

SELF-PACED MASTERY LEARNING IN AN ACADEMIC PHYSICAL SCIENCE
CLASS AND ITS EFFECT ON STUDENT ACHIEVEMENT,
ENGAGEMENT AND SELF-EFFICACY

by

Amanda Corinne Stone

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DEDICATION

This is dedicated to the people who I love who encouraged me to pursue this degree and believed in my abilities as a teacher, writer and communicator.

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ABSTRACT

Research has shown that tiered instruction and self-paced activity progression improves student achievement and motivation. This study examined the use of self-paced mastery learning units in a high school academic physical science class. Following a grid of learning opportunities, students progressed to new learning objectives only after reaching 80% mastery on their current learning objectives. Data was collected to determine the interventions' effect on student achievement, engagement and self-efficacy. Medium to large academic learning gains were reported using the mastery learning interventions. Survey data indicated that students had a more difficult time paying attention while working through units with mastery learning grids, and that class was not as easy after the interventions. Some felt more challenged. Student self-efficacy increased, as they became more confident accessing resources for help. Implications for further research include testing the method at the beginning of the school year, adjusting the incorporation of hands-on activities in the mastery learning format, and using the strategy for a few select concepts as opposed to a full unit.

INTRODUCTION AND BACKGROUND

In the five years that I have been a high school science teacher, a constant challenge of mine has been to find ways to engage and formatively assess students for their various levels of understanding. In my classes, I would notice that some students would rather sit quietly than do a task that they were not interested in. Often because of lack of motivation, these quiet students did not advocate for themselves when they had questions or misunderstandings. I struggled to identify and inspire these students to care about their learning and to put effort into making sense of science.

I started devising a classroom-based research project on differentiation when I was teaching high school biology at my first school district in Dubuque, Iowa. My idea began taking form after attending a research presentation on strategies to teach stoichiometry in chemistry. The presenter asserted that she wanted to extend her study by implementing checkpoint quizzes to monitor student proficiency and to pace their lessons. Learners would have to pass a quiz of the first stoichiometry topic to move on to the next, harder, stoichiometry topic. Later, I spoke with her about trying this method in my biology classes during an upcoming genetics unit.

We brainstormed that for each inheritance pattern of increasing difficulty, there would be two forms of quizzes and two forms of practice sheets. If a student failed one of these genetics quizzes, he or she would be handed a practice sheet about the topic and would be allowed to take a different form of the same quiz the following day. The passing students could move on to a harder inheritance topic, where they could either practice the skill, or take the next quiz. Each quiz would consist of one Punnett square

problem, and scoring would be either pass, or fail. If a student passed the quiz, no matter how many different forms of it she took, she would get full credit.

I piloted this technique with my classes as a review for their genetics test. It seemed beneficial, especially with my less-motivated students who would typically sit silently. I saw students who were further ahead instructing others, which I had rarely observed before. One of my classes that was at a higher academic level accelerated to challenging material faster. I saw the potential for instructional extensions, such as station practice and discussion forums.

Although the first run went well, there were still some logistics I needed to figure out, like keeping a certain level of anonymity to having learners taking different level quizzes at different times. Also, I wanted to encourage mentoring, but in a way that was not threatening to the lower- or higher-level students. Having run this pilot using all paper resources, I thought that maybe electronic resources would help with tracking and keeping the learners' progress more anonymous. I wondered if using short instructional videos could aid my students at their various content levels better than paper notes and assistance from myself.

The second district that I taught at was Brecksville-Broadview Heights High School (BBHHS) in Broadview Heights, Ohio. This school was higher performing than my first school, with 98% of students proficient or higher in math, and 99% of students proficient or higher in English on the school's 2013-2014 Ohio Graduations Tests. Per the U.S News & World Report, total enrollment at BBHHS was 1,460, with 11% of students categorized as racial minorities and 11% categorized as economically

disadvantaged (2014). Regardless of the higher level of these students, I continued to notice that some individuals would sit quietly and were unmotivated to ask for help even if they did not understand the material. I observed this the most in my academic physical science classes. These pupils were generally freshmen who were struggling with the increased rigor of high school science, yet lacked the knowledge and initiative to productively study outside of class. Many students and parents were disgruntled at the fact that they were not succeeding in science as well as they did in middle school.

I decided to continue developing a self-paced learning format for my classes that would support my new academic physical science students during the daily time that I had with them. The need for differentiation in these classes, as well my earlier experimentation with checkpoint quizzes teaching biology, led me to developing my research question for the school year: *in academic physical science, what was the effect of a self-paced mastery learning class format on student achievement, engagement and self-efficacy?*

CONCEPTUAL FRAMEWORK

Differentiation is a strategy that aims to support all students by adding individualization into the learning process. Differentiation can be planned in a multitude of ways. Some types involve small instructional changes, while others require more preparation. The various forms of differentiation are typically divided into three distinct categories. Instructors may choose to differentiate the content that each student receives, the process by which he or she learns the material, or the learning product that he or she finally displays (Tomlinson, 1999).

Teachers can effectively differentiate in their classrooms by utilizing flexible grouping. This allows instructors to put together students who have similar needs, interests, or learning styles. With each formative assessment, the teacher groups students accordingly. The groups are short-term and allow for learners to move fluidly through environments that are tailored specifically for them. Flexible grouping is best accomplished when the class has reached a point at which some students are ready to move on, but others need more processing time. It can also be used when some might benefit from a higher-level task, while others might benefit from a more-structured task (Heacox, 2002).

Flexible grouping allows teachers to vary assignments in tiers. One way that instructors can vary tiers is to use Bloom's Taxonomy (Gregory & Chapman, 2007). To start, the teacher determines the concept that he or she wants all students to understand, which is often at Bloom's application level where students must demonstrate content knowledge. He or she can then vary complexity, number of steps, or products. Higher tiers will most likely be at the analysis or evaluation level (Kapusnick & Hauslein, 2001; Heacox, 2002).

One method to tier instruction is to use a *layered curriculum*. In this system, the tier where students learn basic concepts is called the "C" layer, the next tier, where students manipulate information and apply skills, is the "B" layer, and the top tier, where students conduct higher-order thinking tasks, is the "A" layer. The letters correspond to the grade that the student receives depending on the layers that he or she has completed. All students start at the "C" layer until they show proficiency, then they move on to the

“B” layer, and so on. To show proficiency, students must give an oral defense that proves that they mastered the material on that layer (Nunley, 2003).

The term *mastery learning* refers to supporting students of diverse levels gradually develop more challenging skills through performance standards, flexible time, and specialized assistance (Burkman & Brezin, 1981). In an analysis of 108 studies of the effects of mastery learning, Kulik, Kulik and Bangert-Drowns found medium to large gains in student achievement (as cited in Ostrowski, 2015). Inspired by these findings, The Grid Method was developed as a system to set up a self-paced classroom with mastery learning conditions (Ostrowski, 2015).

The way The Grid Method works is that instructors develop an outline of learning opportunities for students to follow consisting of five levels per content standard of increasing depths of knowledge, with the last level being an independent exploration. Learners move along the grid tasks at their own pace and advance only when showing mastery. Mastery in The Grid Method is defined as 85% or higher. A traditional summative assessment is often at the end of the third level of the grid. As students work, the teacher helps with questions and concerns, and provides guidance to those identified as needing the most support. Facilitative suggestions include having students use stoplight-colored cups or table tents to signal for help in a less-obtrusive and more productive way. The teacher can then triage issues based on the colors displayed by the students (Ostrowski, 2015).

In a pilot study of the effectiveness of The Grid Method, a year-to-year comparison was completed. The first year was without any system implemented, and the

second was with The Grid Method implemented. Variables such as school demographics, the instructor, and the instructional unit were all kept consistent. After the implementation of The Grid Method, 90% of students were meeting the content standard at 70% or higher, compared to only 38% the year before (Ostrowski, 2015).

Swanson and Denton point out that although previous research on mastery learning has shown higher student achievement, it also has been argued to take too much instructional time (as cited in Burkman & Brezin, 1981). In response to this, one study implemented a quasi-mastery teaching method to test if a time limit would alter the effectiveness of the strategy. Students were given a set time to complete three mini-courses, but they could move fluidly between these courses depending on their proficiency. In addition, they could pass through activities if they could already perform the skill on an assessment. The study was most effective with medium performance standards. Scores for higher performance standards were not as high, possibly because those skills made the students feel somewhat defeated and, as a result, they gave up with their practice during the learning period (Burkman & Brezin, 1981).

Regardless of the tiering method applied in the classroom, instructors need to focus on how to keep the system fair. Different studies note that no group should be doing more or less work than any other group (Heacox, 2002; Little, Hauser & Corbishley, 2009). Other suggestions include using neutral group names, such as colors or numbers, or using cards or pre-made lists to assign students to groups and to make tiering invisible. The benefit to this is that students in the lower levels do not feel singled out. Invisible tiers can be achieved by varying the groups and the intention of the groups

often. If students are not grouped by ability each time, they will not notice any trends. The type of work should be equally engaging in each of the tiers to not create resentment by the students (Heacox, 2002).

Differentiation takes time. Literature suggests starting small and focusing on one differentiated topic or strategy at a time. It is better to have a few high-quality lessons developed than a lot of mediocre ones. With every passing year, the number of differentiated lessons grows (Heacox, 2002; Tomlinson, 1999).

Studies exist indicating tiering instruction has beneficial effects on student learning. A study of 388 freshmen in their first semester of general science found that the groups for learners with the least background knowledge showed the most academic growth. The groups for learners with high background knowledge showed the least academic growth, but this may have been related to the pre- and post-assessment not being challenging enough. Many students in this group scored the highest possible marks on their post assessments (Richards & Omdal, 2007).

In a Calculus I university course, allowing students to work on activities based on their own level and to progress at their own pace increased overall learning, engagement, and motivation (Konstantinou-Katzi, Tsolaki, Meletiou-Mavrotheris & Koutselini, 2013). In a middle school science classroom, a Capstone Project was performed testing the effectiveness of Nunley's (2003) layered curriculum. The class format increased student enjoyment and engagement, but there was no statistically significant change in student achievement (White, 2015).

One study examined the use of differentiation from the perspective of the students. Data was collected via a survey of 646 students in grades 3-8 on their preference for differentiation strategies in their favorite subject or class. The study showed that students enjoyed tasks that allowed for individualization and self-pacing. The learners disliked being assigned workmates, being taught by classmates, or sharing work with older students (Kanevsky, 2011). A study examining the benefits of online classrooms found that students ranked self-pacing as the greatest positive of the intervention (Edwards & Rule, 2013).

More studies need to be undertaken on the potential benefits of tiering instruction for students with average and high levels of background knowledge (Richards & Omdal, 2007). Other research suggestions include considering the use of differentiated curriculum enhancements with peer mediation in grade levels outside of middle school (Mastropieri, Scruggs, Norland, Berkeley, McDuffie, Tornquist & Connors, 2006). Finally, future studies should examine student attitude toward differentiated lessons and science and content achievement because of them (Maeng & Bell, 2015).

METHODOLOGY

The population for this study was 60 students from Brecksville-Broadview Heights High School. These students were enrolled in one of three morning sections of academic physical science. Most of the population was freshmen, although there was one sophomore, and one senior. 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 (Appendix A).

I modeled the mastery learning intervention after The Grid Method (Ostrowski, 2015) and I conducted it every other unit from January 2017 to May 2017. During the treatment units, students worked through learning objectives at their own pace by following the order of activities outlined on their mastery grids (Appendix B). Because academic physical science is an introductory course that has a fairly rapid pace, student objectives on the course curriculum map rarely exceed level two of Bloom's Taxonomy. I used these learning objectives and reoriented them onto the students' mastery grids. The first level of my mastery grids focused on vocabulary building, and the further levels were then combinations of applying the vocabulary to word problems and calculations, as well as introducing more concepts. The activities on the mastery grid were notes, homework problems, labs and games. Some activities required individual work, whereas others allowed students to work in small groups. Since there were no absolute deadlines, I did not mark any students for having late assignments.

Since the students' mastery grids were specific on which activities were supposed to be accessed to get notes and to do practice, I did not conduct any prior lecture or instruction. Answer keys for homework problems were posted on the class website for students to check their work. During the forces treatment unit, I periodically conducted warmup questions or whole-class practice on individual white boards with free body diagrams and net force.

Level advancement during the treatment units was determined with the use of checkpoint quizzes (Appendix C). If a student scored 80% or higher on a checkpoint quiz, he or she obtained my signature and moved on to the next level of standards on his

or her mastery grid. Students that did not pass their checkpoint quizzes would access the remediation resources on that grid level so that they could sharpen their skills and later try another checkpoint quiz over the same learning objectives. Instead of oral defenses, I used paper and electronic quizzes for the first treatment unit, and I used all electronic quizzes that were auto-graded for the second treatment unit.

The non-treatment units were traditionally taught and had controlled pacing. Notes, practices, and formative quizzes were administered or assigned on the same day for all students. Student work that was missing on the day that it was due was marked as late. Online resources, such as notes, reviews, and answer keys to homework problems were still accessible to students on the class website.

For all treatment and non-treatment units, a content pre- and post-test was administered so that learning growth data could be obtained via normalized gain scores. These tests were the Motion Pre- and Post-Test, the Forces Pre- and Post-Test, the Energy and Work Pre- and Post-Test, and the Waves Pre- and Post-Test (Appendices D-G). Median normalized gains less than 0.3 were classified as *low* gains, 0.3-0.7 were *medium* gains, and above 0.7 were *high* gains (Hake, 1998). Side-by-side box plots of normalized gains for treatment and non-treatment units were used to further analyze any differences.

At the end of the first non-treatment unit and the last treatment unit, students completed 17 Likert-type questions in the Student Engagement and Value of Intervention Survey and submitted responses on Google Forms (Appendix H). Students had to indicate their level of engagement in class, preparation for the unit test, and their value of

class activities. To do this, for each statement, students selected either *strongly disagree*, *disagree*, *neutral*, *agree*, or *strongly agree*. Each statement appeared twice in the survey, once with a positive stem and once with a negative stem. Results for the positively-stemmed and negatively-stemmed questions were separated and organized so that the topics were in the same order. Comparisons between the surveys was done with the use of diverging stacked bar charts. Inferential statistics for each statement was calculated using the Chi-Square Test of Independence. The *p*-value was calculated at the 95% confidence level.

At the end of the last treatment unit, I conducted random interviews about the students' ability to track their own learning, work at their own pace through lessons, their level of engagement, their ability to obtain help, and their overall value of the interventions (Appendix I). Student responses were collected and categorized based on themes and used to support claims made from other sources of data. Other supplemental sources of data included treatment unit checkpoint quizzes, non-treatment unit quizzes, student exit tickets, student written responses at the end of the Student Engagement and Value of Intervention Survey, and instructor journal entries of classroom observations. The data triangulation matrix displays the data forms that were used to answer each of the focus questions (Table 1).

Table 1
Data Triangulation Matrix

Focus Question:	Data Source 1	Data Source 2	Data Source 3
<i>Primary Question:</i> 1. What is the effect of the interventions on student achievement?	Content pre- tests compared to content post-tests for treatment and non-treatment units	Treatment unit checkpoint quiz scores, non-treatment unit quiz scores, student exit tickets	Random student interviews after interventions, Student Engagement and Value of Intervention Survey (before and after interventions)
<i>Sub Questions:</i> 2. What is the effect of the interventions on student engagement?	Student Engagement and Value of Intervention Survey (before and after interventions)	Random student interviews after interventions	Instructor journal entries of classroom engagement observations, student exit tickets
3. What is the effect of the interventions on student self-efficacy?	Student Engagement and Value of Intervention Survey (before and after interventions)	Random student interviews after interventions	Student exit tickets

DATA AND ANALYSIS

For each tested unit, a content pre- and post-test was administered so that learning growth data could be obtained via normalized gain scores. The Motion Pre- and Post-Test was administered during the first non-treatment unit ($N=60$). Due to the non-normal distributions of the normalized gain scores, median scores were used for comparison. The median normalized gain for the Motion Pre- and Post-Test was 0.62, indicating *medium* learning gains. Next, in the first treatment unit, the Forces Pre- and Post-Test was administered. The median normalized gain was 0.74, indicating *high* learning gains. In the second non-treatment phase the Energy and Work Pre- and Post-Test was given. The median normalized gain score was a 0.48, indicating *medium* learning gains. The final tested unit was the second treatment phase, where students took the Waves Pre- and Post-

Test. The median normalized gain for the Waves Pre- and Post-Test was 0.51, again indicating *medium* learning gains. One student stated in an interview that he felt more prepared for the unit test after the treatment unit “because I could do each step before it was due and get farther ahead and know it for the test.” Normalized gain results from these tests are summarized in the side-by-side box plots in Figure 1.

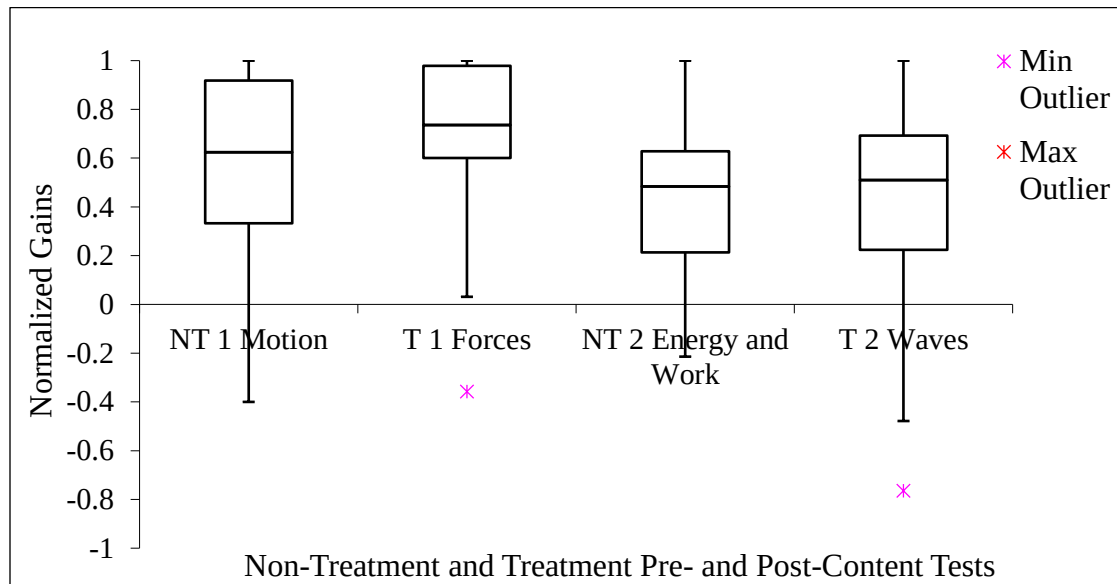


Figure 1. Content pre- and post-test normalized gain scores for non-treatment and treatment units, (N=60).

The Chi-Square Test of Independence for the Student Engagement and Value of Intervention Survey indicated that there was a statistical difference for the question, *I have a hard time paying attention in science class*, with a p -value of 0.018 ($N=59$). After the treatment units, less students *disagreed* or *strongly disagreed* with the statement. In an interview after the last treatment unit, one student stated, “I feel more engaged with the traditional class format because talking in class makes me feel more engaged. It’s easier to get off track on the grid.”

The question stem, *I did not get enough practice in class with this unit's science skills* also had statistically significant results between the non-treatment and treatment administrations of the survey, with a p -value of 0.004. More students who took the survey after the treatment units *agreed* or *strongly agreed* with the statement. After the last treatment unit, one student stated in an interview, "If you fell behind you had to double or triple your speed to catch up to your peers."

The final survey question that was statistically significant between the non-treatment and treatment administrations was, *science class is easy*, with a p -value of 0.055. When the students took the survey after the treatment units, more *disagreed* or *strongly disagreed* with the statement. The positive stem of this question, *I am challenged in science class*, although not statistically significant, had 15 students who *disagreed* or *strongly disagreed* with the statement after the non-treatment unit, followed by 10 students after the treatment units. Eighteen students *agreed* or *strongly agreed* with *I am challenged in science class* after the non-treatment unit, and it increased to 24 students after the treatment units.

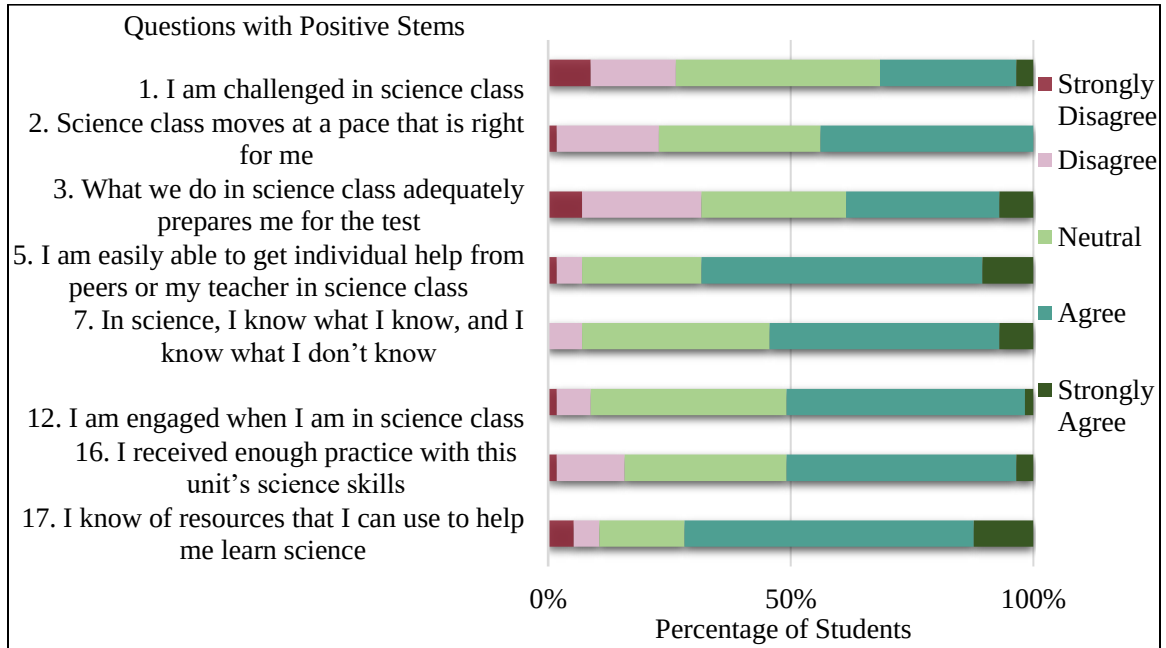


Figure 2. Results of the positively-stemmed questions on the non-treatment Student Engagement and Value of Intervention Survey, (N=57).

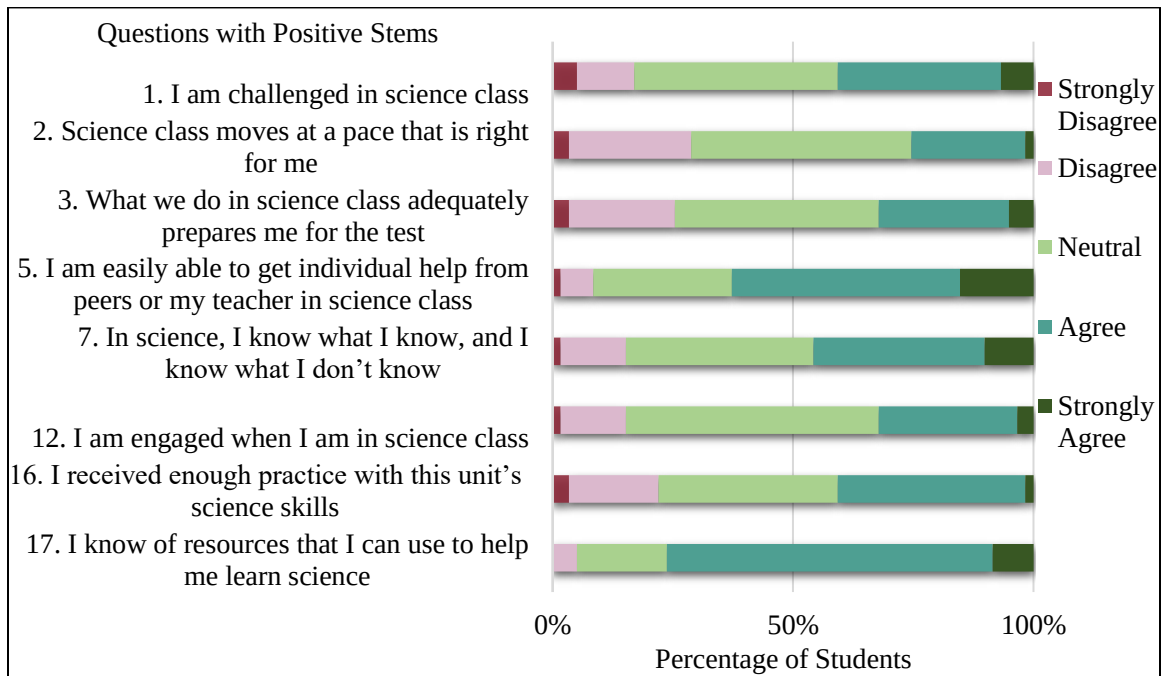


Figure 3. Results of the positively-stemmed questions on the treatment Student Engagement and Value of Intervention Survey, (N=59).

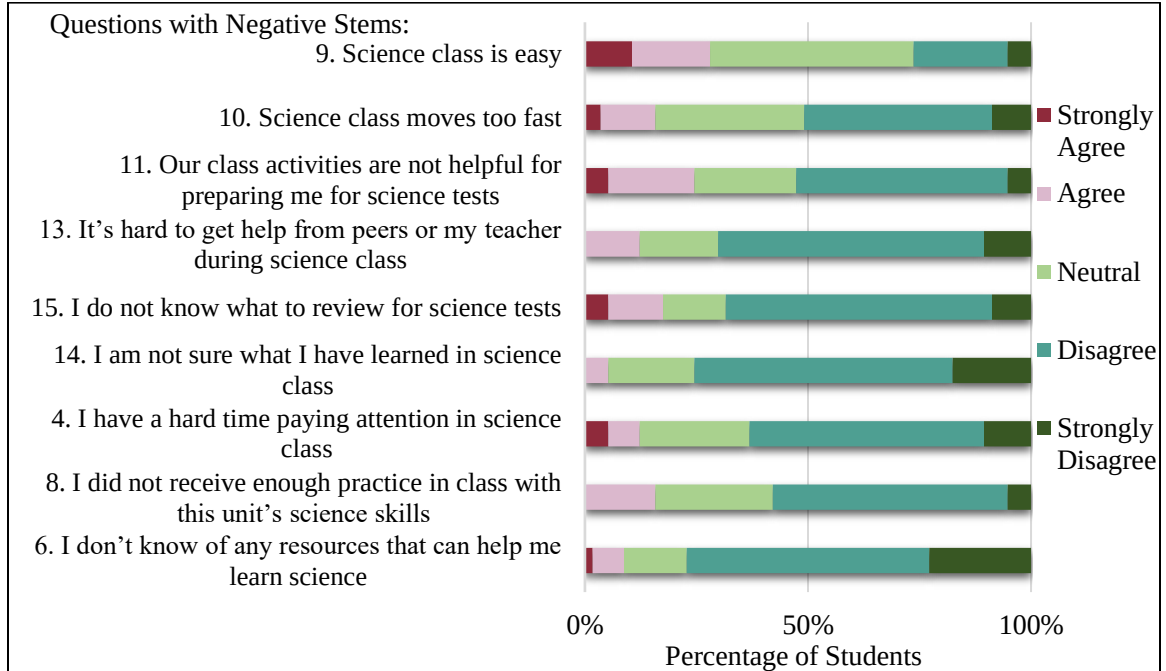


Figure 4. Results of the negatively-stemmed questions on the non-treatment Student Engagement and Value of Intervention Survey, (N=57).

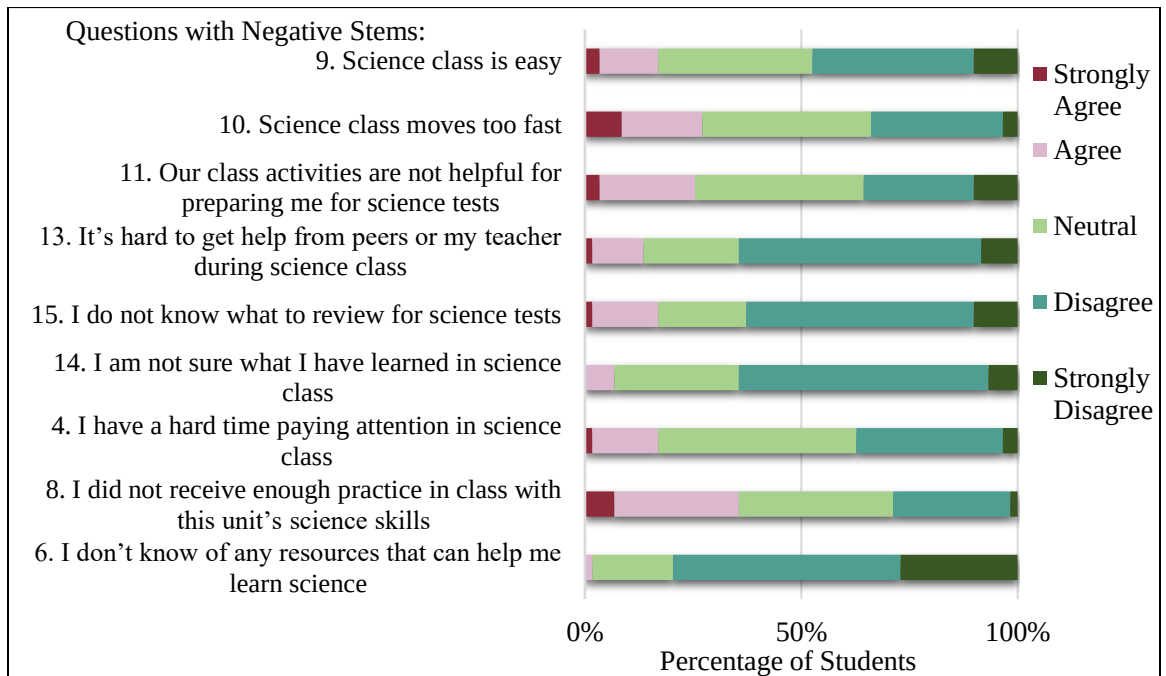


Figure 5. Results of the negatively-stemmed questions on the treatment Student Engagement and Value of Intervention Survey, (N=59).

Although not statistically significant, it was noted that in the Likert-selections for, *I don't know of any resources that can help me learn science*, five students *agreed* or *strongly agreed* after the non-treatment unit, whereas only one student *agreed* after the treatment units. Thirteen students *strongly disagreed* with this statement after the non-treatment unit, and it increased to 16 students after the treatment units. The positive stem of this question, *I know of resources that I can use to help me learn science*, showed similar trends. After the non-treatment unit, three students *strongly disagreed* with that statement, whereas after the treatment units no students *strongly disagreed*. In addition, the number of students that *agreed* jumped from 34 to 40 students. In a post-treatment interview, when asked which unit test he felt more prepared for, one student chose the one from the treatment unit “because if you failed level one you would use the extra resources. If you don't do [well] you can review for the next level.”

It was also noted that after the non-treatment unit, four students *strongly disagreed* and 14 students *disagreed* with the survey question, *what we do in science class adequately prepares me for the test*. After the treatment units, this dropped to two students who *strongly disagreed* and 13 students who *disagreed*. One student in an interview stated that he was more prepared for the unit test after the treatment unit because he “knew all the grid stuff beforehand” and “I remembered it from when I was working.”

INTERPRETATION AND CONCLUSION

My first focus question was how the treatment units would affect overall student achievement. The highest median normalized gain was during a mastery learning unit,

reporting *high* gains, but the second treatment unit had a median normalized gain like the non-treatment units, reporting *medium* gains. This aligns with the prior analysis of 108 mastery learning studies by Kulik, Kulik and Bangert-Drowns, who found medium to large gains in student achievement (as cited in Ostrowski, 2015).

The side-by-side box and whisker plot of the normalized gains revealed that the highest scores were in the first two units and the lowest scores were in the last two units (Figure 1). I wonder if this may also have to do with the time in which the units took place. The last two units were in fourth quarter and it seemed that as the weather became nicer, students were less motivated to do schoolwork. In the future, it would be interesting to test the mastery learning interventions in the beginning of the school year when the students are more ambitious about their academics.

A sub question of my research was how the mastery learning interventions would affect student engagement. There were statistically significant findings from the Student Engagement and Value of Intervention Survey that students had a more difficult time paying attention while working through units with mastery learning grids. Although, this was only confirmed by four of the eight random interviews that I conducted. There were also statistically significant findings that students felt class was not as easy after the mastery learning interventions. Some felt more challenged. As an instructor, I observed an initial increase in engagement, but it tapered off after a few days. Some students became distracted by their friends in class. Although, it should be noted that more students sought help from me outside of class during the treatment units. The second administration of the Student Engagement and Value of Intervention Survey was also

conducted in fourth quarter, where the anticipation of summer may have also played a role in the students' lack of interest in class.

When it came to student engagement, one of the struggles that I found was since there were no firm due dates, students felt that they could accomplish all of their work in class. During traditional units, outline notes were assigned for homework. For the treatment units, students were spending large amounts of class time working on their outline notes. This slowed down their progression through their mastery grids and my efforts to keep them on track made them feel rushed. Taking notes certainly is not engaging, but that was what they chose to use the majority of their class time for.

Another challenge with student engagement was having them perform labs at different times. Without the full-class introduction to labs that I would typically give, the students struggled with following the written lab instructions, which led to them giving up and no longer taking the activity seriously. In addition, as students finished parts of their mastery grids and entered the lab, they joined other groups and copied their data. In the future, I may select days where students pause their progress on their mastery grids so that they can all participate in a lab together. Perhaps introductory videos or podcasts would help with students doing labs at different times.

The mastery grids may work better with the development of a few concepts, as opposed to a whole unit. Although the motion unit was not a mastery grid unit, next year I could see using a mastery grid for part of it to build student proficiency with the various mathematical equations. Perhaps it would be effective to have students start refining their

algebra skills by first showing mastery calculating speed, followed by velocity, acceleration, and then a mixed-practice.

My last research sub question was how the interventions would affect student self-efficacy. Although not statistically significant, the Student Engagement and Value of Intervention Survey revealed that after the interventions, more students knew of resources that helped them learn science, and some felt after the interventions that class activities adequately prepared them for the test. When asked if the mastery learning interventions helped him track his learning in science, one boy replied, “Yes. I know what I know and I know what I don’t know by doing each thing when I had to do it.” In six of the eight random interviews, students mentioned that they liked the organization and structure of the mastery grid. Instead of going out and finding a resource when a student did not understand something, the grid told him or her what to access next. The mastery grid scaffolded students to facilitate their own learning. They learned how to navigate the class website to access answer keys when they finished their homework pages, and review games when they needed to study for quizzes. When students needed remediation, they used the class website to access notes for summaries of topics, and to watch re-teaching videos. It seemed that after the interventions, students went back to these resources because they knew they were available and they knew which resources were useful at which phase of their learning cycles.

VALUE

Allowing students to relearn topics and then retake checkpoint quizzes gave them the ability to build confidence by accomplishing a skill before having to move on. With

learners working on different things at different times, if somebody did not prove mastery on a certain quiz, I was typically available to have a personal chat with him or her about what specifically he or she needed to review to improve. If necessary, students were accessing help along the way instead of right before the test.

With this being my first time teaching academic physical science, this research helped me build a framework of lessons, assessments and student resources which I will be able to use in the following years. I learned to effectively use technology to streamline quantitative and qualitative data about my students. By having checkpoint quizzes on ProgressBook, they could be auto-graded and posted straight into my online gradebook. This provided me with more time to assist students, and I could communicate immediately with parents about their child's progress in class. In addition, the pre-test data and the survey data from Google Forms were useful to reference in conversations about students with parents and administrators.

I have learned that one of my favorite data collection techniques is student interviews. It helped me build a rapport with my students because they understood that they have a part in how class is conducted from day to day. Building a rapport with students has been something that has always been very important to me because I believe that students enjoy class more with a teacher that they respect and see as a human being. I have always been intimidated to hear what my students actually think of my teaching, but throughout this whole process there has not been a single interview that has left me feeling disheartened. In fact, I have learned that students become interested in my

research and are eager to hear my findings. Knowing this makes me less uncertain about trying different class formats in the future.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY IRB EXEMPTION



INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
FWA 00000165

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

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

MEMORANDUM

TO: Amanda Stone and John Graves
FROM: Mark Quinn *Mark Quinn*
DATE: December 5, 2016
SUBJECT: "Self-paced Mastery Learning in an Academic Physical Science Class and its Effect on Student Achievement, Engagement and Self-efficacy" [AS120516-EX]

The above research, described in your submission of December 5, 2016, 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:

- ☒ (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.
- ☒ (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

MASTERY TREATMENT UNITS LEARNING GRIDS

Chapters 5 and 6: Forces
Self-Paced Mastery Unit

I CANS:	Learning Opportunities and Formative/ Summative Assessments			
Level 4: Skills, interpretation of Force Pairs ➤ Explain “interacting force pairs”, name and draw examples of a force pair including the arrows indicating the direction of force. (Newton’s 3rd Law)	LO 1: 1) Video notes on Edpuzzle 2) 6.3 OLN Teacher initials for 6.3 OLN: _____	LO 2: 3) Review pages. Check with answer key.	FORMATIVE: 4) Force Pairs Quiz (from Ms. Stone) <u>Prove mastery at 80% (no resources)</u> If mastered, teacher initials: _____	LO 4: More support (if didn’t get 80%) 5) Physical Science Department Website: Use resources in “Forces Pairs” section. Retake quiz SUMMATIVE ASSESSMENT
Level 3: Skills, Interpretation of Force, Mass and Acceleration ➤ I can explain the relationship between force, mass, and acceleration and use this to calculate force, mass, and acceleration ($F=ma$). This should include calculating an object's weight.	LO 1: 1) Class notes 2) 5.1 OLN (pg. 114!), 6.2 OLN Teacher initials for 6.2 OLN: _____	LO 2: 3) Pgs. 57-58, 64-65. Check with answer key. 4) Force/Mass lab pg. 56 (solo or small group)	FORMATIVE: 5) $F = ma$, $W=mg$ Quiz (from Ms. Stone) <u>Prove mastery at 80% (no resources)</u> If mastered, teacher initials: _____	LO 3: More support (if didn’t get 80%) 5) Pgs. 66-67. Check with answer key. 6) Retake quiz
Level 2: Skills, Interpretation of Force Diagrams and Motion ➤ I can draw a free body (force) diagram for an object with arrows for an applied force, friction, normal force, tension and/or gravity and use it to calculate the net force on an object. ➤ I can explain what happens to the motion of an object when forces are balanced and when forces are unbalanced. (INERTIA)	LO 1: 1) Class notes 2) 5.3 & 6.1 O.L.N (pgs 124-125! 127-128! 138-140!) Teacher initials for 5.3/ 6.1 OLN: _____ 3) ”May the Force be w/ you” pkt. Check w/ answer key	LO 2: 4) PhET Lab: 60-63 in binder. Check with answer key Teacher initials: _____ 5) Inertia tricks! Draw free body diagrams to show how they happened (solo/small group).	LO3: 6) Free body diagram and net force review! Kahoot on website (solo/small group). Score: ____/24 FORMATIVE: 7) Free body diagrams quiz (from Ms. Stone) <u>Prove mastery at 80% (no resources)</u> If mastered, teacher initials: _____	LO 4: More support (if didn’t get 80%) 8) Physical Science Department Website: Use resources in “Forces & Motion” section (first two bullets/categories). 9) Retake quiz
Level 1: The Basics ➤ I can define and give examples of force: normal, applied, tension, friction, drag, and air resistance (fluid friction). ➤ Give examples of field forces (forces at a distance) and explain how they vary in strength.	LO 1: 1) Class Notes 2) 5.1 & 5.2 (some 5.3) O.L.N (pp. 110-113! 136! 117-118! 126!) Teacher initials for 5.2 OLN: _____	LO 2: 3) Online review! Do “Types of Forces Kahoot” (Solo or small group) Score: ____/32	FORMATIVE: 4) Progressbook Quiz: Types of Forces <u>Prove mastery at 80% passing (no resources)</u> If mastered, teacher initials: _____	LO 3: More support (if didn’t get 80%) 5) Physical Science Department Website: Use resources in “Types of Forces” section 6) Retake quiz

Chapters 23 and 24: Waves and Sound
Self-Paced Mastery Unit

<u>I CANS:</u>	<u>Learning Opportunities and Formative/ Summative Assessments</u>			
<u>Level 3:</u> ➤ Illustrate how waves interact with other mediums to be absorbed, reflected, refracted, transmitted or diffracted. ➤ Describe how the type of medium (S,L,G) affects the speed of a wave	<u>LO 1:</u> 1) Class notes (slides 15-20) 2) OLN 567-568, 572-transmission only, 584)	<u>LO 2:</u> 3) In binder, pg. 153, 162-163 #s 1-6 only (check with answer key) 4) Be sure you are capable of DEFINING AND PROVIDING EXAMPLES of all terms described in the I CANS on the left.	<u>FORMATIVE:</u> 4) ProgressBook: 3: Wave Motions and Speed With Various Mediums Quiz (80% mastery) <u>SUMMATIVE:</u> Review on pages 164-165. Check with answer key.	<i>LO 3: More support if didn't prove mastery (80%) on formative</i> <i>5) Use resources on the "Physical Science Department Website" link</i> <i>6) Retake quiz (ask Ms. Stone to reset)</i>
<u>Level 2:</u> ➤ Identify key differences between the parts and particle movement of transverse, longitudinal, and surface waves ➤ Describe energy travels out of a wave source in all directions, and what happens to the energy the further you get from the source ➤ Explain how sound waves must travel through a medium and are mechanical longitudinal waves ➤ Describe how frequency and amplitude are sensed as sound	<u>LO 1:</u> 1) Class notes (slide 1, 13-15) 2) OLN for link on website: "Waves and Particle Movement" (stop after Electromagnetic vs. Mechanical Waves), 24.1 (all), pg. 590 Teacher initials for OLN:_____	<u>LO 2:</u> 3) Pg. 146 (check with answer key) 4) Webquest on Google Classroom: How We Hear the Frequency and Amplitude of Sound Waves <u>LO3:</u> 5) Level 2 Kahoot: Wave Particle Movement, Energy, and Sound (review solo/ small groups) Score:____/16	<u>FORMATIVE:</u> 6) ProgressBook: 2: Wave Particle Movement, Energy and Sound Quiz 7) If below 80%, move on to LO 4 8) If above 80%, teacher initials to move on to next level:_____	<i>LO 4: More support</i> <i>9) Use resources on the "Physical Science Department Website" link</i> <i>10) Retake quiz (ask Ms. Stone to reset it)</i>
<u>Level 1: The Basics</u> ➤ Explain, draw and generate transverse, longitudinal, and surface waves ➤ Identify key characteristics of all waves such as amplitude, frequency, period, wavelength, crest, and trough, rarefaction, and compression ➤ Describe the relationship between energy, amplitude, and frequency, and period for a given wave	<u>LO 1:</u> 1) Class notes (slides 1-12) 2) OLN pgs 556-559, 23.2 (all), pg 569 Teacher initials For OLN:_____	<u>LO 2:</u> 3) Pgs 134-136, 137 (wave 7) in binder. Use a ruler (cm!). Check with answer key up front 4) Slinky inquiry lab in groups of three (cm!) Teacher initials for lab completion:_____	<u>FORMATIVE:</u> 5) ProgressBook: 1: Types of Waves and Wave Properties Quiz 6) If below 80%, move on to next learning opportunity (LO 3) 7) If above 80%, teacher initials to move on to next level:_____	<i>LO 3: More support</i> <i>8) Finish rest of p. 137 in binder. Check with answer key.</i> <i>9) Watch types of waves (stop at 4:09) and surface waves reteaching videos on the "Physical Science Resources" tab of the class website</i> <i>10) Retake quiz (ask Ms. Stone to reset)</i>

APPENDIX C

MASTERY TREATMENT UNITS CHECKPOINT QUIZZES

Level One: Types of Forces Formative Quiz**Question 1** 5 point(s)

Select the correct term to complete each sentence. Each term may only be used once, some may not be used at all.

The metric unit of force needed to accelerate a 1-kg mass at 1 m/s^2 .

[Choose] Applied Friction Gravity Newton Normal Spring Tension

Resists the relative motion of objects or surfaces.

[Choose] Applied Friction Gravity Newton Normal Spring Tension

A pulling force carried by a rope.

[Choose] Applied Friction Gravity Newton Normal Spring Tension

Contact force always perpendicular to the surface.

[Choose] Applied Friction Gravity Newton Normal Spring Tension

"At a distance" or field force.

[Choose] Applied Friction Gravity Newton Normal Spring Tension

Question 2 2 point(s)

Select the correct term to complete each sentence. Each term may only be used once, some may not be used at all.

Fluid friction

[Choose] Air resistance Rolling Friction Sliding Friction Static Friction

Friction when there is no motion

[Choose] Air resistance Rolling Friction Sliding Friction Static Friction

Question 3 1 point(s)

Almost always at slow speeds, sliding friction is _____ static friction.

A) equal to B) less than C) greater than

Question 4 1 point(s)

A person is pushing a desk across the room. What is the force exerted on the desk by the person?

A) Normal B) Applied C) Tension D) Friction E) Spring

Question 5 1 point(s)

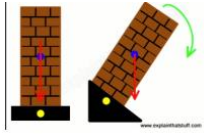
The force that the man is enacting on the box:



A) Applied B) Spring C) Tension D) Friction E) Drag

Question 6 1 point(s)

The red arrow is signifying what force?



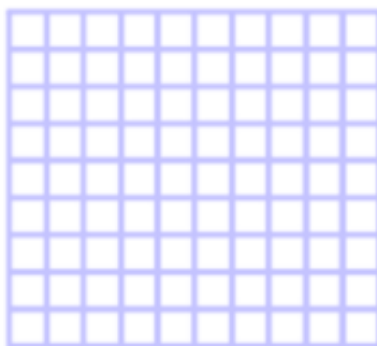
- A) Normal B) Friction C) Drag D) Gravity E) Applied F) Tension

Name: _____ PER _____

/5

Physical Science: Forces and Free Body Diagrams #1

1. Austin joins the football team and needs to practice his defense. The coach tells Austin to push the practice dummy to the right as far as he can. Austin pushes the practice dummy to the right over the rough, bumpy ground. Ignore air resistance. **Draw the free-body (force) diagram for the practice dummy. Be sure to show and LABEL arrows for ALL the forces acting on the dummy.** (1pt arrow shapes, 1pt labeled correctly)



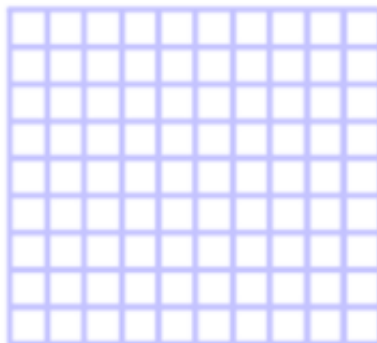
2. If the dummy weighs 50 Newtons, Austin pushes with 100 Newtons to the right, and friction is 10 Newtons, **label all the arrows you drew in Question 1 with the amount of force in Newtons.** (1pt)
3. **What is the Net Force on the dummy?** _____ (2pt)
(Don't forget Force is a vector!)

Name: _____ PER _____

/5

Physical Science: Forces & Free Body Diagrams #2

1. Ashley goes shopping and buys an entire crate of new shoes. She has to get the shoes out of the store and into her car. She pushes the crate to the left across the rough concrete of the parking lot to her car. **Draw the free-body (force) diagram for the crate. Be sure to show and LABEL arrows for ALL the forces acting on the crate.** (1pt arrow shapes, 1pt labeled correctly)



2. If the crate weighs 60 Newtons, Ashley pushes with 80 Newtons to the left, and friction is 15 Newtons, **label all the arrows you drew in Question 1 with the amount of force in Newtons.** (1pt)
3. **What is the Net Force on the crate?** _____ (2pt)
(Don't forget Force is a vector!)

Name: _____ Score: ____/10

Physical Science: Newton's 2nd Law #1

$F = m \cdot a$	$W = m \cdot g$	$g \text{ (on Earth)} = 9.8 \text{ m/s}^2$
-----------------	-----------------	--

- 1) Explain why does a bullet hit a wall with more force than a baseball, even though the baseball has more mass than a bullet? (1pt)

- 2) Calculate the mass of a box which falls out of a window and is pulled down by gravity, smashing into the ground with a force of 30 Newtons. SHOW ALL WORK! ROUND TO SIG FIGS! (3pt)

- 3) A physical science test book has a mass of 2.2 kg. What is the weight on the Earth? SHOW ALL WORK! ROUND TO SIG FIGS! (3pt)

- 4) If the textbook weighs 19.6 newtons on Venus, What is the strength of gravity on Venus? SHOW ALL WORK! ROUND TO SIG FIGS! (3pt)

Name: _____ Score: ____/10

Physical Science: Newton's 2nd Law #2

$F = m \cdot a$	$W = m \cdot g$	$g \text{ (on Earth)} = 9.8 \text{ m/s}^2$
-----------------	-----------------	--

- 1) Describe how you could increase the force of the bowling ball hitting the pins when you are bowling. (1pt)

- 2) Calculate the acceleration of a tennis ball which has a mass of 2.0 kg and is being hit with a force of 10.0 Newtons by a tennis racket. SHOW ALL WORK! ROUND TO SIG FIGS! (3pt)

- 3) If a 0.5 kg pair of running shoes would weigh 11.55 newtons on Jupiter, what is the strength of gravity there? SHOW ALL WORK! ROUND TO SIG FIGS! (3pt)

- 4) How would the weight of the shoes compare on Pluto? Why?

1: Types of Waves and Wave Properties Quiz

Question 1

5 point(s)

Match the correct term to the definition. Terms will only be used once. Some will not be used at all.

1. The time it takes for each complete cycle

[Choose] amplitude compression crest frequency longitudinal wave period rarefaction transverse wave trough wavelength

2. The amount a cycle moves away from equilibrium

[Choose] amplitude compression crest frequency longitudinal wave period rarefaction transverse wave trough wavelength

3. How often something repeats, expressed in hertz

[Choose] amplitude compression crest frequency longitudinal wave period rarefaction transverse wave trough wavelength

4. The distance from any point on a wave to the same point on the next cycle of the wave

[Choose] amplitude compression crest frequency longitudinal wave period rarefaction transverse wave trough wavelength

5. Its oscillations are not in the direction it moves

[Choose] amplitude compression crest frequency longitudinal wave period rarefaction transverse wave trough wavelength

Question 2

2 point(s)

$$V = \lambda f$$

Solve the following problem using proper significant figures and unit abbreviations (Ex: 0.01 m)

Include Units. Make sure you **put a space** between the number and the units.

The wavelength of a wave on a string is 1m and its speed is 5 m/s.

6. Calculate the frequency of the wave: _____

7. Calculate the period of the wave: _____

Question 3

3 point(s)

Match the definition with the proper term. Terms will only be used once. Some may not be used at all.

8. Area where particles are close together

[Choose] Compression Longitudinal Rarefaction Reflection Surface Transverse

9. Area where particles are spread out

[Choose] Compression Longitudinal Rarefaction Reflection Surface Transverse

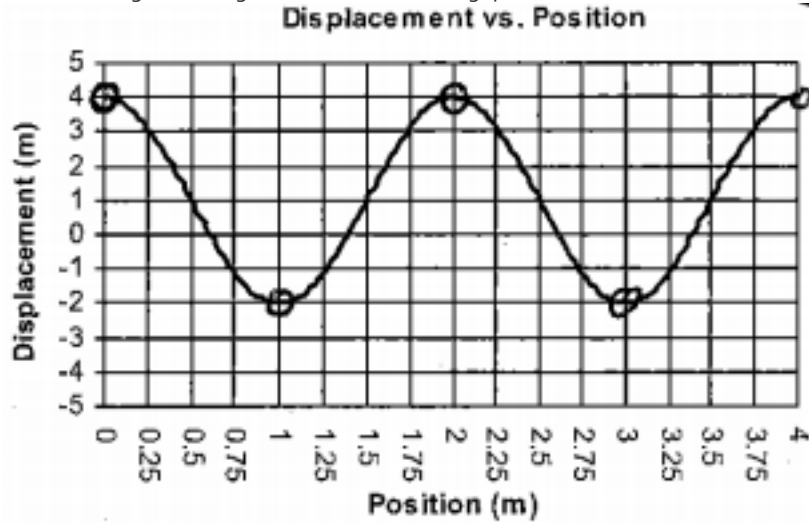
10. The previous two definitions are found in which kind of wave?

[Choose] Compression Longitudinal Rarefaction Reflection Surface Transverse

Question 4

3 point(s)

Click to enlarge the image. Answer the following questions.



11. Wavelength = ____ m

[Choose] 0.25 0.5 0.75 1 1.25 1.5 1.75 2 2.25 2.5 2.75 3 3.25 3.5 3.75 4.25 4.5 4.75 5 5.25 5.5 5.75 6

12. Amplitude = ____ m

[Choose] 0.25 0.5 0.75 1 1.25 1.5 1.75 2 2.25 2.5 2.75 3 3.25 3.5 3.75 4.25 4.5 4.75 5 5.25 5.5 5.75 6

13. Frequency?

[Choose] 0.25 0.5 0.75 1 1.25 1.5 1.75 2 2.25 2.5 2.75 3 3.25 3.5 3.75 4.25 4.5 4.75 5 5.25 5.5 5.75 6

2: Wave Particle Movement, Energy and Sound Quiz

Question 1

1 point(s)

A wave in which particles of the medium move in a direction perpendicular to the direction that the wave moves.

- A) Longitudinal B) Transverse C) Surface D) Electromagnetic

Question 2

1 point(s)

A sound wave traveling through air is a classic example of a(n) _____ wave.

- A) transverse B) longitudinal C) electromagnetic D) surface E) seismic

Question 3

1 point(s)

Only the particles at the top of the medium undergo the **circular motion**. The motion of particles tends to decrease as you go deeper. What kind of wave is this?

- A) Surface wave B) Longitudinal wave C) Electromagnetic wave D) Seismic wave E) Transverse wave

Question 4

1 point(s)

A low-pitch sound has a _____.

- A) high frequency B) high amplitude C) low frequency D) low amplitude

Question 5

1 point(s)

A loud sound always has a _____.

- A) large wavelength B) high frequency C) large amplitude

Question 6

1 point(s)

Mechanical waves require a medium to travel through.

- True False

Question 7

1 point(s)

When I hit this tuning fork, sound waves will travel _____.



- A) Upwards B) In the direction of the hit C) In all directions

Question 8

1 point(s)

As they travel, sound waves lose their energy.

True False

3: Wave Motions and Speed with Various Mediums Quiz

Question 1

6 point(s)

Match the definition or example to the correct wave motion. Some responses may be used more than once and some responses may not be used at all.

1. Waves bend around an object or outward after exiting a hole
[Choose] Absorption Diffraction Reflection Refraction Transmission
2. Heavy curtains are used to help keep a room quiet
[Choose] Absorption Diffraction Reflection Refraction Transmission
3. The process of the amplitude of a wave diminishing as it enters another material
[Choose] Absorption Diffraction Reflection Refraction Transmission
4. You hear music even though you are seated behind an obstruction at a concert
[Choose] Absorption Diffraction Reflection Refraction Transmission
5. An echo (sonar)
[Choose] Absorption Diffraction Reflection Refraction Transmission
6. The distortion of your partially submerged arm in water makes it look "broken" when viewed from the air
[Choose] Absorption Diffraction Reflection Refraction Transmission

Question 2

1 point(s)

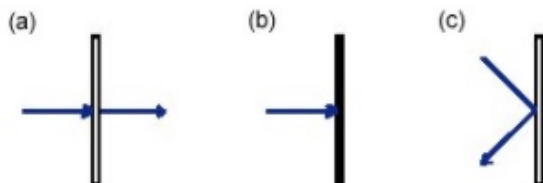
7. Sounds travel slower in ____.

- A) solids B) liquids C) gases

Question 3

3 point(s)

Name the wave motions. Each option will be used once. Some will not be used at all.



8. A
[Choose] Absorption Diffraction Reflection Refraction Transmission
9. B
[Choose] Absorption Diffraction Reflection Refraction Transmission
10. C
[Choose] Absorption Diffraction Reflection Refraction Transmission

Question 4

1 point(s)

11. In which medium would sound travel fastest?

- A) Carbon dioxide B) Pure water C) Sea water D) Glass

Question 5

1 point(s)

12. In outer space, sound waves travel _____.

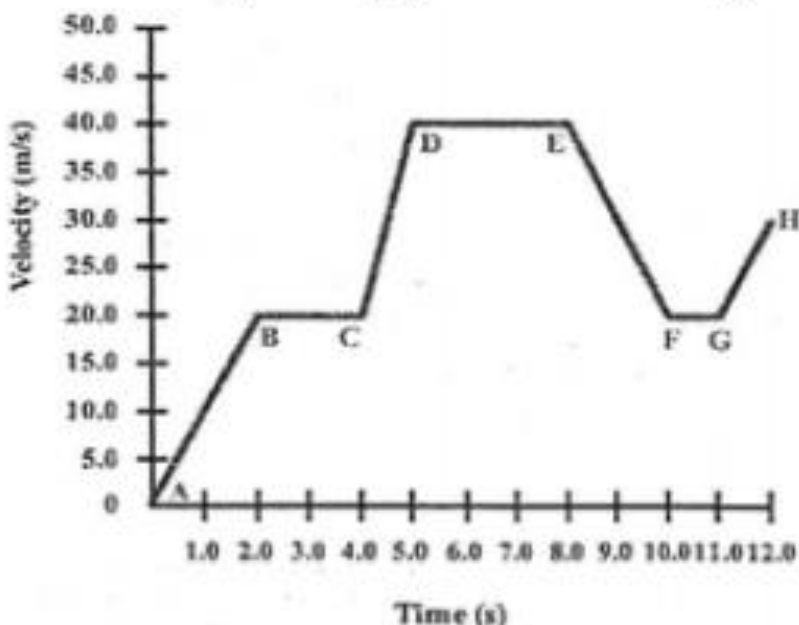
- A) slow B) fast C) not at all

APPENDIX D

MOTION PRE- AND POST-TEST

CHAPTER FOUR: MOTION

Directions: Use the velocity vs. time graph to answer the following questions (4 pts).



- ___ 1) The slope of the line is the object's ____.
- a. acceleration
 - b. time
 - c. speed
 - d. distance
- ___ 2) From A to B, the object is ____.
- a. accelerating
 - b. traveling at a constant speed
 - c. not moving
 - d. decelerating
- ___ 3) From B to C, the object is ____.
- a. accelerating
 - b. traveling at a constant speed
 - c. not moving
 - d. decelerating
- ___ 4) From E to F, the object is ____.
- a. accelerating
 - b. traveling at a constant speed
 - c. not moving
 - d. decelerating

Directions: Solve these problems. SHOW YOUR WORK. Make sure answers reflect proper SIGNIFICANT FIGURES, UNITS and DIRECTION (6 pts).

- 5) Suppose an object goes backward at 0.2 m/s for 4 seconds. What is its change in position?

Work:

Answer:

-
- ☐ Correct Value
 - ☐ Accurate Sig Figs
 - ☐ Proper Unit
 - ☐ Direction from origin

- 6) A train travels at 100 km/h heading east to reach a town in 4 hours. The train then reverses and heads west at 50 km/h for 4 hours. What is the train's position now?

Work:

Answer:

-
- ☐ Correct Value
 - ☐ Accurate Sig Figs
 - ☐ Proper Unit
 - ☐ Direction from origin

- 7) A sailboat moves at 1 m/s. A strong wind increases its speed to 4 m/s in 3 s. Calculate acceleration.

Work:

Answer:

-
- ☐ Correct Value
 - ☐ Accurate Sig Figs
 - ☐ Proper Unit
 - ☐ Direction from origin

APPENDIX E
FORCES PRE- AND POST-TEST

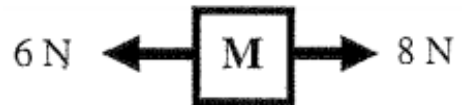
CHAPTERS FIVE AND SIX: FORCE AND MOTION

Directions: For each question, select the best choice from the options given (4 pts).

- ___1) If an object is in equilibrium, _____.
 a. only normal forces are acting on the object
 b. the object has zero total mass
 c. no forces are acting on the object
 d. the net forces on the object is zero
- ___2) The tendency of all objects to resist any change in motion:
 a. Gravity c. Inertia
 b. Momentum d. Centripetal force
- ___3) The acceleration due to gravity on a planet where a 35-kg mass has a weight of 455 N is _____.
 a. 13 m/s² c. 16,000 m/s²
 b. 1600 m/s² d. 490 m/s²

Directions: Solve these problems. SHOW YOUR WORK. Make sure answers reflect proper SIGNIFICANT FIGURES, UNITS and DIRECTION (6 pts).

- 4) Which way will this box accelerate, and by how much?



Work:

Answer:

-
- ☐ Correct Value
☐ Accurate Sig Figs
☐ Proper Unit
☐ Direction from origin

5) A student is pushing a crate of papers. She pushes the crate to the left across rough concrete to get it to the recycling dumpster. If the crate weights 60. Newtons, she pushes it 80. Newtons to the left, and the concrete friction is 15 Newtons, what is the Net Force on the crate? For your work, draw a free-body (force) diagram for the crate. Label all the arrows with the amount of force in Newtons.

Work:

Answer:

-
- ☐ Correct Value
 - ☐ Accurate Sig Figs
 - ☐ Proper Unit
 - ☐ Direction from origin

APPENDIX F

ENERGY AND WORK PRE- AND POST- TEST

Name: _____

CHAPTER 7: ENERGY
PRE- AND POST-TEST

$KE = E_k = \frac{1}{2} mv^2$	$PE = E_g = mgh$	$Conservation\ of\ Energy: E_k + E_g (before) =$
	$E_k + E_g (after)$	
	$W = F \Delta x$	

_____ 1) What happens to the kinetic energy of a moving car if you double the mass of the car?

- | | |
|----------------------------|----------------------------|
| a. It decreases by 4 times | c. It increases by 4 times |
| b. It increases by 2 times | d. It decreases by 2 times |

Scenario: Kevin jumps straight up in the air to a height of 1 meter. At the top of his jump, he has potential energy of 1,000 joules. Answer the following questions based on these numbers.

_____ 2) If Kevin's potential energy at the highest point of the jump is 1,000 joules, what is his speed when he leaves the ground?

- | | |
|------------|-------------|
| a. 1 m/s | c. 19.6 m/s |
| b. 4.4 m/s | d. 440 m/s |

_____ 3) An extended spring stores:

- | | |
|----------------------|--------------------|
| a. potential energy. | c. kinetic energy. |
| b. chemical energy. | d. radiant energy. |

_____ 4) How high would you need to lift a 2-kg bottle of soda to increase its potential energy by 500 joules?

- | | |
|---------|-----------|
| a. 0 m | c. 250 m |
| b. 25 m | d. 1000 m |

_____ 5) The brakes on an automobile become hot when they are used continuously because:

- a. potential energy is being converted to thermal energy.
- b. kinetic energy is being converted to thermal energy.
- c. the friction of the brakes causes an increase in kinetic energy.
- d. the friction of the brakes causes an increase in potential energy.

6) Name the forms of energy in this example. Don't include 'wasted' energy:
A battery is placed into a flashlight to make it light up (3 conversions)

7) A cart was pulled for 1,000m, and the amount accomplished equaled 40,000 joules.
With what force was the work accomplished? *Show work, round answer according to significant figures, and label with the correct unit.*

APPENDIX G
WAVES PRE- AND POST-TEST

CHAPTERS 23 AND 24: WAVES AND SOUND
PRE- AND POST-TEST

Solve the following problems. Show all work including equation, set-up, answer, units and sig figs.

$V = \lambda f$

1. A wave has a frequency of 46 Hz and a wavelength of 1.7 meter. What is the speed of this wave?

Knowns / Unknowns	Equation	Set-Up with Units	Answer, Units and Sig Figs

2. If a wave travels at a speed of 3.00×10^8 m/s with a frequency of 8.68×10^{16} Hz, what is the wavelength?

Knowns / Unknowns	Equation	Set-Up with Units	Answer, Units and Sig Figs

3. A wave traveling at 230 m/s has a wavelength of 2.1 meter. What is the frequency of this wave?

Knowns / Unknowns	Equation	Set-Up with Units	Answer, Units and Sig Figs

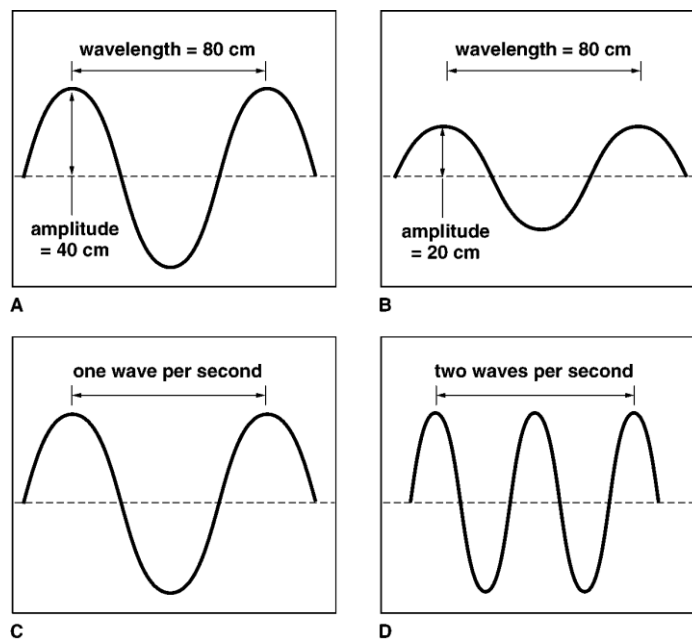


Figure 17-3

6. How do wave A and wave B sound different? _____
7. What about wave A and wave B sounds the same? _____
8. How do wave C and wave D sound different? _____
9. What about wave C and wave D sounds the same? _____
10. Consider both frequency and wavelength in Figure 17-3. How does each variable change between wave C and wave D? What is the relationship that explains the change? Assume the waves travel at the same speed.

Frequency from C to D:

Wavelength from C to D:

How are wavelength and frequency related?

11. In Figure 17-3, both wave A and wave B were started by the same up and down force. What conclusion can you make about the amount of energy used to start these two waves?

APPENDIX H

STUDENT ENGAGEMENT AND VALUE OF INTERVENTION SURVEY

Directions: Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way. For each statement, check the box that matches your level of agreement.

		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	I am challenged in science class					
2	Science class moves at a pace that is right for me					
3	What we do in science class adequately prepares me for the test					
4	I have a hard time paying attention in science class					
5	I am easily able to get individual help from peers or my teacher in science class					
6	I don't know of any resources that can help me learn science					
7	In science, I know what I know, and I know what I don't know					
8	I did not receive enough practice in class with this unit's science skills					
9	Science class is easy					
10	Science class moves too fast					
11	Our class activities are not helpful for preparing me for science tests					
12	I am engaged when I am in science class					
13	It's hard to get help from peers or my teacher during science class					
14	I am not sure what I have learned in science class					
15	I do not know what to review for science tests					
16	I received enough practice with this unit's science skills					
17	I know of resources that I can use to help me learn science					
18	Is there anything else you would like me to know?					

APPENDIX I
INTERVIEW QUESTIONS

Information for students: Participation in this research is voluntary and participation or non-participation will not affect your grade or class standing in any way.

- 1) What about the mastery learning intervention was the most beneficial to you?
- 2) Has the mastery learning intervention helped you track your learning in science? If yes, how? If no, why not?
- 3) What challenges did you face when you were completing lessons at your own pace?
- 4) Do you feel like you can access help better when completing lessons at your own pace? Why or why not?
- 5) Which class format made you feel more engaged and stimulated in class? Why?
- 6) Which unit test did you feel more prepared for? Why?
- 7) How might you improve the mastery learning intervention?
- 8) Is there anything else that you would like me to know?