THE EFFECT OF SPECIFIC FORMATIVE FEEDBACK METHODS IN A STANDARDS-BASED GRADING SCIENCE CLASSROOM

by

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STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the MSSE Program shell make it available to borrowers under rules of the program.

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INTRODUCTION AND BACKGROUND

One of the most important aspects of standards-based grading in a high school science classroom is that students are given multiple opportunities to show improvement or mastery on a specific standard. I feel that effective feedback on both formative and summative assessments is an essential part of helping students reach levels of mastery throughout the school year. For my research, I incorporated different types of formative feedback in order to see which type students preferred, and whether one type of strategy was more effective than others.

I have now taught at my school for five years and have taught regular physics using standards-based grading for the past four years. I truly believe that standards-based grading is one of the best ways to assess students and allows them more opportunities to show growth than a traditional classroom. This is because students know exactly what standard they are being assessed on during each quiz. By giving more deliberate assessments, it is now easier to identify areas in which my students excelled and which areas they needed further instruction on. I have always felt that standards-based grading has also allowed me to more easily communicate these needs back to my students and coworkers.

Another area I have wanted to investigate is how student engagement inside and outside of class relates to how they perform on assessments. I have always had students that felt homework completion is not essential to their learning. As part of my research I tracked student engagement and looked at how it relates to their scores on assessments.

In the past, I have always had trouble getting students to take advantage of retakes in my regular physics class. I tracked the number of students that took an additional quiz

outside of class to try to improve their grade. I recorded both qualitative and quantitative data on these students. Going into my action research, I believed that there may have been a correlation between a student's mindset, fixed vs growth, and whether they were more likely to take advantage of retakes.

Standards-based grading is not the normal type of grading at my current high school. Regular physics is the only science course that incorporates this method. Because of this, I plan to share my results with my coworkers as well as administration. It has been discussed in the past whether more subjects should adopt standards-based grading. I hope that my research will provide insight into how both formative feedback and summative assessments in a standards-based grading classroom can positively impact student grades.

Focus Questions

The primary research question I investigated was "What type of formative feedback results in the highest scores on summative assessments?" My secondary research questions were:

1. What type of feedback do students prefer at the beginning and end of the balanced forces unit?
2. How does student engagement in class and homework completion align with student scores?
3. How does student learning mindset (fixed mindset vs growth mindset) relate to the likelihood of them taking an optional quiz #3 to improve their grade?
4. How does each type of feedback strategy effect the teacher?

CONCEPTUAL FRAMEWORK

Introduction

Effective feedback is an essential part of positively impacting student grades. Feedback, if used properly, can have positive impacts on student attitudes toward learning and their success in class. Using feedback effectively depends on many different factors. Researching different feedback strategies was necessary for me to properly implement feedback in a standards-based grading classroom.

Direction for Action Research

In order to ensure having a strong understanding of effective feedback strategies, I researched articles pertaining to best feedback practices. There were common themes between articles and how students respond to feedback. According to an article written by Hatziapostolou & Paraskakis (2010), students are introduced to feedback as "an essential component in all learning contexts and serves a variety of purposes including evaluation of students' achievements, development of student competences and understanding, and evaluation of students' motivation and confidence" (Hatziapostolou, 2010, p. 111). For me to provide my students with quality feedback, it needs to be used effectively no matter the type of feedback they are receiving. The first step to providing students effective feedback is getting it to them in a timely manner. Timely feedback is essential because the assessment is still fresh in students' minds, and they can still remember how they answered the original question. Another important aspect is the way in which feedback is worded to the students. Wording may have a positive or negative effect on how students respond. When writing teacher provided feedback, it should be worded constructively in order to increase student motivation. When I wrote feedback to my students, I tried to personalize it to them based on our past interactions and their

strengths and weaknesses in my class. There is a fine balance on how much feedback should be written to students. While you want the feedback to be descriptive and detailed, too much feedback can confuse the student and be overly time consuming for the teacher. Students need to easily interpret the feedback given by their teacher. Lastly, the feedback should directly relate to the standard that is being assessed (Hatziapostolou, 2010).

Another article used to provide context for my action research was written by Cauley and McMillan (2010). The focus of this article was on implementing feedback into the classroom. One of the discussion points that most resonated to my own classroom was "effective teachers use formative assessments during instruction to identify specific student misunderstandings, provide feedback to students to help them correct their errors, and identify and implement instruction correctives" (Cauley, 2010, p. 1). Using assessments to provide feedback and improve instruction and learning is extremely important in a standards-based grading classroom. This lends itself to incorporating formative feedback cycles with summative assessments.

Assessments and feedback are a continuous process that should be used throughout a unit. Formative assessments can be beneficial to both teachers and students. The teacher can use this process to adjust instruction in order to better meet the needs of their students. The students can use feedback given by the teacher to identify their own misconceptions and make changes before taking their next assessment. This circular cycle is ongoing throughout the entire year and will likely take place multiple times over the same standard. This process aligned with my action research and standards-based grading because of the frequency in which students will be taking both formative and

summative assessments. After each assessment, student received a specific form of feedback to identify misconceptions and improve their understanding. This process naturally allows for feedback cycles to take place in my classroom.

Theoretical Framework

The way in which students are graded on assessments has changed significantly over time. According to an article written by Schinske and Tanner (2014), the original 100-point grading scale was used to compare students to each other from school to school. Consistency in grading has always been difficult to maintain between schools as well as between teachers. The purpose for reporting grades has changed over time as well. According to the article, "constructing a grading system that rewards students for participation and effort has been shown to stimulate student interest in improvement" (Schinske, 2014, p. 163). One of the possible ways to incorporate this is by building in classroom time to allow students collaborating to self or peer review with each other. This does not need to take an extended amount of time, but small activities like this allow students more opportunity to reflect on their work. Traditionally, feedback and grading has been the role of the teacher, and because of this, the teacher needed to devote large amounts of time grading outside of class. Allowing more time for participation and reflection grading can free up time for teachers to improve classroom activities.

Another shift in teaching is a changing perspective on how to use assessments. Assessments originally were a way of ranking students based on how they performed on an end of unit test. It was believed that a high stakes test would be something that motivates students to do well. This was not the case for all students, and the achievement

gap between successful and unsuccessful students was very large. According to an article written by Stiggins (2005),

> The mission of sorting has not been eliminated from the schooling process. For the foreseeable future, students will still be ranked at the end of high school. However, society now dictates that such a celebration of differences in amount learned must start at a certain minimum level of achievement for all. (p. 326).

Schools are now emphasizing using assessments for learning instead of simply assessing what students have learned. Incorporating formative feedback in instruction has become more and more important to ensure that students learn the essential standards. If students do not meet those standards, instruction is adjusted, and students are reassessed to show growth. For this approach to teaching to be successful, the learning outcomes must be clear to students. No longer should students have to guess what they will be assessed on.

In my own standards-based grading classroom, students typically are assessed once a week. This may be a summative or formative assessment, depending on where we are at in a unit. This allows students to receive feedback more often than in a traditional classroom. While students first quiz is technically summative, their scores can be fully replaced by improved scores on a later quiz. Students are not punished for not learning the material as quickly as other students. Our primary concern is that students show growth over time and eventually meet the essential standards.

Methodologies

Looking at the differences between traditional grading vs standards-based grading, it is typically agreed upon that standards-based grading gives a more accurate depiction of what a student knows. In a standards-based grading classroom, grades are reported multiple times on a specific standard. It is very easy to see the progression of a

student's understanding based on how they scored over long periods of time. In traditional grading, a student's final grade is calculated from many different types of assignments. In a science classroom, this may include assessments, labs, projects, and homework. The end grade does not clearly show what a student does and does not know. Even using standards-based grading, there is debate about the best way to report student scores. This debate typically involves the number of assessments and whether scores should be replaced or averaged between assessments. There is no perfect answer to this debate.

Before explaining how my school uses standards-based grading, I would like to provide background on different methods of grade reporting. According to Hooper and Cowell (2014), there are four common methods of reporting scores with standards-based grading. These methods include "a simple average, averaging only the more recent scores, mathematical models of growth over time, and basic teacher judgement" (Hooper, 2014, p. 58). Each method has flaws associated with them and student's final grade may not perfectly reflect a student's understanding. Taking a simple average of student scores on a standard may be weighted disproportionately due to missing assignments that are in the gradebook as a zero. This method may not show how students' scores either improved or regressed over time.

The next method, averaging only more recent scores, does a better job of showing current understanding. The downside to this method is there may be factors that are unaccounted for that may influence student grades. An example would be a student scoring 100% on the first 4 assessments of a standard, and then a 60% on the most recent

one. This student's grade is negatively skewed, when they show clear understanding of the material prior to the most recent assessment.

Using a mathematical model to show student growth ideally would be able to predict how any individual student will score on an assessment. This does not work because there are too many variables that can affect student scores and no two students follow the exact same trend.

The final method of basic teacher judgement leaves a lot of room for bias. Ideally, a teacher can make accurate judgments on what score a student deserves, but depending on student behavior and effort in class, teacher judgement may be skewed one way or another. For the purpose of my action research project, I will collect student data and record final scores on standards using a combination of averaging the most recent two scores or simple replacement of scores when students show growth from one assessment to the next.

During my action research, I also collected student reflection data using a Likert scale survey. To gain a better understanding on writing an effective Likert questionnaire, I researched sentence structure and how it can influence student responses on surveys. When writing a Likert scale survey, you want to consider the number of questions given, a balance between positive and negative statements, and writing valid attitude statements (Moneim, 1984). When giving my students surveys, I focused on reflection statements that addressed homework completion, preparedness for assessments, and attitudes toward scores on assessments. When writing survey questions, it is important not to inadvertently cause a student to respond a certain way based on their previous questions. This can be prevented by incorporating a mixture of positive and negative statements. In

my surveys, I primarily used belief statements, and avoided complex statements that could be interpreted more than one way.

METHODOLOGY

Classroom Treatment

The main treatment for my action research was incorporating formative feedback cycles into my instruction for each standard being assessed in the balanced forces unit. In the past, I have always used formative feedback through problems on the board, but these cycles were more deliberate. The balanced forces unit had three standards, and I used a different type of feedback strategy for each standard. The standards assessed were on paired interaction forces, representing a system as balanced or unbalanced using free body diagrams, and problem solving for unknown forces. For these three standards, the feedback types given were teacher provided written feedback, student collaborate feedback using whiteboards, and student self-written feedback.

Each standards feedback cycle included four instances where students were given a specific type of feedback. The sequence in which students were given the feedback was the same for each standard to remain consistent (Figure 1).

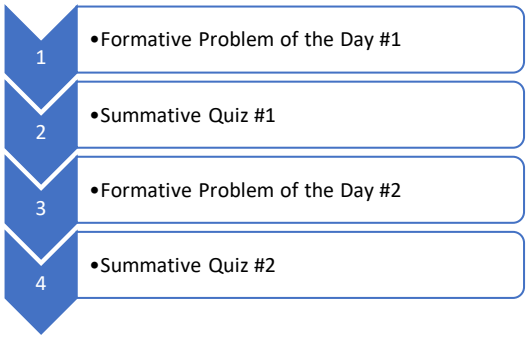

Figure 1. Assessment Sequence.

A problem of the day is essentially an entrance ticket or exit slip. These were given on a half sheet of paper, and typically took about 10 minutes to complete. There was a total of three feedback cycles during the balanced forces unit. Each standard assessed had its own specific feedback cycle that involved one type of feedback. The treatment unit lasted about six weeks. Each week students typically took one formative problem of the day and one summative quiz.

Sampling

The student sample involved in this research study involved three regular physics classes. A total of 73 students participated in the study. Of the 73 students that are enrolled in my classes, 66 of them are juniors and seven are seniors. I do not have any freshman or sophomores in regular physics. Prior to taking regular physics, these students took chemistry as their freshman course, and biology their sophomore year. Forty of my students are female and 33 are male. Four of these students have Individualized Education Plans (IEPs) and two students have 504 plans. The IEP and 504 plans differ between students, but most of the accommodations are for preferential seating and extended time on assessments when needed. One of the classes was during a lunch hour and the other two will be at the end of the day. As a school, our student demographic is 67.3% White/Caucasian, 16.2% Asian, 8.3% Hispanic, 4% Black, and the remaining 4.1% Two or More Races. Overall, 13.4% of our students considered low income students. This is well below the state average of 48.8%.

Data Collection

The first step in collecting data on my students was with a student survey (Appendix A). This survey was given using Google forms. I had all 73 of my students

participate in the survey before the start of the balanced forces unit. The survey used a mixture of Likert style questions and free response questions. The free response questions were used to help clarify why students responded the way that they did on the Likert questions. After the completion of the balanced forces unit, a very similar survey was given to identify if any students' opinions on feedback had changed.

Another set of data was collected on student mindset prior to the balanced forces unit (Appendix B). The purpose of recording student mindset was to see if there was a correlation between student mindset and their likelihood to take a retake on an assessment when they qualify. This mindset quiz was completed in class on paper, and then was scored based on a pre-made assessment tool. This quiz was originally adapted from the book *Mindset: The New Psychology of Success* by Carol Dweck (2007). Student choices on the quiz ranges from strongly disagree, disagree, agree, and strongly agree. Each of the responses were then given a score of 0-3 and then scores were tallied out of 30. Once scores were tallied, students were grouped as either strong growth mindset, growth mindset with some fixed ideas, fixed with some growth ideas, and strong fixed mindset. This data was tracked to students that completed optional quiz #3 to try and improve their grade.

My third, and primary, data collection instrument was the combination of short formative problems of the day (POD), and standards-based grading (SBG) quizzes. All 73 of my students were assess in my regular physics class. The PODs and SBG quizzes were given in the order mentioned in the Treatment section. Students were scored on a scale of 1-4. At my school each score is assigned a percentage in the gradebook. The scores are 1-50%, 2-70%, 3-85%, and 4-100%. Students that scored a 4 on a quiz are

considered to “exceed expectations.” A score of a 3 represents “meeting expectations.” A score of a 2 is considered “partial understanding.” A score of a 1 is “little to no understanding.” The formative PODs were entered in the gradebook, so they were weighted as 0% but SBG quizzes went into the gradebook as summative scores that accounted for 50% of students’ grades.

The way that our school treats SBG is in a way that if students improve from quiz 1 to quiz 2, quiz 1’s grade is replaced in the gradebook. If students do worse on quiz 2 than quiz 1, we average the two percentages in the gradebook. The decision to grade students this way was made between both high schools in the district. We felt that the replacement and average was the fairest way to assess students on their current knowledge levels. Students always have an optional quiz 3 that they can take outside of class to improve their grade. If they score a 4/4 on quiz 3, they score a 100% on the standard.

After each SBG quiz, I used a Google form survey that was a mixture of free response questions and Likert scale questions. The focus of this survey was for students to reflect on their attitudes towards each quiz, preparedness for the quiz from homework completion and classroom engagement as well as their attitudes toward the feedback they were given. Students took this survey a total of six times during the treatment unit. Once after each quiz.

My next data collection method will be student interviews. I interviewed students using a baseline set of questions (Appendix C). These interviews were conducted once students had received feedback on their summative quizzes. Most of the interviews were conducted in student lab groups. To randomly choose groups, I rolled a dice in class to

choose which group to interview. The interview provided me with qualitative data that was then paired with quantitative data recorded from the PODs and SBG quizzes.

The final data collection tool used during the treatment unit was an informal journal that I kept. In this journal, I recorded what went well each week and how students seemed to be involved during each feedback type when going over assessments. I also recorded instances when students were not engaged in class. If students were not mentioned in this journal, I felt that met the normal requirements of engagement in order to succeed in class. I later compared students that were not fully engaged to their scores on assessments. The main purpose of the journal was to remind me of smaller details about each class that I would have likely forgotten otherwise.

Data Triangular Matrix

During my treatment unit, I used a variety of methods to look at student results both quantitatively and qualitatively. In order to gain a better understanding of why my results came out the way that they did, I tried to triangulate student results from multiple angles. Below are all the methods used to record student data.

Table 1
Action Research Data Collection Methods

Data Triangulation Matrix Research Questions:	Data Source					
	Beginning of the year student survey	Homework completion checks	Problem of the day Quiz 1, Quiz 2, Quiz 3	Student Reflection Google Form Surveys	Student Interviews	Teacher Reflection Journal
What type of formative feedback results in the highest scores on summative assessments?	A, B, X	C, D X	E X	B, C, D X, Y	A, B, C, D, E X, Y	F
What type of feedback do students prefer at the beginning and of the semester?	A, B Y		E X	B Y	A, B Y	F Y
How does student engagement in class and homework	A, C Y	C, D X	E X	B, C, D X, Y	C, D	D Y

completion align with scores on assessments?						
How does student learning mindset (fixed vs growth) relate to the likelihood of them taking quiz #3 to improve their grade	A Y		A, E X		A, Y	F
How does each type of feedback strategy effect the teacher?	A Y	C, D X	E X		A, B Y	F Y
Key: Reasons for collecting this type of data A) Data will show student learning type (growth vs fixed) B) Data will show student preference on types of feedback C) Data will show student homework completion D) Data will show student engagement in class E) Data will show student academic progress F) Data will show teacher reflections X) Quantitative data collected Y) Qualitative data collected						

To ensure the validity of all assessments given during the treatment unit. The standards-based grading quizzes were all developed as part of the district wide regular physics curriculum team. This ensured that the quizzes properly aligned with the districts grading guidelines and address our essential standards. I collaborated on the formative problems of the day with additional physics teachers in the building to make sure that both the content and rigor of the PODs were in line with the summative quizzes.

To also ensure the validity of my research, the research methodology used for this project received an exemption by Montana State University's Institutional Review Board (Appendix D) and compliance for working with human subjects was maintained throughout the course of the study.

DATA AND ANALYSIS

Introduction

The majority of the data collection for my action research project centered on a combination of formative and summative assessments. This was intended to provide

detailed information on my primary action research question “What type of formative feedback results in the highest scores on summative assessments?” Secondary data collection methods were used to provide insight into student thinking through feedback surveys, mindset quizzes, and student interviews. Student engagement during class and homework completion was also tracked using a teacher journal and homework checks.

Student Surveys

To start and end my data collection, students were given a beginning and end of the semester survey (Appendix A). This was used as my first and last method of data collection. The survey was broken into sections that focused on homework completion, classroom engagement, teacher provided feedback, student collaborative feedback, and student self-written feedback. Each section used Likert style questions that allowed students to respond with Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. I analyzed all Agreement and all Disagreement together because no two students are the same. Each section also had a free response question asking why students answered a certain way. I used these free response answers to look for patterns in student thinking.

The first set of questions asked students about their views on homework completion (Figure 2).

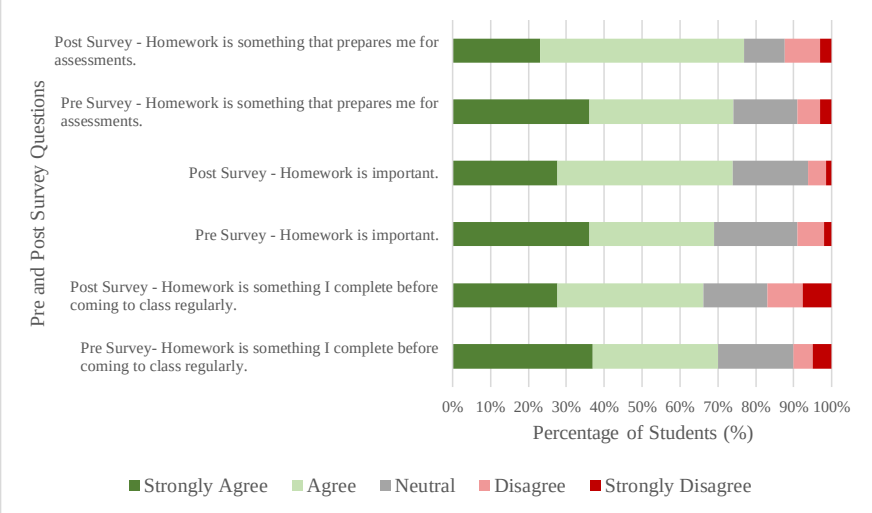

Figure 2. Pre- and Post-Treatment Student Opinions on Homework Completion, (*N*=73).

Looking at data on homework in general, the data from Pre- and Post- survey questions do not show a significant difference in student attitudes. In the Pre-treatment survey, 70% of students either strongly agreed or agreed about all three statements regarding homework. The only statement that dropped in agreement was "Homework is something I complete before coming to class" and this was lowered from 70% to 66%. One thing that I found interesting was that the number of students that disagreed with this statement increased from 10% to 17% on the Post-treatment survey. During one of my interviews, a student said, "I know I should be doing my homework, but I have a hard time completing it outside of class." That same student then agreed that they would have benefitted on assessments if they had done more outside of class. Another student said "I don't think homework is always necessary. It's only 5% of our grade, and if I understand what we are doing, I focus on other classes first." Some of my students also felt that they would rather not do the homework, than do it incorrectly. They wanted more clarification

on the problems before doing it on their own. I personally disagree with this type of student opinion. I try to instill in my students the mentality that you can learn from past mistakes, but this is difficult for some students to do.

The second question set addressed student opinions on classroom engagement (Figure 3).

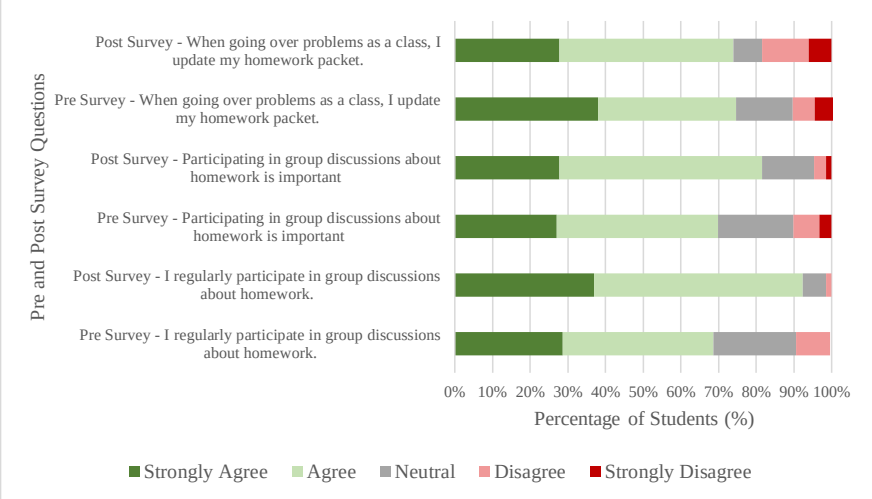

Figure 3. Pre- and Post-Treatment Student Opinions on Classroom Engagement, (*N*=73).

Looking at results on classroom engagement, students believed that engagement in class is more important than their homework completion outside of class. This was consistent with student responses in this section. One of my students was quoted as saying "I usually do fine in classes without doing much homework as long as I talk to the teacher about things that I am confused on." Of the three questions asked, the biggest increase in students' agreement was on "I regularly participate in discussions about homework." This increased from 69% to 92%. The statement "When going over homework in class, I update my homework packet" went from 11% to 19% either

strongly disagreeing or disagreeing. Some of my students that disagreed with this felt it was hard to pay attention, listen, and update problems at the same time.

The third set of questions started to gauge student opinions on different feedback methods they were given throughout the treatment unit. The first feedback addressed was teacher provided feedback.

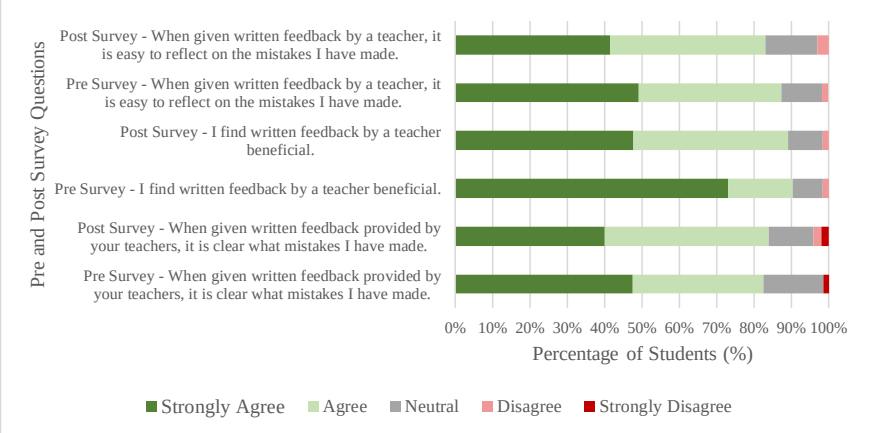

Figure 4. Pre- and Post-Treatment Student Opinions on Teacher Provided Feedback, (*N*=73).

Looking at this data in comparison to the other sets of feedback data, it is clear that students prefer getting feedback directly from their teacher. This feedback type had the highest percentage of students selecting strongly agree and agree of all three types given. The results stayed fairly consistent from pre-treatment to post-treatment. All three sets of questions were within 4% of each other and the lowest percentage of agreement was only 82% on the pre-treatment survey for the "it is clear what mistakes have been made" statement. Even with such a high percentage of students preferring teacher feedback, they still had some issues with it. During an interview, one of my students indicated that "teacher feedback is great but when there is not a clear answer, I

can still find it confusing. I feel like there is usually more than one way to do a problem and it would be easier to just talk to the teacher directly." Most students felt that they had a better understanding of what to do next time after reading teacher feedback.

The next feedback method that was addressed was student collaborative feedback using whiteboards. The structure of the three statements are the same as past segments of the survey (Figure 4) on teacher feedback to allow comparison between data.

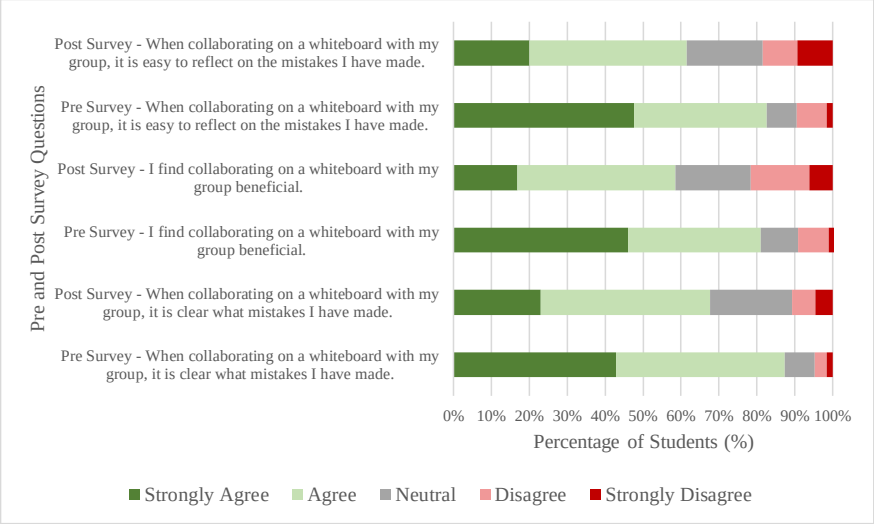

Figure 5. Pre- and Post-Treatment Student Opinions on Student Collaborative Feedback, (*N*=73).

The first thing that stood out to me from the collaborative data was that each of the three statements decreased significantly from the pre- to post-treatment survey. The lowest percentage of agreement in the pre-treatment survey was 81% for the "I find collaborating on a whiteboard with my group beneficial" statement. All three statements agreement decreased by over 20% from the beginning to end of the treatment unit. After discussing this with my students, it was clear why they felt this way. A common theme I

discovered when interviewing students was that students did not like the order in which we went over problems. One of my students said, "I felt the most engaged during whiteboarding, but because we did not have our quiz in front of us while making the whiteboards, I wasn't completely sure what I did wrong until the very end." Not all of my feedback about collaborative learning was negative. A common theme among students was that they were able to see that other students were making the same mistakes as them. This was beneficial because they did not feel as if they were making stupid mistakes because other students in the class had the same problem. Even with this significant drop off in student opinions this was still the second most preferred feedback at the end of the unit.

The final feedback method analyzed was student self-written feedback.

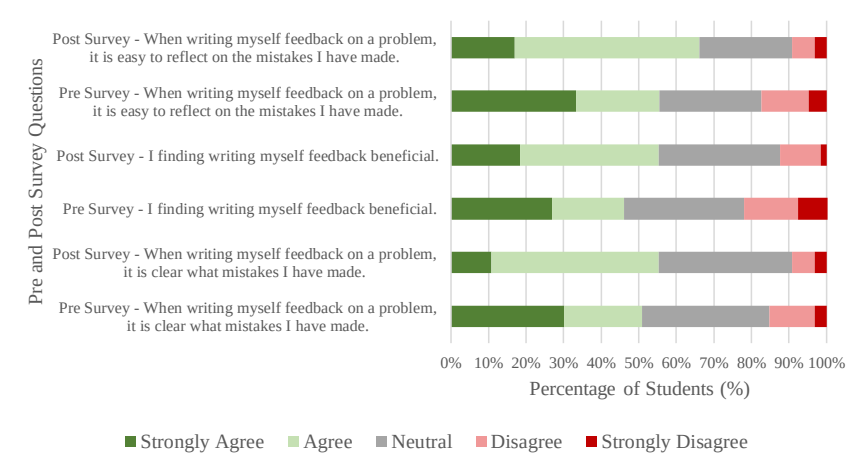

Figure 6. Pre- and Post-Treatment Student Opinions on Self-Written Feedback, (*N*=73).

Looking over the final form of feedback, student self-written feedback had the opposite trend in comparison to collaborative whiteboarding. While the number of students that strongly agreed or agreed about whiteboarding decreased, the number of

students that strongly agreed or agreed about self-written feedback increased for all three statements. While each statement did increase, the post-treatment results are still very similar or below the results of collaborative whiteboarding. The only statement with more agreement for self-written feedback was the first statement about being able to reflect on mistakes. For self-written feedback, 66% of students were in agreement, in comparison to 62% for whiteboarding. When looking at the how clear the mistakes are to students, collaborating whiteboarding had a higher percentage of students in agreement than self-written. While interviewing students, a common theme among students was that they did not feel that they could write themselves good feedback because they did not fully understand the material.

Overall, looking at the survey results and having students rate each type of feedback it became clear that the preferred method of feedback for most students was from their teacher. Below is a table showing the percentage of students preferred feedback type.

Table 2
Students Preferred Feedback Type

Students #1 choice of feedback type received	Pre-Treatment Results	Post Treatment Results
Teacher Provided	40%	69%
Student Collaborative Whiteboarding	26%	24%
Student Self-Written	34%	7%

Looking at the preferred feedback results, it can be seen that collaborative whiteboarding stayed relatively the same before and after the treatment unit. The biggest shifts were in teacher provided and self-written feedback. Teacher provided increased by

29% while self-written decreased by 27%. Even though overall students' opinions on self-written feedback positively increased during the treatment unit, the number of students that preferred this type decreased significantly.

Assessments

In the balanced forces unit, I collected data across three different standards using both formative problems of the day and summative standards-based grading quizzes. The order in which these assessments were given were formative POD #1, summative quiz #1, formative POD #2, and lastly summative quiz #2. This order was the same for each standard assessed. Below shows the percentage of students that scores a 1/4, 2/4, 3/4, and 4/4 on balanced forces standard 1 (Figure 7). To provide context to these scores, students that score 1/4 receive a 50% on an assessment, 2/4 receive a 70%, 3/4 received an 85% and 4/4 score a 100%. The formative PODs were designed to model the rigor of the quiz that followed them. Typically, the rigor of quiz #1 increases slightly to quiz #2. The feedback technique given to students for standard 1 was teacher provided written feedback.

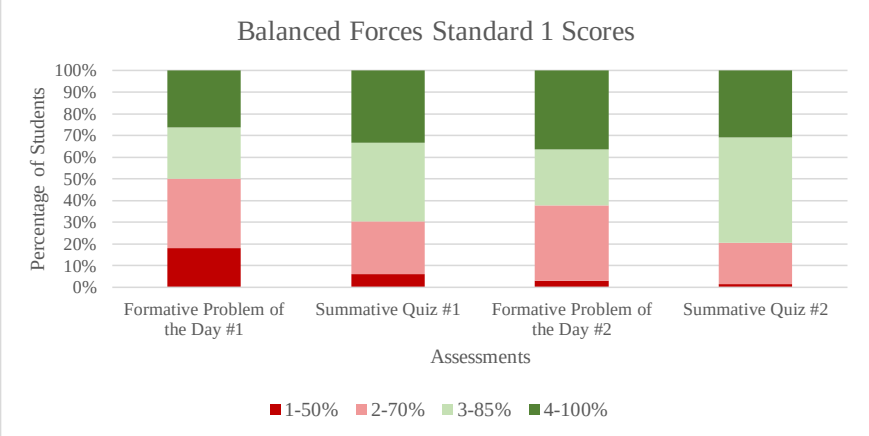

Figure 7. Student Assessment Results for Balanced Forces Standard 1, (*N*=73).

Standard 1 focused on students being able to identify paired force interactions between multiple objects. Looking at the PODs in relation to each quiz, scores improved. On POD #1 and quiz #1, the number of students that met the standard, scored 3 or above, increased from 50% to 69%. On POD #2 and quiz #2, students meeting the standard increased from 62% to 80%. While the number of students scoring a 4/4 decreased slight from 33% on quiz #1 to 31% on quiz #2, the number of students meeting the standard requirements for my class increased from 69% to 80%. This data is showing that the incorporation of feedback cycles using PODs before each quiz was beneficial to my students.

On balanced forces standard 2, students were given feedback by collaborating with their peers using whiteboards. During this standard, I refrained from providing written feedback on student assessments. Each lab group was given a blank copy of the assessments to use as a reference, and then discussed and made a whiteboard key for each assessment. After groups completed their keys, they were given back their assessments to compare (Figure 8). We then had a student led discussion as a class.

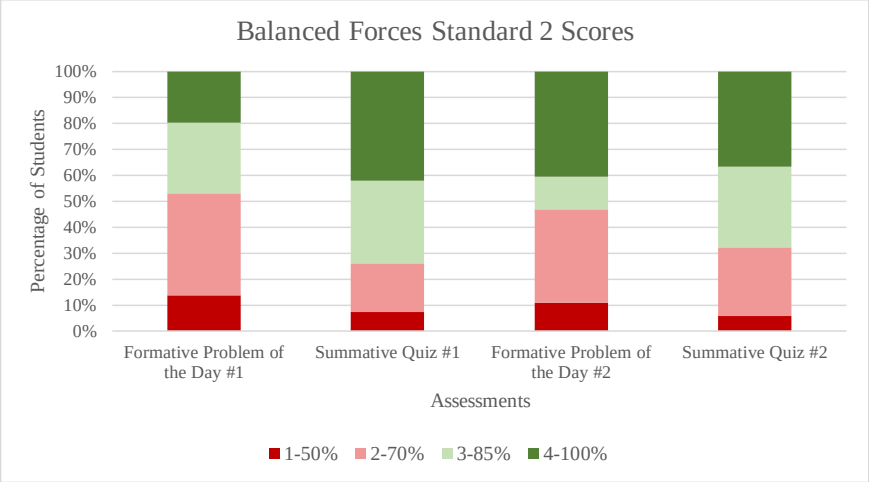

Figure 8. Student Assessment Results for Balanced Forces Standard 2, (*N*=73).

Overall, the second feedback cycle followed a similar trend as the first cycle on standard 1. Student scores increased from POD #1 to quiz #1 as well as POD #2 to quiz #2. The most significant piece of data that stood out to me about this standard was that a higher number of students met the expectation on quiz #1 for standard 2, than did for standard 1. On standard 1, 69% of students met expectations after quiz #1 in comparison to 74% of students meeting expectations standard 2. Looking at scores from quiz #1 to quiz #2, fewer students met expectations on quiz #2. The percentage of students dropped from 74% on quiz #1 to 69% on quiz #2. This drop was primarily due to lack of justification in student answer on the second quiz. When looking at the rigor of the first two standards, I would consider standard 2 to be slightly more rigorous than standard 1. The second standard required students to analyze problems more deeply and justify their answers in writing.

After completing balanced forces standard 2, students were assessed on problem solving for standard 3. While going over this standard, students were providing themselves feedback on assessments. Prior to giving students their assessments back, I scanned in a copy of their work to ensure that no changes were made to assessments. While going over these assessments, students graded themselves using a different color pen while listening to teacher instruction. As the teacher, I did not write any feedback on their assessment, but I did put a score on the top of their quiz. This allowed students to know what they scored on the quizzes before giving themselves feedback (Figure 9).

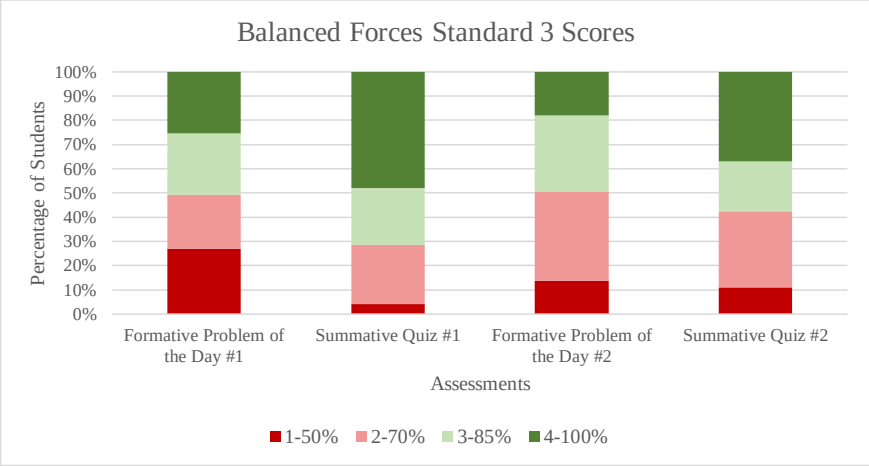

Figure 9. Student Assessment Results for Balanced Forces Standard 3, (*N*=73)

The third feedback cycles followed a similar trend as the first two. After each formative POD the summative quizzes scores improved. Looking at this assessment data specifically, it had the smallest gain from POD #2 to quiz #2. On POD #2 only 50% of students met expectations for the standard. On quiz #2 only 58% of students met expectations. This 8% increase was the smallest percentage gain of all three standards in

the unit form POD #2 to quiz #2. The final percentage of students meeting expectations for standard 3 was also the lowest out of the three standards.

Mindset Quiz and Optional Retake Data

Prior to starting the balanced forces treatment unit, students took a mindset quiz to see if there was a correlation between mindset and their likelihood of taking an optional quiz #3 to try to improve their grade. The mindset quiz categorized students into four groups. These groups were strong growth mindset, growth mindset with some fixed ideas, fixed with some growth ideas, and strong fixed mindset. I then looked at the number of students that did not meet or exceed expectations on quiz #2 and how many of them took the optional quiz #3 to try to improve their grade. This information was over all three feedback cycles instead of only one of the standards. Table 3 below shows this data.

Table 3
Student Mindset and Retake Assessment Data

Student Mindset Groups	Total number of students in each Group	Number of instances where students did not meet expectations after Quiz #2	Total number of Quiz #3's taken	Number of Quiz #3's taken when students did not meet expectations
Strong Growth Mindset	20	20	10	6
Growth Mindset with some Fixed Ideas	47	45	8	6
Fixed Mindset with some Growth Ideas	6	7	1	1
Strong Fixed Mindset	0	0	0	0

Looking at the data on student retakes I found a few things interesting about its results. None of my students fell into the strong fixed mindset group. Most of my

students were considered growth mindset with some fixed ideas. The smallest number of students fell into the fixed mindset with some growth ideas. What this tells me is that most of my students believe that their knowledge grows over time and that they can improve and correct past mistakes.

The second piece of information I found interesting was that the number of students in each group was similar to the number of instances where students did not meet expectations after completing quiz #2. This means that there is not a correlation between mindset group and how a student did on quiz #2. The mindset group did not necessarily impact how well students performed on quiz #2.

In comparison, there does seem to be a correlation between mindset group and a student's likelihood of completing optional quiz #3 to try to improve their grade. Just looking at the instances where students did not meet expectations after quiz #2 the strong growth mindset group was significantly more likely to take quiz #3. During these instances, the strong growth mindset group took quiz #3 30% of the time. The growth mindset with fixed ideas took quiz #3 only 13% of the time and the fixed mindset with some growth ideas took quiz #3 only 14% of the time.

Classroom Engagement and Homework Completion

During the balanced forces unit, I also recorded student scores on homework as well as student engagement in class. The homework was recorded quantitatively based on the percentage students turn in while the classroom engagement was qualitative based on teacher observations. For the homework, I simply took the average of all homework scores during the balanced forces unit. I chose to separate the students into two groups based on whether they had a homework score of greater or less than 70% overall. The

70% average was chosen because it would represent a standards-based grading homework score of 2 or greater. Table 4 below shows this data.

Table 4
Student Homework and Assessment Data

Student Homework Score Group	Average Quiz Percentage	Highest Student Quiz Average	Lowest Student Quiz Average	Number of students below 80% Quiz Average
Homework average less than 70%	83%	100%	57%	8
Homework average greater than 70%	89%	100%	74%	2

When looking at the overall student quiz averages, there is not a significant difference between the two groups. The difference between the two groups is only 6% but there does seem to be a difference between the ranges of student scores. Students that completed less than 70% of their homework had a bottom quiz range of 57% compared to 74% for the other group. The number of students that average a C or lower of quizzes was also significantly higher for the less than 70% group. The higher achieving students in both groups had very comparable quiz averages.

I next compared assessment scores to in class engagement. Classroom engagement was recorded qualitatively based on student observations. Students that were off task were mentioned in my teacher reflection journal. I then gave students a weekly rating of either meeting or not meeting expectations. I then decided to group the students into those same two group but over the entire balanced forces unit. I based student grouping on which group students fell into most of the time during the unit. These results can be seen below in Table 5.

Commented [JD1]: Try to get rid of some of the "I" starting sentences

Table 5
Classroom Engagement and Assessment Data

Student Engagement Group	Average Quiz Percentage	Highest Student Quiz Average	Lowest Student Quiz Average	Number of students below 80% Quiz Average
Does Not Meets Expectations	78%	94%	57%	7
Meets Expectations	92%	100%	78%	3

When comparing classroom engagement data to homework data it appears that classroom engagement has a bigger impact on assessment score than homework completion. There is now a 12% difference between the two different student groups. The range of data between the two groups is still very similar to the homework completion groups. One difference being that the high quiz average for the group of students that did not meet expectations is now only 94%. Most of the students that did not meet expectations, also were also part of the less than 70% homework completion group.

Teacher Reflection Journal

The final piece of data collected was my own reflections using a teacher journal. During the treatment unit, I recorded information in my reflection journal relating to the amount of time I spent grading assessments, the amount of time in class going over assessments, and the relevant levels of student engagement when going over the assessments in class. Between the three different feedback methods, they all had pros and cons associated with them.

When providing students with written feedback. I usually would spend roughly one hour per class grading their assessments. This was the longest amount of time outside of class of the three feedback types. The trade-off was that I spent less time in class going over these assessments. In class, I would go over the assessments while

students looked at my written comments. Students then asked specific questions about their feedback. I would usually spend about ten minutes going over the assessment in class with the students.

Collaborative feedback had almost the opposite effect on the teacher. I graded these assessments very quickly before getting them back to the students. I usually spent about 20-25 minutes per class grading assessments. In class, students would spend roughly 20-25 minutes as well creating their own key to the assessment before getting it back. While this feedback type took the most classroom time it was the most engaging in terms of student discussions and conceptual questions from groups. There were a lot of great discussions when going over the assessments this way. I felt that this was by far the most engaging feedback type.

When students wrote themselves feedback, I felt it did not take very long to grade as the teacher. This was because I wanted students to make their own corrections, so I simply graded the assessments by looking at them and writing a score. While students were engaged in analyzing their own quiz, they were typically quiet while going over the assessment. It was hard to judge students' reactions while going over assessments. I also felt that my lower achieving students had a hard time identifying their mistakes. When we would finish going over the assessment, I would check in with each group to see if anyone had questions, and some of my students simply did not know what questions to ask. Completing all three feedback cycles was rewarding from my perspective. Listening to student opinions gave me a lot to reflect on that I had not thought about in past years.

INTERPRETATION AND CONCLUSION

As previously stated, the primary purpose of this action research was to determine which type of formative feedback was most effective and whether or not students prefer a certain type more than others. This research looked at the effects of teacher provided feedback, student collaborative feedback using whiteboarding, and student self-written feedback. Based on the data collected during the balanced forces treatment unit, my findings are inconclusive as to which feedback type is most effective. All three feedback cycles followed the same trend from formative to summative assessments.

When looking specifically at summative assessment data through the standards-based grading quizzes all three feedback types resulted in student improvement from quiz #1 to quiz #2. Teacher provided feedback saw the number of students that meet or exceed expectations increase from 69% to 80% from quiz #1 to quiz #2. Collaborative feedback stayed relatively constant with 74% initially meeting or exceeding on quiz #1 followed by 68% on quiz #2. This is a difference of two fewer students meeting expectations. Self-written feedback went from 71% to 58% of students meeting or exceeding expectations. One thing to point out is that the rigor of quiz #1 to quiz #2 does increase which could have also played a role in some of the scores decreasing. I personally believe the results would have been similar if I had switched the order of the feedback types.

Another thing to look at is that these three standards are over different concepts. To more thoroughly investigate my results, I would need to repeat this process again while altering the feedbacks to different standards. I do believe that in general the inclusion of feedback cycles has helped students improve during the treatment unit. On

more than one occasion students told me that they appreciated the quick check-ins prior to being assessed on quizzes.

One thing that was very clear is that students prefer to receive teacher provided feedback. Looking at Table 2, 69% of students preferred teacher provided feedback at the end of the treatment unit. The second most preferred feedback type was collaborative feedback. I believe that a combination of these two feedback types will result the highest scores for students. Based on my own observations this combination would result in a good mixture of content feedback provided by the teacher and student engagement through discussions to identify misconceptions and common mistakes. Students clearly liked self-written feedback the least as only 7% of students preferred this at the end of the unit.

My next sub question focused on student engagement and homework completion and how it aligned with student scores. Based on the data it appears that classroom engagement had a bigger impact on my student quiz scores than their homework completion did. This is not surprising as we spend a lot of time reviewing homework in class. Students often felt that if they participated in discussion, they would be ready for assessments. This also agrees with students' opinions on homework completion (Figure 2) and classroom engagement (Figure 3). One of biggest differences between higher and lower achieving students in these two groups was the range of student data on quizzes. The higher achieving group in both cases had a much smaller range of average assessment scores.

The mindset data was another interesting part of my research. I wanted to know if student mindset had an impact on the likelihood of a student taking an optional quiz #3 to

try to improve their grade. Based on my results, it appears that students with a strong growth mindset were most likely to take an optional quiz #3 to try to improve their grade. This only occurred 30% of the time when students did not meet expectations on quiz #2. I still believe that that percentage of students is very low, but it was significantly higher than the remaining student mindset groups. Talking with my strong growth mindset students they had multiple things motivating them to take quiz #3. These motivations included their grade point average, parent encouragement, and personal desire to understand the material better to name a few.

The last sub question focused on how this affected me as the teacher. I am very confident in the results of this section. Based on my journal reflections, the most stressful feedback type was teacher provided feedback. During the treatment unit, I always went over the assessments the next day in class. Teacher provided feedback required the most amount of time outside of class to grade the material. This put stress on me to get students feedback in a timely manner. Collaborative feedback is my preferred method of going over an assessment. I believe this fits my teacher style the best and I prefer to have students leading discussions when going over assessments instead of the teacher being the provider of knowledge at the front of the room. Whiteboard discussions allowed for more students to be engaged in discussion and asking questions about misconceptions and mistakes made. I felt that when going over quizzes using teacher provided feedback and student self-written feedback my students were quieter than I would like. It was hard for me to gauge student understanding based on lack of questions and discussion.

VALUE

During the process of incorporating my action research I learned a lot about my students as well as myself as a teacher. In my classroom I believe I can conclusively say that my students prefer teacher provided feedback over student collaborative and self-written feedback. I believe the incorporation of formative feedback cycles has benefited my students. Frequent check-ins with students on formative assessments allow them to identify their misconceptions before taking summative quizzes. I witnessed students having great discussions while going over formative problems with the goal of trying to identify what they did incorrectly.

Based on my observations this year I need to decide what I should continue to do in the future and what I should adjust to better meet the needs of my students. The first thing that I plan to continue to do is incorporate feedback cycles into my instruction. My students appreciated the opportunities that they were given to receive feedback. Talking with some of my students, they felt they got more feedback in my class than other science classes in the past. I would focus my feedback to incorporate more teacher feedback and collaboration using whiteboards. I feel these two areas are my strengths as a teacher. Student self-written feedback did not seem to have as great of an effect on my students.

One sub question that I would like to investigate in more detail in the future is how student motivation impacts their engagement, homework completion, and likelihood to take an optional third quiz to improve their grade. I was disappointed with the number of my students that took advantage of retakes during my treatment unit as well as throughout the remainder of the school year. As a physics team, we put deadlines on quiz #3 as two weeks after getting back quiz #2. Students don't seem to have the sense of

urgency to improve their grade until the end of the semester when it is too late. I want to know how I can improve student motivation so that they do take advantage of this while they still can. Higher levels of motivation is something that all of my students can benefit from. The students that would likely benefit the most are students that do not meet or exceed expectations on assessments. I think that if I can improve my lower level students' motivation, it will have a positive impact on their grade.

REFERENCES CITED

Bembenutty, H., & White, M. C. (2013). Academic performance and satisfaction with homework completion among college students. *Learning and Individual Differences, 24*(1) 83-88.

Cauley, K. M., & McMillan, J. H. (2010). Formative assessment techniques to support student motivation and achievement. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83*(1), 1-6.

Hatziapostolou, T., & Paraskakis, I. (2010). Enhancing the impact of formative feedback on students learning through an online feedback system. *Electronic Journal of e-Learning. 8*(2), 111-122.

Hooper, J., & Cowell, R. (2014). Standards-based grading: History adjusted true score. *Educational Assessment, 19*(1), 58-76.

Iamarino, D. L., (2014). The benefits of standards-based grading: A critical evaluation of modern grading practices. *Current Issues in Education, 17*(2), 1-12.

Moneim, A., Hassan, A., & Shrigley, R. L. (1984). Designing a likert scale to measure chemistry attitudes. *School Science and Mathematics, 84*(8), 659-669.

Schinske, J., & Tanner, K. (2014). Teaching more by grading less (or differently). *CBE Life Science Education. 13*(2), 159-166.

Stiggins, R. (2005). From formative assessment to assessment for learning: A path to success in standards-based schools. *Phi Delta Kappan, 87*(4), 324-328.

APPENDICES

APPENDIX A

STUDENT SURVEY

For the following statements, read each statement carefully and choose the answer that you best identify with. These questions will be used for educational purposes only and will not affect your grade. Your answer choices for the following statements are:

HOMEWORK COMPLETION

1. Homework is something I complete before coming to class regularly.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
2. Homework is important.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
3. Homework is something that prepares me for assessments.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
4. The amount of homework I complete aligns with how I do on assessments.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
5. Why did you answer the above questions the way that you did?

CLASSROOM ENGAGEMENT

1. I regularly participate in group discussions about homework.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
2. Participating in group discussions about homework is important.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
3. When going over problems as a class, I update my homework packet.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
4. Why did you answer the above questions the way that you did?

TEACHER PROVIDED FEEDBACK

1. When given written feedback provided by the teacher, it is clear what mistakes I have made.
   Strongly Disagree Disagree Neutral Agree Strongly Agree
2. I find written feedback provided by a teacher beneficial.
   Strongly Disagree Disagree Neutral Agree Strongly Agree

3. When given written feedback provided by a teacher, it is easy to reflect on the mistakes I have made.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

4. Why did you answer the way that you did?

STUDENT COLLABORATIVE FEEDBACK

1. When collaborating on a whiteboard with my group, it is clear what mistakes I have made.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

2. I find collaborating on a whiteboard with my group to be beneficial.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

3. When collaborating on a whiteboard with my group, it is easy to reflect on the mistakes I have made.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

4. Why did you answer the way that you did?

SELF WRITTEN FEEDBACK

1. When writing myself feedback on a problem, it is clear what mistakes I have made.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

2. I find writing myself feedback beneficial.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

3. When writing myself feedback on a problem, it is easy to reflect on the mistakes I have made.

   Strongly Disagree Disagree Neutral Agree Strongly Agree

4. Why did you answer the way that you did?

FEEDBACK RANKING

1. Of the three types of feedback discussed in this survey (teacher provided, student collaborative, self-written) rank them from most effective to least effective.
2. What other types of feedback not mentioned have you had success with in the past?

APPENDIX B

MINDSET QUIZ

For each of the following statement, check the box that you most identify with	Strongly Agree	Agree	Disagree	Strongly Disagree
Your intelligence is something very basic about you that you can't change very much				
No matter how much intelligence you have, you can always change it quite a bit				
Only a few people will be truly good at sports, you have to be born with the ability				
The harder you work at something, the better you will be				
I often get angry when I get feedback about my performance				
I appreciate when people, parents, coaches, or teachers give me feedback about my performance				
Truly smart people do not need to try hard				
You can always change how intelligent you are				
You are a certain kind of person and there is not much that can be done to really change that				
An important reason why I do my school work is that I enjoy learning new things				

APPENDIX C

STUDENT INTERVIEW QUESTIONS

1. How do you feel the balanced forces unit is going so far? Why do you feel that way?

2. After taking quiz, did you expect to get the score that you did? Why or why not?

3. What is the first thing you typically do when you get back a quiz? What is the second thing you do?

4. What did you like or dislike about the type of feedback you got on the quiz?

5. After getting the feedback on the quiz, do you think the grading guidelines are clear?

6. What do you plan to do with feedback you got? Are there any changes you need to make before taking quiz 2/3?

APPENDIX D

INSTITUTIONAL REVIEW BOARD EXEMPTION

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: David Lawrence Johnson and Walter Woolbaugh

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

DATE: November 12, 2019

RE: *"The Effect of Specific Formative Feedback Methods in a Standards Based Grading Classroom" [DJ111219-EX]*

The above research, described in your submission of November 10, 2019, 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; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).

___ (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.

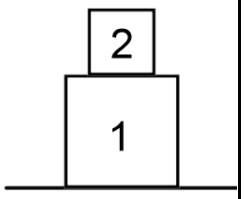
Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX E

BALANCED FORCES STANDARD 1 POD 1

Physics Unit 3: Balanced Forces **Name**
BFPM 1 POD 1 - Force Interactions **Date** **Hour**

Two boxes are stacked on top of each other at rest.



Draw the **interaction diagram** for **Box 1** and **Box 2**.

Free Body Diagram for **Box 1**

Free Body Diagram for **Box 2**

What is the **force interaction pair** between Box 1 and Box 2? Label this force on all three diagrams above with a triangle.

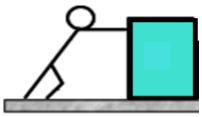
APPENDIX F

BALANCED FORCES STANDARD 1 QUIZ 1

Unit 3: Balanced Forces **Name** _____
BFPM Standard 1 Pass #1 **Date** _____ **Hour** _____

	**Standard**	**Score**
	BFPM 1: *I can identify force as an interaction between a pair of objects.*	

1. Rosie Hawk pushes a refrigerator across the floor of her apartment at constant velocity. For the situation below, draw the interaction diagram for Rosie and the refrigerator.



Interaction Diagram

2. Draw the free body diagrams for Rosie and the refrigerator.

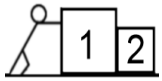
FBD Rosie **FBD Refrigerator**

3. State the **Force Interaction Pair** between Rosie and the refrigerator. In addition, label this force on all three diagrams with a triangle.

APPENDIX G

BALANCED FORCES STANDARD 1 POD 2

Physics Unit 3: Balanced Forces **Name**
BFPM 1 POD 2 - Force Interactions **Date** **Hour**

<table>
<tr><td>Redhawk pushes two boxes across the floor at a constant velocity
 
</td><td colspan="2">Draw the interaction diagram for Box 1 and Box 2.</td></tr>
<tr><td colspan="2">Free Body Diagram for Box 1</td><td>Free Body Diagram for Box 2</td></tr>
<tr><td colspan="3">What is the force interaction pair between Box 1 and Box 2? Label this force on all three diagrams above with a triangle.</td></tr>
</table>

APPENDIX H

BALANCED FORCES STANDARD 1 QUIZ 2

Unit 3: Balanced Forces **Name**_____
BFPM Standard 1 Pass 2 **Date** _____ **Hour** _____

	**Standard**	**Score**
	BFPM 1: *I can identify force as an interaction between a pair of objects.*	

1. Red Hawk is on the soccer team and the game is about to start. The ball starts at rest and is kicked into play by Red. Draw an interaction diagram for the moment Red's foot is in contact with the soccer ball.

Interaction Diagram

2. Draw the free body diagrams for the soccer ball and Red. Identify the force interaction pair(s) in all three diagrams.

FBD Soccer Ball **FBD Red**

3. For the following sets of forces, identify if they are force interaction pairs and if they are equal in magnitude (size).

	Forces	**Are the forces interaction pairs? Circle answer.**		**Are the forces equal in magnitude? Circle Answer.**	
a	F_g on Red by Earth & F_g on Earth by Red	Yes	No	Yes	No
b	F_g on Red by Earth & F_N on Red by ground	Yes	No	Yes	No
c	F_a on Red by ball & F_a on ball by Red	Yes	No	Yes	No
d	F_f on Red by ground & F_a on Red by ball	Yes	No	Yes	No

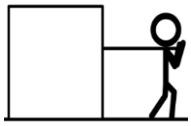
4. Choose one of the force combinations from question #3 and explain your reasoning.

APPENDIX I

BALANCED FORCES STANDARD 2 POD 1

Physics Unit 3: Balanced Forces **Name**

BFPM 2 POD 1 - Balanced or Unbalanced Forces **Date** **Hour**

Redhawk pulls on a box the moment the box begins to move. 	Draw the interaction diagram for the **box**:	Draw the Free Body Diagram for the **box**. (indicate with tally marks any forces that are equal).
Write the force equations for the box:		
Explain how the motion of the box relates to whether or not the box has balanced forces acting on it.		

APPENDIX J

BALANCED FORCES STANDARD 2 QUIZ 1

Unit 3: Balanced Forces **Name** _____
BFPM Standard 2 Pass 1 **Date** _____ **Hour** _____

	Standard	**Score**
	BFPM 2: I can distinguish between balanced and unbalanced forces and how they relate to the motion of a system.	

1. A soccer ball rolls across a field to the right and slows down.	Draw the Interaction diagram.	Draw the Free Body Diagram for the Ball. (indicate with tally marks any forces that are equal).
		
Write the Force Equations:		
How does the motion of the soccer ball relate to **balanced** or **unbalanced** forces that are acting on the system? Refer to your Free Body Diagram in your explanation.		

2 A hockey puck glides across a smooth patch of ice at a constant velocity to left.	Draw the Interaction diagram.	Draw the Free Body Diagram for the puck. (indicate with tally marks any forces that are equal).
		
Write the Force Equations:		
How does the motion of the hockey puck relate to **balanced** or **unbalanced** forces that are acting on the system? Refer to your Free Body Diagram in your explanation.		

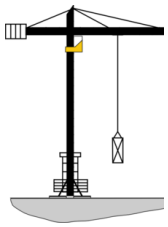
3 An elevator speeds up as it rises.	Draw the Interaction diagram.	Draw the Free Body Diagram for the elevator. (indicate with tally marks any forces that are equal).
		
Write the Force Equations:		
How does the motion of the elevator relate to **balanced** or **unbalanced** net forces that are acting on the system? Refer to your Free Body Diagram in your explanation.		

Commented [2]:

APPENDIX K

BALANCED FORCES STANDARD 2 POD 2

Physics Unit 3: Balanced Forces **Name**
BFPM 2 POD 2 - Balanced or Unbalanced Forces **Date** **Hour**

A crane lowers a box while it is slowing down to a stop. 	Draw the interaction diagram for the **box**:	Draw the Free Body Diagram for the **box**. (indicate with tally marks any forces that are equal).
Write the force equations for the box:		
Explain how the motion of the box relates to whether or not the box has balanced forces acting on it.		

APPENDIX L

BALANCED FORCES STANDARD 2 QUIZ 2

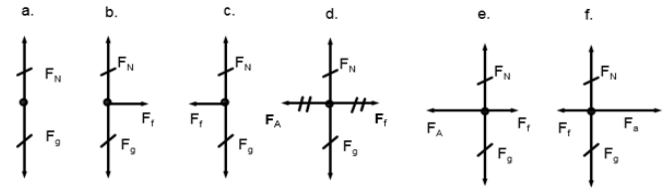
Unit 3: Balanced Forces

BFPM Standard 2 Pass #2 Date _____ Hour _____

	Standard	**Score**
	BFPM 2: I can distinguish between balanced and unbalanced forces and how they relate to the motion of a system.	

Match the descriptions of the motion of the event to the appropriate force diagrams. Choose **one** of the force diagrams that you think applies to each situation (there may be more that work) and provide an explanation of your choice in the space provided. Your explanation should include the **force equations** and whether they are **balanced or unbalanced** in both the horizontal and vertical directions.

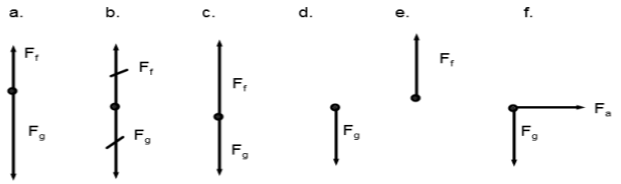
Description of the Motion	Force Diagram	Force Equations & Justification of your Answer
Ruby Hawk is gliding to the right across the ice at a constant speed.		
Ruby is skating to the right but slowing down.		
Red Hawk is driving the Zamboni to smooth the ice. He is traveling at constant speed to the left.		
Red Hawk is now speeding up to the left.		



Match the descriptions of the motion of the event to the appropriate force diagrams. Choose **one** of the force diagrams that you think applies to each situation (there may be more that work) and provide an

explanation of your choice in the space provided. Your explanation should include the **force equations** and whether they are **balanced or unbalanced** in both the horizontal and vertical directions.

Description of the Motion	Force Diagram	Force Equations & Justification of your Answer
Red Hawk hit a baseball, and now it is rising up through the air (ignore air resistance).		
The ball is now at the top of its trajectory and about to fall back down (ignore air resistance).		
Ruby Hawk is skydiving. She just jumped out of the plane and is speeding up.		
Ruby Hawk has opened her parachute and is traveling at constant speed.		

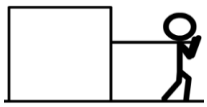


For the above free body diagrams, air resistance will be labeled as a frictional force.

APPENDIX M

BALANCED FORCES STANDARD 3 POD 1

Physics Unit 3: Balanced Forces **Name**
BFPM 3 POD 1 A - Solving for Unknown Forces **Date** **Hour**

Redhawk pulls a box at a constant velocity with 35 N of force. 	Draw the interaction diagram for the **box**:	Draw the Free Body Diagram for the **box**. (indicate with tally marks any forces that are equal).

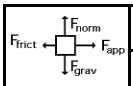
The box has a mass of 7 kg. Clearly solve for <u>every unknown force</u> that is acting on the box.

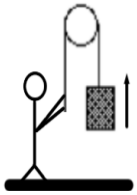
Start your solution by writing out your Force Equations. Show all math models before substituting in numbers.

APPENDIX N

BALANCED FORCES STANDARD 3 QUIZ 1

Unit 3: Balanced Forces **Name _____**
BFPM Standard 3 Pass 1 **Date _____ Hour_____**

	**Standard**	**Score**
	BFPM 3: I can model balanced forces acting on a system by drawing a free body diagram and writing force equations to solve for unknown forces.	

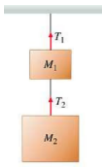
Using a pulley, a student raises a box at a constant velocity.	Draw the Interaction diagram.	Draw the Free Body Diagram for the Box. (indicate with tally marks any forces that are equal).
		

The box has a mass of 12 kg. How much force must the student use in order to raise the box at a constant velocity?
Start your solution by writing out your Force Equations in both directions.
Show all math models before substituting in numbers.

APPENDIX O

BALANCED FORCES STANDARD 3 POD 2

Physics Unit 3: Balanced Forces **Name**
BFPM 3 POD 2- Solving for Unknown Forces **Date** **Hour**

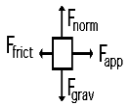
Two boxes are hung from a ceiling.  	Draw the interaction diagram for **box #1**:	Draw the Free Body Diagram for **box 1**. (indicate with tally marks any forces that are equal).

Box 1 has a mass of 5 kg and box 2 has a mass of 8 kg.
Clearly solve for every unknown force that is acting on box 1.
Start your solution by writing out your Force Equations. Show all math models before substituting in numbers.

APPENDIX P

BALANCED FORCES STANDARD 3 QUIZ 2

Balanced Forces **Name** _____
BFPM Standard 3 Pass #2 **Date** _____ **Hour** _____

	**Standard**	**Score**
	BFPM 3: I can model balanced forces acting on a system by drawing a free body diagram and writing force equations to solve for unknown forces.	

Snoopy the dog is sleeping on his doghouse. Snoopy has a mass of 4.8 kg. The doghouse has a mass of 16.3 kg.

Interaction Diagram 	FBD for Snoopy AND FBD for doghouse
Force Equations for Snoopy	Force Equations for Doghouse
Solve for **ALL forces** acting on the doghouse. Show all math models before substituting, and show all work.	