THE EFFECTS OF WRITING STRATEGIES EMPHASIZING DIFFERENTIATION OF PHYSICAL SCIENCE VOCABULARY ON STUDENT UNDERSTANDING AND ENGAGEMENT

by

Holly B. Faris

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2013

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 shall make it available to others under the specified rules of the MSSE program.

Holly B. Faris

July 2013

DEDICATION

With great appreciation for the love and support of my husband Don and our daughters Jessi and Jaimi, this is dedicated to public servants in admiration for what the public school system of the United States does and will do for young people and our futures.

TABLE OF CONTENTS

INTRODUCTION AND BACKGROUND 1

CONCEPTUAL FRAMEWORK 4

METHODOLOGY 9

DATA AND ANALYSIS 18

INTERPRETATION AND CONCLUSION 35

VALUE 39

REFERENCES CITED 42

APPENDICES 45

APPENDIX A: Project Timeline 46
APPENDIX B: Self-Confidence in Concept Appraisals 49
APPENDIX C: Nontreatment and Treatment Sample Lessons 53
APPENDIX D: Writing Strategies, Topics and Focus Ideas 58
APPENDIX E: Student Interview Guidelines and Prompts 60
APPENDIX F: Student Surveys 65
APPENDIX G: Concept Assessment 70
APPENDIX H: Colleague Observation Prompts and Worksheet 76
APPENDIX I: Teacher Surveys 79
APPENDIX J: Teacher Journaling Prompts 81
APPENDIX K: Student Sample Responses on Post-assessments with Scores 83
APPENDIX L Sample Nontreatment Lab Injected for Understanding 87

LIST OF TABLES

1. Data Triangulation Matrix 14

2. Average Percentage Scores of Unit Preassessments and Postassessments.....18

LIST OF FIGURES

1. Preassessment and postassessment student scores for nontreatment and two treatment units.....19

2. Pretreatment and postunit student survey responses on their perceptions regarding vocabulary term understanding and writing applications.....20

3. Student scores on postunit and delayed unit assessments.....22

4. Delayed student survey responses comparing perceived retention of knowledge and understanding of nontreatment and two treatment concepts and the helpfulness of writing about cause and effect or explaining reasons.....24

5. Percentage of positive responses on postunit student surveys regarding increases in attitudes to learn concepts and to write about concepts during each concept unit 25

6. Comparisons of quantitative and qualitative scores on postassessments requiring inference writing with vocabulary terms 33

ABSTRACT

This capstone research project applied daily writing treatment strategies, such as concept mapping, analogies, story problem writing, one-sentence summaries, diagramming, and embedded lab prompts using unit word-banks, for the purpose of improving student attitude and engagement, understanding and long-term memory, and application of vocabulary terms into written explanations. Seventy ninth-grade physical science students were surveyed, interviewed, assessed, and observed. The study found an increase in students' engagement, attitude, and motivation to practice technical writing as students' perceived an increase in understanding and retention of mechanical energy concepts. The study also found a positive effect on teacher attitude and motivation due to improvements in the quality and quantity of student explanations of cause and effect situations when word banks were provided and when customized writing opportunities were embedded into the science lab curriculum.

INTRODUCTION AND BACKGROUND

I have come to realize that my main goal for teaching ninth-grade physical science is to help my students develop the ability to make reasonable inferences from everyday observations by applying science knowledge and ideas. These higher-order thinking skills, including generalizing and applying concepts already learned, require my students to express their understanding of science through a process of explanations. Sir William L. Bragg, a British scientist and Nobel Prize of Physics winner, said "The important thing in science is not so much to obtain new facts as to discover new ways of thinking about them" (Koestler & Smithies, 1958, p. 115). Physical science learning experiences are aimed at recognizing and explaining the interactions between matter, forces, and energy in our everyday lives. It becomes critical that students distinguish between these three terms, since energy causes changes to matter and one object responds to an applied force by a second object.

From my experiences working on Montana's State Science Benchmarks, I realized most essential science vocabulary was introduced before high school, but the applications of science vocabulary in written explanations, reasoning, and understanding are further developed in high school. Physical science provides opportunities, using math models and calculations, to measure and follow the transformations of matter and energy through processes of change. Knowledge integration is necessary as explanations become multi-step reasoning tasks with causes, effects, and inferences deduced from observations, models, measurements, or experiences.

Incomplete understanding of concepts and vocabulary becomes obvious as students move beyond measurement and into the inquiry processes of problem-solving

and reasoning. I specifically noticed this when students were asked to explain observable changes in chemicals or objects, or to defend the reasonableness of their explanations or derived calculation. Often the word *it*, *stuff* or *thing* were used. Students' meaning was difficult to ascertain when appropriate and descriptive science terms were missing.

I have been a secondary science or math teacher since graduating from Montana State University in 1980. This is my ninth year at Hamilton High School in beautiful Hamilton, Montana. There are five high schools within a 22 mile radius, but we have the largest student population with 534 students in grades 9 through 12. Nearly 94% are Caucasian, and 46% qualify for free or reduced lunch (Hamilton, 2012). I am fortunate to teach all six sections of physical science, a required class of most incoming freshman.

Montana has recently adopted the Common Core Standards of literacy, writing, and math manipulations. Science is a natural integration of these skills, with an emphasis on more technical writing to inform or persuade--using data or evidence. Giving ninth-grade students the opportunity to experience, infer, and explain science as a problem-solving endeavor, encourages them to be life-long learners. As better communicators of evidence-based viewpoints, students develop the confidence to explain what they know.

My project focus question was what are the effects of using customized writing strategies, designed to differentiate physical science vocabulary, on students' understanding of physical science concepts. The project subquestions were as follows: what are the effects of using writing strategies designed to differentiate physical science vocabulary on students' overall attitude; what are the effects of using writing strategies emphasizing differentiation of physical science vocabulary on students' overall engagement; what are the effects of using customized writing strategies emphasizing

differentiation of physical science vocabulary, on students' ability to synthesize and integrate knowledge and ideas to develop reasonable inferences to observations and situations; what are the effects of using customized writing strategies emphasizing differentiation of physical science vocabulary, on students' long-term memory of physical science concepts; and lastly, what are the effects of developing customized writing strategies, designed to differentiate physical science vocabulary, on my attitude toward planning, implementing, teaching, and assessing physical science concepts. Writing strategies included concept mapping, analogies, one-sentence summaries, diagramming, and embedded lab prompts using unit word-banks. Modeling, practicing, and revising written responses to formative probes, daily reality-check prompts, and calculated story problems attempted to engage reluctant writers and promote conceptual understanding as reasoning developed through each unit of study.

Support and validation for this AR project was provided by Dr. Jewel Reuter as my Master of Science in Science Education capstone advisor. Dr. Greg Francis of the Montana State University Physics department provided teaching and content advice and was my project reader. Computer processing and writing support was provided by my husband, Don Faris, and by Sharon Mattix and Ryan Shupp. These individuals, and Marty Lord, are nonscience teachers at Hamilton High School who observed, read, edited, and reflected on this project. Mr. Kevin Conwell, Hamilton High School's principal, provided support, observations, and evaluations of my capstone project as part of my professional evaluation.

CONCEPTUAL FRAMEWORK

The constructivist view of knowledge and learning progression requires vocabulary knowledge, comprehension, and application. Novak (1989) said science learning needs to be made "conceptually transparent" to help students relate concepts and recognize connections between terms, processes, experiences, and principles (p. 6). Using a physical science example of Newton's Law of Motion, F = ma, Novak asserts a knowledgeable student would know each variable, and also the influence of each variable on the other two variables. Meaningful learning of science concepts is enhanced by simultaneously learning the historical development of the ideas, science terms, and misconceptions that led to modern-day explanations (Wandersee, 1992). Science understanding develops when secondary students encounter new ideas in a variety of interconnecting contexts, and construct meaning by developing more accurate and sophisticated explanations of the natural world (Linn, Lee, Tinker, Husic, & Chiu, 2006; Driver, Squires, Rushworth, & Wood-Robinson, 1994).

Smith, Wiser, Anderson, and Krajci (2006) showed science knowledge progression at the high school level by embedding matter and molecular theory vocabulary in Chemistry performance and assessment documents. Synthesis and analysis of science vocabulary terms help achieve an understanding of energy transformations and matter in motion, which are benchmarks of freshman-level physical science (Montana, 2012). Seah, Clarke, and Hart (2011), used lexicon-grammatical resources, such as word banks or math formulas, to promote integration of seventh-grade science concepts into student predictions, explanations, and justifications for observed changes in volume and density situations. Predictions of measurement and derived calculation values indicate students'

understanding and awareness of factors, such as mass, gravity or temperature, influencing final outcomes.

Students come into high school with common sense beliefs about motion and changes in matter, based on years of instruction and personal experience. Discriminating between an object undergoing change, the cause of the change, and the observations during the process of change, force a student to be an active-learner while thinking critically about cause and effect. McDermott and the Physics Education Group (1996) consider this construction of explanatory models, which are also capable of predicting future responses, active mental engagement.

The development, interpretation, and use of different forms of scientific representation, including operational definitions of science vocabulary, establish lasting scientific literacy in preservice teachers and students. Nordine, Krajcik, and Fortus (2011) found middle school physical science students developed a more realistic and applicable conception of energy by experiencing lessons that focused on six different energy transformations occurring as everyday phenomena. Synthesizing and integrating these energy concepts allowed students to develop inferences explaining obvious motion changes and less obvious energy conversions resulting in heat. Hand, Prain, and Keys-Wallace (2002) found 14 to 16 year-old students had a better overall understanding of light energy and behaviors after completing innovative writing tasks, specifically one comparing a laser beam to a moving bullet in water in terms of reflection and refraction.

Higher-order thinking skills, beyond just the comparisons of science terms such as matter, force, or energy, involve the interactions of these basic concepts into scientific reasoning about an actual circumstance (Brown**,** Furtak, Timms, Nagashima, & Wilson,

2010). Keeley (2011) has compiled two-tiered assessment probes to target a student's idea about a concept, and then guide students through a conceptual change of reasoning by having students describe the cause, process, and effect of changing matter. As Keys (1994) wrote, "The task of creating a written product can be a powerful tool for developing science understandings because it requires the writer to retrieve, synthesize and organize information" (p. 1019). Students' ability to synthesize and integrate knowledge and new ideas, to develop inferences about what they are observing, indicate higher-order cognitive applications of science concepts. Writing explanations requires content and process skills. Secondary science students formalize their own thinking by generating models, designing experiments, and deducing evidence-based reasoning (Brown-et al., 2010).

Active learning, using writing strategies that emphasize differentiation of vocabulary, build confident attitudes and interest during lab activities and class discussions. Bransford and Schwartz (1999) engaged students in what-if problem-solving prompts and asked them to consider the qualitative effects of science concepts from multiple perspectives. This demonstrated the relevance and value of science knowledge and concept integration. A positive progression from situational interest (teacher provided) to individual interest (self-motivation) was discovered when high school biology and chemistry students found topics useful and relevant for other situations or their own life goals (Hulleman & Harackiewicz, 2009). Other research showed that low-achieving students knew more science knowledge than they generally express in explanations, but providing a word bank or concept map of related vocabulary terms resulted in more focus and accuracy in written responses and explanations (Gregson, 2005). Helping upper-elementary students

to distinguish between everyday language and the specialized vocabulary of science concepts motivated them to verbally express their reasoning more effectively. Discussing, generalizing, and even debating abstract concepts and vocabulary terms, such as energy, resulted in cooperative learning and discerning applications of science terms to different situations and experiences (Cavagnetto, Hand, & Norton-Maier, 2010).

Braaten (2011) differentiates science explanations in science research from “everyday ways” of explaining occurrences in high school science classrooms (p. 644). She highlights differences between explanations of concepts, of causes, and of effects, and therefore the need for open-ended questions to motivate students to offer explanations. Novak (1989) insists meaningful learning motivates students because of the integration of thinking to actual happenings in their lives, which can empower them to continue to be life-long learners. Acknowledging the persistence of force and energy misunderstandings through history, and in modern day observations, motivate high school to university physics students to recognize the need for differentiation of vocabulary, especially mechanical energy terms (Hestenes, Wells, & Swackhamer, 1992).

BouJaoude and Tamim (2008) used generative learning strategies such as analogies, summaries, and answering questions to help middle school science students organize meaningful relations of science vocabulary and meaning. When learners organize their thinking as relationships, they increase their integrated science knowledge and improve their long-term memory and retention of concepts to solve problems and offer explanations. Nordine, Krajcik, and Fortus (2011) using delayed testing with middle school physical science students, found students’ generalized energy concept, learned as six separate energy transformation lessons, continued to be used to explain new

situations. Reasonable understandings became part of long-term memory, ready to be applied to critical thinking and problem solving situations when evidence is available to support and refine explanations (Braaten & Windschitl, 2011).

Mills (2011) states action research by a teacher effects positive educational change. Customized writing strategies, designed to differentiate physical science vocabulary, take a variety of forms and approaches. When focusing on the basic vocabulary distinctions of energy, forces and matter, and the First Law of Thermodynamics involving conservation of matter and energy, junior high physics students are better served with a more integrated approach based on diagramming energy transformations (Mualem & Eylon, 2010). According to Gerard, Spitulnik, and Linn (2009), customizations initiated by three junior high teachers based on three years of their science students' responses on text-based assessments, result in tailored and concrete connections between student reasoning, instructional activities and science content. These teachers developed their own versions of worksheets and assessments to develop, highlight, and apply their students' specific applications of conceptual understanding. Young (2005) suggests bridging comprehension and integration with vocabulary-application strategies that use known words and associations to understand the unknown or more abstract vocabulary terms. In addition to science content, students need instructional modeling of technical forms of expression, such as formulas, and individual practice using different writing tactics or formats (Baker et al., 2008). Development of operational definitions to physical science vocabulary terms and expressions, builds the confidence of teachers and students in content knowledge and in explanations of lab demonstrations and results (McDermott et al. 1996). Ogilvie (2009) claims K-12 classroom instruction rarely offers opportunities

for students to solve open-ended challenges, but instead has students completing tasks quickly and efficiently with memorized facts and formulas applied in rote fashion. Studying 500 incoming freshman university physics students, he found successful novice problem-solvers "develop a solution that is both internally consistent and externally valid with respect to the rest of their domain knowledge" (p.020102-2). Teachers devising writing strategies that focus on forces causing motion or energy conversions or transfers, appears to encourage students to employ an understanding-based approach to observable situations. Teachers using more open-ended questions about physical science concepts could require a qualitative explanation with a quantitative, perhaps calculated, answer.

Using writing for knowledge learning, integration, transformation, and practical arguments, instead of just describing or answering, is academically advantageous to high school students (Hand, Prain, & Wallace 2002). Getting ninth graders to think about physical science concepts begins when their own ideas or knowledge-levels are inadequate, inconsistent, or incompatible with what is happening right in front of them. Science takes the natural world beyond magic, and ninth grade physical science students are building the vocabulary, knowledge, and confidence to intelligently explain what is happening.

METHODOLOGY

Project Treatment

With this capstone project, a nontreatment and two treatment units for the study of mechanical energy provided comparisons and conclusions of the implementation of writing strategies emphasizing the differentiation of physical science vocabulary terms. The three concepts units included Motion and Forces, Newton's Laws of Motion, and

Work and Power as transfers of mechanical energy. This project involved four classes of ninth graders taking physical science at Hamilton High School in Hamilton, Montana. 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. A Project Timeline, showing nontreatment and treatment approaches and interventions is shown in Appendix A.

All classes began learning motion and forces concepts with the nontreatment approach the first days back from winter break. An introductory self-confidence appraisal, shown in Appendix B, provided learning objectives and vocabulary words pertaining to these concepts. Speed, acceleration, and momentum were demonstrated and experienced to enable students to develop operational definitions. Formative assessment probes had students explain or defend their chosen answer to a described situation. Answers to motion story problems were calculated and appropriate units applied. By diagramming the forces on various objects, students recognized that forces come in pairs, and the effects of common forces such as weight, gravity, and friction. Students were expected to use observations and data collected in their lab experiences to answer questions and write inferences, using appropriate science vocabulary and units. Students were also directed to apply and relate their conclusions to every-day situations of relevance. A nontreatment sample lab activity worksheet is shown in Appendix C.

During each treatment class period, formative reality checks, which are questions or prompts students write written responses to, were implemented with 10-15 minutes spent practicing various writing strategies incorporating and distinguishing specific vocabulary terms. These strategies included concept mapping, diagramming and labeling,

paraphrasing or summarizing, correlating concepts to every day applications and situations, formulating analogies, and generating a one-sentence summary using the "what does what to what, when, where, how, why" format (Angelo & Cross,1993, p. 183). Formative assessment probes and discrepant events were also used to generate responses, to practicing writing explanations, and to guide instruction. Writing strategy topics and focus ideas used in treatment interventions are shown in Appendix D. Treatment classes used these opportunities to observe and practice vocabulary differentiation and critical thinking, by integrating knowledge and ideas into their explanations. Treatment responses were written in a class set of anonymous spiral notebooks and were evaluated for progress and response, but not formally graded. Physics story problems were analyzed using formulas, such as $s = \frac{d}{t}$, $p = mv$, $F = ma$, And $PE = mgh$, with metric units such as meters/second, newtons, and joules. Then, students wrote a one-sentence summary describing what happened in the story problem, to focus on cause and effect and to differentiate energy and forces and objects.

The Newton's Laws concept study concentrated on the interactions of forces and objects beginning with a self-confidence appraisal, shown in Appendix B, to introduce the learning objectives and vocabulary terms. Newton's Laws of Motion were analyzed with relevant applications, problem-solving situations, and current events such as winter sports. Treatment writing topics provided opportunities to apply the three laws to actual situations of acceleration, as shown in Appendix D. The Acceleration Inquiry Report, shown as a sample treatment lesson in Appendix C, asked a student to predict, observe, and then infer and explain the motion of an air bubble in a jar of water that the student manipulates, by applying the Laws of Motion to the different matter involved.

The work and power concept unit was designed to develop an operational definition of work, as a transfer of energy, and power, as the rate of work being done.

All classes began with a self-confidence appraisal, shown in Appendix B, to introduce learning objectives and specific vocabulary terms. All classes used 10-15 minutes of each period to engage in specific writing intervention activities, shown in Appendix D, where students considered situations that illustrate the concept of distributing effort forces over distance to make work seem easier. Story problems applying W = Fd and P = $\frac{W}{t}$, mechanical advantage as a ratio of forces or distances, and efficiency as a comparison of work output to work input were analyzed, as well as metric units of joules and watts. Analogies, short summaries, common applications, and graphic organizers were completed, as students individually and cooperatively analyzed specific situations or observations. A sample treatment lesson is shown in Appendix C.

The development of a rule or reasoning allows for knowledge integration for future problem solving situations. For motion, a rule could take the form of calculating acceleration or momentum to represent interaction of matter and force and motion. For forces, an accepted rule such as Newton's second law of motion, distinguishes when gravity causes the weight of an object, when gravity causes constant acceleration toward the Earth, or when friction causes moving objects to slow down or turn. When considering work and power, a rule of force causing an object to undergo displacement, includes the rate of work done, the mechanical advantage of using a simple machine to reduce the effort force or the effort distance, and the loss of efficiency due to friction. Generating consistent rules or reasoning helped all students with the visualization and the

retention of abstract terms and concepts, like force and energy, and in intelligently expressing what they know and observe about moving objects.

Data Collection Instruments

The 132 ninth-grade students at Hamilton High School are required to take physical science unless they are enrolled in advanced math classes beyond Algebra I and are tracked into a biology/chemistry track, or they have Individualized Education Plans and take a more general science track. Hamilton has 534 students in the high school, of which 46% qualify for free or reduced lunch. The student population is 94% Caucasian, 3% Hispanic, 2% Asian, and 1% American Indian (Hamilton, 2012). A large majority of the ninth graders verbalize an expectation of going to a state college or university upon graduation. Seventy students in four physical science classes participated, using 90-minute class periods on alternating days.

Various quantitative and qualitative data for each of the project questions were collected to allow for triangulation and to help evaluate the project focus questions. Table 1 is the data triangulation matrix. Data were gathered from the students, from me as the teacher, and from observations and reflections by a colleague and the high school principal, who were not directly associated with the project.

Table 1
Data Triangulation Matrix

Focus Questions	Data Source 1	Data Source 2	Data Source 3
1. Effects on students' understanding?	Preunit and postunit concept assessments, with measurement analysis, application, and reasoning	Preunit and postunit concept student interviews	Pretreatment, preunit self-confidence, and postunit concept student surveys
2. Effects on students' ability to integrate science knowledge and vocabulary into inferences?	Pre and postunit and delayed concept assessments using probing question with choice (quantitative) and reasoning (qualitative)	Pretreatment and postunit concept student interviews, with prompt of applications and evidence-based reasoning	Pretreatment and postunit concept student surveys of perceptions of reasoning
3. Effects on students' attitude?	Nontreatment and treatment observations, with prompts by colleague & principal	Pretreatment, pre and postunit concept student interviews	Pretreatment, preunit self-confidence, and postunit concept student surveys
4. Effects on students' engagement?	Nontreatment and treatment observations, with prompts by colleague & principal	Pretreatment and postconcept student interviews	Pretreatment and postunit concept student surveys
5. Effects on students' long-term memory?	Postunit concept assessment and delayed concept assessment with probing questions	Postunit concept and delayed concept student interview bridging concepts and integration	Postunit concept and delayed concept student surveys
6. Effects on teacher attitude and motivation to teaching?	Instructor daily observations and journaling with prompts	Nontreatment and treatment observations by colleague and principal, with prompts	Pretreatment and posttreatment, preunit and postunit teacher surveys

Six students, with a low, medium, and high range of achievement levels as determined by their eighth-grade criterion-reference test scores in English, math, and science, were initially interviewed before the Mechanical Energy Unit began. These students, chosen from the four class periods participating in the project, were available before school, during lunch, or their study halls. Their efforts and honesty were appreciated and useful to compare student viewpoints regarding understanding, attitude, and class room engagement before and after treatment, as well as before and after each concept study unit. Students' long-term memory or retention of concept understanding and reasoning

skills were also evaluated with some delayed concept interviews of the same six students about two weeks after each concept postassessment. Questions, prompts, and activities are described as the Student Interview Guidelines in Appendix E.

Six random high-achieving students, including two of the interviewees, were individually tracked for assessment progress and survey comments due to the large sample size. High-achieving students scored 92-100% on their eighth-grade criterion-referenced test (CRT) tests for English, Math, and Science. Additionally, these six students work at learning and understanding classroom concepts and applications by completing assignments, participating in class discussions, and achieving grades of 88% or better.

Six random medium-achieving students, including two of the interviewees, were also individually tracked for assessment progress and survey samples. Medium-achieving students all scored 92-100% on their eighth-grade English CRT test, but 72-88% on their Math and their Science tests. These students exhibit good class participation and achieve quarter grades of 70-85%.

Six low-achieving students were similarly tracked for assessment progress and survey comments, including two interviewee volunteers. All of these students had eighth-grade CRT scores below 70% on their English, Math, and Science tests. Low-achieving students often have incomplete or missing assignments and are reluctant to participate in class discussions unless called upon with a specific question, but their attendance was fairly regular. Quarter grades are 73% or less. One of these students had an Individual Education Plan for testing accommodations and additional math resources and assistance.

The effects of writing strategies emphasizing the differentiation of vocabulary terms on students' concept understanding and students' ability to integrate vocabulary and concepts into inferences and explanations of everyday observations were compared using a pretreatment student survey given before the nontreatment approach, three self-confidence appraisals before each unit, and three postunit concept student surveys. These are shown in Appendix F. For consistency, survey data were analyzed from about 12 anonymous and voluntary student responses from each of four classes for a total of 50 physical science student surveyed. Pre and postunit concept assessments were also used to compare nontreatment and treatment concept understanding, as well as the development of higher order thinking skills and evidence-based reasoning. For consistency, scores and responses from the same seventy students in four classes were always used for assessments comparisons. Comparisons of postunit assessments and delayed assessments were used to show the integration of mechanical energy knowledge, vocabulary terms, and observed evidence into more intelligently expressed inferences and deductions. Assessments are all shown in Appendix G. Delayed concept assessments and delayed student surveys were given about two weeks after each postunit concept assessment, and involved the same seventy students used in previous assessments.

The effects of writing strategies emphasizing the differentiation of vocabulary terms on students' long-term memory of physical science concepts was determined by comparing postunit concept assessments to the delayed concept assessments for each unit, as well as postunit student surveys to delayed concept student surveys answered after the delayed assessment.

Student attitudes and student engagement in class discussions and activities were compared with pretreatment and posttreatment student surveys and student interviews. Additionally, observations by a nonscience teaching colleague and the principal of the high school were done during a nontreatment science lesson. Each colleague also spent a class period observing during a treatment lesson on either Newton's laws or work and power. Having two critical colleagues observe and comment provided valuable quantitative and qualitative data. Both were prompted to focus on particular levels of learning and on particular learning-level students, on student activity in general, and on nuances of student attitude about science and student engagement in writing. Observer prompts and worksheets are shown in Appendix H. Both also provided enlightening qualitative data during our discussions afterward regarding their observations, impressions, and professional suggestions on strategies and student responses.

A pretreatment and posttreatment teacher survey was used to collect quantitative and qualitative perspectives about particular class situations, responses, progressions, attitudes, and concerns. These were done before and after the nontreatment concept approach, and before and after the two treatment approaches. This survey, shown in Appendix I, was used to compare the effects of writing strategies and vocabulary focus on teacher attitude and motivation to plan, implement, teach, and assess mechanical energy concepts. Additional data were collected from the observations, comments, and discussions with observing colleagues, and from teacher journaling prompted by questions shown in Appendix J. Many spontaneous notations and comments made on student papers, in the writing notebooks, or on survey responses were accumulated and considered in determining the effects of this project on teacher attitude and motivation.

DATA AND ANALYSIS

Data were collected in one nontreatment and two treatment units involving the study of mechanical energy concepts, to determine the effectiveness of customized writing strategies designed to differentiate physical science vocabulary, on students' understanding of physical science concepts. Table 2 reveals there was a gain in understanding in all three units.

Table 2
Average Percentage Scores of Unit Preassessments and Postassessments

Unit Data	Nontreatment Unit: Motion and Forces				Treatment Unit I: Newton's Laws				Treatment Unit II: Work, Power, Machines			
	T	H	M	L	T	H	M	L	T	H	M	L
Preassessment	23	37	23	8	28	47	26	14	24	39	6	4
Postassessment	70	87	76	58	62	83	71	54	74	91	76	52
Percent Change	204	135	230	625	121	77	173	286	208	133	117	120
Normalized Gain	0.61	0.8	0.7	0.5	0.5	0.7	0.6	0.5	0.7	0.9	0.7	0.5

Note. Total possible score is 100. Total student participation is 70 (T) $N = 70$; High-achieving (H) ($n = 6$); Mid-achieving (M) ($n = 6$); and Low-achieving (L) ($n = 6$).

In order to compare results from different units, the percent change from preunit to postunit assessment score was calculated according to the following formula:

$$\text{Percent Change} = \frac{\text{postunit score} - \text{preunit score}}{\text{preunit score}}$$

Due to varying preunit scores, a normalized gain was also calculated to compare the change in understanding between units. The normalized gain was calculated as follows:

$$\text{Normalized Gain} = \frac{\text{postunit \%} - \text{preunit \%}}{100 - \text{preunit \%}}$$

Comparison of the three units showed a decrease in percentage change in scores indicating a decrease in understanding when treatments of intentional writing strategies were used. Writing strategies during treatment units and each unit assessments were designed around the use of specific vocabulary words, such as acceleration, gravity,

friction, effort, and efficiency, in the instructions and in the student responses. Students were only given partial credit when assessment answers did not include the target vocabulary words associated with the focus of the question. Figure 1 shows the range of student scores as quartiles, with 50% of students scoring in the box, and the whiskers plots indicating the high and low extremes of the large sample size of ninth graders. This also indicates gains in understanding with each concept unit, yet no increase with the use of specific writing practice treatments.

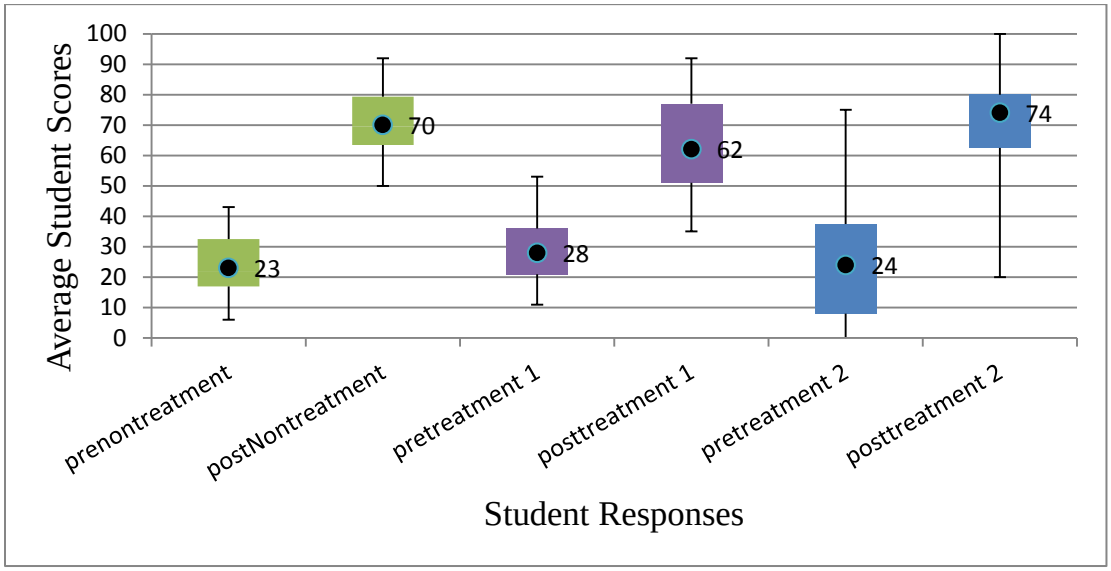


Figure 1. Preassessment and postassessment average student scores for nontreatment and two treatment units, (N = 70).

Data were collected in a pretreatment survey of students regarding familiarity with vocabulary terms to be applied in the subsequent mechanical energy units of study. Additionally, postunit student surveys after each unit provided data of students' perceptions of their understanding of the concept unit focus terms. These data, shown in Figure 2, demonstrate growth in confidence regarding how to apply these terms to objects in motion, and in applying these terms when writing explanations about how and why objects move or do work.

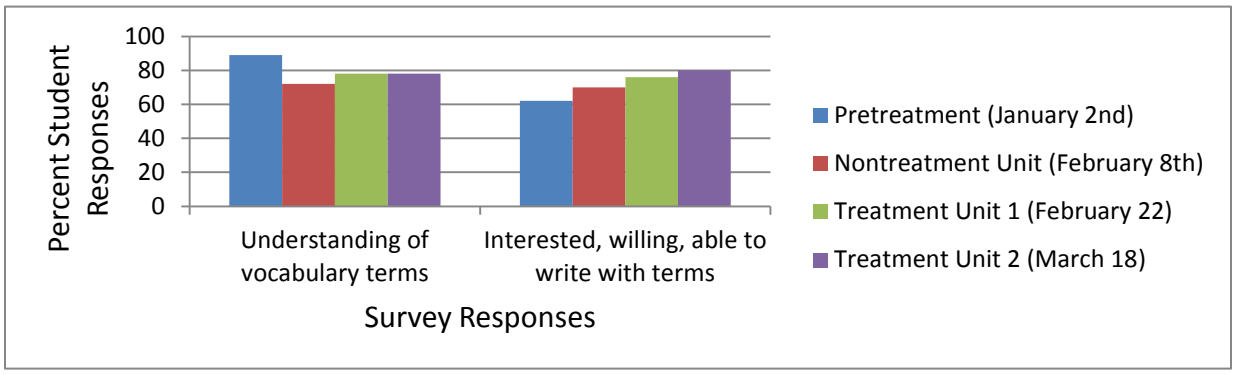


Figure 2. Pretreatment and postunit average student survey responses on their perceptions regarding vocabulary term understanding and writing applications, (N = 50).

Interviews with six students throughout the mechanical energy units of study also highlighted the self-confidence in student perception of understanding vocabulary terms and the lack of term application in assessment denoting understanding. A mid-achieving student indicated she had studied motion at several grade levels and in math story problems, so the terms were familiar. But she added, "The formulas and units are new and I get confused between velocity and acceleration, and momentum and inertia, and even mass sometimes." After the final treatment unit, this same student said she needed to diagram the machine situation before she could distinguish between effort and work input. When prompted to apply units, she could quickly and correctly identify the differences between force and energy.

A low-achieving student revealed an evolving level of understanding than his postunit assessment indicated, by verbally describing moving objects and how simple machines "break up the work load." He continued to use combinations of terms inaccurately, but had acquired the concept of energy transfers and conversions to describe and explain situations more clearly than with nontreatment concepts. The interview opportunities built his confidence and he admitted he learned the terms when he had to write with

them. He said," When we had to write a math problem to fit the answer you gave us, I finally figured out what each of the letters was for. A drawing really helped, too." Writing daily in treatment phases developed understanding of nontreatment terms and applications, as well as relationships of terms often expressed as formulas or laws.

The association of formulas, such as F = ma and W = Fd, to gravity, friction, effort force and weight were noted by both high level students. They each acknowledged they could write less by using the formulas or specific vocabulary to justify their reasoning for causes and effects. Yet neither student specifically recognized gravity and friction as opposing forces in Newton's second law of motion formula of F= ma on the assessment. One said she was trying to remember what was said in class about free-falling objects to answer the assessment question, instead of applying the law to explain the downward acceleration of the feather and the rock. The assessment of unit understanding measured qualitative explanations; correctly using vocabulary terms featured in the treatment units was contingent on understanding the basic motion terms of the nontreatment unit.

Data were triangulated to determine the effect of customized writing strategies, designed to differentiate physical science vocabulary on students’ long-term memory of physical science concepts. Analysis of postassessment and delayed assessment scores in Figure 3 below indicates retention of knowledge regarding concepts, vocabulary terms, and the formula applications needed to determine measurements and calculations with metric units.

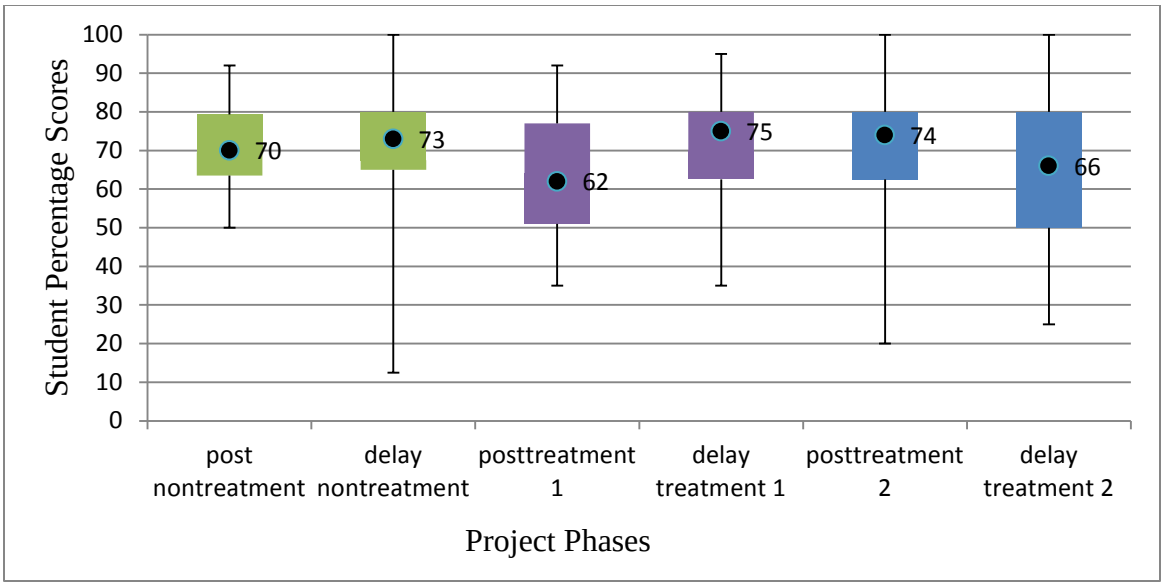


Figure 3. Student scores on postunit and delayed unit assessments, (*N*=70).

The lower 25% quartile whiskers of the box plot indicate that low-achieving students retained less understanding of the nontreatment concepts which included graph analysis, motion vocabulary, and ranking of acceleration and force measurements with metric units. Low-achieving students improved their knowledge retention for the two treatment units with no scores below the postassessment scores. Occasionally students did not attempt to write answers, thereby getting zero credit. The upper 25% quartile improved for all concept units, both treatment and nontreatment. Most of the motion and forces vocabulary of the nontreatment unit continued to be applied and practiced in the last two treatment units.

Delayed concept interviews required students to explain the concept maps they had previously constructed during postunit interviews, and evaluate a fabricated student response to an assessment questions. Constructing and explaining concept maps continued to be an unpleasant and difficult undertaking for one of the mid-achieving and both low-achieving students; troublesome vocabulary terms at the end of the unit

remained difficult to define or associate. However, all six students seemed to appreciate the challenge of evaluating and explaining another student's thinking and written responses. Nontreatment responses were generally recognition of right or wrong answers, whereas treatment responses improved in quality by offering insight of misconception or misuse of vocabulary term and how the term could be better utilized.

A high-achieving student agreed that writing about cause and effect or explaining reasons for observations helped her remember because,

> "Working with actual tools made it easier for me to retain some of the knowledge and terms. I could figure out the mechanical advantage which helped me decide whether force or distance was the advantage of that particular pair of scissors."

She acknowledged that writing experiences made the force and distance relationship more clear for her and helped her retain and use that knowledge later.

Students were also specifically asked on the delayed treatment student survey if they continued to understand the main objectives of the previous concept unit and if they felt the writing practices in lab and class helped them retain concept knowledge. Figure 4 below, shows comparisons of delayed survey responses and the responses for each learning level.

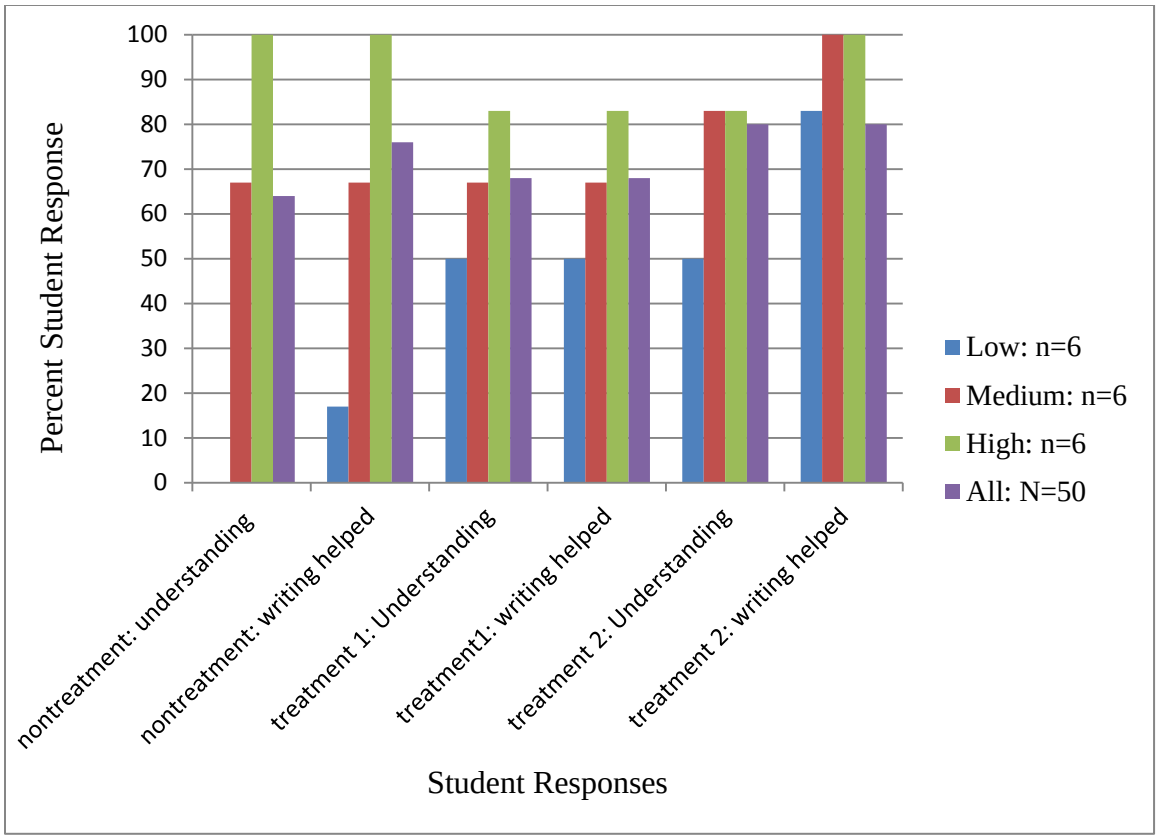


Figure 4. Delayed student survey responses comparing students' perception of retention of knowledge and understanding of nontreatment and two treatment concepts and the helpfulness of writing about cause and effect or explaining reasons, (*N*=50 for all students, *n* = 6 for each achieving level group).

This chart especially shows a positive effect of writing for the low and medium level learners, as the units and practice became part of their daily class experiences and expectations. These students acknowledged improvements in their writing, their understanding, and their overall confidence in the learning process using writing to learn.

Writing strategies, custom designed to differentiate science vocabulary terms, had a positive effect on students' overall attitude about physical science. A presurvey, taken before the mechanical energy units began, showed a generally positive attitude about science class. When asked on postunit surveys to describe their motivation to learn during each particular concept unit, students maintained an overall positive attitude when they

agreed or strongly agreed to the statement, as shown in Figure 5 below. Additionally, more students agreed or strongly agreed that the practice of writing about cause and effect, or explaining reasons, improved their decision-making skills for lab work, discussions, quizzes, or tests.

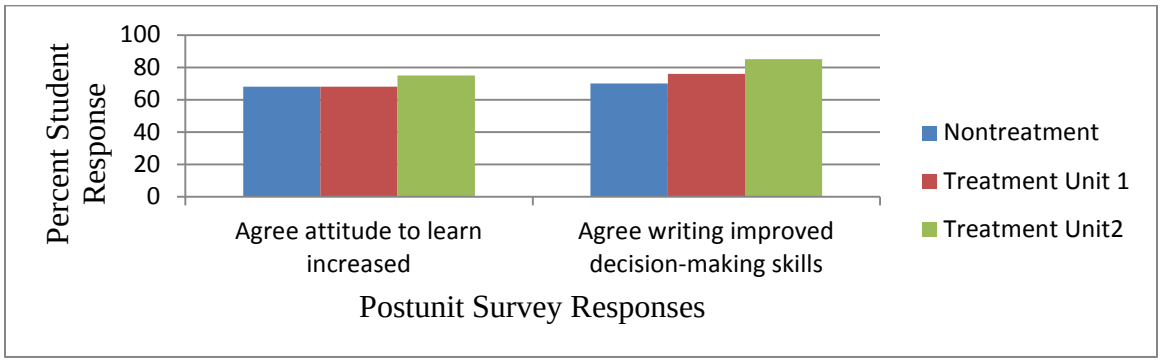


Figure 5. Percentage of positive responses on postunit student surveys regarding increases in attitudes to learn concepts and to write about concepts during each concept unit, (N = 50).

Qualitative data, gathered from anonymous student survey responses, also indicated that students perceived discussions and written explanations of everyday observations helpful in learning science concepts. In pretreatment survey responses, students described science as "fun, but challenging, so it keeps [them] interested" and" hard, but [they] like that [they] do something each class period." In the postnontreatment survey, a student commented on writing: "I learned the most in lab and I used that memory later on the test." On the second posttreatment survey, another student wrote, "If you can get all of your understanding and developments out in words, I think you are more likely to understand and work through new situations and problems."

Attitude was also related to understanding; both low-achieving students mentioned in interviews that as they learned the vocabulary and formulas each unit of study became more enjoyable. One said, "I was less stressed about tests when I knew the words to use

from writing in the notebooks." A mid-achieving interviewee developed a more positive attitude toward building concept maps from the unit vocabulary terms, pointing out during her delay interview that she was more confident in the differences between inertia, mass and momentum after writing about the bubble of air in the water bottle. She said, "Writing my answer made me prove my thoughts. I remembered *that* on the test!"

Two different colleagues observed a lab activity in each of the three concept units. Lab activities involved writing inferences and explanations of lab measurements and calculations. Both colleagues mentioned the students, in nontreatment and treatment situations, seemed intent on their lab tasks and willing to write, although the high-achieving students were quicker to ask for help or have their answers read or verified. Both colleagues found at least twice as much unsolicited teacher-prompting of low-achieving students to use specific science vocabulary or units of measure in the treatment units. The high school principal noted that every student, at all levels of learning, seemed optimistically involved in group discussions and open-ended writing responses in the second treatment unit, compared to the nontreatment lab where students collected and analyzed data and answered questions, embedded in their worksheets, more often as individuals. He observed the positive diligence of all levels of students to get meaningful data and was pleased, as an administrator, to see students practicing technical and relevant writing outside of an English class.

While observing each of the lessons in the mechanical energy units, colleagues noticed a direct correlation between student engagement and the use of writing strategies designed to differentiate physical science vocabulary. The high school principal's observation of a second treatment class period indicated more time was given to high-

and mid-achieving learners for answering open-ended questions, whereas low-achieving learners were asked more closed-response questions and given less wait time before the question was rephrased or partially answered. During writing time, he noticed that more low-achieving students were approached to check for understanding and prompted with formulas or specific vocabulary applications. Nontreatment observations of a data collecting and analyzing lab had embedded questions in the paperwork.

A science colleague offered the following observation during the first treatment unit:

> "High learners often seemed to say 'it won't work' hastily and were *[then]* challenged to make connections between math class, basic skills, logic, vocabulary, and units. There was emphasis on being accountable for part of their learning. Medium and lower level learners got a recap of the directions or purpose or expectations. When students realized they weren't going to get a straight-out answer, they got more intent on problem-solving themselves."

Student survey results also showed the lab and writing activities encouraged students to be engaged each day of class. The pretreatment survey ascertained students preferred hands-on activities with follow up questions and notes generated as class discussions and worksheets, rather than class notes, demonstrations, and video clips with minimum hands-on activity. Only 8% of students wanted no hands-on activities, preferring only class notes, textbook and story problems as their classroom approaches to best learn and remember science knowledge.

On each of the postunit surveys, at least 72% of students agreed or strongly agreed they were more engaged in daily class activities involving lab and a writing exercise. Only student interview questions distinguished between the labs and writing done in

nontreatment units and the specific writing strategies practiced during treatment units. Of the six students interviewed, all but one low-achieving learner considered the writing practices useful and engaging. Although all six declared in pretreatment interviews, they would like to be better technical writers, the dissenting low-achiever remarked in both posttreatment interviews that she did not like writing her answers because it took too much time to figure out how to explain something and then write it down.

Daily perusal of spiral notebooks with students' formative writing indicated some prompts were more engaging than others. Some responses were short and incomplete, some were diagrams with labels, and some inspired an entire page of explanation. According to the posttreatment survey responses, more than 62% of the students remembered and valued the treatment writing exercise which required them to explain a video clip, using the 'what does what to what, when, where and how' writing strategy. More than 80% of delayed treatment student survey responses specifically mentioned the hands-on screw cap analysis of recognizing simple machine components and calculating the mechanical advantage as meaningful and advantageous for learning the concepts and vocabulary term applications.

The effects of developing customized writing strategies designed to differentiate physical science vocabulary, on my attitude and motivation as a teacher of ninth-grade physical science was mostly positive. The planning and implementation of a specific class time to practice writing was the greatest challenge. Time management and organization were essential to encourage writing efforts and develop the practice of technical writing. As a teacher, I was expected to model evidence-based reasoning and writing, and then provide practice time. The study of mechanical energy has commonly

been frustrating each school year, because the vocabulary and benchmarks have been covered in previous science and math classes. Yet the concept of mechanical energy being measureable, with new metric units of measurement, is a new perspective for students. Tracking energy conversions and transfers requires commonly used terms like effort, acceleration, work and power to be understood as formulas with influencing factors. Students have heard and used motion and force vocabulary in everyday life and previous classes, and tend to hold onto their basic definitions as concepts develop instead of adjusting for direction or influencing variables. Time management became a stress with many interruptions of class and absences of students in the month of February, and evaluations of formative writing situations revealing a lack of student understanding of the concepts. Each unit was extended by at least two days, as basic understanding and review of terms and concepts were essential. I was motivated by these adjustments, because they resulted in productive student learning.

An extra lab lesson, shown in Appendix L, was incorporated into the first nontreatment class time with graphing, embedded vocabulary, and more opportunities for students to summarize the lab applications using specified vocabulary terms. This was observed by a colleague who described my attitude during that lab in this way: "While realistic expectations are reasonable and the basic expectations were stated early and often, at times frustration is perceived between students and teacher. This was evident when [a high level learner] constantly wanted verification of their group's work, and another lab group was off task and hadn't made any efforts to set up experiment." She also wrote "I specifically like the connections between math classes and basic skills and

logic, and how students need to be accountable for part of their learning by trying. You often asked a group 'Is that [answer] reasonable?' which encourages them to think."

On a particular journaling prompt during nontreatment, I had written

> "Be more positive to get kids to move past their comfort-level and use 'velocity' and 'acceleration'. Perhaps more notes and lecture instead of review and discussion—just because they use the word everyday doesn't mean they pick up the science-nuance or meaning."

Student difficulty with metric units and calculations tended to be closely related to homework completion, and to not having a calculator in class to follow along with class examples. This prompted me to write "I need to get the noncompliant students to buy into wanting to improve the quality of their thinking and work. Develop a 'bring your own car' lab to improve graph analysis and distinguish positive and negative acceleration."

The self-confidence surveys developed for each unit were well received by students and useful for me as a teacher. As a formative implementation, the students were forced to acknowledge the unit objectives we were about to study, and to begin distinguishing the science versions of the vocabulary terms. Closing the loop with students by showing them the class percentages for different responses seemed to encourage confidence to learn. I wrote in a journal prompt to consider allowing these surveys to be used on final summative assessments to help students recognize the learning objectives in assessment questions. A low-achieving interviewee mentioned the helpfulness of word banks for explanation questions, and filling in concept maps made more sense to him. Journaling notes indicate students responded well to a writing strategy of using their survey words to write a one sentence summary, and then working

cooperatively with another student to edit and improve their writing. Perusal of their daily writing attempts in class notebooks gave me an opportunity to help individual students incorporate more specific vocabulary, and to notice misconceptions about a term or concept. This had a positive effect on teaching and learning and willingness of students to ask questions.

The same colleague who observed the nontreatment lab, also observed a practice writing session during the first treatment unit and remarked "You were focused, positive, and direct. Humor made it relevant and interesting for the students, so they were enthused to write. Good checks for understanding, and nice use of the balloon to help visualize the cause and effect." She also noticed that high achieving students were encouraged to write more articulate answers and a reluctant writer was encouraged to "start with a drawing and action-reaction labels."

The high school principal also observed a class period during the second treatment unit. He mentioned teacher attitude influenced student engagement throughout the period. He wrote "By staying positive, her students stayed positive despite working through some difficult and challenging concepts for them." He suggested slowing discussions and giving more wait time to low-achieving learners who may be trying to think of an answer. With the new Common Core standards being implemented in public schools, he was also encouraged to have students practicing technical writing and improving reasoning skills.

Posttreatment teacher surveys completed at the end of each unit, showed a progressive and positive response to student writing. Modeling writing strategies in class, gave insight into student struggles and responses, or lack of response for some topics. Several activities seemed to provide students with enlightening moments to connect activities to

terms and the main concept. Inquiry Report assessments during the treatment phases, encouraged recognition and use of science vocabulary based on observations of an actual moving object. The first was custom designed with a fill in the blank conclusion followed by an open-ended summary to practice technical writing progression. The second assignment allowed more individual creativity, but required accurate application of terms to confirm student understanding of how a tool worked. Word banks proved valuable resources for students to organize their thinking into understanding-based answers.

Progressive writing activities and assessment questions were used to gage the effects of using customized writing strategies, designed to differentiate physical science vocabulary, on student ability to synthesize and integrate knowledge and ideas to develop reasonable inferences regarding observations and situations. Questions were scored quantitatively based on the concept knowledge being correct, and qualitatively based on student explanation and reasoning. Qualitative scores were also based on the accurate use of appropriate vocabulary in their inferences. Figure 6 below, compares the postassessment scores as students progressed through the mechanical energy units over a two month period. Two samples of student responses with scores, from each of the cited postassessment questions shown in Figure 6, can be read in detail in Appendix K.

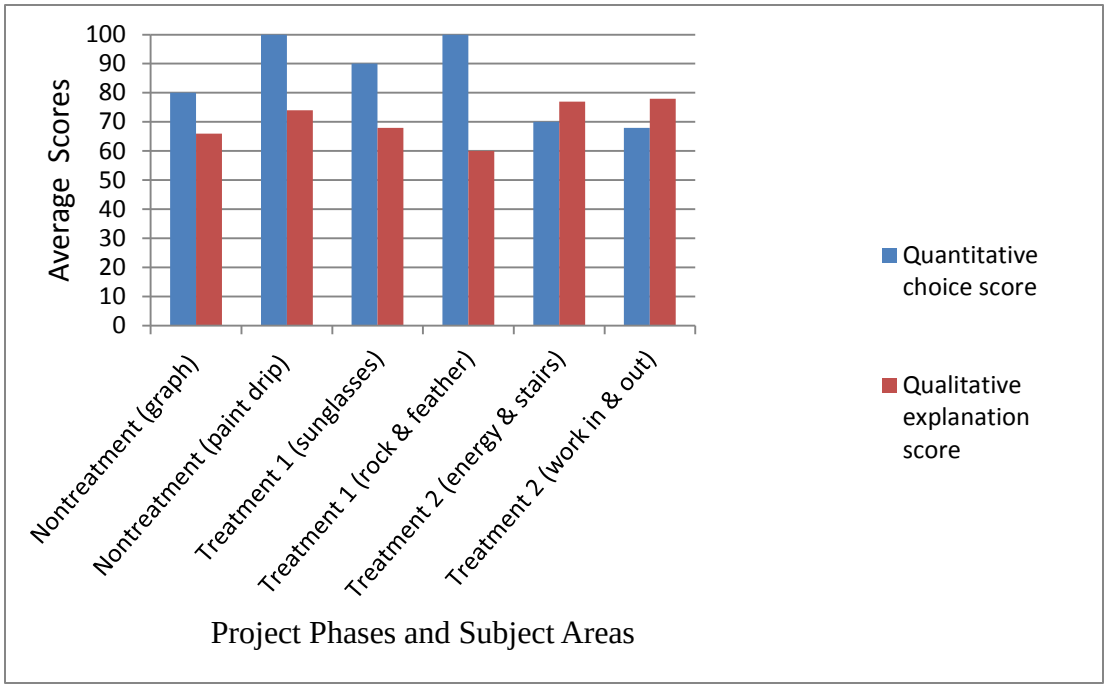


Figure 6. Comparisons of quantitative and qualitative answers on postassessments requiring inference writing with vocabulary terms, (N = 70).

Students developed more technical writing skills, such as embedding vocabulary terms into their presumptions, to more clearly distinguish between objects, the balanced and unbalanced forces on an object, and the transfer of energy between objects as work or by a conversion into another type of energy. A low-achieving student, who had maintained since pretreatment interviews that he disliked writing, did well when applying Newton's Laws and defending his choice. He said he could remember the laws by name but not by their number. "When a word bank is given, I can use words like these [pointing to inertia, friction and acceleration], but not if I have to think of them on my own—or spell them." This student was frustrated with constructing the concept maps asked of the interviewees before and after each concept unit, saying he liked "fill in the blank better." Completing concept maps has been a portion of all science unit summative assessments during this

physical science class. Both mid-achieving interviewees also mentioned how the available word banks helped them choose which words to put into their written answers.

All six students said becoming a better 'technical writer' was important to them in their pretreatment interviews, and in every postunit interview they were asked the question. A high-achieving student said after the first treatment unit, "sometimes writing messed with how I was learning and made me think I had to learn a new way." The same student, after the second treatment clarified what being a technical writer meant to her, said,

> "Applying the specific words like effort and load or output to a specific tool part really helped me see how a science definition is more detailed than the everyday way of saying stuff. Like effort is force here, but it could be how much work or power or how hard you have to work at home. Being a technical writer is knowing *when* to use the words right."

Postunit student survey comments also indicated a progressive awareness by the students of the effects of practice writing. In regards to the "explain your thinking" writing, 46% of students had negative opinions on the nontreatment postunit survey, including "these make me over think the problem and question myself—I'd rather explain verbally." Another wrote "writing is boring, I like doing stuff like labs better." A high-achieving student wrote, "I usually understand what to do but not how to explain what I got or how I got the answer, so writing it out gets frustrating."

After the first treatment unit, which included daily practice writing in class, only 11 of the 50 students surveyed, or 22%, still disagreed that writing or explaining reasons improved their decision-making skills. After the second treatment unit, 20% maintained a negative opinion of writing about cause and effect or explaining reasons, but 80% of

students agreed or strongly agreed that writing improved their decision-making skills. A high-achieving student wrote, "Writing about cause and effect makes you really think about what is going on and why it's happening, giving you better understanding." A mid-achieving student, who has improved his grades significantly this year, wrote on his delayed survey for the second treatment, "I agree because backing up your answers makes you think about why. I can remember most of my answers because big responses have greater impact than yes or no answers so I had to really figure out why." Several low-level students also wrote agreeable and positive opinions about writing, including "explaining something, instead of just saying yes or no, burns it into [our] mind for good" and "writing helps [us] become more comfortable using the right words about the subject and gets [us] to understand it all a little more."

A notable development was the number of students who improved their response efforts by even attempting to write explanations, or by writing longer explanations than a single sentence. This observation, as a teacher, was also revealed in the formative daily writing during class time. More students chose to spend more time writing during the second treatment unit than the first treatment unit, asking for more time to finish some days. In both treatment postunit surveys, students mentioned specific writing strategies that were particularly helpful in learning concepts or in finding relationships between vocabulary terms or units of measurements.

INTERPRETATION AND CONCLUSION

The goal of this action research project was to determine the effects of using customized writing strategies, designed to differentiate physical science vocabulary, on students’ understanding of physical science concepts. Although student assessments did

not show an increase in understanding when treatments of intentional writing strategies were used, student comments in interviews and on surveys indicated specific writing tasks did help discriminate many of the vocabulary terms and formulas for them. As previously mentioned, many of the terms continued to be referenced, and calculated, as the study of mechanical energy progressed, which also enhanced student understanding evidenced in their written explanations and inquiry reports. Gains in understanding were achieved in the treatment units, which were more difficult concepts and relationships, as students became more familiar with science versions of terms and the process of writing explanations using specific focus words provided as word banks. Assessment scores indicate students misinterpret word recognition as term understanding and have difficulty composing understanding-based answers.

The effects of using customized writing strategies designed to differentiate physical science vocabulary, on students' long-term memory of physical science concepts was especially evident for mid and low-achieving learners. In delayed surveys, students overwhelmingly claimed their formative writing practices in class helped them remember concepts and apply concepts to related situations later. However, low-achieving students had difficulty defining specific words or illustrating vocabulary term relationships as a concept map. Critical thinking, using analysis and synthesis thinking skills, is developing in ninth grade level learners. As the literature suggested, word banks prompt recall and relationships to aid low-achieving learners in explain their reasoning and encourages efforts with integration of understanding and everyday life situations.

Another goal of this project was to gauge the effects of using writing strategies, designed to differentiate physical science vocabulary, on students' overall attitude and on

students' overall engagement in science class. Colleague observations confirmed lab experiences and specific writing opportunities involving manipulatives and hands-on experiences were engaging to students. Student survey also confirmed the positive attitude students felt for science activities that included measurements, observations, collecting and interpreting data, and relating mechanical energy to everyday occurrences. Although the majority of students had a negative view of writing about cause and effect of their pretreatment survey, a majority of students, on post treatment surveys, agreed that their writing experiences were influential in learning the concepts and decision-making on assessments. Student willingness to attempt or elaborate their written responses also improved as treatment units provided brief, daily, and formative writing experiences with relevant everyday life topics.

This project also attempted to determine the effects of developing customized writing strategies, designed to differentiate physical science vocabulary, on my attitude toward planning, implementing, teaching, and assessing physical science concepts. Teacher surveys and journal prompts supported critical friend observations regarding the reluctance of students to learn and apply common motion terms and formulas into evidence-based reasoning of everyday occurrences. Customizing lessons, labs, and even assessment questions resulted in a variety of opportunities to use understanding-based approaches to explaining observable situations and keep teacher-student relationships positive and learning relevant. Persistence in following the treatment plans of daily formative writing resulted in a much more positive attitude toward writing time in class, and the acknowledgement of developing writing skills of the various learning levels of students. Expectations were replaced with acceptable improvements in students using

vocabulary terms and in efforts and willingness to write explanations; ninth grade students are developing as technical writers and need to have models and practice to improve. Both customized inquiry assessments enhanced student learning by requiring written responses that developed from basic concepts, to fill in the blank statements, to summarizing cause and effect. As supported by the literature, developing open-ended questions requiring calculations and analysis of data, builds critical thinking skills in science students, but developing good questions takes creativity, review and vigilance of interpretation by a teacher. Evaluation and qualitative scoring of student written responses will need to be developed as a teaching skill for consistency. Assessment questions that ask for qualitative explanations in addition to objective or factual answer promote the development of evidence-based reasoning and communication of decisions.

A major goal of this project was to improve students' ability to synthesize and integrate knowledge and ideas when developing reasonable inferences of observations and situations. Students became more comfortable with explaining their reasoning for a chosen answer as the units progressed, which was evident by fewer questions not answered, and by more complete answers using concept vocabulary word and formulas as justification. Student surveys and interviews also indicated a student awareness of critical thinking and reasoning incorporated into their written expressions of understanding. As ninth graders, this is an emerging and developing skill that seems especially productive when formative writing efforts are practiced daily for short amounts of time with relevant topics of interest. As students see the value of becoming a better technical writer they are willing to practice writing more meaningful answers, a

sentiment exemplified by mid- and low-achieving learners in their writing efforts and their interview responses.

VALUE

As the states of our nation turn to Common Core Standards to measure public high school achievement, the focus becomes informational reading and technical writing to prepare high school graduates for college or careers. I have come to believe that building vocabulary application proficiency in ninth-grade students is synonymous with developing their intelligence for life-long learning. The ability to explain one's thinking, such as the reasoning for a cause and effect situation, is a valuable skill in the classroom and the real world. Using science terms that have specific associations or implications, or even units of measurement, helps convey unambiguous meaning and relates general concepts of science to the real natural world. Evidence-based reasoning is persuasive, defensible, and progressive.

I will need to become proactive in finding and developing classroom activities and discussions that promote the integration of knowledge, terms, and critical thinking. To become a better writer or explainer will take practice with a variety of subjects and situations, and a positive attitude to want to improve. This applies to teachers in preparation for lessons, and students doing lessons. Physical science offers many opportunities, and the chance to recognize the need to distinguish terms that are often used casually in the real world, but specifically when critically thinking about science. I will also need to be proactive in developing professionally as a writing-instructor and evaluator. Heuristic writing methods for science have progressed as the new science standards move toward more inquiry-based learning, problem-solving, and explanations.

This project has influenced a change in scope and sequence for teaching physical science to ninth graders. Incorporating purposeful and succinct writing into daily class work is productive for gaining and integrating knowledge, and developing skill and confidence in reluctant learners. Using formative writing strategies allows for modeling and practice, and substantiates learning of concepts, but this teacher needs professional development to add writing structure skills to her science content cache. Self-confidence surveys provide unit objectives and vocabulary terms, and motivate students to engage in learning accountability and concept associations; I intend to use them to introduce every unit of study. Word banks encourage effort in reasoning type responses by promoting accurate associations of related science terms, especially for cause and effect explanations.

This project was beneficial to me as a teacher because I reworked many classroom experiences and approaches in developing customized writing strategies that would appeal to disinclined writers and be useful for learning mechanical energy concepts. This improved the quality of my teaching and serves the current professional development for integrating writing skills across all academic subjects for life-long learning and applications. My strengths of content knowledge and enthusiasm for science battled with my impatience for students who don't seem willing to put effort into learning. I believe our school needs a more conceptual approach to the physical sciences for some reluctant learners, and more evidence-based reasoning approach for college-prep students. The understanding of mechanical energy concepts is fundamental and essential to everyday life, so finding relevant connections and activities for students to experience and recognize was engaging for me as well as my students. Working

particularly with the interviewees gave great perspective to the process of student learning, and achievement levels, throughout a unit of study. Each level of learners struggled and excelled with different aspects, and as an effective teacher my goal is to promote positive and productive learning experiences for all.

This capstone project provided learning opportunities for my students and for me. Technical writing is a life-long skill that develops and evolves with interest and self-motivation. Vocabulary terms and knowledge integration are factors that enhance the quality of explanations. Using science concepts to practice writing and to fortify explanations builds confidence and credibility in all students.

REFERENCES CITED

Angelo, T., & Cross, K. (1993). *Classroom assessment techniques*. San Francisco, CA, Jossey Bass.

Baker, W.P., Barstack, R., Clark, D., Hull, E., Goodman, B., Kook, J., et al. (2008). Writing-to-learn in the inquiry-science classroom: Effective strategies from middle school science and writing teachers, *Clearing house: A journal of educational strategies, issues and idea*, *81*(3), 105-108.

BouJaoude, S. & Tamim, R. (2008). Middle school students' perceptions of the instructional value of analogies, summaries and answering questions in life science, *Science Educator*, *17*(1), 72-78.

Braaten, M. & Windschitl, M. (2011). Working toward a stronger conceptualization of scientific explanation for science education, *Science Education*, *95*(4), 639-669.

Bransford, J.D. & Schwartz, D.L. (1999). Rethinking transfer: A simple proposal with multiple implications, *Review of Research in Education*, *24*(6), 1-100. Retrieved as an online version http://rre.sagepub.com/content/24/1/61

Brown, N., Furtak, E., Timms, M., Nagashima, S., & Wilson, M. (2010). The evidence-based reasoning framework: Assessing scientific reasoning, *Educational Assessment*, *15*, 123–141.

Bulman, L. (1985). *Teaching language and study skills in secondary science,* London, Heinemann Educational Books Ltd.

Cavagnetto, A., Hand, B., & Norton-Maier, L. (2010). The nature of elementary student science discourse in the context of the science writing heuristic approach, *International Journal of Science Education*: *32*(4), 427-449.

Driver, R., Squires, A., Rushworth, P., & Wood-Robinson, V. (1994). *Making sense of secondary science—research into children's ideas*, London, Routledge.

Gerard, L.F., Spitulnik, M., & Linn, M.C. (2010). Teacher use of evidence to customize inquiry science instruction, *Journal of Research in Science Teaching*, *47*, 1037-63.

Gregson, R. (2005). Improving student writing in science: a help or hindrance, Retrieved Feb 11, 2012 from http://www.aare.edu.au/05pap/gre05212.pdf

Hamilton School District #3 (2012). Retrieved from www.hsd3.org/HighSchool/

Hand, B., Prain, V., & Wallace, C. (2002). Influences of writing tasks on students' answers to recall and higher-level test questions, *Research in Science Education, 32,* 19-34.

Hellden, G. & Solomon, J. (2004). The persistence of personal and social themes in context: long- and short-term studies of students' scientific ideas, *Science Education*, *88*(6), 885-900.

Hestenes, D., Wells, M, & Swackhamer, G. (1992). Force concept inventory, *The Physics Teacher, 30, 141-158.*

Hullemen, C., & Harackiewicz, J. (2009). Promoting interest and performance in high school science classes, *Science*, *326*(5958), 1410-1412.

Keeley, P., Eberle, F. & Farrin, L. (2005). Formative assessment probes: Uncovering student ideas in science, *Science Scope*, *1,* 18-21, January 2005.

Keys, C. (1994). The development of scientific reasoning skills in conjunction with collaborative writing assignments: An interpretive study of six ninth-grade students, *Journal of Research in Science Teaching*, *31*(9), 1003-1022.

Koestler, A. & Smithies, J.R. (1958). *Beyond reductionism*, London, Hutchinson.

Linn, M.C., Lee, H.S., Tinker, R., Husic, F., & Chiu, J.L. (2006). Teaching and assessing knowledge integration in science, *Science, 313,* 1049-1050.

McDermott, L.C., Shaffer, P., Rosenquist M., & Physics Education Group (1996). *Physics by inquiry*, John Wiley & Sons, Inc.

Mills, G. E. (2011). *Action research: A guide for the teacher researcher*, Boston, Pearson.

Montana K-12 science content standards framework, (2010). Montana office of public instruction, accreditation division, Helena, MT. Page 9. Retrieved October 13, 2012, from http://opi.mt.gov/pdf/Standards/10ContStds-Science.pdf

Mualem, R. & Eylon, B.S. (2010). Using a qualitative strategy for successful problem-solving, *Journal of Research in Science Teaching*, *47*(9), 1094-1115.

Nordine, J., Krajcik, J., & Fortus, D. (2011). Transforming energy instruction in middle school to support integrated understanding and future learning, *Science Education*, *95*(4), 670-699.

Novak, J. D. (1989). Helping students learn how to learn: A view from a teacher-researcher, modified from a paper presented to the Third Congress on Research and Teaching of Science and Mathematics, September 10, 1989, retrieved October 13, 2012 from http://ppp.unipv.it/PagesIt/StoriaScienza/PDF/Novak.pdf

Novak, J. D., & Cañas, A.J. (2008). The theory underlying concept maps and how to construct and use them, Florida Institute for Human and Machine Cognition, Retrieved October 13, 2012, from http://cmap.ihmc.us/Publications/ResearchPapers/TheoryUnderlyingConceptMap

Ogilvie, C.A. (2009). Changes in students' problem-solving strategies in a course that includes context-rich, multifaceted problems, *Physical Review Special Topics-Physics Education Research, 5*(2), 020102-1-020102-15.

Seah, L.H., Clarke, D.J., & Hart, C.E. (2011). Understanding students' language use about expansion through analyzing their lexicon-grammatical resources, *Science Education*, *95*(5), 852-876.

Seimears, C.M., Graves, E., Schroyer, M.G., Staver, J. (2012). How constructivist-based teaching influences students learning science, *The Educational Forum, 76*(2), 265-271.

Smith, C. L., Wiser, M., Anderson, C., & Krajci, J. (2006). Implications of research on children's learning for standards and assessment: A proposed learning progression for matter and the atomic-molecular theory, *Measurement: Interdisciplinary Research and Perspectives*, *4*(1-2), 1-98.

Solomon, J. (1983). Messy, contradictory and obstinately persistent: a study of children's out-of-school ideas about energy, *The School Science Review, 65*(231), 225-229.

Wandersee, J.H. (1992). The historicality of cognition: Implications for science education research, *Journal of Research in Science Teaching*, *29* (4), 423-434.

Young, E. (2005). The language of science, the language of students: Bridging the gap with engaged learning vocabulary strategies, *Science Activities: Classroom Projects and Curriculum Ideas*, *42*(2), 12.

APPENDICES

APPENDIX A

PROJECT TIMELINE

Appendix A

PROJECT TIMELINE

Hamilton High School is on an A-B schedule of four 90-minute classes each day.

December 20th: Explanation to students of upcoming ME unit with AR project activities
Pretreatment general student survey
Pretreatment interviews with 2 high, 2-3 medium, 2-3 low level students]

January 2nd: Pretreatment teacher survey + journaling habit established
Finish pretreatment student interviews, do preunit student interviews
Preassessment for nontreatment motion & forces unit study
Self-confidence CAT for motion & forces concept, with objectives & terms
Strides lab to introduce motion, distance, time, speed and review graphing

January 4th: Dripping ice cream cone formative assessment probe class activity
Speed, velocity, and acceleration story problems and graphing
Teacher reflections journal

January 8th: Dripping ice cream cone formative assessment probe class activity
Speed, velocity, and acceleration story problems and graphing
Teacher reflections journal

January 10th: Intro/review Forces and drawing force diagrams of balanced and unbalanced forces: banana on desk, cork & candle in oil & water, rock.
Forces lab with embedded writing exercises focusing on vocabulary terms.

January 14th: Acceleration of a car lab w/ graphing and inferences of speed changes
Observation of Lab situation w/embedded writing by colleague (nontr.2)
Teacher reflections journal

January 18: Postconcept assessment & survey of motion & forces (nontreatment).
Postconcept student interviews (2 high, 2 medium, 2 low)
Postconcept teacher survey

January 22nd: *(semester testing)* Interviewing, data processing;
January 25th: (semester testing) Teacher reflections, Pretreatment Teacher Survey

January 28th: Post concept interviews finished for Motion & Force, +preconcpt Intv.
Preassessment of Newton's Laws of Motion Concepts
Self-confidence CAT about Newton's Law of Motion (w/ vocab. terms)
Treatment: demo for 1st Law of inertia: sentence summary, sketch, reasons.

January 30th: Intro/review Newton's Laws (3) using ball drop, target answer & reasoning
Treatment: Concept mapping to integrate concepts & terms …or…
Inertia VS F= ma VS p = m*v* story problems (derived units & applications)

February 1st : Delayed assessment of motion and forces concepts
Delayed concept student surveys and interviews
Treatment: given answers, write story problems to 'fit'; unit analysis
Lab activity with Newton's 1st and 2nd LAWs (air in the water bottle)

PROJECT TIMELINE continued

February 5th : Finish lab activities for each of 3 Laws of Motion (N' cradles)
Treatment: watermelon+sandwich video (2nd Law; gravity/air-resistance/free-fall)
Observations by colleague (treatment option 1) 3rd Law period B-4

February 11th: Postassessment for Newton's Laws of Motion Concept, post interviews
Post concept student survey, post treatment Teacher Survey
Preconcept interview w/ concept mapping, pretreatment Teacher survey

February 13th : Preassessment for work & power concept, + preconcept interviews
Treatment: decide if 'work' is being done in 5 different pictures
Work Lab to review mass, weight, force and introduce work and power

February 15th: **Treatment:** Sci vocab vs common use: energy, work, power, MA, weight
work and power story problems and analogies, concept mapping
Colleague observations (treatment option2)
Teacher reflections journal,

February 19th: **Treatment:** Story problem analysis (given answers, write a problem/scenario)
Simple machines and Mechanical Advantage (pliers, screwdriver, wedge)
Teacher reflections journal
February 21st -22nd: (basketball tournaments—ltd. School, interruptions)

February 25th: **Treatment:** analyze the flip-top & screw-on lids
Lever Lab focus on effort, load, Fd= fD, colleague observations
Teacher reflections journal

February 27th: **Treatment:** tool and vocabulary associations: Intro Tool Story IR
Pulley Lab (moveable, fixed support lines)

March 1st: **Treatment:** Delayed concept assessment (written response!),
Delayed student survey & interviews for Newton's Laws of Motion
Wheel and axle, block and tackle, stairs….adjustments in everyday life.
Incline plane and wedge applications to make work easier

March 4-8th: Postassessment of work and power concepts, postconcept survey
Postconcept interviews, delayed concept interviews caught up
Teacher Posttreatment survey and reflections journal

March 11th: Delayed assessment, student survey and interviews for work & power

March 13th: (1/2 day): finish assessments and surveys (get same 70!!)(get IR from 70)

March 20th: Delay assessment and survey for work, power and simple machines
(18-22nd) Delay interviews for work and power unit, Teacher postsurveys

APPENDIX B

SELF-CONFIDENCE IN CONCEPT APPRAISALS WITH OBJECTIVES AND VOCABULARY TERMS

Appendix B

Name _____ period ____-_____ DATE:

Additionally, this survey is to help both of us understand your level of confidence and attitude about **Motion** and **Forces**. Please indicate how confident you feel about your ability to respond to the activities listed below. (Circle the most accurate response for each.)

Physical Science Activity	***Self-Confidence in Your Ability to do This.***			
1) Recognize when an object is in **motion**.	None	Low	Medium	High
2) Distinguish between the terms **distance**, **speed**, **velocity**, and **acceleration**, by definition and by metric units of measurement.	None	Low	Medium	High
3) Apply s = $\frac{d}{t}$ to calculate speed in meters/second.	None	Low	Medium	High
4) Apply a = $\frac{\Delta v}{t}$ to calculate **acceleration**, in metric units of *m/s/s* or m/s^2.	None	Low	Medium	High
5) Draw arrows on a diagram to distinguish **unbalanced** and **balanced forces** on an object.	None	Low	Medium	High
6) Apply F **=** ***mg*** to recognize how **gravity** affect the weight of a mass or object.	None	Low	Medium	High
7) Use a force diagram to explain buoyancy.	None	Low	Medium	High
8) Distinguish between the terms and units of **mass**, **weight, inertia, force,** and **momentum**.	None	Low	Medium	High
9) Recognize that all moving objects have **momentum**.	None	Low	Medium	High
10) Apply $p = mv$ to calculate and compare momentum of objects in kg-m/sec.	None	Low	Medium	High

Please *briefly* explain your high and medium confidence ratings.
When and how did you reach this level of awareness and ability?

Name _____ period ____-_____ Date:

This survey is to help both of us understand your level of self-confidence and attitude in understanding **Newton's Laws of Motion.** Please indicate how confident you feel about your ability to respond to the activities listed below. (Circle the most accurate response)

Physical Science Activity	***Self-Confidence in Your Ability to do This.***			
1) Distinguish between the terms and units of **mass**, **weight, inertia, force, momentum, gravity,** and **acceleration**.	None	Low	Medium	High
2) State **Newton's Laws of Motion** (3).	None	Low	Medium	High
3) Apply Newton's **1st Law** of Motion to an every-day motion situation.	None	Low	Medium	High
4) Apply Newton's **2nd Law** of Motion to an every-day motion situation.	None	Low	Medium	High
5) Apply Newton's **3rd Law** of Motion to an every-day motion situation.	None	Low	Medium	High
6) Apply F **=** ***ma*** to recognize how forces *affect* or change the motion of an object.	None	Low	Medium	High
7) Predict the affects and effects of **gravity** on moving and **free-falling objects**.	None	Low	Medium	High
8) Predict the influences of **friction** on a stationary, moving, or falling object.	None	Low	Medium	High
9) Recognize forces come in pairs, often distinguished as **action** and **reaction forces**.	None	Low	Medium	High
10) Apply the **Law of Conservation of Energy**, and momentum, to the collision of 2 or more objects.	None	Low	Medium	High

Please *briefly* explain your high and medium confidence ratings.
When and how did you reach this level of awareness and ability?

Name _____ period ___-_____ Date:

This survey is to help both of us understand your level of self-confidence and attitude in understanding **Work and Power.** Please indicate how confident you feel about your ability to respond to the activities listed below. Circle the most accurate response for each.

Physical Science Activity ***Self-Confidence in Your Ability to do This.***

1) **Diagram** the **forces** on an object.	None	Low	Medium	High
2) Distinguish between the terms **force**, **effort, load**, **work, power,** and **energy.**	None	Low	Medium	High
3) Apply W = ***Fd*** to calculate work.	None	Low	Medium	High
4) Apply P = $\frac{mgd}{t}$ to calculate power.	None	Low	Medium	High
5) Distinguish between the two families of **Simple Machines.**	None	Low	Medium	High
6) Apply **mechanical advantage** to explain how machines make doing work *easier.*	None	Low	Medium	High
7) Recognize the effects of **friction** and resultant **efficiency** when *doing* work.	None	Low	Medium	High
8) Diagram the forces involved in using a simple machine to move an object.	None	Low	Medium	High
9) Distinguish between the types of **mechanical energy (potential, kinetic, sound, heat).**	None	Low	Medium	High
10) Explain the relationship between energy and work, and the **Law of Conservation of Energy.**	None	Low	Medium	High

Please *briefly* explain your high and medium confidence ratings.
When and how did you reach this level of awareness and ability?

APPENDIX C

SAMPLE NONTREATMENT AND TREATMENT LESSONS

Appendix C

STRIDES LAB QUESTIONS and APPLICATIONS

1) Why did we run three trials, and then *average***?**

2a) Define speed:

b) Write the formula for speed:

c) What are the units for speed for *this* lab?

d) Predict which stride will result in the *fastest speed***:**

3) Calculate ***average* SPEED** for each trial:

Variable	**average SHORT stride**	**average REGULAR stride**	**average LONG stride**
5 seconds			
5 meters			

4a) *Which* stride did you FEEL you performed with the most ACCURACY? _____

b) *How* did you control your walk to increase accuracy? _____

5) Which stride would best cover **32 meters in 20 second?** _____
HOW did you decide this**?** *(HINT: what speed is needed? Use math **or** use your graph! EXPLAIN!)*

6) Which stride would best cover **150 meters in 1½ *minutes*?** _____
HOW did you decide this**?**

7) How FAR (distance!) can you travel in **30 seconds** with **short** stride**: _____**
EXPLAIN how you decided.

….. with **regular** stride**: _____**

…. with **long** stride**: _____**

8) **How *long*** would it take **(TIME!)** to go **50 meters** using a **short** stride: _____***minutes!***
HOW did you decide?

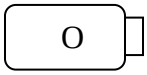
… using a **regular** stride: _____ _____

….using a **long** stride: _____ _____

9) Write a *one-sentence summary* to compare and contrast **"strides"** and "**speed"**

ACCELERATION of a BUBBLE of AIR in a JAR of WATER

PURPOSE: Use the Laws of Motion to observe, predict & explain an object's acceleration.

DATA! MOTION description	YOU in a car (memory of experience)	*PREDICTED* bubble motion	*ACTUAL* bubble motion	INFERENCES! *Explanation* of *observations*
1) starts moving forward				
2) speeds up quickly				
3) speeds up slowly				
4) slows down				
5) constant speed				
6) tilt upward				
7) tilt downward				
8) turning to left				
9) counterclockwise spin				
10) coming to stop				
11) NO motion				

INQUIRY REPORT RUBRIC

Applying Newton's Laws of Motion to observation of an air bubble in a moving jar of water.

Focus Question Outcome	**Advanced (4)** Experienced	**Proficient (3)** Competent	**Nearly Proficient (2)** Transitional	**Novice (1)** Needs Improvements
Identify target concept	Laws of Motion, mass, inertia, F = ma, action & reaction forces	Force & Acceleration cause & effects	Person in car VS air in water	ΔMotion from push
Apply vocabulary terms	Correctly uses & applies 90% unit vocabulary terms	Correctly applied 80% vocabulary terms	Uses at least 60% wordbank terms, usually correctly	Missing basic terms ("*it, stuff, thing"*)
Distinguish cause & effect (HOTS: infer)	Evidence and concept knowledge to support observations & situation	Explain observations with concept knowledge	With help, relates observations and concept knowledge	State observations & concept knowledge, if/ when prompted
Apply analogy, summary, or application (HOTS: relate)	Relate science topic to everyday life situation.	Compares science observations to real-life	Uses real-life situations to explain science topic	Offers a related real-life situation or experience.
Apply rule or law (HOTS: evaluate)	Forces cause acceleration, less mass, quicker react	Variables, terms and proportions applied	State the Laws of Motion & Laws of Conservation	Can describe the basic laws when prompted
Technical writing quality	Clear and coherent, evidence supports claims, appropriate organization & style	Edited for clarity & organization, observations supported	Organized and edited, situations connect to science concepts in writing	Attempted to explain action using science terms and concepts
Attitude and Engagement	Progressive in inquiry & knowledge acquisition	Enlightened by process of inquiry & explanation	Willing to write on a given science topic, given wordbanks	Unwilling to write about science & happenings

VOCABULARY *mass, inertia, direction, speed, velocity, acceleration, balanced & unbalanced forces, buoyancy, weight due to gravity, static-, sliding-, fluid-, rolling-friction, momentum, conservation, conversion, transfer, Newton's 1st, 2nd ,3rd Laws of Motion..*

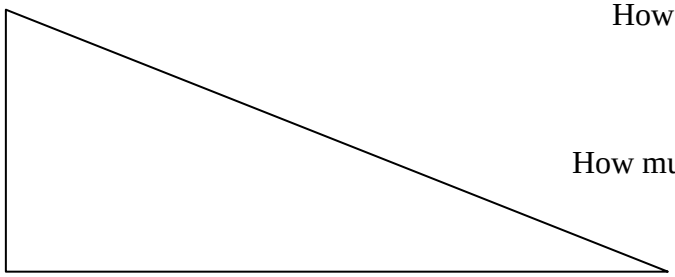
Name_____ PERIOD ___-___ DATE:
WORK!ing with Simple Machines LAB activity

PURPOSE: To *distinguish* between __(*mass)*_____, ___(*weight = load)*_____, __(*effort force)*__ , & ____*(energy)*___ using **incline planes** to make __(*work)*__'easier', by increasing __(*distance)*__ and decreasing ___(*effort-force*)__to do the **same _(***work)***_.**

CLASS DEMO:

MASS	LOAD	EFFORT *expected*	EFFORT *actual*	height	length	MA	Work IN	Work OUT

How much is the 'pull of gravity'? _____



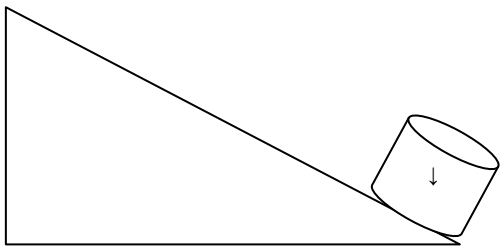
How much is the *resisting push* of friction?

MASS	LOAD	EFFORT	*FRICTION*	height	length distance	MA	Work IN	Work OUT
setup1		*ideal* *actual*						
Setup 2		*ideal* *actual*						

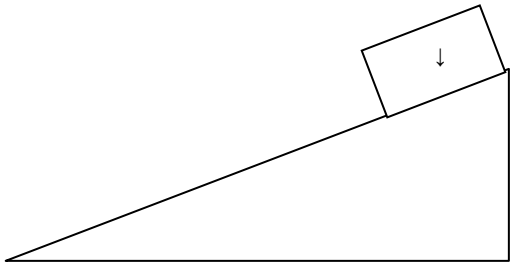
What is the **efficiency** of this set-up? _____%

YOUR LAB-group's SET-UP and 'explanation':

SETUP #1



SETUP #2



Name_____ period___-____ DATE:

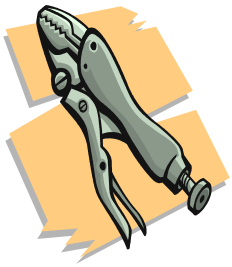
FILL in the BLANK: use the terms below to best complete each sentence. Obviously, the terms can be used more than once or not at all.

distance force work power mechanical advantage

joule newton watt time efficiency friction

1) Power is the amount of _____ per unit of time and can be calculated by multiplying _____ and _____ and dividing by _____.
2) The unit of power is equal to one _____ per second and is called a _____.
3) A push or pull is called a _____ and an *example* is _____.
4) A 600-watt machine can do more _____ in the same amount of time than a 300-watt machine can.
5) "Effort" is a measure of _____ and has a **SI unit** of _____.
6) The 'transfer of mechanical energy' is called _____ and has the same units as energy in general, which is the _____.
7) Mechanical Advantage is a measure of more or less _____.
8) Efficiency is calculated by dividing the _____ needed or produced from a machine by the _____ put into the machine or exerted using the machine.
9) Efficiency can be improved by decreasing the _____ involved in doing work
10) An Incline Plane will always lessen _____ and increase _____ to do the same work without the machine.
11) A pulley will always lessen _____ and increase _____ to do the same work without the machine.
12) The Mechanical Advantage of a 3rd class lever is *less than one*, so the _____ **applied** is always more than the load, and the _____ is always less.

IDENTIFY at least one simple machine in each of the pictures below. Use arrows! *Be specific!*



APPENDIX D

WRITING STRATEGIES, TOPICS, AND FOCUS IDEAS FOR TREATMENT INTERVENTIONS

Appendix D

WRITING STRATEGY TOPICS and FOCUS IDEAS

NEWTON's LAWS of MOTION:

1. Build a concept map with the concept vocabulary. After 5 minutes, work cooperatively.
2. Use the Newton's 1st Law of Motion to explain a situation. Attempt an analogy.
3. Use Newton's 2nd Law of Motion to predict & infer a situation's cause & effect
4. Use Newton's 3rd Law and momentum to describe and explain an action picture.
5. Summarize a video clip of a sandwich and a watermelon falling from a hot air balloon.
6. Write a story problem with an answer of F = 100 Newtons. [or a = 66.0 m/s^2]

WORK and POWER:

1. Given pictures of situations, decide if "work" is being done and then write an operational definition for the physical science term *work* as it relates to force, distance and energy.
2. Given pictures of situations, decide if "power" is being generated, and then write an operational definition for the physical science term *power* as it relates to work & energy.
3. Make a list of specific Mechanical Energy words or phrases "misused" in common day occurrences. Rewrite 2 sentences offered by you or a classmate "correctly."
4. Use an incline plane situation to distinguish effort, load, work input, work output and mechanical advantage. Diagram and label with vocabulary terms.
5. Apply "what does what to what, when, where, how and why" to a flip-cap. Analyze as a compound machine to distinguish effort, load, work, affects of friction, advantage of cap.
6. Build a concept map with the unit wordbank. Work cooperatively. If time, present to class and relate with an everyday life application or example.
7. Write a story problem with the answers mass =50 g, distance= 5 meters and *friction* force = 25 Newtons. Diagram the set-up. (cooperative learning?)

APPENDIX E

PRETREATMENT, PREUNIT CONCEPT, POSTUNIT CONCEPT AND DELAYED CONCEPT STUDENT INTERVIEW GUIDELINES AND QUESTIONS

Appendix E

PRETREATMENT INTERVIEW GUIDELINES

from 3 P.Sci classes

2H 2M 2L

STATEMENT: *I appreciate you being here, your efforts and honesty. Please remember, participation is voluntary, anonymous and will not affect a student's grade or class standing in any way. You may choose to answer all, some, or none of the questions. We can stop anytime.*

1) Describe the [situation, diagram, set-up, picture] you see before you in terms of matter, forces and energy. You might also think of these as objects, causes, affects, actions, changes, results, or effects. Here is a list of these words in case you want to refer to them.
Please think out loud as you decide on your reasoning.

MATTER	FORCE	ENERGY
objects	mass	weight
causes	affect	actions
changes	results	effects

2) How do you feel about "science" this year at Hamilton High School?
Please be open and honest, as I need your feedback for my research data☺!

PROMPTS: Do you find science interesting? **Engaging?** Are you happy to come to class?
Challenging? Overwhelming? What part is most difficult?
We are about to study Mechanical Energy, any thoughts about that?
Has this year in our science class, so far, influenced your attitude about science as a subject?
Do you like the probes & 'explain your thinking' we do? Do you mind that these aren't graded?
Do you have your own calculator? How is "the math" & calculations in the class going, for you?

3) Is becoming a better 'technical' writer (explanations versus story-telling) important to you? Why, or why not?

PROMPT: Do you try to use new, more specific or appropriate vocabulary in your writing?
What is your attitude toward about 'practicing writing' in a science-class?
Most of the vocabulary terms were introduced in middle school or elementary science, according to the state of Montana benchmarks; are you finding this to be true? Any *new* terms?

4) Is there a "best method" -- *for you*-- of getting feedback, assistance, help, or corrections? Please explain:

5) Is there anything else you'd like me to know?
Are there other questions you think I should ask? If so, please ask and answer them!

PREUNIT CONCEPT STUDENT INTERVIEW GUIDELINES

2H 2M 2L

STATEMENT: *I appreciate you being here, your efforts and honesty. Please remember, participation is voluntary, anonymous, and will not affect a student's grade or class standing in any way. You may choose to answer all, some, or none of the questions. We can stop anytime.*

1) Please build your own version of a concept map using all 13 words on the sticky notes. Feel free to add any more words you need to show the relationship of these words to each other. Please verbalize your thinking as you work.

motion
distance
time
speed
velocity
acceleration
turning
faster & faster
slower & slower
meters/second
$\frac{meters/second}{second}$
distance VS time graph
speed VS time graph

Where would you put "FORCE"? Explain why.
Where would you put "MASS"? Explain why.
Where would you put "ENERGY"? Explain why.
Where would you put "FRICTION"? Explain why.

Newton's Laws of Motion
1st Law
2nd Law
3rd Law
Force(s)
balanced
unbalanced
Action-reaction
gravity
friction
no change
acceleration
momentum

Where would you put 'free-fall of an object?" (from an airplane to the Earth)? Explain why.
Would your placement be different if the object was attached to a parachute? Explain why.

Mechanical Energy
Potential Energy
Kinetic Energy
Work
Sound
'Heat' Energy
Power
Force
Position or height
distance
velocity
transfer
conversion
conservation

Where do you put an object or "mass" into this concept map? Explain why.
Would you put friction into this concept map?
If so, where and why? If not, why not.

2) Does this unit of study sound interesting and useful to you? Why or why not?
3) Are you curious about any vocabulary terms or objectives in particular?
4) What motivates you to learn? Do you like doing lab, story problems, taking notes?
5) How does my attitude and teaching style influence your attitude about science?
6) Is there *anything else* you'd like me to know?
Are there other questions you think I should ask? If so, please ask and answer them!

POSTUNIT CONCEPT STUDENT INTERVIEW GUIDELINES

2H 2M 2L

STATEMENT: *I appreciate you being here, your efforts and honesty. Please remember, participation is voluntary, anonymous, and will not affect a student's grade or class standing in any way. You may choose to answer all, some, or none of the questions. We can stop anytime.*

1a) Concept mapping: Using the vocabulary words on the sticky notes (same as preunit concept interview) show the uses and relationships of these words to Mechanical Energy.
b) After reviewing the vocabulary terms and your concept map, describe your *current level of understanding*:

1 2 3 4 5

with 1 being not very sure of most of these as science terms,
3 being a decent understanding of how to apply these terms to objects in motion,
5 being an understanding of these terms well enough to teach/explain to others.

2) Did you find that this unit of study kept you *engaged*? Was it the activities or the content? What parts were more engaging, and which parts were less? What about them kept you engaged or made you less interested? How might these science concepts (or parts) be *useful* to you later in your every-day life?

3. Did you find a relationship to the initial probe you answered about _____and this unit? Have you learned anything in this unit that provides more evidence to your reasoning or evidence to *adjust your original way of thinking*? Which experiences gave you this evidence?
Would you like to adjust your initial explanation on that probe? (offer paper) If so, explain how?

4. NONTREATMENT: 60% of your grade in this class is based on lab work and write-ups. How do you feel about that? Would you rather do measurement & calculation labs or take notes with class discussions and demos? Have you/do you use your textbook? If so, how? How do you feel about formative assessments where students offer what they know or don't know, but there is no grade for that effort? Do you feel your responses are worthwhile in adjusting the lessons or discussions for more learning? Did the probes make you think or more curious?

4a. TREATMENT: How do you feel about these written-response reality checks at the beginning of each class? (*offer journal*) Why or why not? How do you feel about formative assessments where students offer what they know or don't know, but there is no grade for that effort? Do you feel your responses are worthwhile in adjusting the lessons or discussions for more learning? Did the probes make you think or curious?

4b. Do you feel your science explanations and writing has *improved* during this unit with the emphasis on vocabulary and (the writing strategies) we have been doing in this class? If so, how? If not, why not? Is becoming a better 'technical' writer important to you? Why or why not? What is the best method, *for you*, of getting feedback or help?

5. Is there anything else you'd like me to know? Are there other questions you think I should ask? If so, please ask and answer them.

DELAYED CONCEPTS INTERVIEW GUIDELINES

2H 2M 2L

STATEMENT: *I appreciate you being here, your efforts and honesty. Please remember, participation is voluntary, anonymous, and will not affect a student's grade or class standing in any way. You may choose to answer all, some, or none of the questions. We can stop anytime.*

1a) On a recent Motion and Forces Concept Test, a student described the following set-up:





The yellow car is going faster than the blue car and the green car, because it is ahead of them, and the background is blurry.

Do you agree with this student's thinking**?** **YES. MOSTLY YES. MOSTLY NOT. NO.**
Explain WHY:

If the yellow car & green cars are both going a constant 40 MPH, and the blue car is speeding up at 20 MPH/sec, can you describe how the cars will be positioned in 3 seconds**?** Why?

Please draw the force diagram for the accelerating blue car here:
Explain each arrow (size, direction, & width as you draw):



1b) On a recent Newton's Law Concept Test, a student answered as follows:

Newton's 2nd Law of Motion and *F= ma* means the Earth's gravity pulls on a bowling ball with about 10 Newtons for every kilogram of mass. But a bowling ball and an apple (with less mass) both accelerate the same during free-fall toward the Earth, because of the pull of gravity, at about 10 meters/second faster every second. (offer picture of apple and bowling ball falling down through air toward Earth).

Do you agree with this student's thinking**?** **YES. MOSTLY YES. MOSTLY NOT. NO.**
Explain WHY:

If both an apple and a bowling ball are dropped from the roof of the Hamilton High School building at the same time, which will hit the ground first**?**
Why?

1c) On a recent Work & Power Concept Test, a student answered as follows:

Because a screwdriver cannot *output* more work than the human effort put into it, there is no advantage to using that simple machine. It is useless! Use a power tool, instead. (have 3+ different screwdrivers)

Do you agree with this student's thinking? **YES. MOSTLY YES. MOSTLY NOT. NO.**

Explain why, including how a screwdriver "works".

OR Give this student an example of a screwdriver that *is* "useful"**?**

APPENDIX F

PRE and POSTTREATMENT, POSTUNIT AND DELAYED CONCEPT STUDENT SURVEYS

Appendix F

PRETREATMENT STUDENT SURVEY

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

1. How do you feel about "science" this year at Hamilton High School?

Please be open and honest, as I need your feedback for my research data☺!
CONSIDER: Do you find science interesting? Engaging? Challenging?
Are you happy to come to class? What part of class work is the most difficult for you?
Has this year, in our science class so far, influenced your attitude about science as a subject?

The Mechanical Energy unit of study will involve the following physical science terms:

distance*	speed*	time*
direction	velocity*	d/t graphs
acceleration*	reference	*v*/t graphs
mass*	weight*	force*

mass* weight* inertia* gravity*
friction* acceleration* momentum*
unbalanced force* kinetic energy*
action force reaction force free-fall

*F= ma *work= W= Fd = m*g*h
*power = P = $\frac{W}{t}$ vector, direction
conversion, transfer, conservation
mechanical, potential, kinetic*

2a. Review the vocabulary terms above, then describe your *current level of understanding*:

1 2 3 4 5

with **1** being not very sure of most of these as science terms,
3 being a decent understanding of how to apply these terms to objects in motion,
5 being an understanding of these terms well enough to teach/explain to others.

b. Briefly explain why *you* chose that number**:**

3. The terms marked with (*****), indicate measurements with units (meter/sec, Newtons, watts).
Describe your *attitude* about "doing the math" for this unit and in physical science in general.

1) its too difficult & frustrating: I can't do the set-ups or math.	**2)** do-able with class and tutorial help during Studyhall	**3)** do-able with class instruction & occasional help	**4)** too easy and simple, even boring at times.

1 2 3 4 5

Briefly explain why *you* chose that number**:**

4. MECHANICAL ENERGY is obviously some "thing" we experience and observe in the natural world. How *motivated are/were you* to discuss and write explanations of everyday observations using the above physical science vocabulary terms instead of just calculating?

1) interested & willing 2) willing & able 3) capable 4) not interested & not willing

Briefly explain why *you* chose that number**:**

5. HOW do YOU *remember* learned knowledge best? (EX: metric units, math formulas, terms)

1) by taking notes from the board or power point and doing textbook problems. (little action, note-taking & calculations, no hands-on-lab)

2) by doing class worksheets as notes from teacher-demos and video clips. (observing action, class discussions & written explanations, minimum hands-on)

3) by doing class worksheets as notes, and lab activities with worksheet data & analysis. (some observing, maximum hands on, inferring & explaining as written responses)

6. With this Mechanical Energy unit, will ***YOU*** be

☐ gaining new and additional knowledge,

☐ reviewing knowledge previously taught and learned,

☐ adjusting with more accurate knowledge**?**

Please, briefly explain:

POSTTREATMENT QUESTIONS:

2b. List 2-3 words from the units above that you are still unsure about after our Mechanical Energy Units. **Explain your confusion about at least one of these words.**

5. Did you learn more through these Mechanical Energy Units by

☐ doing formula and math 'story problems' about force, speed, work. Mechanical Advantage, acceleration, power, efficiency, etc.

☐ writing and diagramming science situations to distinguish vocabulary meaning,

☐ doing class worksheets as notes & lab activities with worksheet data & analysis**?**

Please, briefly explain:

POSTUNIT CONCEPT STUDENT SURVEY

Please remember, *participation in this research is anonymous and voluntary and will not affect a student's grade or class standing in any way. I appreciate your honest efforts and remarks.*

Using your returned preunit self-confidence survey and learning objectives as a guideline, please answer the following questions by circling an appropriate response based on

☺1 = Strongly Agree	2 = Agree	3 = Disagree	4= Strongly Disagree☹

1) Do you feel you now *understand* the main learning objectives of this unit?

1 2 3 4

Please comment on your choice:

2) Did your *attitude* or motivation to want to learn this material increase during this unit?

1 2 3 4

Please comment on how, when, why, or why not:

3) Did the lab and writing activities encourage you to be involved or *engaged* each day in class?

1 2 3 4

Do comment on any one particular activity or situation you found useful for learning.

4) Do you feel writing about cause and effect, or *explaining reasons* for observations you make, improves your decision-making skills for lab work, discussions, quizzes, and tests?

1 2 3 4

Explain why, perhaps using an example.

5) Give *your opinion* regarding the "explain your thinking" writings we often do in class. Do these probes make you curious? Did you get more comfortable not being completely sure of an answer, but getting a chance to defend *your* choice?! Did you clarify your initial answer as we continued studying the topic?

DELAYED UNIT CONCEPT STUDENT SURVEY

Please remember, *participation in this research is anonymous and voluntary and will not affect a student's grade or class standing in any way. I appreciate your honest efforts and remarks.*

After you have finished your delayed assessment of the concept unit, please answer the following questions by circling an appropriate response based on

☺1 = Strongly Agree	2 = Agree	3 = Disagree	4= Strongly Disagree☹

1a) Do you feel you *continue to understand* the main learning objectives of this unit, even though we studied this unit more than 2 weeks ago?

1 2 3 4

b) Explain your choice:

2a) Do you think you just did as well on the delayed assessment questions, as you had done on similar questions (postunit assessment) two weeks ago?

1 2 3 4

b) Please comment on your choice:

2) Do you feel writing about cause and effect, or *explaining reasons* for observations you made, helped your retention of knowledge or long-term memory about this unit, terms, units of measurement, and formulas?

1 2 3 4

Please comment on your choice, giving an example (if possible) to explain your choice:

3) Are there other questions you think I should ask? If so, please ask and answer them!

APPENDIX G

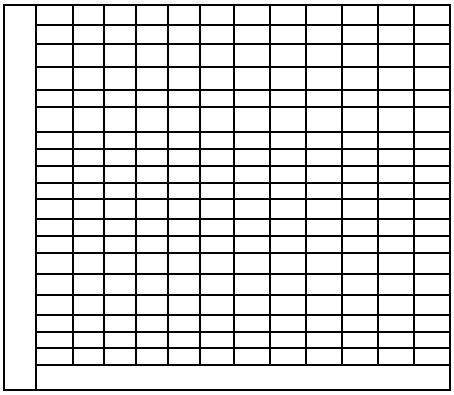
PRE AND POSTUNIT AND DELAYED CONCEPT ASSESSMENTS

MOTION & FORCES PRE- and POST-ASSESSMENT:

1. A small toy car at rest on the ground was pushed and had moved 2 meters by the 1st second. Two more meters were displaced by the 3rd second, and a total of 10 meters was traveled in 4 seconds. The toy car continued moving out to a 15 meter-mark by 6th second, but came to a stop, when the car hit a rock, 20 meters from the start after a total of 10 sec.

SUMMARIZE (in 1-3 sentences) the movement of the toy car above, in terms of speed, acceleration, and momentum during the 10 seconds (over the 20 meters).
NOTE: You *may* use the tools below, but their use does NOT affect the score of your summary.

Distance	Time	Speed	Acceleration

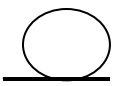


a) SUMMARY:

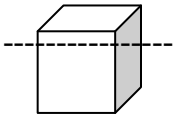
b) INFER when, *if ever*, the toy car was traveling down a hill.
Explain why, *or* why not.

2. Using the size and direction of arrows to indicate force,
draw all the forces on the following:

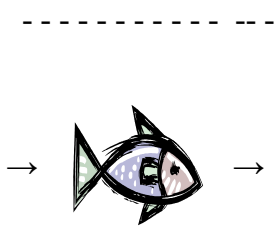
APPLE on a table



ICE CUBE in water



FISH swimming to the right IN H_2O



3. RANK in order from GREATEST *to* LEAST:

a) <u>SPEED</u>: 10 mm/hour; 100 cm/sec; 10 m/sec; 10 km/ hour

FASTEST = _____then _____ then _____& SLOWEST is _____

b) <u>ACCELERATION</u>: *(1=greatest, same number means equal)*

_____ slowing 2 m/s each second while turning

_____ + 5m/s^2

_____ - 5 m/s/s

_____ stopped

_____ constant speed of 10 m/s

c) <u>MOMENTUM</u>: *(1=greatest, same number means equal)*

_____ bullet shot from a gun

_____ sports car going 80 MPH

_____ loaded semi-truck going 40 MPH

_____ *you* coming to science class!

d) Choose <u>ONE</u> of your *above* answers and **<u>explain your reasoning</u>.**

4. Use the *evidence* of the *paint drips* BELOW to completely describe the motion of the painter with the constantly dripping paintbrush. Also, offer an explanation for the *shape* of the paint drips changing. A word bank of terms describing motion and forces is provided at the left.



<u>WORD BANK</u>

displacement distance direction
speed velocity acceleration
mass weight force
gravity friction

Name _____ Period ___-____Date:
NEWTON'S LAWS of MOTION PRE, POST, and DELAYED ASSESSMENT:

INDICATE WHICH OF NEWTON's LAWS of MOTION ***BEST EXPLAINS*** THE FOLLOWING:

1st Law of Motion **2nd Law of Motion** **3rd Law of Motion**

_____ 1. Objects at rest remain at rest.

_____ 2. Unbalanced forces cause changes in the speed or direction an object is moving.

_____ 3. A rocket launches up into space as the gas products of burning fuel exit out as exhaust. EXPLAIN your choice:

_____ 4. During the final spin cycle of a washing machine, the clean rinse water is removed from the clothes through the little holes on the inside of the machine. EXPLAIN your choice:

_____ 5. The force of gravity causes an object to fall faster and faster toward the earth.

_____ 6. When several objects collide**,** the speed, direction & mass of all the objects will influence the resulting velocity of each of the objects.

_____ 7. Sliding friction makes a moving object slow down and change direction. EXPLAIN your choice:

_____ 8. Sunglasses on the dashboard of a moving car slide to the left as the car turns right. EXPLAIN your choice:

_____ 9. A satellite can revolve continuously above and around the Earth. EXPLAIN your choice:

10. Use Newton's 2nd Law of Motion to EXPLAIN the different results when a rock and a feather are dropped, from the same height at the same time, to the surface of the Earth and to the surface of the moon.









EARTH's SURFACE

MOON's SURFACE

WORD BANK

F = ma

mass weight inertia

speed direction acceleration

gravity friction free-fall

balanced & unbalanced forces

action force reaction force

WORK & POWER CONCEPTS PRE, POST and DELAYED ASSESSMENT

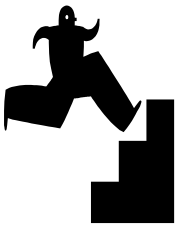
1) A weightlifter presses an 800 N weight 0.5 meters over his head in 2.0 seconds.



How much <u>work</u> does the lifter do?
(Show formula, setup, answer and correct units!)

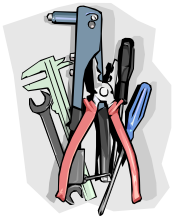
How much <u>power</u> does the lifter generate?
(Show formula, setup, answer & correct units!)

2) EXPLAIN HOW *YOU* could have more energy after going up two flights of stairs to the 2nd floor, then you had when you were at ground level. Does the magnitude of your new energy (on the 2nd floor) depend on if you ran up, walked up, skipped every other stair going up, or took the elevator!? Please be specific.



3) APPLY the Law of Conservation of Energy to EXPLAIN WHY the <u>work output</u> of a human, simple machine, compound machine, or even a power tool, <u>can never exceed the work *in*put</u>. Use an example or tool in your answer.







<u>WORD BANK</u>
mass, weight, force, energy
friction, gravity, direction
work, mechanical advantage
conversion, transfer, conservation
mechanical, potential, kinetic energy

APPENDIX H

GUIDELINES AND WORKSHEETS FOR COLLEAGUE OBSERVATIONS OF STUDENTS, TEACHER, AND LESSONS

Appendix H

COLLEAGUE OBSERVATION PROMPTS

DATE: _____ Phase of Research Project_____

The following are prompts for a classroom observer to use during an observation. *The colleague is not limited to the list below in any way.* I appreciate your efforts and perspectives.

1 = Strongly Agree 2 = Agree 3 = Not sure 4= Disagree 5 = Strongly Disagree

1) The teacher shows preparedness and motivation for teaching science. 1 2 3 4 5
Explain.

2) The teacher is attempting to engage <u>all</u> the students in today's lesson. 1 2 3 4 5

Especially: _____(H) _____(Med) _____(Low)
Comments:

4) *<u>HOW</u>* does the attitude of the teacher affect the students today?

Especially: _____(H) _____(Med) _____(Low)
Comments:

5) *<u>HOW</u>* does the attitude of the teacher change with the attitude of the students today?
EXAMPLE 1:

EXAMPLE 2:

6) Were students engaged in and focused on working at learning, even without the teacher constantly prompting, directing, or questioning them?
Did they appear to work at *writing*?

MOST About HALF, maybe MORE About HALF, maybe LESS Mostly NOT

Especially notice: High-level: _____ Medium-level:_____ Low-level:_____
Comments:

7) Suggest improvement in terms of the teacher's attitude, motivation, or teaching techniques and strategies.

Date _____ Time _____ Phase of Intervention _____
Concept and general lesson objectives today:

Opportunities to Respond and Quality of Responses

Question Type		**Closed Ended** *Convergent: Procedural Fluency*	**Open Ended** *Divergent: Conceptual Understanding*
Instructor	Shout-Outs		
	Called On		
	Writing Practice		
	Written responses		

(initials- learning level) setup for 3 different classes	( ) ( )	( ) ( )			

APPENDIX I

PRE AND POSTTREATMENT TEACHER SURVEY

Appendix I

PRENONTREATMENT and POSTTREATMENT TEACHER SURVEY *Date:*

1 = Strongly Agree 2 = Agree 3 = Disagree 4= Strongly Disagree

The Mechanical Energy unit of study will involve the following physical science terms:

distance*	speed*	time*
direction	velocity*	d/t graphs
acceleration*	reference	*v*/t graphs
mass*	weight*	force*

mass*	weight*	inertia*	gravity*	
friction*	acceleration*	momentum*		
unbalanced force*	kinetic energy*			
action force	reaction force	free-fall		

*F= ma *work= W= Fd = m*g*h

*power=P = $\frac{W}{t}$ vector, direction

1. Review the vocabulary terms above, and describe your *current level of understanding*:

1 2 3 4 5

with 1 being not very sure of most of these as science terms or how they apply to science, and 5 being an understanding of these terms enough to teach/explain to 9th grade students.

EXPLAIN why *I* chose that number!

2. Am/Was I REALLY ready to begin this action research project? _____ Explain:

3. Do I recognize the differences and significances between my NONTREATMENT unit & my TREATMENT "intervention" units? _____ Explain:

4. I am looking/did look forward *to teaching* (i.e. positive attitude):

- MOTION and FORCES Concepts _____ Explain:
- NEWTON's LAWS Concepts _____ Explain:
- WORK and POWER Concepts _____ Explain:

5. I am/was motivated *about teaching:*

- MOTION and FORCES Concepts _____ Explain:
- NEWTON's LAWS Concepts _____ Explain:
- WORK and POWER Concepts _____ Explain:

6. I am/was committed to encouraging explanatory writing in science, promoting evidence-based reasoning and writing, and taking the time to improve students' writing by modeling and practicing during class, and promoting vocabulary development and use: _____ Explain:

APPENDIX J

TEACHER JOURNALING PROMPTS

Appendix J

DAILY Teacher Journal PROMPTS *today's date:* _____

Consider doing surveys often, for <u>each</u> class period, and for <u>each</u> unit, for comparison purposes!

<u>Forces & Motion</u> <u>Newton's Laws of Motion</u> <u>Work & Power</u>

1) Was I prepared for this unit/lesson/day? If not, what needs/needed to be done?
1 (totally!) **2** (almost) **3** (nearly) **4** (day to day) **5** (winging it!)
Comment :

2) *How* does this _____ approach to '**DISTINGUISHING VOCABULARY**' compare
to how I remember this unit of study being taught before**?** Or the previous nontreatment?
Comment :

3) The students are generally _____ to practice writing in journals.
Comment :

4) The students _____ react positively to the formative & anonymous writing practice.
Comment :

5) Did I realize something new about me, my teaching approach, or my students? Did some 'situation' make you feel motivated to *change my* teaching *methods*?

6) What will be/was the most interesting, challenging, or awesome aspect of this particular unit or approach? Is/was it worthwhile? If so, why? If not, why not?

MORE Comments:

7) <u>Affirmative Example(s):</u> <u>Non-Supportive Example(s):</u>

\

APPENDIX K

STUDENT SAMPLE RESPONSES FROM POSTASSESSMENTS WITH SCORES

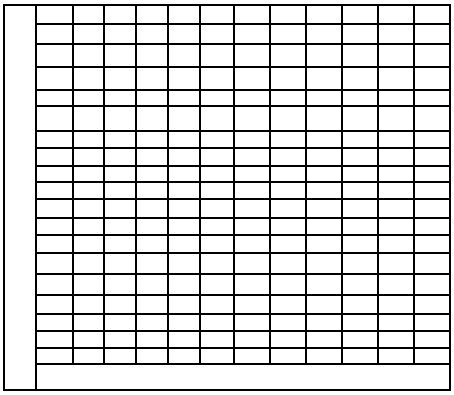
Appendix K

STUDENT SAMPLE RESPONSES FROM POSTASSESSMENTS with SCORES

NONTREATMENT graph analysis: A small toy car at rest on the ground was pushed and had moved 2 meters by the 1st second. Two more meters were displaced by the 3rd second, and a total of 10 meters was traveled in 4 seconds. The toy car continued moving out to a 15 meter-mark by 6th second, but came to a stop, when the car hit a rock, 20 meters from the start after a total of 10 sec.

SUMMARIZE (in 1-3 sentences) the movement of the toy car above, in terms of speed, acceleration, and momentum during the 10 seconds (over the 20 meters).
NOTE: You *may* use the tools below, but their use does NOT affect the score of your summary.

Distance	Time	Speed	Acceleration



a) SUMMARY: (3 points possible)

STUDENT SAMPLE ONE: The car was always accelerating, faster the 1st second, slowing down between the 1st and 3rd second, then faster again the 4th second, then slower until it stopped. The car only had momentum when it was moving. The average speed was 2 meters/sec.
(3/3 points)

STUDENT SAMPLE TWO: The car went 2m/s, then 0.66 m/s, then 2.5 m/s, then 2m/s until it stopped when it hit a rock. The car was speeding up and slowing down. (1/3 points)

b) INFER when, *if ever*, the toy car was traveling down a hill.
Explain why, *or* why not. (2 points possible)

STUDENT SAMPLE ONE: A hill would give the car more energy, so more speed like between 3-4 seconds (1/2 points).

STUDENT SAMPLE TWO: The car probably went down a hill at the 4 second mark because it went from 4 meters to 10 meters in one second and suddenly dropping downhill would cause acceleration like that.(2/2 points)

NONTREATMENT 'paint drip' inference: . Use the *evidence* of the *paint drips* BELOW to completely describe the motion of the painter with the constantly dripping paintbrush. Also, offer an explanation for the *shape* of the paint drips changing. A word bank of terms describing motion and forces is provided. (5 points possible)

WORD BANK

displacement distance direction
speed velocity acceleration
mass weight force
gravity friction

STUDENT SAMPLE ONE: The higher the painter went up the ladder, the bigger the drips were when they fell because of the force of gravity. (1/5 points)

STUDENT SAMPLE TWO: The painter was standing in one spot then accelerated to the right because the drops are farther apart in distance so the painter kept moving faster. Gravity pulled the weight of the paint down and the splatters are bigger because the drop hit at an angle as the painter moved faster this way →. (5 points)

TREATMENT 1 'sunglasses' reasoning: Sunglasses on the dashboard of a moving car slide to the left as the car turns right. EXPLAIN why using *one* of Newton's Laws of Motion. (2 pts)

STUDENT SAMPLE ONE: 1st law because the sunglasses are at rest and try to stay that way as the car turns. (1.5/2)

STUDENT SAMPLE TWO: 2nd Law, because a car turning is changing acceleration by turning and everything on the dashboard and loose in the car will go the opposite way the car is turning.(0/2 points).

Treatment 1 'rock & feather' inference: Use Newton's 2nd Law of Motion to EXPLAIN the different results when a rock and a feather are dropped, from the same height at the same time, to the surface of the Earth and to the surface of the moon. (5 points)

EARTH's SURFACE

MOON's SURFACE

WORD BANK

F = ma mass weight inertia speed direction acceleration gravity friction free-fall
balanced & unbalanced forces action force reaction force

STUDENT SAMPLE ONE: There is less gravity on the moon so the mass and weight of the rock and feather don't matter. (1/5 points)

STUDENT SAMPLE TWO: On the Earth gravity acts differently to objects than on the moon. The feather has balanced forces and the rock has unbalanced forces, causing the rock to drop faster. (3.5/5 points)

STUDENT SAMPLE THREE: F=ma, and a = F/m so even though the moon has less gravity, the acceleration because of gravity will be the same (just less). But the moon doesn't have air resistance, which causes friction and slows the feather down as it falls to earth. The force of friction (up) balances gravity (down) on the feather, but the rock-with more mass and weight-- will just free-fall at 9.8 m/s^2 down or accelerate faster to the earth. (5 points)

TREATMENT 2 'stairs" Inference: Based on your lab experience, EXPLAIN HOW *YOU* could have more energy after going up two flights of stairs to the 2nd floor, then you had when you were at ground level. Does the magnitude of your new energy (on the 2nd floor) depend on if you ran up, walked up, skipped every other stair going up, or took the elevator!? Please be specific. (4 points)

STUDENT SAMPLE ONE: You have to do work going upstairs which gives you potential energy to fall down faster the higher up you go. W = Fd Energy depends on how much you weigh, not how fast you go up or if you skip stairs—it's the same distance. (3/4 pts)

STUDENT SAMPLE TWO: As you go upstairs, your body starts to work so it gives you energy as you go up and afterwards. The faster you go the more power you have. And the more kinetic energy. (.5/4 points)

TREATMENT 2 'work in and out' explanation: APPLY the Law of Conservation of Energy to EXPLAIN WHY the work ***out***put of a human, simple machine, compound machine, or even a power tool, can never exceed the work ***in***put. Use an example or tool in your answer. (5 points)

STUDENT SAMPLE ONE: Simple machines have a mechanical advantage to simplify our jobs, but if the effort force is less, then the distance has to be more. There is more motion. The best example is a ramp where you can push or roll a heavy load up a longer distance but not have to lift it straight up. The efficiency depends on the friction—so rolling is more efficient and there is less wasted work. I feels easier because less force is used, but the work is the same or more (due to friction). (4.5/5 pts)

STUDENT SAMPLE TWO: A simple machine like a wrench or a screwdriver can't exceed its work input because a human is using it as they can only use as much energy as the human puts into it. (1/5 points)

APPENDIX L

SAMPLE NONTREATMENT LAB 'INJECTED' FOR UNDERSTANDING

Appendix L

Name _____ period _____-_____ DATE:

PURPOSES:

1) To OBSERVE _____ due to the _____ of gravity.

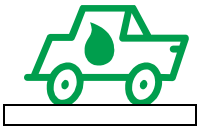
2) To COMPARE _____, _____, _____ (velocity↓), and _____.

3) To GRAPH _____ (distance VS time) and _____ (speed VS time).

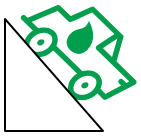
4) To DETERMINE the _____ and _____ ***acceleration*** of a Hotwheel® car.

HYPOTHESIS: Unbalanced forces cause acceleration to an object (mass).

Force diagrams:



SET-UP:



Car:

MASS=

Launcher/recorder: _____

Timer: _____

timer #1: _____

timer #2: _____

timer #3 :

Controller/R#2: _____

Ramp length = _____

Practice run#1:

Time(s)	Position(cm)
1.0 s	
2.0 s	
3.0 s	
4.0 s	

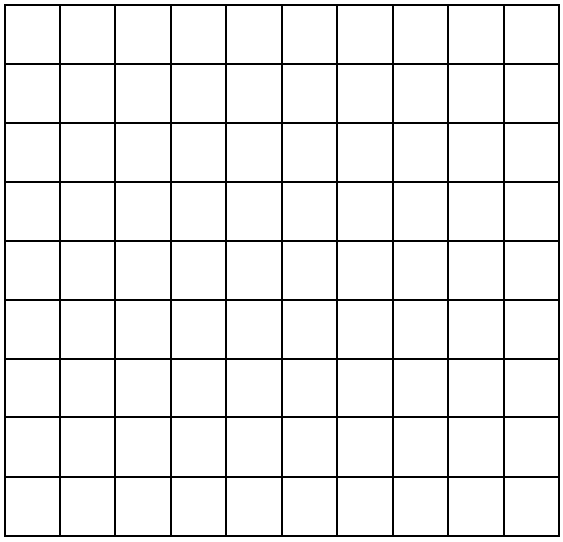
Practice run#2:

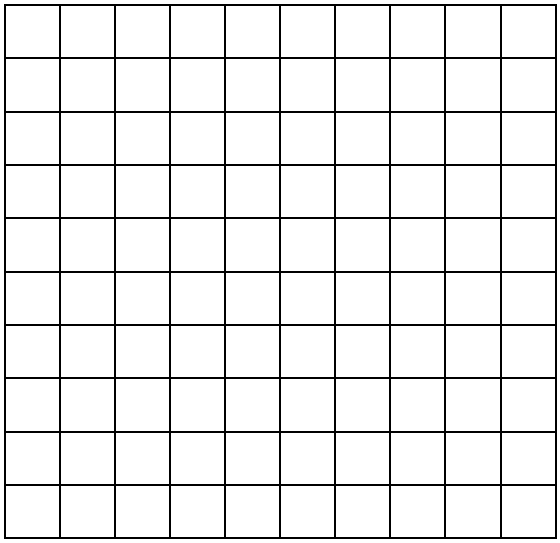
Time(s)	Position(cm)
	20 cm
	40 cm
	60 cm
	80 cm
	100 cm

DATA for **1 book height** of _____ cm.

Trial # → control ↓				"best" distance/time	Velocity (cm/s)

Create a **distance** (position) **VS time graph** for your two heights using your average positions.
Create a **velocity VS time graph** for your two heights. *Be sure to <u>TITLE</u> and <u>label</u> your graphs!*





Determine **acceleration** of your car, for each height, by finding the slope of the lines on your graph….remember slope = $\frac{rise}{run}$.

1-book height acceleration= $\frac{rise}{run}$ **=** _____ = _____ _____
quantity units!

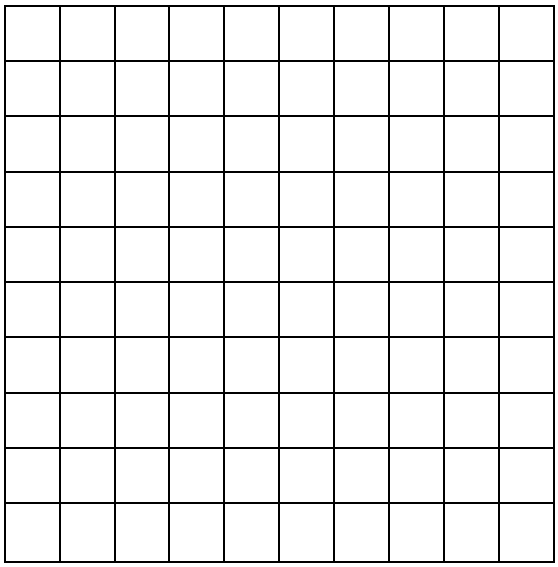
2-book height acceleration = $\frac{rise}{run}$**=** _____ = _____ _____

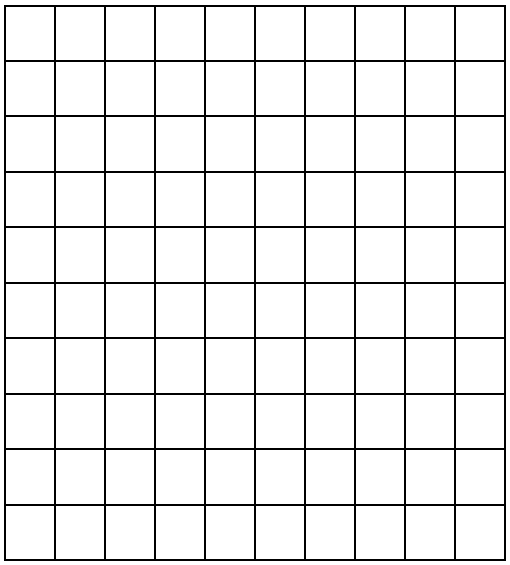
Now, collect data for negative acceleration or deceleration by timing run-out distances.

DATA for **3+ book height** of _____ cm. Mass of car = _____

				"best" distance/time	Velocity (cm/s)

Now <u>create</u>, ***<u>label</u>*** and <u>title</u> a graph to show **speed** and a graph to show **negative acceleration**.





Use your graph to determine the **deceleration rate of your car: _____**

<u>Questions and Inferences</u>:

1) What is the main difference between your **d/t** and your **v/t graphs** for your <u>first 2 trials</u> (ramp data)**?**

2) What is the main difference between your two **d/t graphs?**
(HINT: the slope indicates _____)

3) What is the main difference between your two **v/t graphs?**
(HINT: the slope indicates _____)

4) ***<u>HOW</u>*** does the angle of your inclined plane (ramp) affect the acceleration of your car**?**

5) What are some factors that might influence error into this experiment**?** How could you make this experiment better**?**

<u>Evaluation:</u> Sketch the resulting graphs ***<u>if</u>*** data from **the top of ramp to the end of the run-out** for your car:

