IMPROVING STUDENT METACOGNITION THROUGH STANDARDS BASED GRADING IN A HIGH SCHOOL CHEMISTRY CLASS

by

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DEDICATION, ACKNOWLEDGEMENTS

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ABSTRACT

In this investigation, standards-based grading (SBG) was implemented with the purpose of improving student metacognition. Grades were earned according to a 4-Point Scale and the student's trend was the final grade. Metacognition was accessed through predictive scoring of assessments. Results indicate that students benefit from the detailed feedback inherent to SBG while predictive scoring quantifies metacognition for the student and teacher. A mixed-methods design was used in the data collection and analysis to provide a holistic view of the impact of SBG on student metacognition. The metacognitive improvement was verified quantitatively by a calibration score indicating 97% accuracy of student final exam score prediction (*n=43*).

Keywords: High School/Introductory Chemistry; Chemical Education Research; Curriculum; Philosophy; Testing/Assessment

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INTRODUCTION

Students in a high school general chemistry class often remark how they thought they did so much better on a test than the score that is returned to them. Additionally, students rarely recognize that what is worked on in class will be present on the test. Student self-awareness is a difficult skill to measure and even more difficult to improve. Therefore, a pedagogical technique was developed and employed with the goal of improving student metacognition as its focal point.

To this end, standards-based grading (SBG) was utilized. SBG seeks to improve a student's awareness of their progression. It is a method of grading that is based on the student's trend of learning rather than the averaged learning that is used in the traditional or total points system[1]. SBG is a record of all assignments and assessments, but each will be aligned with a standard, or statement of understanding, the student should reach[2]. The grades then are used to determine the trend in learning. Therefore, standards-based grading will show the progression of learning as well as the final understanding of the student, whereas, traditional grading will be the average learning throughout the entirety of the course[3]. In addition, frequent self-checks can be used to give students the opportunity to qualitatively refine their metacognitive skills. Most importantly, students predict the score they thought they would earn on each assessment, including near daily quizzes and unit tests. This predictive scoring gave the opportunity for quantitative data on metacognitive development.

The purpose of this work is the improvement of student metacognition through the use of Standards Based Grading (SBG). The system uses the same learning targets as are used in the development of the teaching/learning units[4]. Most importantly, metacognition is the keystone of this work with SBG as the treatment method toward improving metacognition. Second, SBG can be interpreted a variety of ways and the current literature and research directly connected to the methods used in this work are addressed. In order to quantitatively measure metacognition, predictive scoring was also integrated and is addressed throughout this framework.

BACKGROUND

Metacognition

Metacognition is the self-awareness students use to think, evaluate their own learning, generate strategies to meet these needs, and implement those strategies[5]. Metacognition is important in the problem-solving abilities of chemistry students, and this skill is difficult to measure and difficult to improve. "The challenge for teachers is to understand how metacognition can be assessed and developed in our classrooms"[6]. There is hope that "improving metacognition is possible"[7]. In the Miller and Geraci study, college chemistry students were asked to predict their own exam performance. Many of the low-performers would overestimate their performance while high-performing students were much more accurate[7]. Additionally, low-achieving students demonstrate weak metacognitive processes and their learning is affected accordingly[8-9]. As the research semester of Miller and Geraci progressed, low-performing students became more accurate but did not improve the actual test score.

The research in this case indicates that feedback was given but "not tailored to each individual…which concepts that student understood and which ones they did not understand"[7]. To create an avenue for this individualized feedback, SBG was identified as the main treatment method. Teachers must identify what skills, defined by the standards, need to be taught, and how to teach them while students need to self-regulate their learning through metacognition[10]. Therefore, students received individualized feedback on the class standards during this research (Appendix B). The model Miller and Geraci provided was a predictive scoring method that was altered to include individualized feedback through SBG. The result of improved prediction scores[7] is in support of the research topic in that as the student improves their metacognition it will follow that their understanding, and thereby their grade, will improve with individualized feedback communicated through SBG.

Standards-Based Grading

Utilizing SBG, students can see their current grade in each standard individually. While an overall grade is present throughout the course, these standards are separate categories within the grade book. Within SBG, "Every student should have the opportunity to practice without penalty"[11]. Essentially, each artifact or assessment students complete will be chosen in order to align with standards[2]. These standards are the main concepts or essential outcomes of the class. Grades are earned by a comparison to the standard. The semester grade is determined by use of the most current trend demonstrated by the student and each standard carries equal weight in the semester grade[12]. By comparison, traditional grading is an average score, expressed in percent, of all work the student did or did not complete during the course[1,3].

SBG utilizes a 4 Point Scale instead of the traditional method of using a 100-Point scale that expresses grades as a percent. The SBG scale is more accurately described as a rubric. All work completed by the student is assessed on this scale. Each numerical value is referred to as a level and questions or probes are developed to fit these levels. This scale describes the level of understanding and is the communication device to describe grades. The academic achievement grades in this work are based on a body of evidence measured against the Colorado Content Standards. The standard is broken down into a grade level expectation – one that the student should know and be able to do after instruction. For example, significant figures is a concept in any chemistry class. As students learn about significant figures and begin to practice with them, grades are earned. In the standards-based system, these grades are recorded without weight. Meaning, they do not affect the overall grade in the course. However, there is a progress grade for each standard. In the case of significant figures, students may only earn a score of 1 or 2 on the first few assignments, but by the unit test they could improve to a stable level 4. Therefore, their grade would reflect their current understanding of 4. The grade is derived from the work associated with class and focuses on the most recent evidence and trends. Thus, students use SBG as 'the guided construction of knowledge' with the additional benefit of improved accountability and engagement[13,14].

Through SBG, students receive individualized feedback for themselves aligned with the topics in class. The focus is on the students and how they are progressing through the content, instead of on the content and how the students should be progressing[15]. The student is able to see their scores while tying those scores to the class content. This study will support the use of feedback in the SBG system as effective in guiding students toward stronger metacognitive development.

Assessing Metacognition

In this mixed-methods research, a variety of data collection instruments were utilized. These were developed from previous studies as "…explicit teaching is required for students to acquire and apply metacognitive processes"[6]. Standards-Based grading was determined to be the treatment method in improving metacognition by providing individualized feedback to students. Through predictive scoring, metacognition was assessed. Next, students provided feedback to themselves in the form of reflective writing using test reflections (Appendix C). Test reflections also incorporated student perception surveys. Additionally, focus groups were formed from a pool of student volunteers to further expose how metacognition is improved using SBG. Finally, parents participated in qualitative surveys in which they provided insight into their child's progress.

To assess a student's metacognitive ability in this research, a technique was derived from the Miller and Geraci study. Predictive scoring was measured using a student-generated graph representing their predicted score compared to their actual score. These were created with data from all formative and summative assessments throughout the semester. This allowed students the opportunity to judge their own understanding and then compare to the actual score. Students were able to track their level of metacognition. In doing this, students became accurate in their predictions and even used them as motivation to improve scores. A calibration score was used in the metacognitive monitoring that describes the relation between task performance and a judgment about that performance[16-18]. The calibration score was altered for use in an SBG system but originally developed by Hacker, Bol and Bahbahani[19]. By comparison, students in this study were asked to predict their standards-based score ranging from zero to four. The equation:

$$\left(1-\frac{|Predicted-Actual\ Grade|}{4}\right)\ x\ 100 \tag{1}$$

Using this equation, students received a calibration score from 0 to 100 where 0 indicates complete inaccuracy and 100 indicates perfect accuracy. This gave a quantitative value to metacognitive skill acquisition.

Reflective writing was used to qualitatively develop a metacognition analysis[20]. Students completed test prediction and reflection pages in order to more fully develop their own sensitivity to their understanding. The questions were adapted to connect to the perception of the student and were taken from Angelo and Cross[21]; these were completed at the end of a unit. This allowed students to reflect after learning cycles to better qualifying their feelings on their own understanding.

Focus groups were crucial to further define the process of metacognitive development. These groups were patterned after questioning techniques from Mills[21]. Data taken from the previous techniques were analyzed and refined through these focus groups. Probing questions[23] were employed to capture the quality of feedback provided by SBG and improvement in metacognition[24].

To provide further insight, parents were surveyed to utilize their insight into the metacognitive development of their own child. These surveys were developed from Knaack, S., Kreuz, A. & Zawlocki, E.[25]. This further supported the assessment of metacognitive development as it gave the established perspective of the student's parent[26].

Through the use of various data collection instruments from valid resources the reliability of the data collected is supported. In addition, these instruments directly connect with the treatment method as well as provide feedback for stakeholders. This supports the purpose of this action research, and provides data to explain how student metacognition was improved through the use of Standards Based Grading.

RESEARCH SUMMARY

In order to answer how student metacognition is improved through the use of standards-based grading (SBG) a variety of methods were utilized and synthesized. These data collection methods were triangulated in order to best answer the research question and validate those answers.

The sample for this action research project was two sections of honors chemistry classes. All students were utilized in the research with the exception of focus groups. The students selected for focus group participation were randomly selected from a pool of volunteers. Demographically, there are a total of 45 students. Twenty-five were male and 20 were female with 26 sophomores and 19 juniors. As an honors class, students are motivated to succeed. The highest GPA in the sample was a 4.4 with the lowest at 2.8. Within this set of students, 12 were identified as Talented and Gifted. Additionally, nine students were in the AVID (Advancement Via Individual Determination) program. Finally, 37 students are white, four African-American, two are Hispanic and one American Indian/Alaskan Native. Two students are identified as biracial. The school boundaries are designated as upper-middle class economically, urban-suburban setting[26] and there is a strong culture of parental involvement and support. The graduation rate is 89.9% with a total enrollment of 1453[26]. The free/reduced lunch is 6.5% of the student population[28].

The research project spanned the 17-week semester. It was comprised of three units of study. Classes are in a 90 minute block schedule. However, one of the two sections met every day for 45 minutes. A typical unit in Honors Chemistry using standards based grading and metacognitive analysis proceeded as follows. Students completed a pretest to provide a baseline for each student and standard. This way they tracked their own progression. Information was given through direct instruction or online tutorials. Students also completed practice work, labs and various activities such as presentations and projects. For assessment, all quizzes were predicted first then graded in class by the student, and the actual score was recorded as well. All of the quizzes and practice work were available to retake or redo so that students had the opportunity to improve their understanding.

In addition, when an assignment was given they were prompted to write the standard it addressed across the top to remind them of the assignment's importance and use. As each unit test approached, students used their grade book and predictions page to help direct their test preparation. One block period was designated for a review session that consisted of the students filling out a test prediction page and retaking the pretest. The test prediction page asked students to align all the standards and assignments completed during the unit. It also had students record their progress grade associated with each of the standards and underlying objectives. Next, students recorded the score they earned on the unit pretest and predicted their score on the pretest. Students then took the pretest again, received their grade and recorded it on the test prediction page. Ideally, students would then use time outside of class to study and seek help on their areas of concern.

During the next block students took the test. They began the period with the test reflection page. Students recorded all pretest scores as well as predicted the unit test score, and explained why they would receive this score. Once it was graded and returned students would finish the test reflection. Students answered questions prompting metacognition and alignment with standards in class. Each unit of study had a different timeframe. However, units lasted between four and seven weeks.

Student Perception

As the direct recipients of the research on SBG, students' voices were of the utmost importance. Focus groups, surveys and assessment scores were used to determine the effect of SBG on their metacognition and success in class.

First, focus groups were utilized at the midpoint and end of the treatment period[23]. These sessions involved three to five students chosen from a random sampling of volunteers from each of the two class periods involved in this study. Due to the use of volunteers, data from focus groups may not apply to the entire class, but provided insights valuable understanding the impact of using SBG and how this led to improvement of metacognition. The midpoint focus groups centered their discussion on the variety of tools used in class to help learning. Students were clear that SBG is a tool they can use in order to both track and improve their own understanding of chemistry.

Qualitatively identified during these discussions, students felt that predictive scoring, quizzes available for retake and the standards were most helpful. Shown by this quote, five of the ten students are comfortable in a predictable environment they can choose to use in their own way; "…notes, practice, mini and then pretest, test. So it's in order, it's nice. You know what's coming." Metacognition is improved through the predictable, purposeful use of teaching tools. For example, one student remarked, "…you predict everything and we really focus on what you know and what you don't know." Success was promoted by SBG because of the breakdown of standards. This allowed students to know what the grade represents and how to use that in order to improve their understanding. "I know what to study. Normal grading you just know how you did. But no specific in what you know." This specificity in grading allowed students the opportunity to focus their energy in and out of class to better help themselves to become more successful.

At the end of the treatment semester students again participated in focus groups. The results from these sessions further identified the impacts of using SBG. Students identified trend grading as the most helpful aspect of SBG due to its focus on learning instead of scores. However, students also identified SBG as confusing for those that have not experienced the grading system. Metacognition was improved due to the effective feedback of the grading system. One student remarked, "…when things were input to the grade book I was able to see specific assignments that I lacked in but thankfully…it allowed me to see what kind of things I needed to study more instead of a list of assignments. Studying was easier." In addition, the breakdown of the content from class into standards was helpful. This would, essentially, give a checklist of knowledge for students to gather throughout the semester. Six of the eight students interviewed agreed "That paper you gave us with the main focus questions. It gives you the main point of the standard and that brings the focus in and if you do bad on the standard you can go back and look at it and then study from there."

Success in class is shown in the improvement of understanding. Students identified SBG as one vehicle for improvement. "I feel like SBG in general is … a neutral thing. I like the trend grading. You shouldn't start off with a perfect grade because you're learning it and you shouldn't be penalized for that." Trend grading is the final outcome of an SBG score. The work related to a standard is recorded through the learning period then the overall trend is determined as the summative score for that standard. Therefore, students are not penalized for the practice in the beginning stages of learning; the summative score is where the student's knowledge is at the end of the learning period[29]. In addition, this trend coupled with the breakdown of content into standards allows students access to their own level of understanding. "[SBG] really has helped me because I totally understand why my grade is what it is." Students are able to determine their own level of success due to the quality of information they receive from their grade.

Student surveys were conducted at the beginning, midpoint and end of the treatment (Appendix C). These included questions evaluated on a Likert scale as well as open-ended responses. All students in both class periods participated in these surveys (*N=43*). Students felt they knew how well they were learning with 61.5% indicating slightly agree and 34.5% agree. Their preconception of SBG revealed 44% felt it was more effective than traditional methods. At the end of the treatment period, SBG was more accepted with 51% of responses indicating it is a helpful grading system that provided a way to improve themselves.

Throughout the treatment semester, students were surveyed at the end of each unit test for a total of three surveys during treatment. These free response questions analyzed the change in student perception throughout the treatment (Appendix C). The most common response was that SBG identifies what they need to work on. This supports the acquisition of metacognition[7,19]. The breakdown of standards allows students to clearly identify the gaps in their knowledge. Thus, they can take advantage of help in class to improve their understanding. "I believe SBG helped me to better "know what I know" which made it easier to relearn information and concentrate my studying." In addition, this brings the focus of redoes away from grades and toward the understanding of the actual concept. "SBG affected my metacognition by allowing me to re-take minis [quizzes] and stay on top of my grade. By allowing me to fix my grade, it also gave me extra practice which increased my grade."

Students identify their grade by the standards instead of the percent. This identification aids them in improving their understanding. Progression in class is also identified as a strength because students can readily see the change in the grade book.

This allows a communication piece supporting metacognition. Classroom tools allow a method for students to study, practice and self-assess. There was a slow descent of the importance of the standards creating categories of content information. This was alarming at first but indicated that students were becoming more accustomed to the system and in less need of the categories.

A handful of students indicated that SBG was confusing or unhelpful in each survey. While 5% is not a significant amount of the class, these students are still struggling to understand the grading system after an entire semester of school. One of these students received a C- in Honors Pre-Calculus while the other earned a B- in Functions, Statistics and Trigonometry. Grades in their other classes are an indication they may simply be struggling with the material and frustrated with the class in general. One student expanded his response by explaining "I could not tell whether or not I was learning it well enough." This individual participated minimally in class activities and discussions thus suggesting that weaker students are unable to fully utilize their grading system. This is best explained by the Dunning-Kruger effect. These researchers first identified that people with little knowledge are not capable of correctly answering the question and further compound an inaccurate prediction by not having the metacognitive capability to recognize how deficient they are[30]. Further support could be offered to these students in order to better develop their skills.

Finally, assessment data was utilized to determine the effect of SBG on student perception of metacognition and success in class. The results from the calibration scores was determined by a combination of their predicted scores and actual test scores as shown in eq 1. Students predicted what score they thought they would earn on every formative and summative assessment throughout the semester.

To quantify the improvement of metacognition, a comparison, or calibration score, of the predicted scores and the actual scores on the final exam is given in *Figure 1*. The calibration score describes the proximity of the predicted score to the actual score[16-19]. The calibration scores indicate that most students are effective in predicting their score on the test for individual standards. The average of the predicted score and the average of the final exam score was calculated to have a calibration score indicating 97% accuracy (*Figure 1*). This supports the improvement of metacognition as students were able to predict their scores on the final exam.

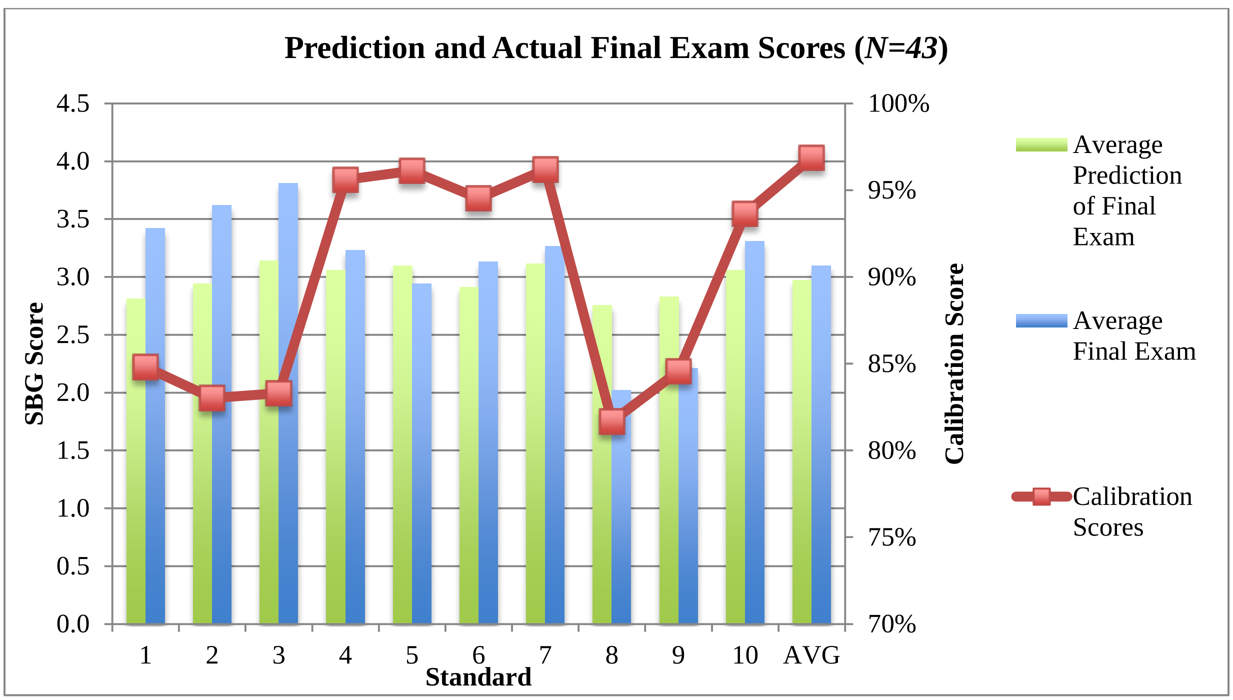

Figure 1. Prediction and Actual Final Exam Scores. (*N=43*)

The left y-axis identifies the SBG score while the right y-axis identifies the calibration scores, expressed as a percent. The x-axis identifies the individual standard scores as well as the average scores on the final exam.

To further determine the usefulness of SBG on improving metacognition, each standard was analyzed. The higher exam scores show a better prediction score than lower exam scores. For example, standards 8 and 9 had low class average scores on the final exam. This would suggest that the students did not know enough to properly predict their score; again, supporting the Dunning-Krueger effect[30]. By contrast, conservative prediction scores were observed for standards 1-4 compared with the resulting high exam scores. Most students predicted within the "B" range on all standards. Ultimately, the average for the prediction of the final exam was a “B+” while the actual average on the final exam was an “A-”.

Students perceive SBG to be a helpful tool in supporting the acquisition of metacognition and an aid toward their success in class. Students are confident in areas but still recognize their weak points. This supports metacognition. The differentiated instruction built into the grading system has allowed students to control their learning. They are free to focus their energy where it needs to be. Through the variety of tools available in class, students indicated that SBG supports them in defining the areas they need to concentrate and, thus, promoting their success in class. “SBG has made me more aware of what I am learning, helped me better prepare for tests, help redeem grades, organize my learning better and how to improve.”

Parent Perception

The intuition and wisdom of parents is a largely untapped resource for teachers. Surveys were given at the beginning, twice during the treatment and at the end of the treatment. In the beginning, parents did not know what SBG was nor did they have strong opinions about metacognition. Data was split in the Likert survey addressing these topics with 44% (*N=33*) of parents in disagreement that SBG should be used, while 58% were supportive of the change. The parents' perception of their student's metacognitive skills was positive; 89% of parents felt their child could explain what he/she was learning. While 79% felt their child could accurately predict the score he/she would earn on a test. Short response answers were cynical. They preferred a traditional system they were familiar with and questioned the change. "I am used to traditional grading. Haven't used other kinds enough to know if they are effective." There were two anecdotal negative experiences shared in the survey responses. The consensus of the parents at the beginning of the treatment is captured in this quote: "I do have a bit of trepidation about the grading system, but I will withhold judgment at this time."

Parents were given a voice at the end of Unit 1 and Unit 2. There was a third unit during the treatment, but a survey at this time would be redundant with the end of treatment survey following only two weeks later. The responses of the Unit 1 survey showed a great need for educating parents about SBG. Parents responded that they needed more time and information about this system of grading (46%) (*N=36*). Unfortunately, 27% were not supportive of the grading system due to a misconception or a previous negative experience. However, 24% did approve and cited the trend grading to have a positive effect on their child as well as the consistency of grading by comparison to a standard. At the culmination of Unit 2 the same survey was administered to parents. Again, some negative feedback was received. This round showed 32% (*N=33*) of parents were not in favor of SBG because they felt it was not as accurate. By contrast, 37% were in favor because the grading system took the emphasis away from the grade and placed it instead on understanding. Metacognition, in the eyes of parents, was stable with 47% on the Unit 1 survey and 50% on the Unit 2 survey characterized by their child's ability to explain what they were learning.

At the end of treatment parents participated in a final survey. When parents compared the grading system, 66% (*N=6*) were now favorable toward SBG. "My child was aware of [what] was expected of him and was able to meet those expectations." In regards to metacognition, 100% of parents felt their child could explain what he/she was learning, how well they were learning it and that the grade was an accurate reflection of the child's understanding. This strongly supports the use of SBG as a way to improve metacognition. Thirty percent of parents felt this grading system helped their child to excel. "I feel this way of grading is much more clear cut for the children to understand." Therefore, metacognition is improved due to direct and specific feedback given through the grading system.

CONCLUSION

The purpose of this research was to determine how student metacognition was improved through the use of standards-based grading (SBG). A mixed-methods action research study was conducted. This revealed the importance of individualized feedback, reflective writing, and predictive scoring to improve metacognition. Data confirmed that metacognition was improved by an unbiased standard deviation value of 5.97. This indicates student predictions were accurate to within 6% of the final exam score.

Data taken throughout the study provided both quantitative and qualitative information. The individualized feedback of SBG was integral to supporting students with information necessary for development of metacognitive skill[4]. In addition, reflective writing was used to qualitatively assess their metacognitive growth[20]. These provided students the framework to assess themselves. This further prompted students to use the feedback from SBG to identify gaps in their knowledge. Students then focused their efforts on weaknesses prior to an assessment.

Metacognition is difficult to quantify but, through the use of predictive scoring and the resulting calibration score, metacognitive improvement was given a value. Students expressed gains in metacognition during focus group discussions. The predictive scoring was utilized as a data collection tool but showed an effect on student metacognitive growth. Students used these scores to motivate themselves.

Application of SBG

The effectiveness of SBG was shown by the improvements in training students to study effectively and enhancing their awareness of their level of understanding. SBG is a reliable tool that can be used to provide increases in these areas. The grading system was helpful in identifying specific areas of weakness or strength. Through the use of predictive scoring, students were able to check their metacognitive skill. Students practiced throughout the semester and became accurate by the end of the semester.

This system of grading can be used in any class and at any level. However, it is through focused effort that students are able to make gains in their metacognition. The combination of SBG and reflective writing are powerful tools, but coupled with predictive scoring, students can easily realize their misconceptions. When this is practiced in preparation for an assessment, students are able to direct their efforts and become successful in class. This skill provides a scaffold for study in any class. Students are able to learn a transferrable skill of self-assessment.

The use of SBG to improve metacognition was determined to be successful during this action research. The use of predictive scoring gave a quantitative value to measure how accurate the student was becoming. In addition, the breakdown of content in the class to definable standards provided the individualized feedback necessary for metacognitive improvement. These standards gave students a target to focus on during preparation for tests. Student metacognition was improved through SBG by the focused use of feedback and predictive scoring.

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APPENDICES

APPENDIX A

IRB APPLICATION: REQUEST FOR EXEMPTION

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained.

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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c/o Immunology & Infectious Diseases
Montana State University
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MEMORANDUM

TO: Courtney Harrell and Walt Woolbaugh

FROM: Mark Quinn, Chair *Mark Quinn clj*

DATE: August 10, 2012

RE: *"Improving Student Metacognition through Standards Based Grading" [CH081012-EX]*

The above research, described in your submission of August 13, 2012, 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

CLASS ACADEMIC STANDARDS

Honors Chemistry Fall Semester Standards

<table>
<tr><td>Point</td><td>Description</td></tr>
<tr><td colspan="2">Unit 1: Introduction the Science of Chemistry
Colorado State Standards Addressed:
2b. Gather, analyze and interpret data on chemical and physical properties of elements such as density, melting point, boiling point, and conductivity
2d. Develop a model that differentiates atoms and molecules, elements and compounds, and pure substances and mixtures</td></tr>
<tr><td colspan="2">Standard 1: What role does science play in chemistry?</td></tr>
<tr><td>4</td><td>Infer the connection between chemistry and science</td></tr>
<tr><td>3</td><td>The student will be able to…
• Explain connection of chemistry to matter.
• Recognize, illustrate and apply the scientific method
• Define and utilize lab safety and equipment
• Measure length, volume and mass
• Define and determine density and its units</td></tr>
<tr><td>2</td><td>Recognize and recall basic terms, such as chemistry and matter
Recognize and recall isolated details, such as:
• Recalling the steps in the scientific method
• Volume is one component in determining density</td></tr>
<tr><td colspan="2">Standard 2: Define and utilize mathematical fundamentals as applied to chemistry.</td></tr>
<tr><td>4</td><td>Infer relationships between fundamental mathematics and chemistry.</td></tr>
<tr><td>3</td><td>The student will be able to…
• Create and analyze various graphing strategies/graphs
• Express numbers in scientific notation
• Apply dimensional analysis to solve various types of problems (i.e., convert between the English and metric systems of measurement)
• Define and utilize significant figures
• Convert between the three temperature scales</td></tr>
<tr><td>2</td><td>Recognize and recall basic terms, such as scientific notation, significant figures and dimensional analysis
Recognize and recall isolated details, such as:
• Either creating or interpreting a graph
• Limited use of scientific notation
• Convert within the metric system only
• Limited use of significant figures
• Single step dimensional analysis problems
• Making use of only two temperature scales</td></tr>
<tr><td colspan="2">Standard 3: Distinguish between chemical and physical changes and properties.</td></tr>
<tr><td>4</td><td>Infer relationships between changes and properties of elements and compounds.</td></tr>
<tr><td>3</td><td>The student will be able to…
• Distinguish between physical and chemical properties and changes</td></tr>
</table>

	• Distinguish between the three states of matter
2	Recognize and recall basic terms, such as chemical change, physical change, chemical property, physical property Recognize and recall isolated details, such as: • Classifying a change as physical or chemical
Standard 4: Develop a method that differentiates atoms and molecules, elements and compounds, and pure substances and mixtures	
4	Infer relationships between the complexities of types of matter.
3	The student will be able to… • Evaluate the difference between elements and compounds • Distinguish between mixtures and pure substances
2	Recognize and recall basic terms, such as element, compound, mixture, pure substance. Recognize and recall isolated details, such as • An atom is an example of a pure substance
Unit 2: The Atom and the Periodic Table Colorado State Standards Addressed: 2a. Develop, communicate, and justify an evidence-based scientific explanation supporting the current model of an atom 2c. Use characteristic physical and chemical properties to develop predictions and supporting claims about elements' positions on the periodic table	
Standard 5: Develop, communicate, and justify an evidence-based scientific explanation supporting the current model of an atom	
4	Infer relationships between experimental discoveries and the current model of the atom
3	The student will be able to… • Analyze the discovery of the atom highlighting the contributions of Dalton, Rutherford, Bohr, Thomson, Chadwick and Schrodinger • Recognize and define the subatomic particles • Define and apply isotope, atomic number and atomic mass • Explain radioactivity and its implications
2	Recognize and recall basic terms, such as subatomic particle, proton, electron, neutron, isotope, atomic number, atomic mass and radioactivity Recognize and recall isolated details, such as • Bohr was one contributing scientist to the current model of an atom • Atomic mass is determined by the number of protons and neutrons in an atom
Standard 6: What patterns can be observed in the properties of elements and families in the periodic table?	
4	Infer relationships between an atom's properties and its placement on the periodic table
3	The student will be able to… • Explain the various features of the periodic table • Explain the importance of Mendeleev's discoveries • Recognize and define the properties of metals, nonmetals and metalloids

<table>
<tr><td></td><td>• Predict the formation of ions</td></tr>
<tr><td>2</td><td>Recognize and recall basic terms, such as period, group, family, metal, nonmetal, metalloid, ion
Recognize and recall isolated details, such as
• Metals are located on the left of the periodic table
• Mendeleev predicted unknown elements characteristics
• Luster is one property of metals
• Electron gain is one way an atom forms an ion</td></tr>
<tr><td colspan="2">Unit 3: Compounds and the Mole
Colorado State Standards Addressed:
4a. Develop, communicate, and justify an evidence-based scientific explanation supporting the current models of chemical bonding
4b. Gather, analyze, and interpret data on chemical and physical properties of different compounds such as density, melting point, boiling point, pH, and conductivity
4c. Use characteristic physical and chemical properties to develop predictions and supporting claims about compounds' classification as ionic, polar or covalent
4d. Describe the role electrons play in atomic bonding
4e. Predict the type of bonding that will occur among elements based on their position in the periodic table</td></tr>
<tr><td colspan="2">Standard 7: Predict the type and formation of a chemical bond using an evidence-based scientific explanation.</td></tr>
<tr><td>4</td><td>Infer relationships between bond formation, electrons and elements placement on the periodic table.</td></tr>
<tr><td>3</td><td>The student will be able to…
• Describe the formation of ionic, covalent and acidic compounds
• Define and apply the law of constant composition
• Explain how a formula describes a compound’s composition
• Compare the properties of covalent and ionic compounds
• Identify diatomic molecules based on Periodic Table placement</td></tr>
<tr><td>2</td><td>Recognize and recall basic terms, such as ionic, covalent, acid
Recognize and recall isolated details, such as
• Transfer of electrons is one method of bond formation
• Element symbol is one piece of information crucial to a compound’s formula
• When dissolved, an ionic compound can conduct electricity is one property of this type of compound
• Covalent bonds occur between elements on the right of the periodic table is one trend</td></tr>
<tr><td colspan="2">Standard 8: Determine the name or formula of a chemical compound or molecule</td></tr>
<tr><td>4</td><td>Infer relationships between ionic, covalent and acid naming rules</td></tr>
<tr><td>3</td><td>The student will be able to…
• Name compounds containing one nonmetal and one metal
• Name binary compounds containing only nonmetals
• Identify polyatomic ions and name compounds containing them
• Name common acids</td></tr>
</table>

	• Write the formula of a compound when given its name
2	Recognize and recall basic terms, such as binary, polyatomic, covalent, acid Recognize and recall isolated details, such as • Inconsistent use of naming rules for all bond types
Standard 9: Define and apply the mole.	
4	Infer relationships between mole and other systems of measure.
3	The student will be able to… • Define mole • Define Avogadro's number and its applications • Convert between moles, Avogadro's number and mass for elements and compounds • Define molar mass
2	Recognize and recall basic terms, such as mole, Avogadro's number, molar mass Recognize and recall isolated details, such as • Limited use of conversion
Standard 10: Determine the formula of a compound.	
4	Infer relationships between a compound's formula and the mole
3	The student will be able to… • Define and calculate empirical formula • Define and calculate percentage composition • Determine formula of compound given empirical formula and molar mass
2	Recognize and recall basic terms, such as empirical formula, molecular formula, percent composition Recognize and recall isolated details, such as • Inconsistent determination of empirical formula • Calculator or rounding errors solving percent composition

APPENDIX C

TEST REFLECTION EXAMPLE WITH STUDENT SURVEY QUESTIONS

Name: ____ Date: _____ Period: _____

Unit 1: Intro to the Science of Chemistry (Chap 1, 2, 5)

Test Reflection

	Standard			
	1	2	3	4
Pretest (Beginning of Unit)				
Pretest (End of Unit)				
Unit Test Prediction				
Explain why you think you will earn this score.				
Actual Unit Test				
Briefly describe the test. What was it about?				
Give one or two examples of your most successful responses. Try to explain what things you did that made them successful.				
Give one or two examples, if relevant, of errors or less successful responses. What did you do wrong or fail to do in each case?				
The next time you confront a similar situation, what, if anything, could you do differently to increase your learning?				
Explain why score does/does not match the prediction score.				

Traditional Grading vs Standards-Based Grading
Which grade is more accurate? Why?

Which grade is more helpful to you? Why?

"Success is the sum of small efforts, repeated day in and day out." ~ Robert Collier