed, I was forcing them to learn and learn well. I had removed many of the compliance influences of a grade and made them actually work for their grades. As I saw many of my lower students being empowered by their ability to affect their grades, I saw a number of my students actually working for their grades for the first time.

The most often vocalized complaint of the system was the singular impact of a "1" in the gradebook. When I first decided on a conversion to traditional letter grades, I honestly did not believe that many of my students would be earning 1's on topics. I was very wrong. I think this was one of the ways my students were playing the game. They did really well on the majority of the grades, but did not have to spend time and energy on what they did not know, because there was wiggle room. The SBG system removes that wiggle room. It is worth noting, that at the end of the semester, most students either had multiple scores of "1" or none. Few, if any, had one "1."

I also was concerned about keeping the SBG system easy to understand so as to not create a new system that was even more convoluted than the traditional weighted

grades of first semester. I think if I were to continue this system in the future, I would modify this slightly. It sacrifices the simplicity of the system, but I think it will reduce the stress caused by a singular temporary score. At the moment, my best modification to the "1" flaw, is to make every "1" worth a letter grade. This maintains the importance of learning at the forefront, supports that all essential standards are, in fact essential, while providing a better buffer for students who also answer to coaches and parents regarding grades. This also may create a smoother transition and a more motivation/self-esteem conscience transformation.

From a technology standpoint, this practice is not sustainable. Because of my inability to access the SBG portion of our gradebook, I was keeping two gradebooks for the duration of the semester. This was time consuming and I was prone to make more errors. This means, that despite my modification to the impact of a "1," I do not have a viable means to continue this practice, as it was implemented in this study, until the district modifies access to the learning management system, or grants permission to use an alternative system.

I have come to recognize two positive impacts of the double gradebook experience. The first is that I have learned more coding techniques in Excel. The second is related to my students. Because the grades were tied to specific standards, which were indicated on tests and trackable, many students were able to ask me about grade mistakes or ask about specific grades that had not been updated yet. Another sign, that although they have not internalized the process as much as I would like, my students knew more about what their grades meant and how to manipulate them.

In review, this study empowered me as a professional, to research and plan changes in my classroom that will enhance my students' abilities to find success in my specific class and beyond. I gained further trust in my abilities to face professional struggles because my choices were research-based. I was reminded of the value of supportive coworkers and administration. This study re-emphasized the importance of student relationships and trust, especially in the light of trying something new in a largely stagnant education system. I was also reminded of the value of continuing to pursue the new, better, and different; many of my students *learned* this year. They learned electron configurations and stoichiometry, but much more than that, they learned about learning. They learned that adults are still learning. They learned that making mistakes was not only okay, but part of the natural process. They learned that perseverance was valued. They learned that their opinions were heard and considered. They worked through healthy conflict and learned that resolution is not always getting what you want. They were valued. I was able to challenge even my brightest students while still supporting those that struggled the most. I was able to admit that I had made mistakes and learned from them. I was uncomfortable and worked through that until I was confident. This study has encouraged me to continually approach my pedagogy with a continuous critical lens and for that, I am grateful.

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APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD (IRB) EXEMPTION LETTER

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

2155 Analysis Drive
c/o Microbiology & Immunology
Montana State University
Bozeman, MT 59718
Telephone: 406-994-6783
FAX: 406-994-4303
E-mail: cheryl@montana.edu

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

MEMORANDUM

TO: Katrina Wunderlich and Kathryn Solberg

FROM: Mark Quinn, Chair Mark Quinn CHI

DATE: November 13, 2018

RE: *"The Effects of Metacognition and Standards-Based Grading on Student Achievement and Perception" [KW111318-EX]*

The above research, described in your submission of November 9, 2018, 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.

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APPENDIX B

READY TO TEST (RTT) EXAMPLE

RTT Covalent Bonding

At the end of this unit, I will be able to…

* Required

1. **Name** *

2. **Period** *

Mark only one oval.

- 1
- 2
- 3
- 5
- 6
- 7

3. *

Check all that apply.

	Ready to test	Need more	Don't get it
1. Identify in writing the 7 diatomic molecules	☐	☐	☐
2. Distinguish among the types of bonds (i.e., ionic, covalent)	☐	☐	☐
3. Explain in writing how atoms form covalent bonds including single, double, triple and coordinate	☐	☐	☐
4. Identify in writing the exceptions to the octet rule	☐	☐	☐
5. Sketch electron dot diagrams for molecules including those which exhibit resonance	☐	☐	☐
6. Determine in writing and visually the electron and molecular shape of a molecule based on the VSEPR theory, using reference sheets	☐	☐	☐
7. Describe how electronegativity values determine the distribution of charge in a polar molecule	☐	☐	☐
8. Apply in writing the rules for naming and writing chemical formulas for covalent/molecular compounds	☐	☐	☐

APPENDIX C

STUDENT WORK SAMPLES

One Pager Examples

Words to know!

Cation - positively charged ion that forms when atom loses electrons
Anion - negatively charged ion that forms when atom gains electrons
Monatomic ion - A single atom with a positive or negative charge
Polyatomic ion - A charged species with two or more atoms covalently bonded
Subscript - how many of each type of atom

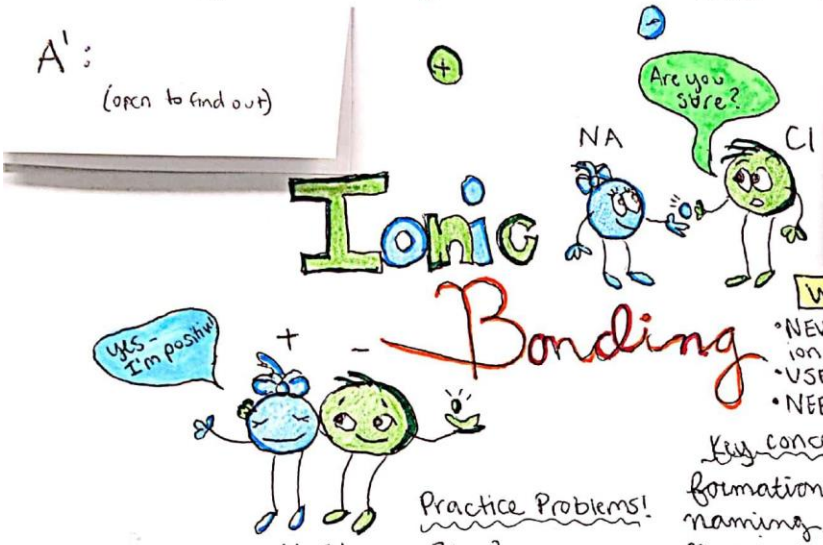
Question & Answer

Q1. What is a property of an Ionic compound? Hypothesis!

Q2. Which Type of ion always comes first in an ionic compound? Explain!

A1:
(open to find out)

A2:
(open to find out)



WARNING!
- NEVER change a subscript of a poly. ion
- USE parenthesis when needed
- NEED LCD in criss - cross

Practice Problems!

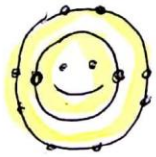
1) $Al^{3+}O^{2-}$

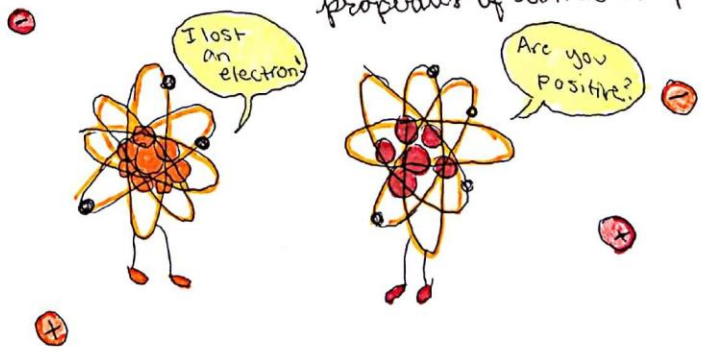
$Al^{3+}O^{2-} \rightarrow Al_2O_3$

2) $Cu^{+2}Br^{-1} \rightarrow CuBr_2$

Key concepts!
formations of ions
naming ions
naming ionic compounds
ionic bonding
formulas
criss-cross method
balancing charges
Lewis Dot Diagrams
Electron Dot Diagrams
properties of ionic compounds

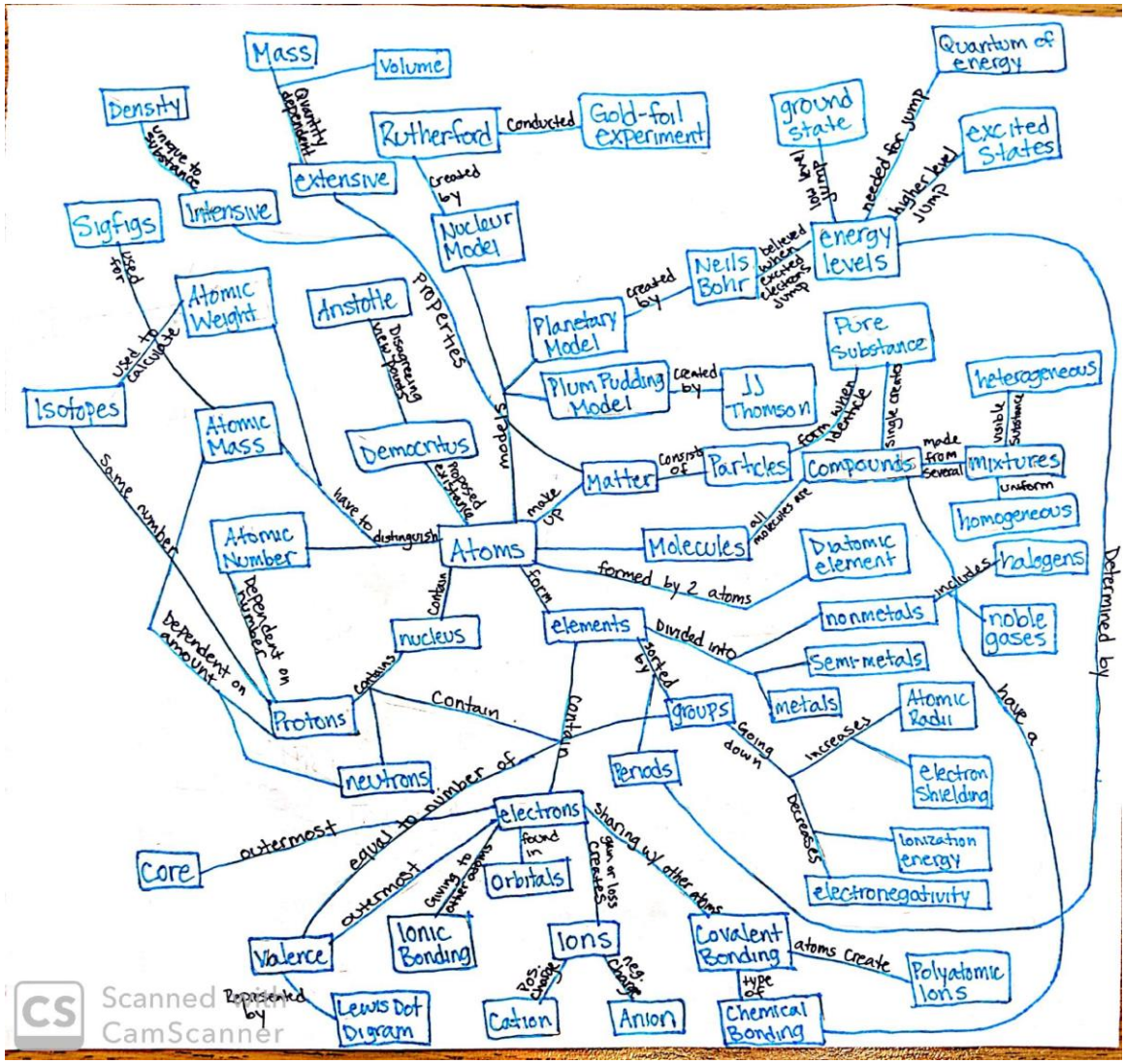
paragraph

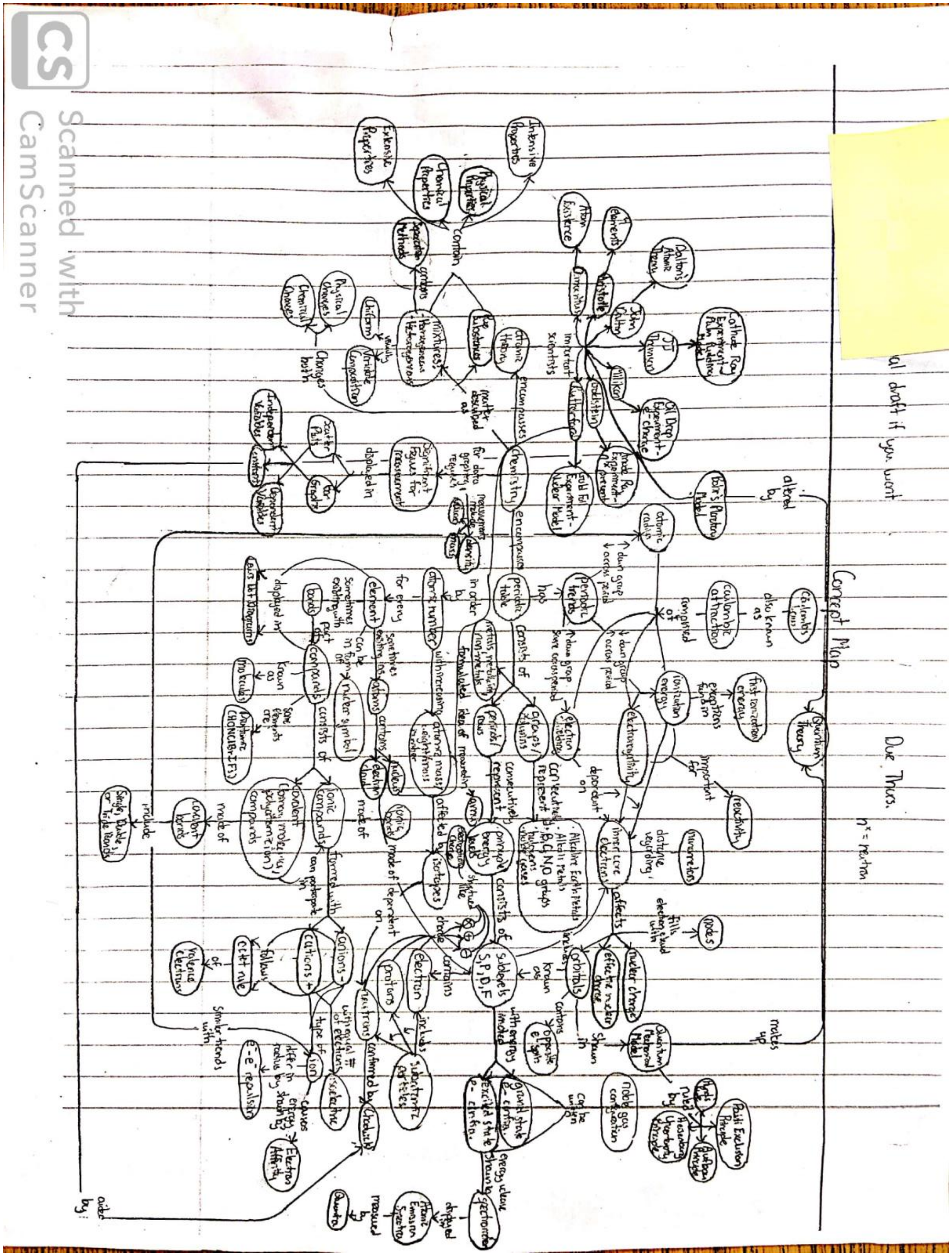




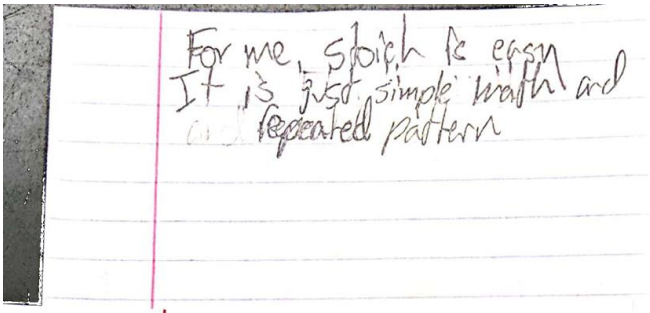
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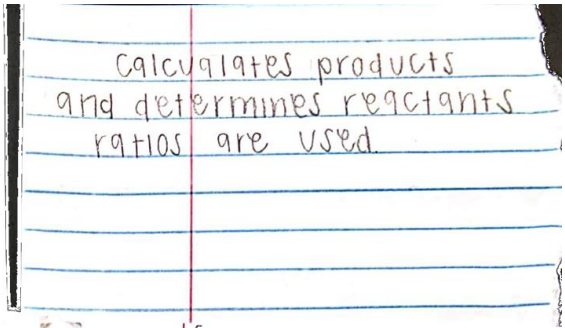
Concept Map Examples

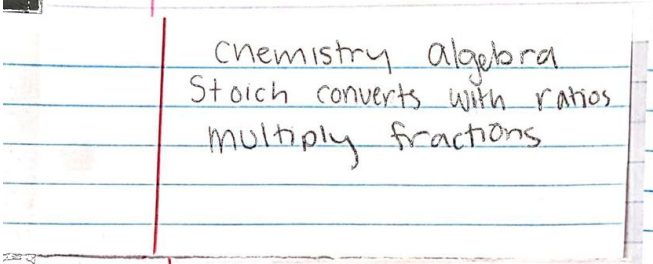


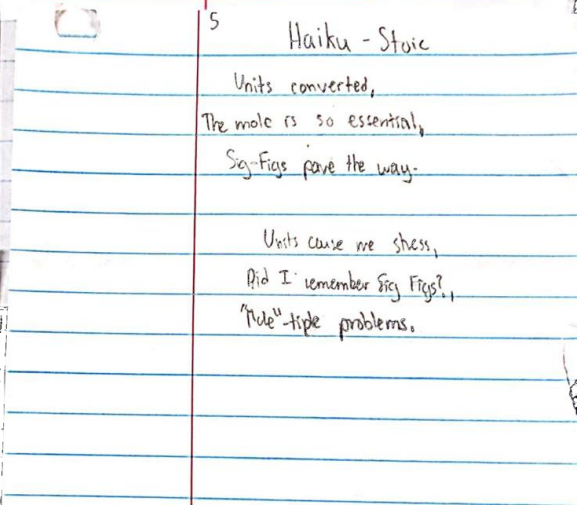

Concept Map
Due Thurs.
n° = neutron
al draft if you want
Intensive Properties
Extensive Properties
Chemical Properties
Physical Properties
contain
Separation Methods
contains
Mixtures
Homogeneous
Heterogeneous
Uniform
Variable Composition
Physical Changes
Chemical Changes
Changes both
Pure Substances
matter described as
atomic theory
encompasses
important scientists
Democritus
Atom Existence
Aristotle
4 elements
John Dalton
Dalton's Atomic Theory
JJ Thomson
Cathode Ray Experiment Plum Pudding Model
Millikan
Oil Drop Experiment e- charge
Goldstein
Rutherford
Gold Foil Experiment Nuclear Model
Bohr's Planetary Model
altered by
Quantum theory
makes up
chemistry
Significant Figures for measurement
displayed in
Scatter Plots
Bar Graphs
Independent Variables
Dependent Variables
Constants
density
mass
atomic radius
periodic trends
coulomb's law
also known as
coulombic attraction
comprised of
ionization energy
first ionization energy
electronegativity
important for
reactivity
dependent on
periodic table
has
consists of
groups/columns
periodic rows
electron shielding
inner core electrons
nucleus
electron cloud
element
atoms
compounds
ionic compounds
covalent compounds
molecules
Lewis Dot Diagrams
nuclear symbol
consists of
anions-
cations+
octet rule
valence electrons
ion
e- -e- repulsion
Electron Affinity
isotopes
subatomic particles
electron
protons
neutrons
confirmed by Chadwick
sublevels S,P,D,F
orbitals
nuclear charge
effective nuclear charge
nodes
Quantum Mechanical Model
Pauli Exclusion Principle
Hund's Rule
Heisenberg Uncertainty Principle
Aufbau Principle
noble gas configuration
ground state e- config.
excited state e- config.
spectrometer
Atomic Emission Spectra
Quanta
principal energy levels
covalent bonds
Single, Double, or Triple Bonds
include
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Student Stoichiometry Haiku Summaries


For me, stoich is easy
It is just simple math and
repeated pattern

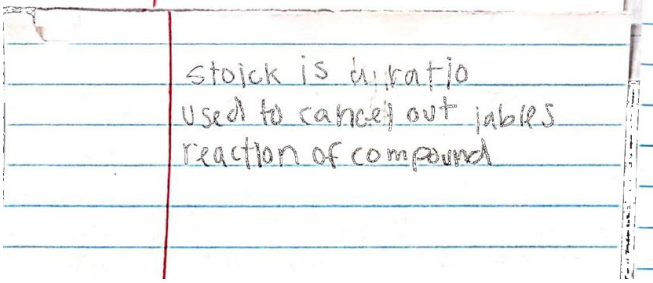

calculates products
and determines reactants
ratios are used.

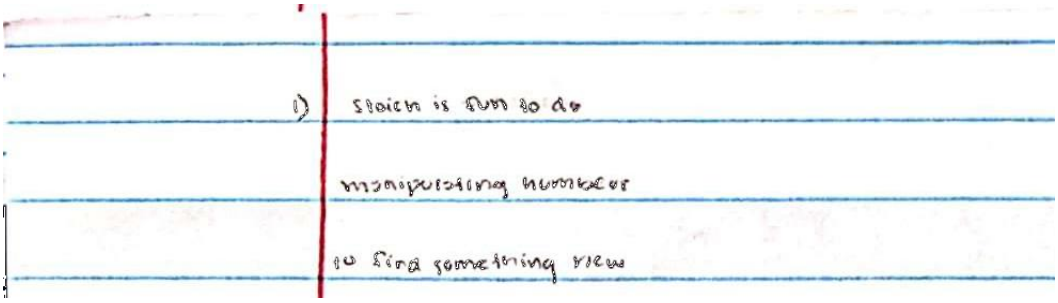

Chemistry algebra
Stoich converts with ratios
multiply fractions


5
Haiku - Stoic

Units converted,
The mole is so essential,
Sig-Figs pave the way.

Units cause me stress,
Did I remember Sig Figs?,
"Mole"-tiple problems.


Stoich is dimensional
used to cancel out labels
reaction of compound


1) stoich is fun to do

manipulating numbers

to find something new

APPENDIX D

METACOGNITION SURVEY

Metacognition Pre-Survey

Please answer the questions below honestly. Your feedback will be used to make our class better. Participation in this survey is voluntary and participation or non-participation will not affect your grades or class standing in any way.

* Required

1. **Student ID** *

2. **Period** *

Mark only one oval.

- 1
- 2
- 3
- 5
- 6
- 7

3. **Please rank the following statements based on your belief for our Chemistry class**
Mark only one oval per row.

	Disagree	Sometimes disagree	Sometimes agree	Agree
I think about what I really need to learn before I begin a task	⬭	⬭	⬭	⬭
I focus on the meaning and significance of new information, relating it to things I already know	⬭	⬭	⬭	⬭
I create a study plan before a test/quiz	⬭	⬭	⬭	⬭
I reflect on my progress in this class	⬭	⬭	⬭	⬭
I am confident I can learn this material	⬭	⬭	⬭	⬭
I have control over how well I learn	⬭	⬭	⬭	⬭
I am confident that I'm studying effectively	⬭	⬭	⬭	⬭
I change strategies when I fail to understand	⬭	⬭	⬭	⬭
I summarize what I've learned after I finish	⬭	⬭	⬭	⬭
I know what kind of information is most important to learn	⬭	⬭	⬭	⬭
I review my notes to help me understand important relationships between topics	⬭	⬭	⬭	⬭
I find myself analyzing the usefulness of strategies while I study/work	⬭	⬭	⬭	⬭
I create my own examples to make information more meaningful	⬭	⬭	⬭	⬭
I am a good judge of how well I understand something	⬭	⬭	⬭	⬭
I find myself pausing regularly to check my comprehension	⬭	⬭	⬭	⬭

4. **Is there anything else relating to the information above you'd like to share? Or clarifications you'd like to provide?**

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Google Forms

APPENDIX E

INTERVIEW QUESTIONS

Interview questions

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

1. Grades in this class are _____
2. What does a grade mean to you?
3. Do you think that grades are meaningful?
4. How do you use your grades?
5. What does metacognition mean to you?
6. Do you think it is important to reflect on your learning? Do you? Expand.
7. How do you know that you are ready for an assessment?

APPENDIX F

EXAMPLE STANDARDS FOR UNIT

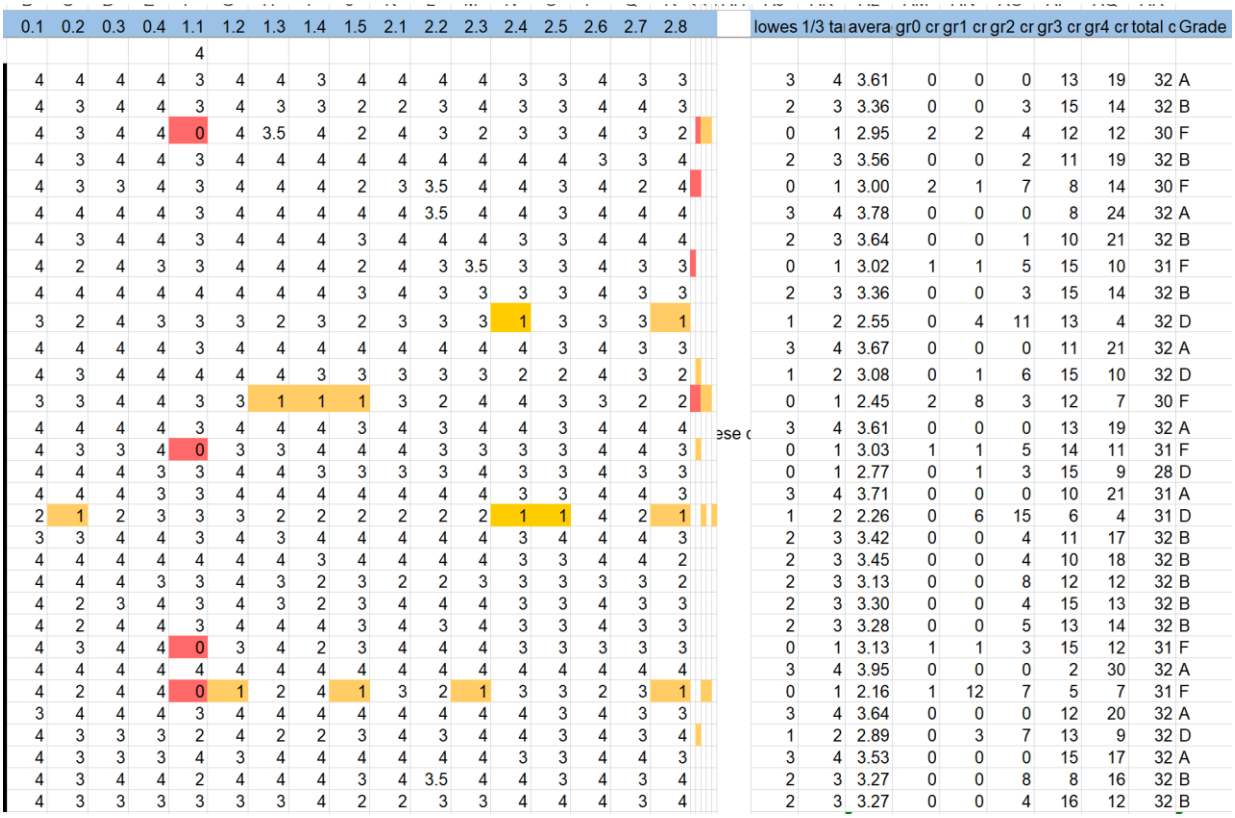
Unit 3: Solutions RTT

Unit 3: Solutions						
	Can I....	Self Assess	1st	2nd	3rd	Plan to achieve mastery. if not achieved the first time you are assessed
3.1	....distinguish between a solute and solvent?					
3.2	....explain what happens to an electrolyte when dissolved in solution?					
3.3	....calculate molarities of different solutions?					
3.4	....use molarity as a conversion factor in stoichiometry problems?					
3.5	....identify the factors that determine the rate at which a solute dissolves?					
3.6	....mathematically manipulate solubility information as determined from a graph?					
3.7	....*describe the effect of dilution using words, pictures and/or mathematics?					
3.8	....*identify three colligative properties of solutions?					

*indicate standards for Honors classes only

APPENDIX G

EXCEL GRADEBOOK



0.1	0.2	0.3	0.4	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	lowes	1/3 ta	avera	gr0 cr	gr1 cr	gr2 cr	gr3 cr	gr4 cr	total c	Grade
				4																						
4	4	4	4	3	4	4	3	4	4	4	4	3	3	4	3	3	3	4	3.61	0	0	0	13	19	32	A
4	3	4	4	3	4	3	3	2	2	3	4	3	3	4	4	3	2	3	3.36	0	0	3	15	14	32	B
4	3	4	4	0	4	3.5	4	2	4	3	2	3	3	4	3	2	0	1	2.95	2	2	4	12	12	30	F
4	3	4	4	3	4	4	4	4	4	4	4	4	4	3	3	4	2	3	3.56	0	0	2	11	19	32	B
4	3	3	4	3	4	4	4	2	3	3.5	4	4	3	4	2	4	0	1	3.00	2	1	7	8	14	30	F
4	4	4	4	3	4	4	4	4	4	3.5	4	4	3	4	4	4	3	4	3.78	0	0	0	8	24	32	A
4	3	4	4	3	4	4	4	3	4	4	4	3	3	4	4	4	2	3	3.64	0	0	1	10	21	32	B
4	2	4	3	3	4	4	4	2	4	3	3.5	3	3	4	3	3	0	1	3.02	1	1	5	15	10	31	F
4	4	4	4	4	4	4	4	3	4	3	3	3	3	4	3	3	2	3	3.36	0	0	3	15	14	32	B
3	2	4	3	3	3	2	3	2	3	3	3	1	3	3	3	1	1	2	2.55	0	4	11	13	4	32	D
4	4	4	4	3	4	4	4	4	4	4	4	4	3	4	3	3	3	4	3.67	0	0	0	11	21	32	A
4	3	4	4	4	4	4	3	3	3	3	3	2	2	4	3	2	1	2	3.08	0	1	6	15	10	32	D
3	3	4	4	3	3	1	1	1	3	2	4	4	3	3	2	2	0	1	2.45	2	8	3	12	7	30	F
4	4	4	4	3	4	4	4	3	4	3	4	4	3	4	4	4	3	4	3.61	0	0	0	13	19	32	A
4	3	3	4	0	3	3	4	4	4	3	3	3	3	4	4	3	0	1	3.03	1	1	5	14	11	31	F
4	4	4	3	3	4	4	3	3	3	3	4	3	3	4	3	3	0	1	2.77	0	1	3	15	9	28	D
4	4	4	3	3	4	4	4	4	4	4	4	3	3	4	4	3	3	4	3.71	0	0	0	10	21	31	A
2	1	2	3	3	3	2	2	2	2	2	2	1	1	4	2	1	1	2	2.26	0	6	15	6	4	31	D
3	3	4	4	3	4	3	4	4	4	4	4	3	4	4	4	3	2	3	3.42	0	0	4	11	17	32	B
4	4	4	4	4	4	4	3	4	4	4	4	3	3	4	4	2	2	3	3.45	0	0	4	10	18	32	B
4	4	4	3	3	4	3	2	3	2	2	3	3	3	3	3	2	2	3	3.13	0	0	8	12	12	32	B
4	2	3	4	3	4	3	2	3	4	4	4	3	3	4	3	3	2	3	3.30	0	0	4	15	13	32	B
4	2	4	4	3	4	4	4	3	4	3	4	3	3	4	3	3	2	3	3.28	0	0	5	13	14	32	B
4	3	4	4	0	3	4	2	3	4	4	4	3	3	3	3	3	0	1	3.13	1	1	3	15	12	31	F
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	4	3.95	0	0	0	2	30	32	A
4	2	4	4	0	1	2	4	1	3	2	1	3	3	2	3	1	0	1	2.16	1	12	7	5	7	31	F
3	4	4	4	3	4	4	4	4	4	4	4	4	3	4	3	3	3	4	3.64	0	0	0	12	20	32	A
4	3	3	3	2	4	2	2	3	4	3	4	4	3	4	3	4	1	2	2.89	0	3	7	13	9	32	D
4	3	3	3	4	3	4	4	4	4	4	4	3	3	4	4	3	3	4	3.53	0	0	0	15	17	32	A
4	3	4	4	2	4	4	4	3	4	3.5	4	4	3	4	3	4	2	3	3.27	0	0	8	8	16	32	B
4	3	3	3	3	3	3	4	2	2	3	3	4	4	4	3	4	2	3	3.27	0	0	4	16	12	32	B

Features of Excel Gradebook

- Student names removed for privacy.
- Standard numbers listed in blue along the top.
- Scores conditionally format to flag low scores.

Code written to calculate letter grade(utilized in last column visible above):

=IF(AJ3=4,"A",IF(AND(AJ3>=3,AL3>=3.333),"A",IF(AND((AN3)=0,

AM3=0,(AP3+AQ3)>(1/3*AR3)),"B",IF(AND(AN3=0, AM3=0,

AO3>0),"C",IF(AND(AN3>=1, AM3=0, (AQ3+AO3+AP3)>(1/3*AR3)),"D","F")))))

APPENDIX H

STANDARDS-BASED GRADING SURVEY

Grades Survey

Please answer the questions below honestly. Your feedback will be used to make our class better. Participation in this survey is voluntary and participation or non-participation will not affect your grades or class standing in any way.

* Required

1. **Student ID** *

2. **Period** *

Mark only one oval.

- 1
- 2
- 3
- 5
- 6
- 7

3. *Mark only one oval per row.*

	Disagree	Sometimes disagree	Sometimes agree	Agree
I believe that my grade accurately reflects my content understanding in this class				
I understand how to calculate my grade in this class				
I believe that grades accurately communicate class progress between me, my teachers and my parents				
My grade helps me understand what I know and what I don't know about course content				
I believe my grade in this class is fair				
I feel encouraged by my grades				
I feel like my grade discourages my learning				
I believe that quiz retakes are a valuable learning experience				
I find quiz retakes frustrating				
I often feel like I learn the material after the test/quiz				

4. Is there anything else relating to the information above you'd like to share? Or clarifications you'd like to provide?

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APPENDIX I

STANDARDS-BASED GRADING FOLLOW-UP SURVEY

Grades Survey

Summary

I feel like SBG encouraged/forced me to focus on my actual learning.

	Disagree	Sometimes Disagree	Sometimes Agree	Agree
I feel like SBG encouraged/forced me to focus on my actual learning.	○	○	○	○
With SBG, I had a better understanding of what to expect on an assessment.	○	○	○	○
I took advantage of the 2 assessment opportunities provided in class.	○	○	○	○
Knowing the standards helped me create a better study plan.	○	○	○	○
I feel like SBG provides me with more control over my final grade.	○	○	○	○

I would like SBG in more of my classes/future.

- ○ Yes
- ○ No
- ○ Yes, but with some modifications.

If you answered the previous questions and would like to explain, or list modifications you recommend, etc, please do so here.

Your answer

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APPENDIX J

GRADE REFLECTION SHEET

Name:

I have a total of _____ assignments in the gradebook.

____ of them are 4s. ____ of them are 3s. ____ of them are 2s. ____ of them are 1s.

This means my grade is a(n) A / B / C / D / F.

I know I need to focus on these standards to improve my grade:

My plan is to…….

Name:

I have a total of _____ assignments in the gradebook.

____ of them are 4s. ____ of them are 3s. ____ of them are 2s. ____ of them are 1s.

This means my grade is a(n) A / B / C / D / F.

I know I need to focus on these standards to improve my grade:

My plan is to…….