Augmenting the Modeling Physics Curriculum with Growth Mindset Strategies and the Effects on Students’ Mindset and Attitudes Toward Science

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ABSTRACT

The purpose of this study is to measure the impact of growth mindset strategies in a Modeling physics classroom. This study assesses how this can affect students' understanding of Newtonian forces as well as student mindset. Extensive research has been done on the benefits of the Modeling method and studies have also demonstrated the benefits of having a growth mindset. Additionally, many of the qualities of growth mindset are found in the modeling method. Some of these qualities include: being able to learn from failures and mistakes, persevering through challenges, and approaching a problem with multiple strategies. Because of this, it is proposed that students who are instructed on the differences between having a growth and fixed mindset will shift their mindset and improve in both their mindset scores and in their understanding of Newtonian physics. Previous research also suggests that minorities (such as women in physics) tended to react more to growth mindset instruction, so results were also compared based on student gender.

To assess these results, students were given pre- and post-tests to gauge their physics understanding and their mindset. To measure students' understanding of Newtonian mechanics, they took the Simplified Force Concept Inventory (SFCI). Students also completed a Personal Beliefs Survey (PBS) to assess whether they had more of a fixed or growth mindset. Students were also surveyed at the beginning and end of the year on their attitude towards science, using the Colorado Learning Attitudes About Science Survey (CLASS). In order to gauge students' attitudes towards growth mindset, they were also given a Student Reaction Survey (SRS) at the end of the year.

Students in both the contrast and treatment groups had the same average increase of 13% on the SFCI. The results of the PBS showed that students who received the growth mindset treatment had a 13% shift towards having a stronger growth mindset. On the other hand, the contrast group did not show a significant change in their mindset. Assessments were also compared based on gender to see if males or females had a greater change in their mindset. This analysis showed that although all students who received the growth mindset treatment had approximately the same positive attitude towards growth mindset (measured using the SRS), male students had a 9% improvement and female students had almost double the improvement (17%) in their overall mindset score.

CLASS results showed that students could have both improvements and decreases in their attitude towards physics. However, with an emphasis on growth mindset, such classes can further improve the beliefs of students, creating large (>10%) shifts in some categories and only minor decreases in others. In addition, women's scores improved more in some categories while in others, the scores of the men were higher. Categories in which men in the treatment group showed major improvements included Personal Interest (+12%), Real World Connections (+10%), General Problem Solving (+13%), and Problem Solving Sophistication (+9%). Categories in which women in the treatment group showed large improvements included Problem Solving Sophistication (+15%), Applied Conceptual Understanding (+15%), and Conceptual Understanding (+15%). In the contrast group, the only shifts greater than 10% were when men had a -11% shift in Real World Connections and women had a +11% shift in Conceptual Understanding. Both genders in both contrast groups showed at least a 5% increase in the Conceptual Understanding category, possibly due to the Modeling style of teaching.

The students in both groups were also assessed using a Student Reaction Survey, asking about their attitudes on the treatment and growth mindset. Students in both groups reported the same amount of outside instruction on mindset, indicating that any results from the study were because of the treatment, not from outside instruction. This survey also showed that the treatment group ended with a significantly more positive attitude about growth mindset. In addition, all of the treatment students either "agreed" or "strongly agreed" that they were confident in their ability to do well in future classes. On the other hand, the contrast group had students who also "disagreed" or "strongly disagreed" with the same statement.

There was not a correlation between mindset and understanding of Newtonian mechanics. However, there were several factors that led the investigator to believe these results may not be consistent for every classroom. There does appear to be a positive correlation between a student's attitude towards mindset and their overall mindset score as well as with a student's confidence that they can perform well in future classes.
RATIONALE

Much of the research done about the Modeling method of teaching physics was done in the 1980s, 1990s, and early 2000s. Because of these studies, physics education was revolutionized and teachers had a new approach to Interactive Engagement. This new technique has shown incredible improvements in student understanding of physics content. This is particularly prevalent when assessing students’ preconceptions. Students in a modeling classroom are constantly forced to confront their current models, including those formed prior to enrolling in a physics class. In doing so, they see that science (and learning) is a process where experts continually learn from their mistakes. From failure, students are exposed to many different representations and strategies to understand content.

On the other hand, the concept of growth mindset is a relatively new one. Recent studies have shown that students with a growth mindset rather than a fixed mindset tend to score higher on content assessments. As stated by Dweck, “there is a growing body of evidence that students’ mindsets play a key role in their math and science achievement” (Dweck, 2008). However, because the study of mindset is a relatively new pedagogical approach, little research has been done relating mindset and the Modeling method. In recent years many teachers and administrators have introduced the concepts of growth mindset to their campuses. The investigator believed that it was important to see if the Modeling method could improve a student's mindset and if those students could then show the improved scores that have been seen in previous studies.
In this study, the correlation between the modeling pedagogy and the mindset of students is investigated. Mindset is generally described as being either a fixed mindset or a growth mindset, but it is generally a combination with the two (Dweck, 2008). Carol Dweck was the founder of the idea of these different mindsets and its influence on student achievement. Fixed mindset is when someone believes that their abilities are fixed and that these are innate characteristics that cannot be changed. People with a fixed mindset tend to avoid challenges and they see no point in trying harder. This is because they believe that their abilities are already established and cannot be significantly improved by their efforts or by varying their approach to problems or challenges (Dweck, 2008). On the other hand, someone with a growth mindset believes that their talents and abilities (such as their ability in physics) can be changed and developed (Aguilar, 2014). People with growth mindsets work hard to overcome difficulties because they believe that over time and with the right approach, they can achieve success. These people also tend to be more open to criticism, because they see it as an opportunity to grow (Dweck, 2008). An important distinction to make when describing growth mindset is that having “a growth mindset isn’t just about effort... Students need to try new strategies and seek input from others when they’re stuck. They need this repertoire of approaches—not just sheer effort—to learn and improve” (Dweck, 2015). Having a specific mindset also affects a person’s attitude of what it means to be “smart.” Students with a growth mindset see being “smart” as someone who can try different methods and keep trying until they overcome a challenge. They see mistakes as opportunities to grow and learn rather than as a hindrance or an expression of inadequacy. On the other hand, those with a fixed mindset see being “smart” as completing something quickly and without making any mistakes (Aldhouse, 2008).

Dweck and her colleagues tracked students with growth and fixed mindsets as they progressed through their seventh and eighth grade math classes. In this study, Dweck came to the following conclusions:

“First, students with the growth mindset, compared to those with the fixed mindset, were significantly more oriented toward learning goals. Although they cared about their grades, they cared even more about learning. Second, students with the growth mindset showed a far stronger belief in the power of effort. They believed that effort promoted ability and that was effective regardless of your current level of ability. In contrast, those with the fixed mindset believed that effort was necessary only for those who lacked ability and was, to boot, likely to be ineffective for them. Finally, those with the growth mindset showed more mastery-oriented reactions to setbacks, being less likely than those with the fixed mindset to denigrate their ability and more likely to employ positive strategies, such as greater effort and new strategies, rather than negative strategies, such as effort withdrawal and cheating.” (Dweck, 2008)

A recent study tracked student mindset and performance on the Force Concept Inventory (FCI). This study was done in Modeling Instruction high school physics courses (general, honors, and AP Physics), which comprised mostly 11th and 12th graders. All classes were considered college preparatory courses. The students in this study were categorized as having either a strong fixed mindset (23 students), a strong growth mindset (14 students), or a "weak" mindset (109 students) that was between having a fixed or growth mindset. The teachers made no attempt to change their students’ mindset. The raw scores on the FCI pre-test were statistically similar among all 3 groups, all being between 7.5 and 10. The results from this study found that “the mean raw gain of the strong fixed mindset student group was 5.83 points gained, and the mean raw gain for the strong growth mindset student group was 11.79 points gained”. This indicates “that a student with the growth mindset will have a greater probability of achieving higher gains on the FCI than a student with a fixed mindset” (Flores, Lemons, & McTernan, 2011). In another study (not Modeling Instruction) done through online modules, a research group “delivered brief growth-mindset and sense-of-purpose interventions through online modules to 1,594 students in 13 geographically diverse high schools.” The results of these interventions were that they “raised students’ semester grade point averages in core academic courses and increased the rate at which students performed satisfactorily in core courses by 6.4 percentage points” (Paunesku, 2015). These results were
particularly prevalent in minority groups:

“Results showed that the typical gender gap in math standardized test performance emerged for the participants in the control condition. That is, boys outperformed girls on the math test if they had been mentored in the harmful consequences of drug use. However, when the participants learned about the expandability of intelligence the gender gap in math performance disappeared. The incremental condition increased both boys’ and girls’ math performance, but this increase in math scores was particularly pronounced for the female students, which is consistent with predictions derived from analysis of stereotype threat processes” (Good, 2003).

As stated in one study,

"The most significant cognitive factor predicting these losses was low grades earned in science courses taken during the first two years of study. With grades held equal, gender was not a significant predictor of persistence in engineering and biology; gender added strongly to grades, however, as a factor associated with unusually large losses of women from a category that included the physical sciences and mathematics" (Strenta, 1994).

To help combat this dramatic drop in female enrollment in undergraduate STEM programs, another study focused on the fact that this drop could be "in part because [women] lack similar role models" (Herrmann, 2016). This group gave struggling women a letter that "built on the story-editing approach, which posits that people can redirect their narratives about themselves to lead to lasting behavioral changes" (Hermann, 2016). The letter was written by a "female role model who normalized concerns about belonging, presented time spent on academics as an investment, and exemplified overcoming challenges on academic performance and persistence" (Hermann, 2016). The philosophy of these letters is in line with the theory of growth mindset, because it encourages people to overcome challenges and that by changing one's approach, you can succeed.

"The crucial part of each of these studies was that “students’ mindsets—how they perceive their abilities—played a key role in their motivation and achievement” and that if students' mindsets can be changed to be more of a growth mindset, their achievement (and academic grades) could be improved (Dweck, 2015). As stated in another study, "attribute interventions encourage students to attribute poor performance to malleable factors so that they can change their behavior in the future to improve performance" (Hermann, 2016). In order to change a student's mindset, certain techniques can be used. Dweck suggests that “educators play a key role in shaping students’ mindsets” and there are several ways in which teachers can change student mindsets (Dweck, 2008):

1. By teaching about neuroplasticity and that attributes can be developed
2. By portraying challenges, mistakes, and effort as being valued
3. By praising processes (perseverance, effort, improvement) instead of praising talents or final products
4. By having a growth mindset about their students

However, one of the dangers of teaching students to have a growth mindset is that students may instead develop a "false growth mindset," which is "saying you have growth mindset when you don't really have it, or you don’t really understand [what it is]" (Gross-Loh, 2016). One of the key concepts of a false growth mindset is that people tend to focus on and encourage effort. "A lot of parents or teachers say praise the effort, not the outcome. I say [that’s] wrong: Praise the effort that led to the outcome or learning progress; tie the praise to it. It’s not just effort, but strategy … so support the student in finding another strategy" (Gross-Loh, 2016). Rather than encouraging effort for just being effort, students need to be encouraged to put that effort towards new strategies. This includes seeking and appreciating feedback from others. "The growth-mindset approach helps children feel good in the short and long terms, by helping them thrive on challenges and setbacks on their way to learning. When they’re stuck, teachers can appreciate their work so far, but add: ‘Let’s talk about what you’ve tried, and what you can try next’" (Dweck, 2015). This helps students to see learning as a process where many steps and variations are needed in order to reach success. Modeling Instruction places emphasis on the process of science by having students develop
models that describe and explain physical phenomena (Wells et al., 1995). A synopsis of the modeling method is shown in Figure 1. Modeling is an example of student-centered curricula that has been shown to improve students’ conceptual understanding in physics compared to lecture style methods as measured by the FCI and Simplified Force Concept Inventory (SFCI) (Malone, 2006; Jackson et al., 2008; Wells, 1987; Hake, 1998). In a modeling classroom, students are required to engage in public discourse and debate about scientific and technical matters (Jackson et al., 2008) and because modeling focuses on the process of knowledge acquisition it is possible that students come to develop a growth mindset, particularly with respect to their own abilities in STEM. Understanding that knowledge can be gained through effort and persistence is inherent in the process of modeling and this is the hallmark of a growth mindset.

![Box 2: MODELING METHOD Synopsis](image)

**Box 2: MODELING METHOD Synopsis**

The Modeling Method aims to correct many weaknesses of the traditional lecture-demonstration method, including the fragmentation of knowledge, student passivity, and the persistence of naive beliefs about the physical world.

**Coherent Instructional Objectives**

- To engage students in understanding the physical world by constructing and using scientific models to describe, to explain, to predict and to control physical phenomena.
- To provide students with basic conceptual tools for modeling physical objects and processes, especially mathematical, graphical and diagrammatic representations.
- To familiarize students with a small set of basic models as the content core of physics.
- To develop insight into the structure of scientific knowledge by examining how models fit into theories.
- To show how scientific knowledge is validated by engaging students in evaluating scientific models through comparison with empirical data.
- To develop skill in all aspects of modeling as the procedural core of scientific knowledge.

**Student-Centered Instructional Design**

- Instruction is organized into modeling cycles which move students through all phases of model development, evaluation and application in concrete situations — thus promoting an integrated understanding of modeling processes and acquisition of coordinated modeling skills.
- The teacher sets the stage for student activities, typically with a demonstration and class discussion to establish common understanding of a question to be asked of nature. Then, in small groups, students collaborate in planning and conducting experiments to answer or clarify the question.
- Students are required to present and justify their conclusions in oral and/or written form, including a formulation of models for the phenomena in question and evaluation of the models by comparison with data.
- Technical terms and concepts are introduced by the teacher only as they are needed to sharpen models, facilitate modeling activities and improve the quality of discourse.
- The teacher is prepared with a definite agenda for student progress and guides student inquiry and discussion in that direction with "Socratic" questioning and remarks.
- The teacher is equipped with a taxonomy of typical student misconceptions to be addressed as students are induced to articulate, analyze and justify their personal beliefs.

**Figure 1 Modeling Method Synopsis**

During modeling discourse students are guided by the instructor using methods such as Socratic questioning and seeding to develop their own models. The instructor does not provide solutions and encourages students to keep working by providing guidance when necessary (Desbien, 2002). The use of the guided-inquiry method to instruct a class challenges the students to be more in control of their
learning. In addition, the goal of the guided discourse is not to arrive at a single correct answer, but rather to develop a method of thinking that allows constant reevaluation of information and knowledge. As in “real-life science” models are continually updated as new information is gained or a new model is developed when needed.

In a modeling classroom, students work in groups to solve problems and are constantly challenging other’s ideas and refining their models. This teaches students that learning is a process that involves effort and refinement as opposed to knowledge being a solution to a problem. Since a growth mindset requires that a person believes that effort and refinement will promote success (Dweck 2008), it could be argued that a modeling pedagogy should also promote a growth mindset in students.

It is also possible that a modeling pedagogy, especially a class emphasizing growth mindset, could also improve a student's attitude towards science. In order to measure student's attitudes towards science, one can use the Colorado Learning Attitudes about Science Survey (CLASS). The purpose of this survey is to assess how closely students' opinions about science compare to those of experts. "Experts think about physics like a physicist. For instance, they see physics as a coherent framework of concepts which describe nature and are established by experiment. Novices see physics as isolated pieces of information that are handed down by authority (e.g. teacher) and have no connection to the real world, but must be memorized" (Perkins et al., 2004). To help measure students' beliefs about physics, the survey includes questions such as "Knowledge in physics consists of many disconnected topics" (see Appendix C). Some research has been done to measure the pre- and post- survey scores of students in different classes using various teaching methods. "Data have shown that, traditionally, student beliefs become more novice-like over the course of a semester. Even in courses using reformed classroom practices that are successful at improving student conceptual learning of physics, student beliefs tend not to improve. Some success has been achieved, however in courses specifically designed to attend to student attitudes and beliefs" (Perkins et al., 2004). The Perkins study was on courses that "range in size (less than 40 to over 600 students), student population (non-science majors; pre-meds; physics, chemistry, and engineering majors), and school setting (from a large state research university, LSRU, to a mid-size multipurpose state university, MMSU)" (Perkins et al., 2004). Since growth mindset ideals specifically address one's attitudes, it is possible that these concepts can also improve someone's attitudes towards science. In addition, classes using the Modeling method have shown improvement in student's attitudes. In a study done using a modeling classroom in 2009, "the Modeling Instruction section had significant positive shifts toward more favorable responses overall, as well as in four of the eight subcategories" (Brewe et al., 2009). Similar results were seen in a calculus-based introductory physics course at Florida International University: "The results presented indicate a consistent pattern of positive attitudinal shifts across a variety of instructors. Positive shifts are rare among research reported on calculus-based introductory physics classes. This compilation of positive shifts, especially when contrasted with negative shifts commonly reported, leads us to attribute the shifts to the Modeling Instruction curriculum and pedagogy" (Brewe, et al., 2013). In that study, students' attitudes increased in every subcategory of the CLASS, with the largest gains being in the Physical Science Sophistication, Conceptual Understanding, and Applied Conceptual Understanding categories (Brewe et al., 2013).

This survey has also been used to measure differences in the responses of minorities and of different genders, particularly in a modeling classroom. "The modeling classes are supportive of student attitudes in the Equity of Fairness sense, where all groups show similar gains" (Traxler, 2015). In previous research, studies have shown that "the responses to nearly half the statements show significant gender differences. Comparing responses from men and women in the same classes, which typically represent the same set of majors, women are generally less expert-like on statements in the ‘Real World Connections’, ‘Personal Interest’, ‘Problem Solving Confidence’ and ‘Problem Solving Sophistication’ categories and a bit more expert-like on some ‘Sense-Making/Effort’ type statements" (Perkins et al., 2004). Because women have traditionally shown a poorer attitude towards science and a more fixed mindset, these areas are of special interest in the modeling classroom.
Models are the basis for theoretical and experimental research, which makes them the basis for knowledge development, reasoning, and problem solving (Brewe, 2008). The modeling method uses multiple representations and makes this process student-centered. These attributes are what make modeling an ideal pedagogy for improving a student’s growth mindset. I am interested in learning if promoting a growth mindset in high school students can 1) shift students’ mindsets to a more growth mindset, 2) improve their content understanding, and 3) improve their attitudes towards science. These results will be assessed both by treatment and by gender.

METHOD

Study Subjects

Investigator: Jerika McKeon teaches in the ASU Preparatory Academy district at the Polytechnic High School. The ASU Preparatory Academy district has five campuses in the Phoenix Valley. ASU Prep also offers online classes through ASU Prep Digital. In the 2018-2019 school year, it served a total of 2842 students in grades K-12. The Polytechnic High School campus had an enrollment of approximately 300 students in grades 9-12. The population of the school was 47.5% Caucasian, 28.6% Hispanic/Latino, 7.3% Black/African-American (not-Hispanic), 7.0% Asian/Pacific Islander and 1.3% American Indian/Alaskan Native. 24.4% of the students receive free or reduced lunch and approximately 10% of students receive special education services. The investigator worked with four sections of Cambridge International General Certificate of Secondary Education (IGCSE) Physics with a total of approximately 100 students during the year. Only 61 students are included in this report (38 total females and 23 total males). Half of the IGCSE classes received the growth mindset treatment from the investigator. In these classes there were a total of 31 students who participated in this study, which included 18 females and 13 males.

IGCSE physics is considered a general physics class and consists of students in grades 9 to 11. IGCSE physics has a prerequisite of Algebra 1. Students are encouraged to take IGCSE Biology concurrently with Algebra 1, then IGCSE physics with geometry, and IGCSE chemistry with Algebra 2. A few students choose to skip physics and take IGCSE chemistry with geometry, but these students tend to struggle much more than those who have already taken physics. This is a relatively new policy, so the goal is for 90-95% of students to take IGCSE physics before they graduate; most students take it in either 9th or 10th grade, whenever they are enrolled in geometry.

Comparison Group: The contrast group consisted of the other two sections of the IGCSE physics classes taught by the investigator. In these classes there were a total of 30 students included in this study, of which 20 were female and 10 were male. In both the 2017-2018 and 2018-2019 school years, the campus introduced growth mindset as a whole, although with much fewer lessons and different direct interventions. Teachers were encouraged to post reminders of growth mindset and associated phrases as well as to incorporate such sayings into their lessons. However, the extent or method of incorporating mindset was up to individual teachers. As a result, most (if not all) students had already learned about growth mindset. To help account for this, the investigator administered a growth mindset pre- and post-test (the PBS) to all classes (Appendix B). All classes were also given the Student Reaction Survey (SRS) to assess how often other teachers discussed growth mindset concepts compared to the investigator (Appendix D). The SRS also measured students' attitudes towards growth mindset. No specific treatment was administered by the investigator; however, there were growth mindset posters in the investigator’s classroom to better influence the treatment in the other classes.

Procedure

The Investigator teaches IGCSE physics using the modeling methods for mechanics and waves. There are several differences between the mechanics modeling curriculum and that of the Cambridge curriculum. The IGCSE curriculum does not include two-dimensional (2D) kinematics, Newton's Laws, 2D forces, circular motion (beyond just identifying the centripetal force in a situation), 2D collisions, or elastic or inelastic collisions. Instead, the IGCSE curriculum includes topics on pressure, waves, optics, electricity, magnetism, atomic physics, and nuclear physics (Cambridge IGCSE Physics (0625)). Due to
the extensive content requirements for the Cambridge IGCSE curriculum, instruction needs to be very fast-paced. As a result, the Investigator teaches all IGCSE mechanics content (1D Kinematics, 1D Forces, Conservation of Momentum, Energy/Work/Power, and Energy Resources) in the first semester. These differences could have greatly influenced students' scores on the FCI test.

A complication that arose during the year that also impacted results was that the investigator's campus had an unexpected focus on growth mindset. As shown in the third question of the Student Reaction Survey, all students received frequent lessons on growth mindset from other teachers. In addition, students began to have an overall negative attitude towards growth mindset and many of the key phrases used such as "yet" and "keep trying." As a result of this, the investigator chose to alter the method of treatment by using fewer and less frequent lessons than was originally planned. Originally, the investigator was going to teach growth mindset twice a month but she altered this plan to teaching students about growth mindset concepts (without referencing "mindset") approximately once a month. Additionally, the investigator waited until later in the year to use the phrase "growth mindset" and to use those key phrases herself.

Permission and Data Security. The investigator obtained parental permission and student assent for all participants, both in the treatment group and in the control group. Student and parent assent were obtained via the “Student Assent Form” in Appendix A. Only individuals with student and parent consent were recorded for this study. Students and parents were informed that they could, at any point, choose to not participate without their decision affecting the student’s grade. All data collected and recorded electronically was kept on the investigator’s password protected computers. All paper assignments that were collected were secured in the locked classroom.

Pre-Assessments.
1. In order to gauge students’ initial mindset all students took the Mindset Survey developed by Dweck and her colleagues. The survey was renamed the “Personal Beliefs Survey” (PBS) as an attempt to keep students from realizing that the survey assessed mindset. The survey is made up of eight Likert scale multiple choice questions and three short essay-style questions. The survey can be found in Appendix B.
2. All students took the COLORADO LEARNING ATTITUDES ABOUT SCIENCE SURVEY (CLASS) to assess their attitude towards physics both at the beginning and end of the year. The survey can be found in Appendix C.
   a. The CLASS is designed to "measure student beliefs about physics and about learning physics" (Adams, 2006). This survey measures that "most teaching practices cause substantial drops in student scores" (Adams, 2006). This survey was used to compare how the modeling method can affect students' attitudes. It was used also to measure the responses of the treatment group compared to those of the control group.
3. All students also took the Simplified Force Concept Inventory (SFCI) to assess their knowledge of Newtonian physics. The Force Concept Inventory (FCI) is a well-established tool for measuring student comprehension of Newtonian physics.
   a. The Simplified Force Concept Inventory assesses the same concepts but with simpler, more student-friendly language. This test was chosen because it was designed for younger students, which better fits the ages of IGCSE Physics students (Popp & Jackson, 2009).
   b. It should be noted that in the IGCSE Physics courses, the curriculum does not cover two-dimensional Newtonian physics, nor does it cover Newton's Laws to the extent that is assessed in the SFCI, so student scores were not expected to improve by very much.
4. The assessments were given on different days so as to not overwhelm the students.

Unit 1: Scientific Thinking and Growth Mindset
1. The investigator taught an introductory unit on the nature of science and on how to
graphically and mathematically model something in life.

2. It was during these discussions that the importance of learning concepts using different strategies was initially introduced, although the phrase “growth mindset” was not used until later in the school year.

**Remaining Units**

1. Whenever possible, students were redirected from a fixed mindset statement to growth mindset one. The investigator chose certain “catch phrases” to repeat at appropriate times. Some of these statements were displayed in the classroom as posters, such as:
   i. “Everyone learns in different ways. Let’s keep looking for what works for you.”
   ii. I can’t do it. I can’t do it because I haven't found the right strategy, yet.
   iii. I’m so dumb. I’m learning! I just need more practice.
   iv. I quit. I have other strategies I haven’t tried yet.
   v. This is good enough. I don’t quit until it’s my best work.
   vi. “X’s time’s the charm! That’s what I always say!”

2. At the end of quarter 2, students completed the DEVELOPING THINKING SKILLS WRITTEN ASSIGNMENT written by John Clement (Appendix E).

3. At various points during the year, the investigator started the class with a short lesson/discussion on growth mindset. There were 8 lessons/discussions on growth mindset topics throughout the year (see accompanying PowerPoint presentation):
   i. 10/22/18: Patterns of Learning
      1. At the start of this lesson, the investigator explained that research has shown that "students whose study strategies aligned with their VARK (visual, auditory, reading/writing, kinesthetic) scores performed no better" (May, 2018). However, by using a VARK survey students can learn about new learning strategies that they have not thought of before.
      2. Students took a simple VARK survey on different learning styles to identify which learning strategies they have used before. The investigator then encouraged students to choose a few new learning strategies to try in the following weeks. ("Learning Styles Inventory")
      3. Overall, students were excited about their results and seemed open to trying new strategies of learning.
   ii. 11/3/18: Neuroplasticity
      1. Students seemed to agree with the conversation and were engaged with discussing examples of this in their life.
      2. The class watched videos of talent competitions to show examples of people who have had to retrain themselves in their talents. The students seemed to appreciate these examples and seemed motivated by them.
   iii. 1/29/19: What are you proud of so far?
      1. Students were generally proud of their efforts so far.
      2. Students had been working harder recently to turn in all homework assignments and to do so on time.
      3. They acknowledged that they are seeing a difference because of their increased efforts.
   iv. 3/26/19: Making Mistakes
      1. A majority of students said that a mistake was mostly a good thing. Even if the mistake itself isn’t a better method, one can learn from the mistake.
      2. The class consensus was that in the moment they make a mistake, they experience a negative feeling but that later on they learn from it and feel more positively about the mistake.
   v. 3/28/19: Famous Failures
      1. The class watched a video giving examples of famous people (musicians,
businessmen, athletes, etc.) and the setbacks they faced. Students seemed to have also heard of some before but were also surprised by some of the examples.

2. All students agreed that everyone faces setbacks and that they can be overcome.

vi. 4/11/19: Electricity Activity - Learning from mistakes
1. After a challenging activity of trying to light a light bulb with only a battery and one wire, the class discussed the importance of making mistakes and learning from them.
2. Students easily recognized the value of learning from mistakes and applying the knowledge they learned to do better.

vii. 5/14/19: Reflect on all that you have this year - Students were asked to record their responses to the following questions:
1. What did you know about physics before taking this class?
   a. Student responses were short and mainly focused on vocabulary or equations that they knew (i.e. speed, distance, force)
2. What do you know about physics now?
   a. Students gave extensive and varied responses from the topics discussed during the school year.
   b. Some students pointed out that although they had heard of some physics vocabulary before, they realized that they now understood what those terms actually meant.
   c. The class discussed how the topics that were most memorable tended to be more hands-on (the investigator reminded students of the varied learning styles and the importance of exploring topics in different ways and with different approaches).
3. Is there a big difference between your answers to #1 and #2? How do you feel about that?
   a. Students were generally proud of what they had accomplished.
4. How do you feel when you look at this list (list of Cambridge standards/objectives the class has learned so far)?
   a. This list of objectives is several pages long. The investigator had printed them double-sided and half-size to reduce paper use.
   b. The students were very surprised and impressed at all they had learned during the school year.

viii. 5/16/19: Growth Mindset
1. Students were asked to record what they felt "growth mindset" and "fixed mindset" were. When asked to do so, students groaned and expressed disinterest but did complete the task. Definitions focused on growth mindset including an increased effort and a positive attitude. Students also included "catch phrases" they had heard frequently from others such as "yet."
2. The investigator asked the class how they felt about growth mindset, and the general consensus was that students were tired of hearing about it and that they were tired of being told to just put in more effort.
3. The investigator (using video games and sports as examples) led a discussion focused on the key component of growth mindset that the students seemed to be missing: the idea that you have to try again with a new approach (and that this is the point and benefit of making mistakes).
4. The investigator explained that when someone says, "I can't do it, yet" what is meant by that is "I can't do it, because I haven't found the right
strategy - yet." Students seemed to really resonate and appreciate this viewpoint and had a much more positive attitude about growth mindset after this discussion.

Completion of All Units (end of semester 2)

1. All students were given the PBS, the SFCI, the CLASS, and a Student Reaction Survey (SRS) on their attitudes and feelings about Growth Mindset (shown in Appendix D). Students were encouraged to be honest in their responses to all surveys.

2. All quantitative and qualitative data including: warm-ups, exit tickets, written responses, class discussions, and teacher observations were analyzed for patterns of growth mindset and were used in the final conclusions. All items that belonged to students who were not a part of the study were destroyed.

3. The results of this report were presented at ASU to the public on July 11th, 2019.
RESULTS

The results of all surveys (Simplified Force Concept Inventory, Personal Beliefs Mindset Survey, Student Reaction Survey, and the Colorado Learning Attitudes about Science Survey) were categorized both by treatment and by student gender. Results were analyzed using non-directional (two-tailed) independent and dependent sample t-tests and used $\alpha = 0.05$. This would indicate that if a calculated p-value is larger than $\alpha = 0.05$, then the samples are not significantly different and statistically come from the same population. On the other hand, if the p-value is smaller than $\alpha = 0.05$, then the samples are significantly different and statistically come from different population.

Pre-Test Results

The SFCI, PBS, and the CLASS were all given as pre- and post-assessments.

Prior to analyzing the mindset survey results (called the Personal Beliefs Survey, or PBS), the Likert scale questions needed to be recalculated. As seen in Appendix B, on half of the questions a score of "4: Strongly Agree" indicates a growth mindset while on the other half, the same response indicates a fixed mindset. This was done to randomize the questions so that student responses would be more accurate and would better represent their mindset. Because of this, half of the responses were reversed so that a score of 4 would always indicate a strong growth mindset and a score of 1 indicates a strong fixed mindset.

Below, the table shows analysis to compare the Simplified Force Concept Inventory (SFCI) and Personal Beliefs Survey (PBS) pre-assessments.

<table>
<thead>
<tr>
<th></th>
<th>Pre-SFCI Raw Scores (out of 30)</th>
<th>Pre-SFCI Percentages</th>
<th>Pre-PBS Raw Scores (out of 32)</th>
<th>Pre-PBS Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No Growth Mindset</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group Totals</td>
<td>7.6</td>
<td>25%</td>
<td>22.8</td>
<td>71%</td>
</tr>
<tr>
<td>Men</td>
<td>9.5</td>
<td>32%</td>
<td>22.4</td>
<td>70%</td>
</tr>
<tr>
<td>Women</td>
<td>6.6</td>
<td>22%</td>
<td>23.0</td>
<td>72%</td>
</tr>
<tr>
<td><strong>With Growth Mindset</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group Totals</td>
<td>7.4</td>
<td>25%</td>
<td>23.6</td>
<td>74%</td>
</tr>
<tr>
<td>Men</td>
<td>7.5</td>
<td>25%</td>
<td>24.6</td>
<td>77%</td>
</tr>
<tr>
<td>Women</td>
<td>7.3</td>
<td>24%</td>
<td>22.7</td>
<td>71%</td>
</tr>
</tbody>
</table>

Figure 2 Pre-Test average scores shown both as raw scores and as percentages, separated by group and by gender

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No GM</td>
<td>25%</td>
<td>0.804</td>
</tr>
<tr>
<td>With GM</td>
<td>25%</td>
<td></td>
</tr>
</tbody>
</table>
Because the p-values from the Sig. (2-tailed) tests were all larger than $\alpha = 0.05$, it was concluded that both the treatment and contrast groups were initially a part of the same population, meaning they had similar levels of understanding of Newtonian mechanics at the start of the school year.
Figure 5 Histogram of PBS pre-test percentages, p-value = 0.365

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No GM</td>
<td>70%</td>
<td>0.068</td>
</tr>
<tr>
<td>With GM</td>
<td>82%</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No GM</td>
<td>72%</td>
<td>0.783</td>
</tr>
<tr>
<td>With GM</td>
<td>71%</td>
<td></td>
</tr>
</tbody>
</table>
Figure 6 Histogram of PBS pre-test results, shown as decimal percentages & separated by gender, $p\text{-value}_{\text{men}} = 0.068$, $p\text{-value}_{\text{women}} = 0.783$

Similarly, all p-values for the PBS results were also larger than $\alpha = 0.05$, indicating that both the treatment and contrast groups were initially a part of the same population, meaning they had similar mindsets at the start of the year. It should be noted that since the average mindset score for both groups was between 70-85%, that the students tended to have more of a growth mindset rather than a fixed one. This was expected because the school had already taught about growth mindset in previous years.

In the CLASS students are given various statements (such as "There is usually only one correct approach to solving a physics problem") and asked to rate their agreement with the statement; which they indicate using a 5-point Likert scale. The purpose of this survey is to measure how many of a student's responses agree with (percent favorable) or disagree with (percent unfavorable) those of an expert physicist. To avoid discrepancies between students' interpretation of "strongly agree" and "agree", these answers were treated as the same response (as well as "strongly disagree" and "disagree"). When students answered, "neither agree nor disagree," this response was not included toward either average.

The survey is scored in eight categories: Sense Making/Effort, Problem Solving (PS) Sophistication, Problem Solving Confidence, Problem Solving General, Real World Connections, Personal Interest, Conceptual Understanding (CU), and Applied Conceptual Understanding (Applied CU). Each of the categories characterizes student views with 4-8 statements. An additional 9 statements are not in any of the eight categories. All responses (including the 9 additional statements) are then averaged to represent a student's "Overall" score. All of this analysis was done using the "CLASS Scoring Sheet" from the University of Colorado Boulder's Science Education Initiative website (CLASS, 2004). The data was divided by treatment/contrast group and occasionally by gender.
Note that even for the categories of Problem Solving Sophistication and Personal Interest, where there was the most discrepancy between groups, the p-values were larger than 0.05, indicating that both groups were part of the same population.

![CLASS Pre Scores](image)

**Figure 8 CLASS pre-test scores, divided by treatment and gender**

### Post-Test Results

The following data table shows the average scores (raw and percentages) for each group as a whole and separated by gender. Note the large percent difference in the PBS percentages between groups.

<table>
<thead>
<tr>
<th></th>
<th>Post-SFCI Raw Scores (out of 30)</th>
<th>Post-SFCI Percentages</th>
<th>Post-PBS Raw Scores (out of 32)</th>
<th>Post-PBS Percentages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group Totals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Growth Mindset</td>
<td>11.4</td>
<td>34%</td>
<td>23.4</td>
<td>71%</td>
</tr>
<tr>
<td>Men</td>
<td>15.4</td>
<td>46%</td>
<td>23.1</td>
<td>65%</td>
</tr>
<tr>
<td>Women</td>
<td>9.4</td>
<td>28%</td>
<td>23.6</td>
<td>74%</td>
</tr>
<tr>
<td>With Growth Mindset</td>
<td>11.4</td>
<td>37%</td>
<td>26.5</td>
<td>83%</td>
</tr>
<tr>
<td>Men</td>
<td>12.4</td>
<td>38%</td>
<td>27.6</td>
<td>86%</td>
</tr>
<tr>
<td>Women</td>
<td>10.7</td>
<td>36%</td>
<td>25.5</td>
<td>80%</td>
</tr>
</tbody>
</table>

![Figure 9 post-test scores shown both as raw scores and as percentages, separated by group and by gender](image)

Comparing the post-test scores with an Independent Samples T-Test (shown below) shows that, again using $\alpha = 0.05$, $t (0.839) = 0.033$ gave $p = 0.973$. Thus, we failed to reject the null hypothesis that the treatment group and contrast group were drawn from statistically similar populations. Therefore, there was no significant difference between the treatment and contrast groups for the SFCI Post-Test. Thus, we can conclude that although all students did improve their scores on the SFCI, and thus improved their understanding of Newtonian Mechanics, both groups had similar gains.
### Figure 10 Data of SFCI post-test percentages, p-value = 0.973

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No GM</td>
<td>51%</td>
<td>0.213</td>
</tr>
<tr>
<td>With GM</td>
<td>41%</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No GM</td>
<td>31%</td>
<td>0.370</td>
</tr>
<tr>
<td>With GM</td>
<td>36%</td>
<td></td>
</tr>
</tbody>
</table>
Figure 11 Data of SFCI post-test results as percentages, $p\text{-value}_{\text{men}} = 0.213$, $p\text{-value}_{\text{women}} = 0.370$

The following graphs show similar comparisons between groups and genders for the PBS. Here we see that the $p$-value comparing the two groups (0.002) was less than the statistical $\alpha = 0.05$, showing that students who received the growth mindset treatment did have a statistically different mindset than the contrast group by the end of the school year.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No GM</td>
<td>73%</td>
<td>0.002</td>
</tr>
<tr>
<td>With GM</td>
<td>83%</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12 Analysis of PBS post-test percentages, $p$-value =0.002
The following data shows the same independent sample t-test results as above but separated by gender. Note that these sample sizes are smaller than those used in the pre-tests because many students were absent the day this survey was given due to end-of-year testing. The p-values would indicate that the men had statistically different mindsets by the end of the year, while women did not. However due to such small sample sizes, it is believed that these results are not entirely indicative of the students' mindsets. This will be analyzed further when the percent change in PBS scores is discussed.

<table>
<thead>
<tr>
<th>Group</th>
<th>Mean</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No GM</td>
<td>72%</td>
<td>0.010</td>
</tr>
<tr>
<td>With GM</td>
<td>86%</td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No GM</td>
<td>74%</td>
<td>0.125</td>
</tr>
<tr>
<td>With GM</td>
<td>80%</td>
<td></td>
</tr>
</tbody>
</table>

![PBS Post-Test Scores](image)

**Figure 13** Analysis of PBS post-test results as percentages, $p_{\text{value}_{\text{men}}} = 0.010, p_{\text{value}_{\text{women}}} = 0.125$

The following table shows the results of a dependent sample t-test performed on the SFCI, in which both groups had a p-value less than 0.05. This indicates that these groups were no longer a part of the population they were at the beginning of the school year. This means there was a statistically significant increase on their pre- and post- SFCI assessment. Note that while both groups improved, they improved by similar amounts, as shown in previous analysis.

The PBS results showed that the Sig. 2-tailed value of 0.422 was larger than $\alpha = 0.05$, which means the contrast group did not demonstrate significant change between pre- and post- Personal Belief Survey (PBS) results. On the other hand, the treatment group did have a statistically significant increase in their PBS post-test results.
The following table shows the dependent sample t-test results separated by gender. Note that the sample sizes of each group have decreased because only students who took both the pre- and post-tests were included in this analysis.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Gender</th>
<th>Pair</th>
<th>FCIT Pre-Test - FCIT Post-Test</th>
<th>Mean</th>
<th>Std Deviation</th>
<th>Std Error Mean</th>
<th>65% Confidence Interval of the Difference</th>
<th>t</th>
<th>df</th>
<th>Sig (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>-1.67</td>
<td>2.054</td>
<td>6.73</td>
<td>-1.980</td>
<td>1.253</td>
<td>-2.240</td>
<td>17</td>
<td>.007</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>1</td>
<td>-5.556</td>
<td>5.766</td>
<td>1.923</td>
<td>-9.980</td>
<td>-1.121</td>
<td>-2.599</td>
<td>8</td>
<td>.020</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>-1.600</td>
<td>2.872</td>
<td>9.67</td>
<td>-3.208</td>
<td>1.208</td>
<td>-1.044</td>
<td>8</td>
<td>.327</td>
</tr>
<tr>
<td>with GM</td>
<td>Woman</td>
<td>1</td>
<td>-3.389</td>
<td>4.440</td>
<td>1.141</td>
<td>-5.796</td>
<td>-0.922</td>
<td>-2.970</td>
<td>17</td>
<td>.009</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>-2.818</td>
<td>5.076</td>
<td>1.533</td>
<td>-6.228</td>
<td>-0.592</td>
<td>-1.841</td>
<td>10</td>
<td>.095</td>
</tr>
</tbody>
</table>

The following chart shows the differences in the gains on the SFCI and the Personal Beliefs Survey. This data shows that both groups improved their SFCI scores by a statistically similar amount but that the level of growth on the PBS was different between the groups. The contrast group had an average shift of -1%, while the treatment group had an average shift of 13% towards a stronger growth mindset. This supports the previous statements that the contrast group's PBS score did not statistically change by the end of the year, while the treatment group's score did show a significant improvement.
The following graphs show correlations between SFCI and PBS post-test scores for each group, shown as a whole and separated by gender. In all charts, the scores for the students in the treatment group tend to be more to the right (higher PBS score, stronger growth mindset) but at approximately the same vertical position (same SFCI scores, similar understandings of Newtonian mechanics).
The following graphs show the results from the CLASS post-test, separated by treatment.
The graphs above demonstrate the differences between the pre- and post- CLASS scores for both groups. The categories with the largest gains were Conceptual Understanding and Applied Conceptual Understanding (in both groups) and Problem Solving Sophistication (in the treatment group). These
results are similar to those of a previous study, shown in the next graph. These results come from introductory physics courses (designed for novices of physics, who did not intend to go into science careers) at seven different universities, of class sizes ranging from 13 to 100 (Otero, 2008).

As summarized in the discussion of the Otero results:

"The highest shifts for PET and PSET students were made in the following categories: personal interest, problem-solving sophistication, conceptual understanding, and applied conceptual understanding. These categories are similar to one another but have subtle differences. Overall, these categories assess students’ beliefs about the structure of knowledge (i.e., is it a set of isolated facts handed down from authority, or connected concepts that should make sense to the learner?). These categories also assess students’ views on the extent to which one’s conceptual understanding (in contrast to formulaic manipulation and memorized facts) can and should be used in the process of solving physics problems" (Otero, 2008).

The following graphs demonstrate the average percentage shifts among students of both the treatment and contrast groups. A higher percentage on the "favorable" score and a lower percentage on
the "unfavorable" score indicates that a student's responses were more in agreement with those of an expert. If a student's answers were more contrary to an expert's, this would be seen as a decrease in their "favorable" score and an increase in their "unfavorable score." The total scores are separated by treatment group and by gender.

For the following graph, ideally the scores for all categories would show a high positive value, showing an increase in the similarity (favorable percentage) between student responses and those of an expert.

![Figure 24 CLASS average gains in favorable score, divided by treatment](image1)

![Figure 25 CLASS average gains in favorable score, divided by treatment and gender](image2)

In the next graph, ideally the scores for all categories would show a high negative value, showing a decrease in the dissimilarity (unfavorable percentage) between student responses an expert's.
Figure 26 CLASS average gains in unfavorable score, divided by treatment

Figure 27 CLASS average gains in unfavorable score, divided by treatment and gender

Figure 28 Highlight of average favorable scores, showing only categories where students' attitudes in at least one treatment group shifted greater than 10%
Figure 29 Overall attitude shift, compared by treatment

Figure 30 Overall attitude shift of women, compared by treatment
The following graphs show the pre- and post- CLASS scores for each group, broken down by gender. Note that ideally students’ scores would shift upward and to the left, indicating a high level of agreement (percent favorable) and a low level of disagreement (percent unfavorable) with expert opinions.
Figure 33 CLASS correlations: men's scores from the group without growth mindset treatment

Figure 34 CLASS correlations: women's scores from the group with growth mindset treatment
At the conclusion of the school year, all students took a Student Reaction Survey (Appendix D) in which they were asked to respond to a series of questions assessing the frequency of growth mindset instruction (both in the investigator's classes and otherwise), and their attitudes about growth mindset (using a 4-point Likert scale). This survey was different from the Personal Beliefs Survey in that students were asked explicitly how they felt about growth mindset (with questions such as, "Learning about growth mindset was helpful to me."). In order to analyze the responses using an Independent Samples T-Test, the responses were recoded as numerical values (1 for strongly disagree and 4 for strongly agree) and then analyzed using SPSS. The following table is a general analysis comparing the treatment and contrast groups to check for statistically significant differences in their responses.

<table>
<thead>
<tr>
<th>Student Reaction Survey Group Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>treatment</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>SRS #1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>SRS #2</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>SRS #3</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>SRS #4-7</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>SRS #9</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Using $\alpha = 0.05$, students in both treatment groups have similar overall responses for questions 1 and 3 of the Student Reaction Survey. Below are the histograms showing the responses for these questions.

Figure 36 SPSS independent sample t-tests for SRS results

<table>
<thead>
<tr>
<th>SRS #1</th>
<th>Equal variances assumed</th>
<th>Levene's Test for Equality of Variances</th>
<th>Student's Test for Equality of Means</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>Sig</td>
<td>t</td>
<td>df</td>
</tr>
<tr>
<td>SRS #1</td>
<td>7.000</td>
<td>.007</td>
<td>-1.185</td>
<td>49</td>
</tr>
<tr>
<td>SRS #2</td>
<td>Equal variances NOT assumed</td>
<td>-1.218</td>
<td>43.955</td>
<td>.230</td>
</tr>
<tr>
<td>SRS #3</td>
<td>Equal variances assumed</td>
<td>.054</td>
<td>.801</td>
<td>-2.481</td>
</tr>
<tr>
<td>SRS #4</td>
<td>Equal variances assumed</td>
<td>.341</td>
<td>.562</td>
<td>-1.134</td>
</tr>
<tr>
<td>SRS #7</td>
<td>Equal variances assumed</td>
<td>.026</td>
<td>.517</td>
<td>-5.199</td>
</tr>
<tr>
<td>SRS #8</td>
<td>Equal variances assumed</td>
<td>.203</td>
<td>.654</td>
<td>-3.781</td>
</tr>
</tbody>
</table>

Figure 37 Responses from Student Reaction Survey question #1, $p$-value $= 0.230$

The following graph shows the frequency of responses for the second question on the Student Reaction Survey, which supports the analysis above that students experienced different levels of growth mindset interaction from the investigator.
This analysis was important because it showed that students in both treatment groups had similar outside exposure to growth mindset concepts. From these results it can be concluded that any changes in growth mindset were due to the investigator's treatment and not from outside influences.

Questions 4-7 on the SRS assessed students' attitude towards growth mindset, asking students to provide their level of agreement with statements such as "Learning about growth mindset vs fixed mindset was helpful to me." Responses were averaged and compared using the SPSS analysis above and using the histogram below. The following chart shows that students who received the growth mindset treatment from the investigator had a more positive attitude towards growth mindset than those who were taught these concepts elsewhere.
The final question of the SRS gauged students' confidence in being able to succeed in future classes. The SPSS table previously and the histogram below demonstrate a clear difference between the treatment and contrast group. They show that all surveyed students who were taught growth mindset felt confident in being able to do well in future classes; and that there was a shift toward the "strongly agree" side of the spectrum.

The following graph shows a correlation between student responses to question 8 of the SRS (shown in the chart above) and their mindset (using their PBS post-test score). Notice that students with a higher PBS gain tended to also be more confident in their ability to succeed in future classes.
Figure 42 Correlation of PBS post-test scores and responses from SRS #8, assessing student confidence to do well in future classes.

The graphs below demonstrate the same correlation separated by gender. Note that, when students were not taught growth mindset by the investigator, women tend to have a shift towards having a fixed mindset and men tend to have a neutral mindset. Both genders show the same correlation that a higher PBS gain also denotes a higher confidence in future classes.

Figure 43 Correlation of women's PBS post-test scores and responses from SRS #8, assessing student confidence to do well in future classes.
Figure 44 Correlation of men's PBS post-test scores and responses from SRS #8, assessing student confidence to do well in future classes.
CONCLUSION

A complication that arose during the year that impacted these results was that the investigator's campus had an unexpected focus on growth mindset. As shown in the third question of the Student Reaction Survey, all students received frequent lessons on growth mindset from other teachers. In addition, students began to have an overall negative attitude towards growth mindset and many of the key phrases used such as "yet" and "keep trying." As a result of this, the investigator chose to alter the method of treatment by using fewer and less frequent lessons than was originally planned. Originally, the investigator was going to teach growth mindset twice a month but she altered this plan to teaching students about growth mindset concepts (without referencing "mindset") approximately once a month. Additionally, the investigator waited until later in the year to use the phrase "growth mindset" and to use those key phrases herself.

Using the analysis described previously, it was proven that the 61 students who participated in this study were from the same initial population. This was true both for their understanding of Newtonian Mechanics (measured using the SFCI) and in their mindset (measured using the PBS).

By the end of the year, both groups showed improvement in their SFCI scores, but the level of improvement was similar for each group. On the other hand, the treatment and contrast groups differed greatly in their Personal Beliefs Survey (PBS) results. Only the students in the treatment group had significant changes in their mindset. The PBS also showed that women (who are typically a minority in science and especially in physics) tended to be influenced more by the growth mindset treatment and had a larger gain towards a growth mindset than men. These results suggest that using the Modeling method of teaching does not inherently shift students' mindsets, at least in the context of an IGCSE Physics classroom. This would also suggest that having a growth mindset does not affect one's final understanding of class content. However, this is in direct contrast to the results of the study done by Flores, Lemons, and McTernan (Flores, 2011). A reason for this may be that the SFCI assesses students on much deeper content than that discussed in the investigator's IGCSE physics class. Another aspect that may have affected these results is the infrequency that growth mindset concepts were taught due to the reasons discussed above. Because of these reasons, the investigator believes there is still the possibility that students could have scored higher on an end-of-year concept assessment under different circumstances.

The SRS demonstrated that at the end of the year, the contrast group had a relatively negative attitude towards growth mindset while the treatment group had a relatively positive attitude. In addition, both men and women of the treatment group had similarly positive views of growth mindset. The treatment group also had more overall confidence that they could succeed in future classes than the classes without the growth mindset treatment.

When comparing contrast and treatment groups, CLASS results showed that students who received growth mindset treatment had a more positive attitude toward science by the end of the year. These results also showed that both groups improved in their attitudes towards Conceptual Understanding by approximately 10%. When this data was separated by gender, at least one gender experienced shifts larger than 10% in the following categories: Personal Interest, Problem Solving General, Problem Solving Sophistication, Applied Conceptual Understanding, and Conceptual Understanding. Men appeared to be greatly influenced in the Real World Connections category, where the attitudes of male students in the contrast group worsened by 11% and the attitudes of those in the treatment group improved by approximately 10%.

Another result of this study is that although all students received some form of instruction on growth mindset during the school year, only the students who were taught by the investigator showed gains in their mindset. This would suggest that the method used to teach growth mindset is extremely important. Prior to the investigator's lesson on growth mindset, students were asked to write down their current definition of having a growth mindset. In general, students completed this task quickly and halfheartedly. Three student examples were "a mindset inclined towards believing that one can achieve anything when attempted with enough effort" and "to be very positive and know making mistakes is okay. It is all about improving and showing growth" and "when you think positive thoughts that allow you to grow in a specific field or as a person in general." Note the common theme of an emphasis on effort and
on thinking positively. When students shared their definitions in an in-class discussion, many students echoed these sentiments. While doing so, students expressed their frustration and boredom with growth mindset. At this point in the year, they said they were tired of hearing about mindset and of being told that all they needed to do to succeed was to "try harder." This is an example of a "false growth mindset" as discussed previously in this report. It is the investigator's conclusion that putting too much emphasis on "improved effort" becomes a hindrance to improving one's mindset. With this emphasis, it is possible that students begin to feel like they are told that their previous effort was not a productive use of time. As a result of this, students become less motivated to overcome difficulties and challenges. After students shared their current definitions of growth mindset, the investigator led a class discussion summarizing the lessons and conversations that had occurred previously in the year. During this discussion the investigator expressed (using analogies about video games and sports) one of the key factors of growth mindset: that it is important not to just try again but to try again with a new strategy. This gave students a new perspective on the importance of learning from mistakes, which the students seemed very appreciative of. Students seemed really receptive of this conversation and, as seen in the Student Reaction Survey results, had a more positive attitude towards growth mindset afterward. At the conclusion of the discussion, students were asked to rewrite their definition of growth mindset. Students took a longer time to do so and were more thoughtful when writing these new definitions. In addition, many students included the idea of trying a new approach or a new strategy. The rewritten definitions from the three students above are as follows: "a mindset inclined towards believing that one can achieve anything when attempted with enough effort with the right approach" (it should be noted that this student specifically called the investigator over to proudly show her this revised definition), "to thrive to be the best you can be and what you want to pursue. There are no perfect ways yet many strategies to try and achieve your goal and even your dream," and "a growth mindset is not only not giving up or trying, it's pushing yourself to find multiple ways around an issue and finding the one that is best for you and helps you achieve things."

Because of these (and many other) responses, an unintended conclusion of this study is that the way growth mindset is taught is vital to student perception and implementation of it. Students who had a negative opinion on growth mindset did not have a significant positive shift in their mindset (some students even had a very negative shift). This may have also then influenced student confidence in facing future challenges and future classes.
IMPLICATIONS FOR FURTHER RESEARCH

This study was limited in its results because of the SFCI and its inconsistency with the IGCSE curriculum. Future studies may want to use a different, more encompassing assessment of physics content knowledge. A concept inventory on physical science may be more appropriate. Alternatively, a teacher may wish to combine various concept inventories to more closely correspond with the IGCSE standards.

Future studies could also focus on the Adams et al. results of the CLASS, which demonstrated that "comparing responses from men and women in the same classes, which typically represent the same set of majors, women are generally less expert-like on statements in the ‘Real World Connections’, ‘Personal Interest’, ‘Problem Solving Confidence’ and ‘Problem Solving Sophistication’ categories and a bit more expert-like on some ‘Sense-Making/Effort’ type statements" (Adams et al., 2006). An analysis for these categories from this investigator's study is included in Appendix F.

Another option would be to introduce the idea of growth mindset earlier and more frequently in the school year as was initially intended in this study. This would allow teachers to more clearly unify each conversation to a central theme of student mindset. This may also allow students to better identify the aspects of the Modeling method of teaching that correspond with the concepts of growth mindset. This is especially true when observing how many different models and methods of representation of the model are used in modeling. Each method includes several different approaches or strategies that students can use to better understand the physics content. If students are able to identify this, they may be more motivated (because of the belief that although one representation did not work, that there is another one that will) and more confident (because in each unit students can look forward to and focus on the representations that they believe work best for them). This may also help students to be more open to the modeling method because they can understand the purpose behind each different representation.

Further research may also include the study of "grit," which takes the idea of growth mindset further. The concept of growth mindset focuses on effort and changing one's approach to a problem, but "grit" is the trait required to keep persevering through each repeated attempt. Grit is defined as "trait-level perseverance and passion for long-term goals, and research showed that grit predicted achievement in challenging domains over and beyond measures of talent" (Duckworth & Quinn, 2009, p. 166). Pairing the idea that one can improve (growth mindset) and the perseverance to keep trying new methods (grit) can be extremely beneficial, especially for students as they are learning new and challenging content.
REFERENCES


Clement, John, DEVELOPING THINKING SKILLS WRITTEN ASSIGNMENT. http://modeling.asu.edu/modeling/weblinks.html in the section on research results.


“Learning Styles Inventory.” San Jose State University. http://www.sjsu.edu/eop/current-students/workshops/ACADEMIC_Learning%20Style%20Inventory.pdf


43
Dear Parent,

Mrs. Jerika McKeon is a high school physics teacher at ASU Preparatory Academy. She is currently a graduate student under the direction of Professor Culbertson in the Department of Physics at Arizona State University and is conducting research to study the correlation between a modeling physics pedagogy and student mindset development (growth vs. fixed).

I am inviting your child’s participation, which will involve taking a pre-mindset and post-mindset survey, a pre- and post-attitude survey and a pre- and post-physics conceptual understanding test. Your child’s participation in this study is voluntary. If you choose not to have your child participate or to withdraw your child from the study at any time, there will be no penalty (it will not affect your child’s grade, treatment/care, etc.) Likewise, if your child chooses not to participate or withdraw from the study at any time, there will be no penalty. The results of the study may be published but your child’s name will not be used. Your child has the right not to answer any question, and to stop participation at any time.

There may be no direct benefit to your child participating in the study. There are no foreseeable risks or discomforts to your child’s participation.

Confidentiality will be maintained by keeping all pre-tests and post-tests locked in a secure location. Additionally, any electronic information collected will be kept on a password protected computer. All student responses will be confidential and student ID codes will be used to minimize any risk of names being used. The results of this study may be used in reports, presentations, or publications but your child’s name will not be known.

If you have any questions concerning the research study or your child’s participation in this study, please contact me at jmckeon2@asu.edu.

By signing below, you are giving consent for your child ____________________ to participate in the above study.

Name: ________________________________
Signature_________________________________ Date: __________________________

If you have any questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at (480) 965-6788. You are also free to contact the Principal Investigator, Dr. Robert Culbertson at Arizona State University at (480) 965-0945 or email robert.culbertson@asu.edu.
APPENDIX B: PERSONAL BELIEFS SURVEY (PBS)

Please answer these survey questions about intelligence and personal qualities. You are asked to identify how much you agree or disagree with a statement. Select a number that best corresponds to your beliefs about the truth of the statement. If you believe completely in a statement you would mark a “1” and if you thought the statement was totally wrong, you would mark a “4”.

Part I:
“1” indicates you strongly agree and “4” indicates you strongly disagree. “2” and “3” are in between at “agree” and “disagree”.

1. You can learn new things, but you can’t really change how intelligent you are.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
2. You can always change basic things about the kind of person that you are.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
3. No matter how much intelligence you have, you can always change it quite a bit.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
4. You can do things differently, but the important parts of who you are can’t really be changed.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
5. No matter what kind of person you are, you can always change substantially.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
6. You are a certain kind of person, and there is not much that can really be done to change that.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
7. You can always substantially change how intelligent you are.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
8. Your intelligence is something very basic about you that can’t change very much.
   (1) Strongly Agree  (2) Agree  (3) Disagree  (4) Strongly Disagree
Part II:
Read the situations. There are three situations given. Choose 2 of the situations that you can most relate to and respond to both. Be as clear as you can, and use complete sentences. For each answer choice try to include the following:

1. Identify 3-4 feelings you would have in this situation.
2. Identify at least two options for how you would respond.

Situation A:
You have started a class to learn a language about which you know little to nothing. After 2 classes, the instructor calls you to the front of the room and starts throwing questions at you one after another.

Situation B:
You are given math problems to solve for homework. At home you try the first problem and it looks really difficult. You skip to the second and it looks harder than the first! You are not sure where to begin. A quick glance at the others in the assignment reveals they are about the same difficulty.

Situation C:
You go to your favorite but most difficult class and wait in anticipation to get your test back. You thought you did really well on it. But when you receive it, you find out you got a C+ on it. After school in baseball practice you struck out twice, popped out and dropped a relay throw. You head home and get caught speeding. The officer gives you a ticket. When you get home, you call your best friend, but the friend says, “I’m at work and can’t talk to you right now.” and hangs up.
Appendix C: Colorado Learning Attitudes about Science Survey (CLASS)

Introduction
Here are a number of statements that may or may not describe your beliefs about learning physics. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean the following:

1. Strongly Disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Survey

1. A significant problem in learning physics is being able to memorize all the information I need to know.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

2. When I am solving a physics problem, I try to decide what would be a reasonable value for the answer.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

3. I think about the physics I experience in everyday life.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

4. It is useful for me to do lots and lots of problems when learning physics.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

5. After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

6. Knowledge in physics consists of many disconnected topics.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

7. As physicists learn more, most physics ideas we use today are likely to be proven wrong.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

8. When I solve a physics problem, I locate an equation that uses the variables given in the problem and plug in the values.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
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<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
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</table>
9. I find that reading the text in detail is a good way for me to learn physics.

10. There is usually only one correct approach to solving a physics problem.

11. I am not satisfied until I understand why something works the way it does.

12. I cannot learn physics if the teacher does not explain things well in class.

13. I do not expect physics equations to help my understanding of the ideas; they are just for doing calculations.

14. I study physics to learn knowledge that will be useful in my life outside of school.

15. If I get stuck on a physics problem my first try, I usually try to figure out a different way that works.

16. Nearly everyone is capable of understanding physics if they work at it.

17. Understanding physics basically means being able to recall something you've read or been shown.

18. There could be two different correct values to a physics problem if I use two different approaches.

19. To understand physics I discuss it with friends and other students.

20. I do not spend more than five minutes stuck on a physics problem before giving up or seeking help from someone else.

21. If I don't remember a particular equation needed to solve a problem on an exam, there's nothing much I can do (legally!) to come up with it.
22. If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.

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<tr>
<th>Strongly Disagree</th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
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23. In doing a physics problem, if my calculation gives a result very different from what I'd expect, I'd trust the calculation rather than going back through the problem.

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<thead>
<tr>
<th>Strongly Disagree</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
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</table>

24. In physics, it is important for me to make sense out of formulas before I can use them correctly.

<table>
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<th>Strongly Disagree</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
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</table>

25. I enjoy solving physics problems.

<table>
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<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
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</table>

26. In physics, mathematical formulas express meaningful relationships among measurable quantities.

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<tr>
<th>Strongly Disagree</th>
<th>1</th>
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<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
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</table>

27. It is important for the government to approve new scientific ideas before they can be widely accepted.

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<tr>
<th>Strongly Disagree</th>
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<th>Strongly Agree</th>
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28. Learning physics changes my ideas about how the world works.

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<tr>
<th>Strongly Disagree</th>
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<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
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</table>

29. To learn physics, I only need to memorize solutions to sample problems.

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<thead>
<tr>
<th>Strongly Disagree</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

30. Reasoning skills used to understand physics can be helpful to me in my everyday life.

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<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

31. We use this statement to discard the survey of people who are not reading the questions. Please select agree-option 4 (not strongly agree) for this question to preserve your answers.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
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</table>

32. Spending a lot of time understanding where formulas come from is a waste of time.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

33. I find carefully analyzing only a few problems in detail is a good way for me to learn physics.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

34. I can usually figure out a way to solve physics problems.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
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<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

35. The subject of physics has little relation to what I experience in the real world.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>
36. There are times I solve a physics problem more than one way to help my understanding.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

37. To understand physics, I sometimes think about my personal experiences and relate them to the topic being analyzed.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

38. It is possible to explain physics ideas without mathematical formulas.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

39. When I solve a physics problem, I explicitly think about which physics ideas apply to the problem.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

40. If I get stuck on a physics problem, there is no chance I'll figure it out on my own.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

41. It is possible for physicists to carefully perform the same experiment and get two very different results that are both correct.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

42. When studying physics, I relate the important information to what I already know rather than just memorizing it the way it is presented.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>1</th>
<th>2</th>
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<th>5</th>
<th>Strongly Agree</th>
</tr>
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</table>
APPENDIX D: STUDENT REACTION SURVEY (SRS)

Please answer all questions openly and honestly. Your responses will not impact your course grade.

1. Had you heard of growth and fixed mindsets before this school year? If so, where did you hear it from?
   a. Never heard of it
   b. A teacher at this school
   c. At another school
   d. At home
   e. Other (please specify): ___________________

2. On average, how often do you remember THIS teacher mentioning growth mindset in this school year?
   a. More than once a class period
   b. Once a class period
   c. Once a week
   d. Once a month
   e. Once a quarter
   f. Less than once a quarter
   g. Never

3. On average, how often do you remember other teachers mentioning growth mindset in this school year?
   a. More than once a class period
   b. Once a class period
   c. Once a week
   d. Once a month
   e. Once a quarter
   f. Less than once a quarter
   g. Never

Please say how strongly you agree or disagree with a statement. “1” indicates you strongly agree and “4” indicates you strongly disagree. “2” and “3” are in between, at “agree” and “disagree”.

4. Learning about growth vs fixed mindset was helpful to me.
   (1) Strongly Agree   (2) Agree   (3) Disagree   (4) Strongly Disagree

5. I will try to have a growth mindset in the future.
   (1) Strongly Agree   (2) Agree   (3) Disagree   (4) Strongly Disagree

6. Having a growth mindset can be helpful to me, outside of school.
   (1) Strongly Agree   (2) Agree   (3) Disagree   (4) Strongly Disagree

7. Learning about mindset has helped me to better face a challenging situation.
   (1) Strongly Agree   (2) Agree   (3) Disagree   (4) Strongly Disagree

8. I feel confident about my ability to do well in future classes.
   (1) Strongly Agree   (2) Agree   (3) Disagree   (4) Strongly Disagree
Please answer the following questions in complete sentences.

9. What is your current attitude (positive or negative) about growth mindset?

10. Help THIS teacher to do a better job teaching growth mindset. What suggestions do you have, to improve the teaching of growth mindset?
APPENDIX E: DEVELOPING THINKING SKILLS WRITTEN ASSIGNMENT
This assignment was given on 11/19/18

This reading is required for this course. To make sure that you have actually done the reading, you are required to turn in a short writing exercise about it, worth one homework grade. It will not be graded for grammar, punctuation or accuracy. Please submit the written response electronically, via the Google form on the class website. You will get full credit if it reflects the reading contents and is not a duplicate of another student’s submission.

Development of Thinking Skills

There has long been a debate about talents and abilities. Some people think that talents are entirely inborn or determined by the genes you get from your parents. Others think that talents are entirely the product of your training. In the middle of the 20th century most psychologists were saying that IQ was fixed when you were born and could not be changed. This opinion was reinforced by giving tests to children as they grew up, and results seemed to always place them in the same relative positions. Unfortunately, they did not consider that the unchanged IQ scores might be caused by the similar schooling of the students.

Since that time scientists have found evidence that the brain is extremely plastic. It can rewire to suit various conditions, and individuals can acquire talents and abilities at all ages. While the ability to learn new concepts does decrease somewhat with age, it never goes away. There have been several dramatic demonstrations of this by researchers since the mid 20th century.

Reuven Feuerstein, an Israeli psychologist, works with students who have grown up in bad conditions. These are students who failed to achieve normal intelligence because of war, discrimination, or poverty. He took teenagers who had IQs as low as 65 and worked with them individually. They often had vocabularies of only a few hundred words and could neither read nor write. After treatment their IQ scores would be a normal 100 or sometimes superior. He went further by working with students at a boarding school for students who were 2 years behind in their schooling in the 1970s. The students were divided into 2 groups. One group was treated by Feuerstein, while the other was taught a teacher-designed enrichment course. When they reached 18 they were all tested for mandatory enlistment into the Israeli army. The Feuerstein-treated students showed normal intelligence while the other group was more than 20 points lower. The treatment had improved intelligence!

Michael Shayer and Philip Adey in England devised a special set of activities to be used in class in the 1980s. They used their lessons in middle schools where students scored lower on standardized tests. At the end of high school, the students in these schools scored higher by 20% in science, 19% in math, and 15% in English. Essentially the students became more intelligent, so they could learn better.

Many other studies show that IQ and various thinking skills can improve. All of the methods for doing this rely on having students do the thinking. The teacher does very little lecturing. Students work together in groups to help one another understand how to do the “thinking” activities. The teacher generally asks questions rather than giving answers, and he solicits answers from students. This style of teaching was invented by Socrates.

This style of education is very different from what most students have experienced, so they may find it stressful. It is like learning to navigate in new city. At first you are lost and confused. Then gradually you build up a mental map of nearby locations. With experience this mental map expands, and eventually you can navigate the whole city. You may need to learn how to use aids such as your smart phone to navigate to unfamiliar areas, but with practice that is not as necessary.
Sometimes you may be confused when tackling something completely new. The good news is that you can improve your ability to think. High school physics teachers have seen students improve their math SAT scores by 100 points!

This should not be surprising. When you exercise with weights your muscles build new cells and become larger. This takes time and can’t be done overnight. It may sometimes be uncomfortable. Improving intelligence and ability requires “brain exercise”. You literally grow new connections, but it also takes time.

Finally, consider how you might change your approach to learning. What would you do differently to improve your learning ability?

Writing: Write a letter to a friend to needs this information. It can be a real friend or an imaginary one, and you can use a made-up name. The letter is no more than one page. Remember this is not an English exercise, but please do not write it like short text messages.

Sample Student Responses:
I have come to tell you about the changes that you can undergo regarding intelligence. It was once thought that the intellectual talents of a person were determined forever once they were born, that they could not improve upon these talents once they were born. However, through many experiments, this was later proven wrong. Experiments showed that one’s intelligence can improve significantly if cultivated in the right manner. The way this works is by creating new connections between the new and larger cells that are made in your brain, improving intelligence.

As of now, you might not feel fantastic about your grades, or your intelligence in total. I’ll have you know that you have no need to feel down about yourself in any way. Our brains aren’t stuck to being “smart” or “dumb.” In fact, our brains really aren’t stuck to anything at all. The human brain has been proven to be (figuratively) more malleable than rubber, if put in the right conditions. Those conditions really just sum down to a will to learn. Anyone can change to be who they want to be, if they have the right mindset. Don’t believe me? Here’s some legitimate proof I’m not just lying to make you feel good. A psychologist from Israel named Reuben Feuerstein works with students who live in struggling conditions, who weren’t given the proper resources to have a good education. He takes students who have IQ’s near 65 and gave a good, individual education to them, and was able to bring their IQ’s up to an average of 100 or more. This obviously isn’t an easy feat, to rewire your brain. It takes time and a lot of effort, as many things do, such as learning another language or building muscle. However, in the end, it’s worthwhile (and absolutely possible) to give full effort to make a change to what you want to accomplish and who you want to be. Besides, you can do anything with a strong belief and a little help from friends!

Believe it or not, you do not stay with the same level of intelligence that you are born with throughout your entire life. According to Development of Thinking Skills, back in the middle of the 20th century, lots of psychologists thought that your IQ never changed. So, if you were a really smart baby, then you would be really smart when you became an adult. If you were a really not-smart baby, then you would be really not-smart when you became an adult. Fast forward a few years to the 1970’s and 1980’s, and treatments are given to high school students that can boost their intelligence. Now it has been realized that you can become smarter by changing the way you learn. The brain is actually “extremely plastic,” and can “rewire.” The brain is moldable and can change your level of intelligence. The brain never loses the ability to learn, so your IQ can change all your life. You may be wondering why I am writing this letter.
That is a very good question. I know that you are not happy with your IQ right now. You are having trouble learning, and you want to learn more. However, I have noticed that your school is very boring, and there is a lot of lecturing done, and not much hands-on activity. Well, according to Development of Thinking Skills, students like you actually learn best when they do things themselves with teacher guidance and little lecturing. The teacher can prompt the students and ask questions, and the students can work together to solve them. This is a very successful way to learn because you are doing the work yourself and putting in the effort. You can teach yourself in a way that works for you, helping yourself understand the concepts being learned. Doing this may help you learn better. How would I improve my learning ability? I would do more practice on my own using teacher guidance. Hands-on activities would help me ensure that I know how to implement the knowledge that I have learned on my own. Anyways, I hope you use this information to better your learning. See you tomorrow.

I just wanted to inform you about a few of the miraculous studies scientist have done regarding human skills and abilities. For example, did you know that people used to think that intelligence was strictly based off of genetics? Crazy right? Well anyways, multiple scientist helped to prove this idea wrong. One such was Reuven Feuerstein. He basically took students who demonstrated lower IQ scores and taught them individually. This worked and made the students have much higher scores. This new thought process began to be used by numerous teachers and scientist, mostly with allowing the students to figure it out themselves with groups of other children, which was a method by Socrates. So, overall what I’m trying to say is, you are smarter than you think, you just need approach your math homework in a different method that works for you. This will help create new connections in the mind.

I hope your Thanksgiving went well. I read this article that I found very interesting, and I thought that you would like it. It was about how to develop your thinking skills. The article stated that intelligence can be learned, and it is not necessarily hereditary/genetic. An evidence provided by the article to support this claim, was that a psychologist worked with students that were raised in not exactly the most beneficial environment, and that had low IQ scores, and could neither read nor write. After working with them, it was shown that their IQ scores had a significant increase. This shows a person's intelligence is greatly impacted by the environment in which they were exposed to, and not necessarily based on their genetics. This also shows that the human brain is elastic (plastic) and can be reshaped based on the conditions and environment the person is exposed to. Someone can also improve their intelligence, based on the way they are taught, or the way they learn, for example a student will learn more when the teacher engages them in the class discussions, makes them work on projects together, and also makes them to answer questions instead of the teacher just lecturing. This makes the student to think more, and also process the information better. Finally, someone can reshape their brain, to learn a new activity (Sport, game, cooking, etc.), and by doing that over and over again, they can be good at that activity. All these prove that a person is not necessarily born with intelligence or the knowledge of a skill, but they have to learn and be familiar with that knowledge, and their knowledge also depends on their environment as well. So, I hope you find this information useful, and if you do help me spread the word. :).

I have just obtained some information about developing thinking skills and growing intelligence. I believe this is very vital for you and can help you develop into a more knowledgeable and smart individual. I have learned myself these new tidbits and recognized a new way in thinking and a better path way in which my brain can grow and thrive. I want to share my knowledge from Developing Thinking Skills Written Assignment with you in order to influence your attitude towards learning in school now. After reading the text, the writer provided many examples in which the intelligence of an organism can improve with the right training and knowledge. Also, in the reading the writer can confirm that beforehand scientists had thought that you were born with your IQ from your parents, but you’re not. You have way more potential and can build up your mind into a stronger and buff brain. I know that sounds pretty weird, yet if you think about it, your brain is a muscle and can grow stronger and make more connections.
In the end, I believe it’s possible to improve both our minds together and build a stronger brain. We can do it!!

I've recently heard that you need help with critical thinking to understand your math and English class a little bit better. I've found a way to help you. The way you should be learning and comprehending new information is to practice the topic at hand and to be asked questions by the teacher in which you answer to your best ability. Hands-on learning and working with groups are better for understanding tough subjects and raising your IQ level. A very good example of how to learn is by Reuven Feuerstein's teachings. He worked with students who faced large disadvantages such as poverty and discrimination and educated them enough so they could be admitted into the Military.

I haven't talked to you in quite a while, but I thought you needed this. In my physics class we discussed the brain and developing thinking skills. Apparently, our brains are able to rewrite themselves to suit conditions and challenges in our lives, and the ability to do this never goes away. When we were learning about this, it made me think of you. You went on about how our brains are hardwired for certain things when in reality... it's actually the complete opposite. You see, the brain is like a muscle, and the more you work a muscle, the stronger it gets. So essentially, whenever you are struggling in a topic, if you keep practicing and working hard, them eventually it will become easier and easier. It’s even been proven though various tests! In the 1980s, two men from England devised special lessons for students who scored low on tests, and by the end, the students had improved by 20% in some cases and reported that they could learn and work easier after the lessons.
APPENDIX F: ADAMS ET. AL. COMPARISON

The Adams et al. group used the CLASS survey in university classes and "administered the CLASS survey before (pre) and after (post) instruction to over 7,000 students in 60 physics courses. In addition, faculty members from at least 45 other universities are using the CLASS in their physics courses" (Adams et al., 2006).

The data was analyzed to see similarities and differences between classes and for different genders. The results of that study demonstrated that "Comparing responses from men and women in the same classes, which typically represent the same set of majors, women are generally less expert-like on statements in the ‘Real World Connections’, ‘Personal Interest’, ‘Problem Solving Confidence’ and ‘Problem Solving Sophistication’ categories and a bit more expert-like on some ‘Sense-Making/Effort’ type statements" (Adams et al., 2006). The following graphs compare the CLASS scores from this investigator's study for these categories.

This first chart (of pre-test scores) shows that in general, women in the contrast group had a lower average for the expected categories and were higher in the Sense-Making/Effort category, again as anticipated. But they did score similarly to the men in the Problem Solving Sophistication section. However, these results were not the same as in the treatment group. In these classes, women began with lower attitudes than the men in their classes in only one category: Problem Solving Sophistication. In the Problem Solving Confidence section, women and men in the treatment group had approximately the same results. In the rest of the sections, the women in the treatment group had more expert-like responses than the men in the same classes.

![Adams et al. Comparison - Pre](image)

**Figure 45 Adams et al. comparison of pre-test scores for both groups, separated by gender**

The next graph shows the average shifts that each gender experienced in each of these categories during the course of the school year. Ideally all categories would have a positive shift in their average scores, showing more similarity with the opinions of experts.
Figure 46  Adams et al. comparison of changes in scores for both groups, separated by gender

Figure 47  Adams et al. comparison of post-test scores for both groups, separated by gender