

The Correlation between Student Growth Mindset and Conceptual Development in Physics

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Abstract

Research by Carol Dweck of Stanford University has demonstrated that all learners have one of two fundamental sets of beliefs about learning and the process of learning. Dweck refers to these beliefs as a mindset¹. (Dweck, 2008). Dweck has shown that students with the belief set termed a growth mindset reach a greater level of understanding in a junior high math classroom and in college pre-med classes. She has shown that it is possible to predict what kind of grades that student will likely earn in junior high if the student's mindset is known. (Aldhous,2008)

At Arizona State University, the investigators have noticed that, even in a modeling physics classroom, large gains in conceptual understanding may require some characteristics that are typical of individuals with a growth mindset. Examples of these characteristics are a willingness to let go of fear of failure and foolishness, an ability to persevere, and a value of work for understanding over work for points.

Using the Force Concept Inventory (FCI), physics students in our study were tested for conceptual understanding before and after a modeling mechanics class. They were also surveyed and observed to determine their mindset. An attempt was made to correlate FCI gains with mindset for the participants in the study whose mindset could be clearly determined. The results indicate 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.

Rationale

The investigators have observed that physics is a field considered by many to be one of the most difficult and frightening subjects. Additionally, the Modeling Method of Physics requires greater interaction among students with greater vocalization of thinking and questioning than does a traditional approach to teaching Physics. It also requires greater perseverance since understanding is not simply handed over to a student by a transfer of information. If the Modeling Method of Physics is to be maximally effective, students should hold a set of "beliefs about what they should value in the learning setting – away from points and right answers and toward deep and well-connected understanding" (Megowan, 2007). But perseverance is one area of the learning experience that is different for fixed and growth mindset persons. Writing of the characteristics of the fixed mindset person, Dweck relates that,

¹ Dweck describes the mindsets at length in her book. Briefly put the two labels she uses are "fixed mindset" and "growth mindset". Fixed mindset refers to the belief that intelligence is fixed and effort and perseverance are not factors in learning. Growth mindset refers to the belief that intelligence is formed through effort and perseverance.

“If things get too challenging - when they [fixed mindset] are not feeling smart or talented – they lose interest.” (Dweck, 2006) Pre-med students who needed to pass a challenging chemistry class in order to move forward in the field lost interest and enjoyment in their studies the harder it became unless the material came easily to them. Students with a growth mindset were more motivated to study the more challenging material. (Dweck, 2008). It seems reasonable, based upon Dweck’s findings and the culture of the effective modeling classroom mentioned above, that students entering such a course might also have predictable grades if their mindset were known.

Every physics teacher has students with a range of mindsets. This range has been identified by Dweck to be about a 50-50 ratio, but she has also pointed out that in a “high power”² situation, the mix will shift so that more students display a fixed mindset and fewer students a growth mindset. (Aldhous, 2008) Thus, if there is a valid model that describes the relationship between the growth mindset of a physics student and the student’s conceptual understanding of physics as it is measured by the Force Concept Inventory, then it would be worthwhile for a teacher to take the time and effort to make students aware of the mindset model and its advantage. While it was outside of the scope of our study to change the mindset of our students, Dweck has further proved that just as any beliefs can be changed by new information, mindset can be changed by even the awareness of the growth mindset advantage. (Dweck, 2008; Blackwell, et al 2007; Good, et al 2003).

Literature Review

In this study, the correlation between mindset of physics students and FCI gains is investigated. A “growth mindset” is a belief system in which basic qualities, abilities, and talents are things that can be cultivated through effort. Someone with a growth mindset would seek new challenges and experiences as a way to become more skilled and talented and as a pathway to future success. Persons with a growth mindset try new things and see little value in repeating what they have already mastered. A “fixed mindset” is a belief system in which basic qualities, abilities, and talents are predetermined by genetics or other things beyond control and these cannot be changed. With a fixed mindset there is no point in taking on new challenges or trying harder, because one might discover or confirm that one is inept in that area of challenge. Persons with a fixed mindset will do the same things they are good at multiple

² Dweck spends a great deal of time discussing the high profile lives and careers of CEO’s and sports figures who have earned ‘superstar’ status. The regular public praise for their work, huge salaries and bonuses, and opulent lifestyles go hand in hand with identification that the ‘superstar’ is solely responsible for their success. Dweck points out that this brings out the worst aspects of the fixed mindset in addition to attracting fixed mindset persons to such a role in the first place. (Dweck, 2006).

times to affirm that they are good at them but will not try something new or difficult as this would not be affirming. Persons with a fixed mindset reported feeling smart when they did not make mistakes, finished quickly, easily, and perfectly. Furthermore, they did not finish things when they did not feel smart. (Aldhous, 2008). A reason for developing the Modeling Method was that the “social norms of conventional schooling can and should be rewritten” (Megowan, 2007; Hestenes, 1997). In American classrooms, students have learned that the road to success is, “getting the answers right, and getting the teacher to give them points.” Colleen Megowan-Romanowicz of Arizona State University points out, “By the time most students reach high school, [they have identified] the classroom practices that will buy them the most points in exchange for the least effort.” (Megowan, 2007; Ames, 1988). The connection between motivation and learning has been studied from a variety of perspectives and an assortment of terminologies has been developed to describe these connections. (Pintrich, 2000). In studying issues of motivation in mathematics education, it has been found that student goals fall into two categories. There are “ego/performance goals” which are extrinsic. Students are measuring their success against external rulers. These students are essentially motivated by earning points, peer respect, and gaining external desired rewards such as public honors and accolades. Alternatively, there are “mastery goals” which are intrinsic. Students with mastery goals are measuring their success against internal rulers. These students are motivated by a desire to learn and become better at something. Those studying motivations in learning have found that the latter types of goals are more likely to be linked to perseverance when material and requirements of learning become challenging. (Middleton & Toluk, 1999; Butler, 1987). In other research, the same connection between motivation and learning is proven yet the terminology used is self-efficacy. Levels of self-efficacy predict outcomes on tasks. For instance, individuals who believe they are capable of succeeding at a task would be given a high score of self-efficacy. Furthermore, self-efficacy measures the attitude towards mastering the task and the likeliness for perseverance. Persons do have varying levels of self-efficacy for different areas of [performance. For instance a person who has high self-efficacy in football might not have the same level of self-efficacy in science. Dweck points out that a major difference in the two mindsets is that persons with a fixed mindset and high self-efficacy in a particular area seek challenges and persevere, but persons with the fixed mindset and low self-efficacy in a particular area will avoid challenge and have low persistence. Important for this study is the research evidence that persons with a growth mindset seek challenge and persist regardless of their self-efficacy. This means that they can seek challenges and persist to succeed in all areas, not solely in areas at which they already excel. (Dweck, &Leggett, 1988)

It has been demonstrated that students can reach a higher level of achievement, satisfaction, and success when these students have a growth mindset. Dweck ran a study with young math students. One group was given tutoring and lessons in study skills. The other was

given these things in addition to lessons in growth mindset development. When the workshops ended, students in the growth mindset group had improved math scores. Dweck explains, “They were now clearly doing better than the students who’d been in the other workshop. This one adjustment of students’ beliefs seemed to unleash their brain power and inspire them to work and achieve...” (Dweck, 2008).

Worthy of note is that even with all the support given math students with no growth mindset training, the students with no mindset training did not improve. “Despite their training in study skills and other good things, they showed no gains...they were not motivated to put the skills into practice. (Dweck, 2006; Blackwell et al, 2007).

Each of the investigators has come to the realization that a large factor leading to student success is the use of the Modeling Method of High School Physics developed by David Hestenes and Malcolm Wells at Arizona State University beginning in 1980. (Hestenes, 1987; Wells et al 1995) “Modeling Instruction in high school physics is nationally recognized as a program of excellence. It is grounded on the thesis that scientific activity is centered on modeling: the construction, validation, and application of conceptual models to understand and organize the physical world. The method utilizes experimental design, control of variables, and calls for reasoning and application of skills in solving various kinematics and dynamics problems. There is strong use of student discourse, as evidenced by the need for students to present and justify conclusions derived in the laboratory. Multiple strategies for problem-solving are encouraged, reflecting sensitivity to individual student differences and abilities.” One of the reasons that physics instruction was designed around physical models is that student beliefs get in the way of their learning in a traditional instruction. (Hestenes, 1996). The beliefs referenced here are beliefs about physical systems. These incorrect beliefs include ideas such as “heavy items fall faster” or “bigger, heavier items push harder on smaller, lighter items.” The Modeling method does an admirable job of addressing these false beliefs and helping students overcome them. Dweck and others would say that beliefs about how persons learn and whether a person can learn something challenging are also important beliefs to address. Perhaps modeling instruction can be improved by attending to the false learning beliefs held by students and helping them to overcome these as well. (Ames, 1982)

Furthermore, it has been shown that in the Modeling Physics classroom, a key determiner of the success of the learning outcome is the quality of Socratic dialogue. (Megowan 2007, Desbien, 2002, Desbein, Wenning, Hestenes, 2000; Ames, 1982). Through the benefits of dialogue, a better overall classroom response occurs. However, the dialogue may prove elusive if students are afraid to look stupid in front of peers. ‘Fear of looking stupid’ is a key characteristic of a fixed mindset, but such a fear is less likely to exert itself in a growth mindset. (Dweck, 2006) Other researchers use different terminology but point out similar roadblocks to learning. “Performance-avoidance orientation” is used to describe the reluctance of a student to become involved in a learning experience due to worries about the student’s

performance in comparison to peers. In simple terms the student does not want to look 'stupid'. (Midgley, Kaplan, Middleton, 2001; Middleton, Midgley, 1997).

Hestenes points out that "special measures may be required to engage reluctant or reticent students." (Hestenes, 1996). One such special measure may be to help students better understand their own beliefs about learning and how these affect them. Students with a growth mindset may be able to overcome a reluctance to enter the dialogue process. In doing so, they may be better situated to learn the concepts taught in a modeling physics classroom. A seventh-grade girl who participated in one of Dweck's studies, here explains how a growth mindset changed her participation in her math class: "I think intelligence is something you have to work for...it isn't just given to you...Most kids, if they're not sure of an answer, will not raise their hand to answer the question. But what I usually do is raise my hand, because if I am wrong, then my mistake will be corrected. Or I will raise my hand and say, 'How would this be solved?' or 'I don't get this. Can you help me?' Just by doing that I am increasing my intelligence." (Blackwell, Trzesniewski, and Dweck, 2007; Dweck, 2006). It is important to notice not only this young woman's active participation in the learning dialogue, but her identification of her peers' lack of participation. Since it has been proved that success in Modeling is dependent upon effective discourse, (Megowan, 2007, Desbien, 2002) nonparticipation would be expected to have a detrimental effect on success. This study will show that mindset has a correlation to FCI scores. Simply put, students with a growth mindset will have a higher overall probability of earning high FCI gains after taking a modeling physics class while those with a fixed mindset will not have a higher overall probability of earning high FCI post gains.

Method

Investigator 1: David Flores teaches at Perry High School, which is in the Chandler Unified School District. The Chandler Unified School District is located in the Southeastern part of the Phoenix metropolitan area. Chandler Unified serves 38,000 students in grades K-12 and encompasses 80 square miles, though not all of the city of Chandler. Perry High School has an enrollment of approximately 2308 students in grades 9-12. The population of the school is approximately 68% Caucasian, 17% Hispanic, 7% Asian, 7% Black, and 1% American Indian. Nine percent of the students receive free or reduced lunch. Investigator 1 worked with approximately 60 general physics students. General physics is populated by about 65 percent seniors and 35 percent juniors. General physics is a college preparatory class.

Investigator 2: Allison Lemons teaches at Rio Rico High School, in the Santa Cruz Valley Unified School District #35. The Santa Cruz Unified School District is located in the South-central part of Arizona. Rio Rico High School has an enrollment of approximately 1048 students in grades 9-12. The population of the school is approximately 5% Caucasian, 94% Hispanic, and 1% Asian. 85 percent of the students receive free or reduced lunch. Investigator 2 worked with four general

physics students and nine honors physics students. Both groups received the same instruction. At Rio Rico High School, both general and honors physics are considered college preparatory. Chemistry and Algebra II are prerequisites for both courses; students must have completed each of these courses with a minimum grade of “C” in both semesters. All physics students must be concurrently enrolled in either Algebra III or calculus.

Investigator 3: Investigator 3 teaches at St Edward High School, in Lakewood, Ohio. Lakewood is located on the western edge of the Cleveland metropolitan area. St Edward High School is a Catholic single sex, male high school. St Edward has an enrollment of approximately 830 students in grades 9-12. The population of the school is approximately 65% Caucasian, 25% Black, 10% Asian/Middle Eastern. Investigator 3 worked with 54 general physics students and 45 AP Physics students. General physics is an algebra trigonometry level college preparatory class, populated by about 90 percent seniors and 10 percent juniors. The AP Physics courses are separated into two distinct classes, each one year long. The first year is Mechanics C (36 students 50% seniors and 50% juniors) and the second year is Electricity and Magnetism C (9 students all seniors). Both AP classes have a minimum math requirement of concurrent enrollment in pre-calculus.

No Contrast Group was necessary for this method.

Procedure for determining the correlation:

1. At the beginning of the course student knowledge of conceptual physics was assessed using the Force Concept Inventory. This is a diagnostic instrument developed to determine student baseline ability to engage in Newtonian thought, especially with regard to fundamental conceptual understanding of forces. (Hestenes, 1992).
2. Also at the beginning of the course, students were given a survey developed by Dweck and her colleagues to determine their mindset. (Dweck, 2006) The survey was titled “Personal Beliefs Survey” in an attempt to mask the fact that it was to measure mindset. This survey is referred to in this report as a Mindset Survey and included two sections, an eight-question Likert scale multiple choice section determining student ideas about intelligence and personal qualities and a second section of essay prompts. Students were asked to respond to one or two of these prompts. The survey was a tool which allowed us to pinpoint whether the student operated primarily with a fixed mindset or a growth mindset or somewhere between these two extremes. Appendix A
3. Permission
 - a. No student 18 or older was included in the study unless that student had provided a signature giving their permission to be part of the study.
 - b. No student under 18 was included in the study unless that student had provided written consent and also the signature of their parent or legal guardian. While permission for videotaping/photographing was acquired, no videotaping or photographing was done.
4. Unit 1: Scientific Thinking

- a. Each investigator completed introductory unit one in a manner fitting the background and ability level of their students.
 - b. Opportunities are provided for all students to receive extra help from the teacher before or after school. Some investigators may have other opportunities for students to get assistance when they are in need of help understanding the material.
5. Unit 2: Constant Velocity Model
- a. The unit which allows for the understanding of the model of constant velocity motion was taught by each investigator with the use of the Modeling Method of Mechanics. Further discussion describing the culture of the modeling classroom and the specific culture of the classroom of each investigator will take place in the individual field reports found later in this document.
 - b. After the first big summative assessment, the score was returned to the student, and all students were taught about mindset. The mindsets were introduced using a brief article in which Dweck is interviewed about her research and findings and further explored by means of a power-point and a brief discussion. Appendix B
6. Remaining units of mechanics are taught in the classrooms.
- a. Occasionally during the course, classes were begun with a vignette about a sports hero, famous scientist, successful person or other famous person who exhibited the growth mindset. At other times students were reminded of ways that growth mindset personalities respond to set-backs and challenges. Appendix C
 - b. Occasionally during the course, students were asked to respond to a short prompt regarding a challenging experience in learning mechanics. This may have been a whiteboard session that was particularly difficult, a lab that was tough to deploy, a HW question that was very hard, or a test/quiz question that many students did not answer correctly. This was accomplished by means of an exit ticket, blog, or journal entry submitted to the investigator. The purpose of the reflection was to provide evidence of mindset in case it was difficult to determine from the survey. Appendix C
The purpose of this response was to elicit student identification of what was difficult and to have them put into their own words how they dealt with the challenge. It was hoped that the language they used and the methods they used would be a window into their mindset at that time in the curriculum.
 - c. When opportunities arose, investigators noted a participant's clear demonstration of either fixed or growth mindset during ordinary classroom events.
 - i. extra effort was put into a very tough problem
 - ii. a student became frustrated and refused to become involved
 - iii. pertinent questions were brought up and attention given to responses
 - iv. questions were left blank,
 - v. questions on a HW assignment were left uncorrected

- vi. extra help was sought
 - vii. a test was looked over to find out how to solve problems missed
- 7. Upon completion of all Modeling Mechanics Units
 - a. All students were given the FCI post-test.
 - b. All students were given the Mindset (Personal Beliefs) Survey to determine their mindset. This is referred to in our analysis as the Mindset post survey.
 - c. Artifacts including all qualitative and quantitative data: survey responses, teacher observations and recorded notes, journal entries, exit tickets, and interviews were coded into evidence if a student was an authorized participant. The analyzed artifacts were used to develop this report of our findings. Any artifact of any student not part of the study was discarded.
 - d. The results recorded and explained in this report, were presented at ASU on July 8, 2011.

Data Analysis

In this study we collected both qualitative and quantitative data. In this section, the analysis of the qualitative data will be addressed.

We reviewed the mindset survey both quantitatively and qualitatively using a Likert scale 1 to 4, adjusting the score of each question to the Likert scale. As the reader will notice in the survey found in Appendix A, for half the questions a response of 4 meant growth but for the other half the score of 4 meant fixed. This was to maintain the random nature of the questions. Scores were simply flipped as required to get each score to the Likert scale where, for example, a value of 4 would always mean the same type of mindset. On our scale 4 represents a strong growth mindset and 1 represents a strong fixed mindset.

The multiple choice portion of the survey was the easiest to score, but also may be the most susceptible to the fixed mindset need for approval and social acceptability. Most of the multiple choice sections for students who in all other areas posted low scores (indicating highly fixed mindsets) had elevated scores for the multiple-choice. This is a part of the nature of this research project which made it quite challenging. It was noted in Dweck's research that students with a fixed mindset are much less likely to have a realistic view of self. (Dweck, 2006) They are also highly motivated to give a socially acceptable answer and so the multiple choice part of the survey seemed to be skewed upwards in a disproportionate number of cases.

The essay section was scored using a rubric with names removed so that the evaluators had no idea who was being scored. While some students were able to answer in a manner that was in opposition to their classroom operative behaviors, the essays appeared to be a more authentic assessment. The essay responses the students gave were in line with things we each noticed they had said and done in the physics classroom. It took some time to get used to the scoring of the essay, so we began by identifying some phrases and words that are typical for each mindset. The following are some examples of these:

- "I would be excited by the challenge" – G
- "I would go to the teacher so I could get it done faster" – F
- "I should pay more attention to my driving" - G
- "I would feel completely defeated and worthless" – F
- "stressed out, confused, nervous, shy, uncomfortable" - not-codable

This list was always used in context to the total response. For instance, it is the reason given by the student going to the teacher that the goal is to get done faster that causes that statement to be coded fixed. Ordinarily seeking help from the teacher would be rated a growth indicator. Included in appendix D are a list of other "catch" phrases and words as well as

samples of essays scored by the investigators and other assessment rubrics that were used. This was still a challenging part of the identification of the mindset of an individual. It seems to be from our observations and after reading more than 475 essays that students may use statements or catchphrases validly in one context but flippantly in an academic context. For instance it was noticed that athletes have a strong work ethic and strongly value hard work in their sport as encouraged by their coaches. However, while these athletes will still use phrases of work ethic and identify quitting as a taboo in their world, they will quickly give up or perhaps never even begin to try in the physics classroom. Our own observations of individuals bore this out many times. Some of these students, when interviewed at the end of the year, even recalled that they had never given up or quit on a difficult physics problem. More than one of these had thrown the high school equivalent of a temper tantrum and been quick to blame the teacher for asking too hard a question if something was seen as too difficult at first glance. The point here is that what might sound like a positive growth statement is frequently masking the fixed mindset.

We began by coding the essays together, each of us highlighting the essay according to a pre-determined color scheme, sharing our ratings and discussing these, and then agreeing about the decisions. We found quickly we began to think alike about the typical comments.

An essay was given a ratio equal to the number of growth responses divided by the number of total responses in that essay. This ratio was turned into the 1 to 4 Likert scale. (Ames and Archer, 1988). The Likert scale was entered into the data set alongside the multiple choice score as one of the three mindset scores given each student. Finally a teacher observation score of the same Likert rating was added into the data set for each student. This was the third of the three mindset scores given the student. The teacher observation score was given using the rubric included in Appendix D, taking into account other observations and artifacts that had been gathered in attempts to be clearer as to an individual student's mindset.

The three scores are each indicators of the mindset of the student. Since there was no way to absolutely determine if one indicator was a better or fairer indicator than another, it was decided that the three are like the components of a three-dimensional vector. Each contributes equally to the mindset of the student. At this point we realized we could not positively and objectively determine the mindset of every student in the study. In fact Dweck describes in her studies that research suggests that only about 40% of the population of a typical classroom will be fixed and 40% growth. The middle 20% will be ambivalent and will change from fixed to growth and vice-versa as situations and activities change. (Dweck, 2008). We looked at all the scores of each student, and where the three scores were in agreement we assigned fixed or growth to that student and selected those students for more rigorous

analysis. For example if a student had a multiple choice score of 1.5, an essay score of 1.8 and a teacher observation score of 1.5 that student would be determined to be fixed and placed into the fixed group. If a student had a multiple choice score of 3.6, an essay score of 3.2 and a teacher observation score of 4 then this student would be placed into the growth group. If a student had mixed scores (3.4, 1.2, 1.7 respectively), we did not assign that student to a group but left the student as “mindset undetermined.” In this way we were able to identify 55 participants whose mindset we were confident had been identified accurately. We did run scatter plots and other analyses on the entire set of 146 and saw some results that mirrored the results of the 55, but the tests were more conclusive when we looked more closely at the 55.

We compared the FCI gains of these 55 students to the Likert scale of their overall mindset. We were looking for evidence to support that student mindset can influence FCI gains.

The post mindset scores were of interest to see if students had changed their mindset as they progressed through the class. In fact we were not trying to change their mindset, at least not in a methodical way. As mentioned previously, the shift of a mindset towards the growth end of the spectrum has been proven by Dweck and others to be possible. We have left this part of the study for others to determine. It is discussed in greater detail only in the final section of this report, “Implications for further research.”

Results

The mindset scores were added linearly to respect the individual differences in each of the mindset scores. The linear score was now on a scale of 3 at most fixed to 12 at most growth. We subdivided these into 4 groups as follows: Strong fixed had a linear addition value between 3 and 5.25. Strong growth had a linear addition value between 9.75 and 12. The weak mindset groups - weak fixed and weak growth - were identified as those with the linear addition value between 5.25 and 7.5 and between 7.5 and 9.75 respectively.

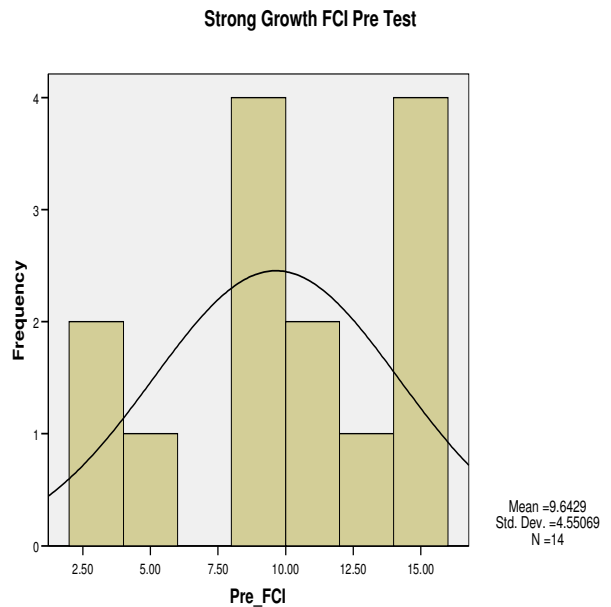
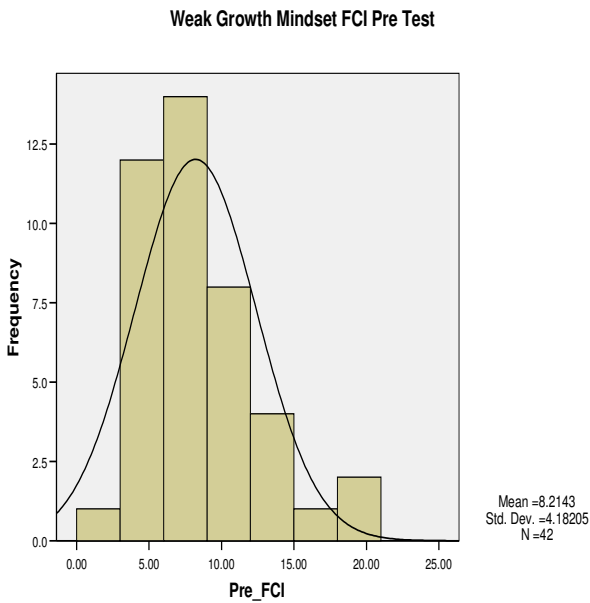
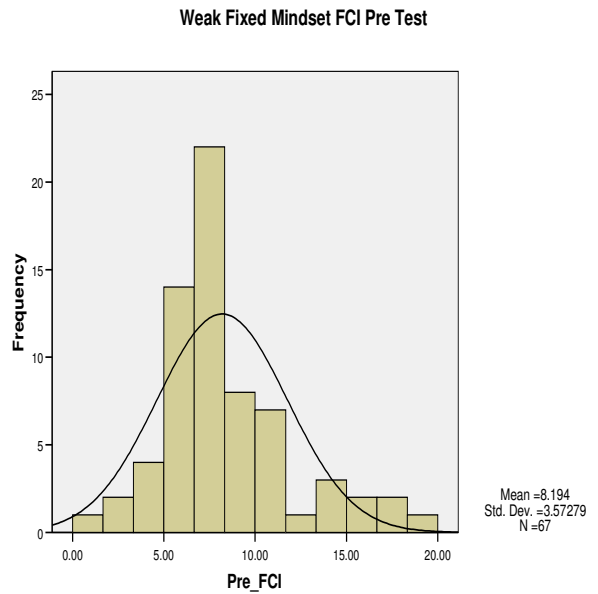
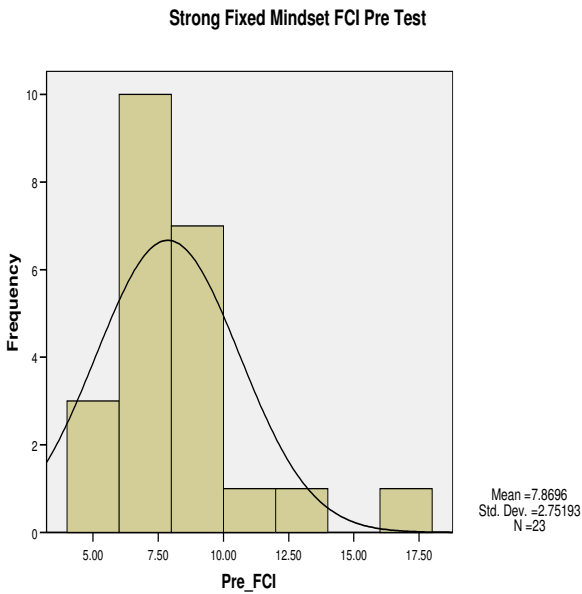


Figure 1: FCI pre test scores for all students, classified according to mindset

Table 1: Descriptive statistics for all four mindset-identified groups

	Strong Fixed	Weak Fixed	Weak Growth	Strong Growth
Mean Raw Score	7.89	8.19	8.21	9.64

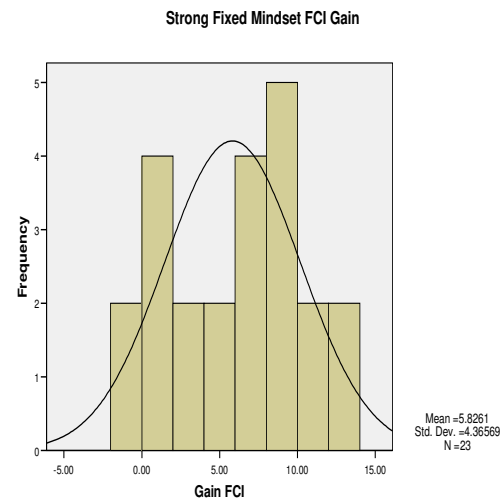
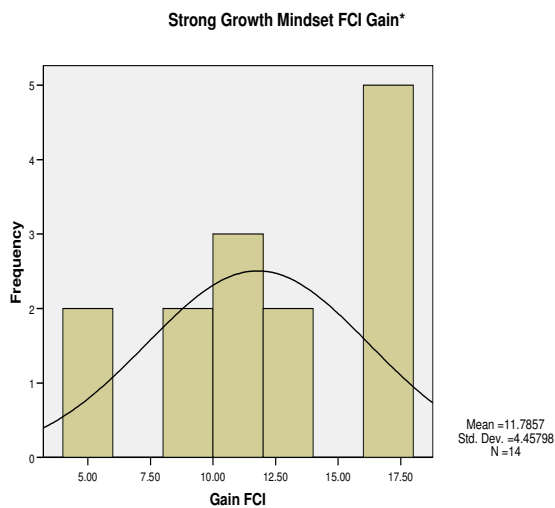
FCI Pre Test				
Standard Deviation	2.75	3.57	4.18	4.55
N	23	67	42	14

SF_SG_WF_WG

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	30.546	3	10.182	.725	.539
Within Groups	1995.372	142	14.052		
Total	2025.918	145			

Table 2: Four-way ANOVA results for strong-fixed, weak-fixed, weak-growth, and strong-growth mindsets

A four-way ANOVA test (Table 1) shows that the mean FCI pretest scores for the four mindset-identified groups are not significantly different. Therefore, we concluded that all students, regardless of mindset, began with the same physics knowledge, they are drawn from



the same population. For Figure 1 and Table 1.

further verification, see

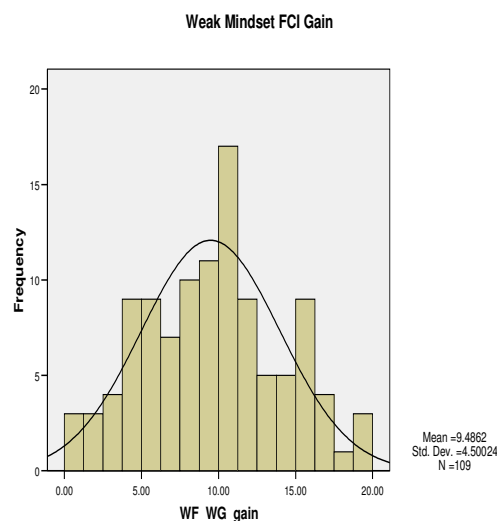


Figure 2: FCI test raw gain scores for strong-fixed, weak, and strong-growth mindsets.

Table 3 SD of 3 groups

	Strong Fixed Mindset	Weak Mindset	Strong Growth Mindset
Mean Raw Score FCI Gain	5.83	9.47	11.79
Standard Deviation	4.37	4.52	4.46
N	23	109	14

Table 3: Descriptive statistics for strong-fixed, weak, and strong-growth mindsets, FCI raw score gain

WF_WG_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.334	1	4.334	.212	.646
Within Groups	2182.895	107	20.401		
Total	2187.229	108			

Table 4: ANOVA results for weak-fixed and weak-growth mindset FCI raw score gain

An ANOVA test (Table 4) compared the weak fixed and weak growth-identified mindset groups compared to their mean FCI raw score gains. The significance value $p=0.646$ indicates that there is no significant difference between weak fixed and weak growth students. We will therefore treat them as a single “weak mindset” group in the remainder of our analysis. See Figure 2 and Table 3 for graphical representations and descriptive statistics of FCI raw score gain analysis.

Now, means were compared to see if there are significant differences between the three distinct mindset categories.

SF_W_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	107.197	1	107.197	7.042	.009
Within Groups	1978.864	130	15.222		
Total	2086.061	131			

Table 5: ANOVA results for strong-fixed and weak mindset FCI raw score gain

Table 5 shows ANOVA comparison of strong fixed mindset raw FCI gain scores to the weak mindset raw FCI gain scores. The significance value 0.009 indicates that there is a significant difference between the strong fixed and weak mindsets.

SG_W_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	159.352	1	159.352	10.606	.001
Within Groups	1817.917	121	15.024		
Total	1977.268	122			

Table 6: ANOVA results for strong-growth and weak mindset FCI raw score gain

Likewise, an ANOVA comparison of raw FCI gains to the strong growth mindset group and the weak mindset group indicate that these two groups are significantly different ($p=0.001$). See Table 6.

SF_SG_gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	309.095	1	309.095	15.964	.000
Within Groups	677.661	35	19.362		
Total	986.757	36			

Table 7: ANOVA results for strong-fixed and strong-growth FCI raw score gain

Finally, an ANOVA (Table 7) compared the raw FCI gains of the strong growth mindset group and the strong fixed mindset group showed a significant difference ($p=0.000$). Taken together, these three tests reveal that the three groups-fixed, weak, and growth-have FCI raw score gains that differ significantly from one another.

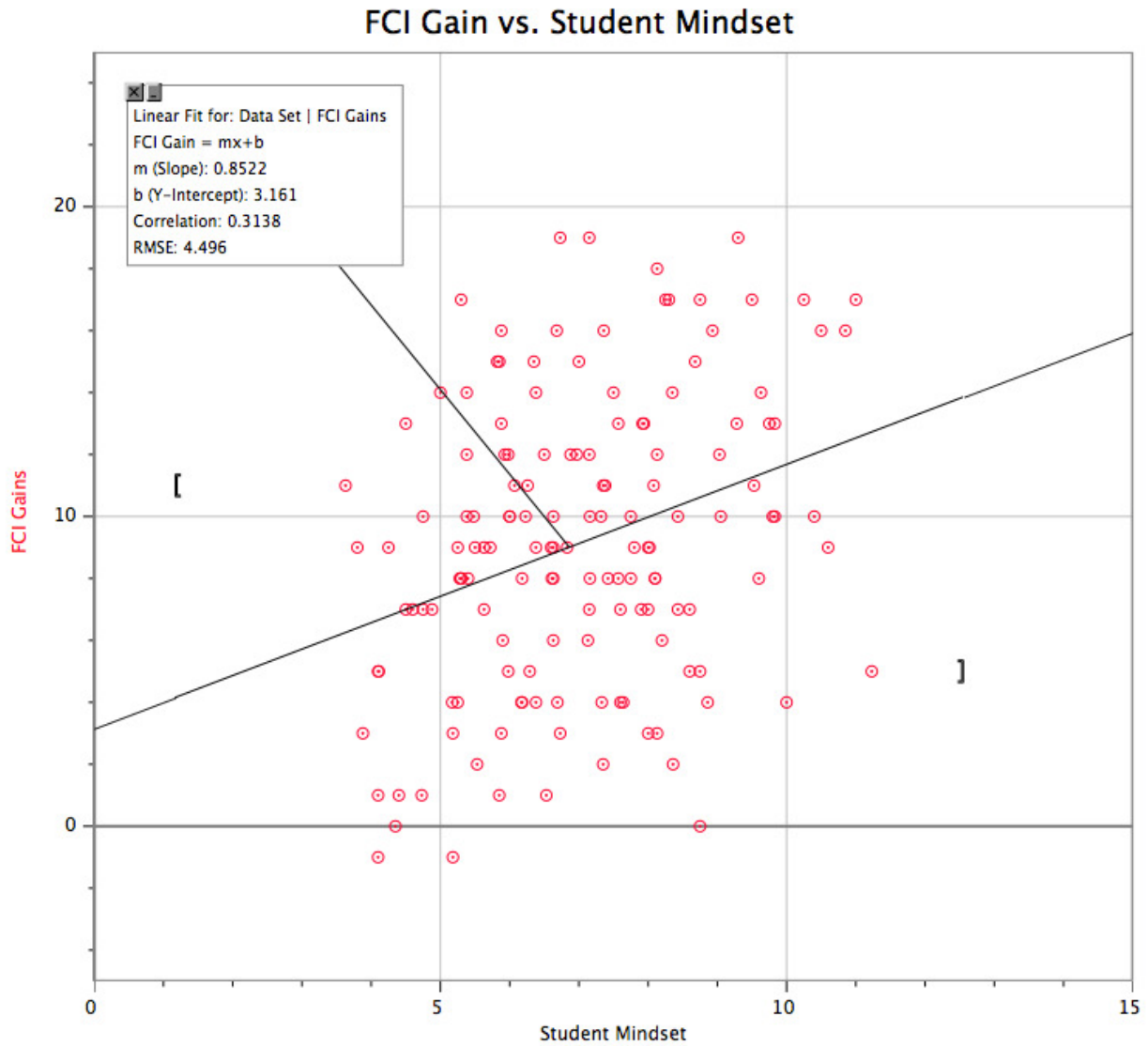


Figure 3 FCI Gains compared to the whole population

The correlation between the FCI Gains and the whole population are shown above in Fig. 3.

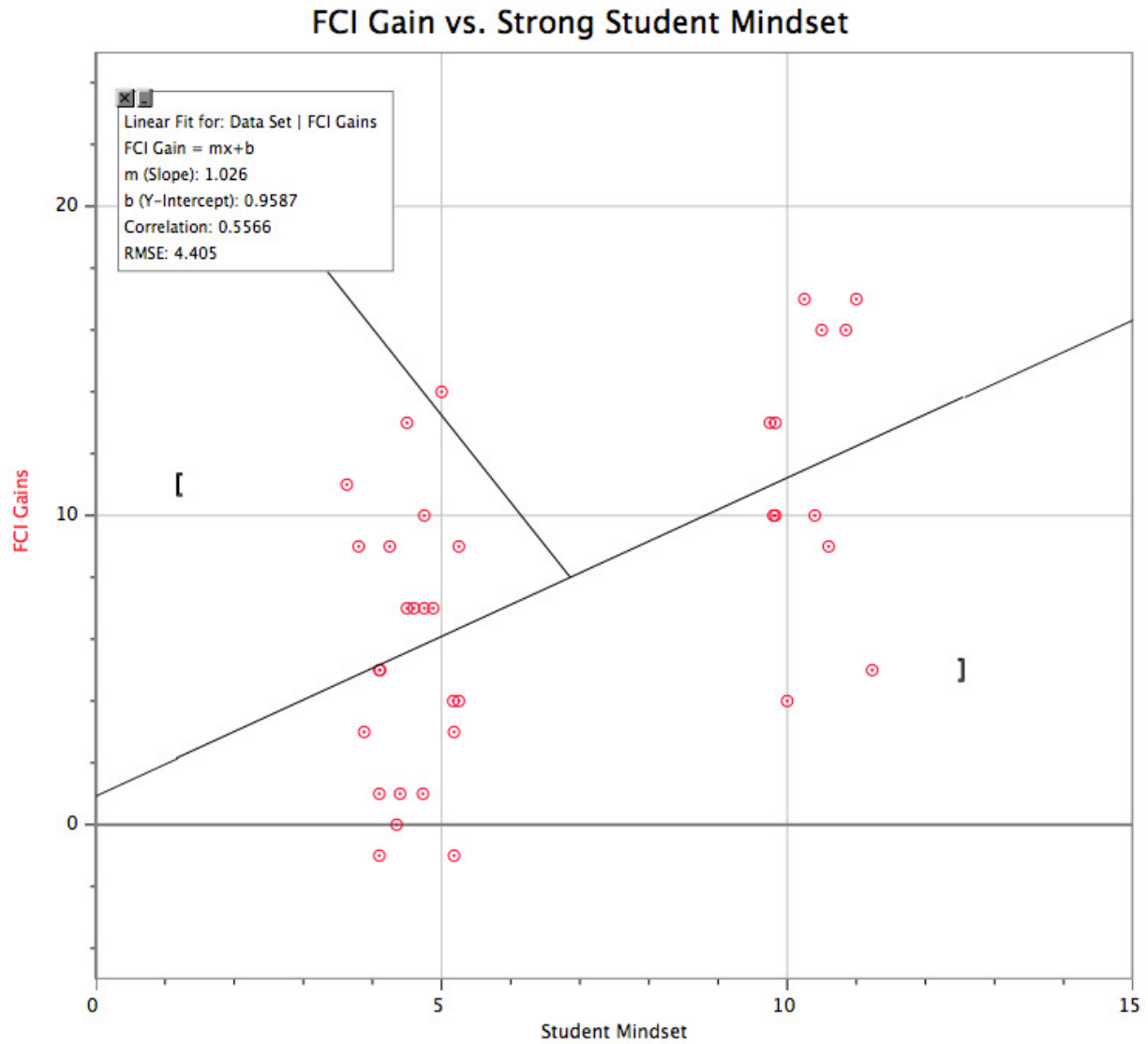


Figure 4 FCI Gains compared to Strong Mindsets

The correlation between FCI Gains and Strong student mindsets can be seen in Fig. 4.

Conclusion:

We proved that the individual groups of students are similar populations to each other and drawn from the same population as the overall population of 146 study subjects. We also proved that the students who were somewhere in the middle of the mindset spectrum but who did not have a strongly identified mindset are drawn from the same population. Finally we compared the raw gains in conceptual development of the strong growth mindset students to the raw gains of the strong fixed mindset students. 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. The standard deviation for each group was about the same at 4.4 and 4.5 respectively. This means that the effect size of the mean difference is 0.559, which is considered to be a moderate effect size. (Coladarci, Cobb, Minium, and Clarke, 2008).

When we performed a linear regression with FCI raw gains as the independent variable, and the linear addition of the three mindset Likert-scale ratings as the dependent variable, the comparison demonstrated a positive relationship between the FCI gains of students and the value of the mindset. Since there is no standardized unit for the mindset value, it is difficult to say in real numbers what the slope will mean, but the regression does show the positive relationship. This means that students with a higher overall linear addition value of mindset had higher overall gains than students with lower overall linear addition value of mindset. In figure 4 only students with scores of strong fixed linear addition value and those with strong growth linear addition value were studied. The linear regression of FCI raw gains to these strong mindsets students demonstrated a positive slope that was a higher value and higher correlation than when the students difficult to identify were part of the correlation. When students had a strongly identifiable mindset, the relationship between their gains and a growth mindset was a data set with a tighter fit around a straight line.

To summarize, if a student had a growth mindset coming in to the class, that student had a statistically significant higher probability of achieving greater FCI gains than if the student had a fixed mindset. The mean FCI gain of students identified as having a growth mindset was higher than the mean FCI gain of students identified as having a fixed mindset.

The qualitative evidence suggests that the student with a growth mindset may be happier in a modeling physics classroom and that a student with a fixed mindset may be less happy in the culture of the modeling classroom. This is evidenced by the artifacts we collected as we gathered data for our study. Fixed mindset students were more inclined to be impatient with the process as well as threatened by the dialogue even in a classroom environment that encourages emotionally safe interactions. Conceptual questions and challenging problems that haven't been taught by rote beforehand but are more in the nature of puzzles are likely to be deemed "unfair" or "unrealistic" by fixed mindset students. Modeling is notorious on the

Modeling lists-serve for “changing the rules” of education and leaving students without “teachers who teach”.

The scope of our study did not include analysis regarding the attitude differences of the two mindsets towards the Modeling Method of teaching physics. We did find anecdotal evidence in the essays and other student responses suggesting it would be an interesting topic for further investigation. The evidence suggests that students with a growth mindset are happier and feel more successful in the Modeling classroom. While the research shows that a growth mindset favors conceptual gains in physics, it also suggests that the modeling physics classroom may favor the growth mindset. The conclusion to our research is that students of the growth mindset do have a higher statistical probability of achieving higher gains on the Force Concept Inventory than do their fixed mindset peers.

Investigator 1 Field Trial Report

Introduction

Investigator 1 is David Flores from Chandler, Arizona. This was my 4th year of teaching physics. I taught at Perry High School, which is in the Chandler Unified School District. The Chandler Unified School District is located in the Southeastern part of the Phoenix metropolitan area. Chandler Unified serves 38,000 students in grades K-12 and encompasses 80 square miles, though not all of the City of Chandler. Perry High School has an enrollment of approximately 2308 students in grades 9-12. The population of the school is approximately 68% Caucasian, 17% Hispanic, 7% Asian, 7% Black, and 1% American Indian. Nine percent of the students receive free or reduced lunch. Investigator 2 worked with two sections of General Physics students of which nearly all were involved in the study (37 total). General Physics is generally populated by about 65 percent seniors and 35 percent juniors and is a college preparatory class.

General Physics is an elective physical science class that students may take to satisfy their graduation requirements of three science credits. Most students at Perry choose to take Investigative Science their freshman year, biology their sophomore year, and have the choice of several different science courses their junior and senior years with physics being one of them. The opportunity to choose physics instead of human anatomy or biology 3-4 may have preselected students that would have a growth mindset. It has been shown that a student's expectancy of success influences their attitudes. (Wigfield and Eccles, 2000)

The 37 students that were part of the study were with me during the course of one academic year. Perry follows a traditional schedule three days a week. On these days, students visit all their teachers for 50-minutes. Two days a week they follow a block schedule, and students visit only half their teachers for 112-minutes. During a typical week I will see a student 4 times. During the study I became cognizant of the types of praise that I would employ to give students feedback regarding performance during presentations and performance on assessments. In an effort to maintain the validity of any findings I found it increasingly difficult to not use forms of praise that might lead to the development of a growth mindset. (Mueller and Dweck, 1998) As for the collection of data and implementation of the study I used practically the same procedures as my colleagues. Where differences in the procedures occurred they are noted below.

Procedure

8. Force Concept Inventory

Upon the first day of entering the class all physics students were given an assessment to measure their knowledge of conceptual physics. The administration of the Force Concept Inventory the first day of class has been the routine in my physics class for the past three years. The Force Concept Inventory (hereto forward referred to as the “FCI”) is an instrument designed to measure a student’s ability to engage in Newtonian thought, with an emphasis on understanding forces. (Hestenes, 1992) All students were given 50 minutes to complete the FCI, and all students completed the FCI within 30 minutes of the beginning of the period.

9. Permission

A permission slip, regarding the study, was sent home immediately after the FCI was given. There were not any students older than 18 that were part of the study. Videotaping and photography were not done in the class.

10. Mindset Survey

A survey, developed by Dweck and her colleagues, was given to determine the mindset of students entering the class. (Dweck, 2006) The title of the survey was altered from mindset survey to “Personal Beliefs Survey” in an effort to illicit actual student responses instead of those they have researched to be in line with the goal of the study. The mindset survey included two sections, a multiple choice section that consisted of eight questions that were used to determine student beliefs about intelligence and learning and an essay section consisting of three prompts. Students were instructed to answer any two of the three prompts. The survey was one of the three tools that were used to help determine student mindset. Appendix A

11. Instruction

a. Unit 1: Scientific Thinking

- a. The unit on scientific thinking took approximately two weeks. During this time period several students dropped from physics and entered physics. Upon entry to the class the student was immediately given the; FCI, Mindset Survey, and permission documents.
- b. All students are given the opportunity to seek assistance before or after school. In order to receive help before or after school all students must first sign-in on the “tutoring” log. This was another tool used to determine if students actively seek help during the course.

b. Unit 2: Constant Velocity Model

- a. The second unit in the curriculum was the constant velocity model of motion. The Modeling Method of Mechanics was deployed in this unit

whereby student understanding was developed through classroom dialogue facilitated through the use of whiteboards.

- b. After the first big summative assessment, the score was returned to the student, and all students were given a brief lesson on mindset using direct instruction materials from the Mindset Brainology website. The topic of mindsets was further developed using the Dweck interview article where she discusses her research and findings. Appendix B
 - c. All students were again given the chance to seek assistance before or after school. The instructor kept a sign-in log and notes of attendance for all these sessions in this unit and subsequent units.
- c. Remaining units of mechanics are taught in the classrooms.
- a. During the course of every unit one segment of Dweck's Mindset book or a news or magazine article was read aloud to the students. After reading these aloud a short classroom discussion ensued regarding mindsets. These book and magazine discussions typically lasted on the order of about 15 minutes and were done during conference time on block days. Occasionally during the course, classes were begun with a vignette about a sports hero, famous scientist, successful person or other famous person who exhibited the growth mindset. At other times students were reminded of ways that growth mindset personalities respond to set-backs and challenges. Appendix C
 - b. Periodically students were given the chance to respond to prompts regarding set-backs or successes in the physics class. This included things like test or quiz items answered correctly or incorrectly, difficult homework problems where they were unable to answer correctly, labs where relationships were supposed to be developed. The responses were recorded in their lab notebooks.
 - c. Students were also given an essay assignment at the conclusion of the first semester. This assignment was a mandatory part of the school improvement plan to implement writing in all classes. Every instructor at Perry had to design a writing prompt in their own classroom. I chose to have the students write about the relationship between student achievement and effort. What follows is an example of a few student responses.

“I think I could have asked questions and received help on what I was struggling with. I know that if I received help, it would have helped me learn more.”

“I believe that talent is more important than effort. I hardly ever study for anything and still get perfect scores on many of my physics tests.”

These artifacts were collected and coded but, not included in the study since they were not given at the same time as the survey essay prompts.

Investigator 1 Results

Gain FCI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	99.386	2	49.693	3.269	.051
Within Groups	486.500	32	15.203		
Total	585.886	34			

The ANOVA test of FCI raw score gains of Investigator 1 (Table 8) compares three groups: strong-fixed mindset, weak mindset, and strong-growth mindset. The significance value $p=0.05$ indicates there are significantly different FCI gains between the strong-growth, weak, and strong-fixed mindset students of this teacher.

Conclusion

Of the 147 students in this study, 37 were students in my modeling classes. There were eight additional students that originally entered the class and were part of the study that dropped at semester so their data could not be included. Additionally, there were three students that entered my class at semester, no data was used from these three students. Prior to completing the study I held the belief that students with a fixed mindset would see similar gains when compared to the group with a growth mindset. I felt the fixed mindset group entering this optional science course would already have a high self-efficacy, based upon their decision to enroll, which would lead to equivalent gains on the FCI when compared to the

growth. After completing the study I found that a strong growth mindset is more likely to lead to a greater conceptual development in my physics class.

Investigator 2 Field Report

Introduction

Investigator 2 is Allison Lemons. I teach at Rio Rico High School in Rio Rico, Arizona. This is my 7th year teaching physics using the Modeling Method. All 13 of this year's physics and honors physics agreed to be part of this study with parental permission.

Graduation requirements at Rio Rico High School call for three science credits. All regular and honors physics students had earth science, biology, and chemistry before enrolling. Therefore, all students were taking this class as an elective.

Because of lack of enrollment, regular physics and honors physics students attended the same class period and received the same instruction. The "honors" designation was earned through extra lab work, more stringent test and lab report requirements and special presentations.

All students had previously completed chemistry with a grade of "C" in both semesters. Likewise, all students had completed at least Algebra II and again had earned a grade of "C" in both semesters. All students were concurrently enrolled in either Algebra III or calculus.

Rio Rico High School has 54 minute class periods and students would see me every day of the week.

Procedure

The FCI and PBS pretests were given late in the first week of the school year and the posttests were given before the final exam at the end of the 2nd semester. The FCI did not count as part of the semester grade. The students had finished the Uniform Circular Motion unit at the time the posttest was administered. Students were encouraged to respond to all portions of each pre and posttest carefully and thoughtfully and it is believed that they did so.

After the PBS pretest was given, we viewed a power point presentation about mindset in the guise of a "psychology lesson". After the power point, students were given a brief and informal quiz to see if they could differentiate between growth and fixed mindset behaviors. The students seemed to catch on quickly and were able to tell the difference easily.

Students were given a “ticket out the door” once per unit for a total of seven units. The ticket asked them to identify topics of understanding or confusion and to return to the comment to write clarifications and sources. This effort was an attempt to encourage students to pay attention to what they were learning and what they still needed to learn. The ticket was supposed to show if students followed up on their confusions and sought sources of clarification (growth mindset). Likewise, it was supposed to show how students felt about their level of understanding of topics, if they made fixed comments like, “I don’t need/want any help” or “that took forever, but I finally got it”, would display a definite mindset. Unfortunately, students did not fill out the ticket in a regular enough manner, sometimes putting more thought and effort into their response. Most responses were not codeable. These artifacts were collected but not used in the study because it was not deemed a reliable source of data.

Once per unit, a quick lesson on mindset was brought up and the class would discuss the topic. Most often, the lesson consisted of the instructor reading a choice segment of the Dweck Mindset book. After the reading, the class would have a short discussion (5-15 minutes). Sometimes, a mindset lesson was a discussion of something that came out of the news or a magazine. Mindset came up on an intermittent basis during whiteboard presentations and class work whenever prompted by a particular student behavior.

Investigator 2 results

Gain FCI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	23.141	1	23.141	1.121	.312
Within Groups	227.167	11	20.652		
Total	250.308	12			

Table 9: ANOVA comparison of FCI raw score gains for weak and strong-growth mindset students of Investigator 2

The ANOVA test of FCI raw score gains of Investigator 2 (Table 9) compares two groups, weak mindset and strong fixed mindset, because only two mindset groups were found amongst this teacher’s students. The significance value of $p=0.32$ indicates that there is no significant difference between growth and fixed mindset students in this class.

Conclusion:

13 of the 146 students in this study were from Rio Rico High School. We had four students who enrolled in the class and dropped before the end of the first quarter of the school

year, they were not included in this study. I believe that each of the kids who dropped would have been just fine, with an appropriate amount of dedication. I wish I could study students such as them further in attempts find a connection between their mindset and their decision to quit, and then change it.

Investigator 3 Field Report

Introduction

Investigator 3 is Holly McTernan of Cleveland, Ohio. I teach at St Edward High School in Lakewood, a suburb located on the west border of Cleveland. This is my 23rd year teaching various levels and courses of science. It is my 12th year teaching some regular level physics, and my 3rd teaching all physics with the modeling method of instruction. It is also my 5th year teaching advanced levels of physics (Honors and AP). At St Edward all students must take 3 lab science classes one in each of Biology, Chemistry, and Physics, and usually taken in that order. We offer multiple levels of physics but students are placed in conceptual or regular levels and apply for the advanced levels of physics. A student in an advanced physics course has usually elected to be there for a variety of reasons which may include parental wishes, concerns for college placement, and/or career plans. A student in a regular level physics class is most likely placed there without any discussion or thought other than prior math and science accomplishments.

The classes from which I gathered my data were five physics courses. Two were regular level physics classes and three were advanced level physics classes. I worked with approximately 55 regular physics students. Regular physics is an algebra trigonometry level college preparatory class, populated by typically above 90 percent seniors and less than 10 percent juniors. The range of math ability is quite varied for this course but almost all students are in or have passed an Algebra II course.

I also worked with 36 students in AP Mechanics taught as a first year course for 2 semesters and consisting of about 50% seniors and 50% juniors. To be accepted into this class the students had to be in the upper percentile of their class in the areas of science and math, and be enrolled in or have passed a pre-calculus course. About 40% of these students were in AP Calculus BC or had already passed that course and moved on to another advanced college level mathematics course.

The final class included in the study was added about halfway through the year when it became clear something was different about the mindset of that small group of individuals. This class consisted of 9 seniors who elected to take AP Electricity and Magnetism having completed the mechanics class at an honors level with me in the prior year 2009-2010. AP Physics C E&M is also taught as a 2 semester course. The 9 seniors had already taken a mechanics class as juniors. Most were enrolled in either AP Calculus or had already passed the

BC level AP Test. The pre and post FCI data collected from these 9 seniors and the mindset pre survey was collected in the fall of 2009 when the study was first begun and then postponed.

Procedure

I followed the same procedure as described under the method. I did retreat on mentioning or bringing up the mindset for a few months when a student became irate about his Constant Velocity Model Test Score and thereby took offense at the lesson on mindset. While his objections and commentary were duly noted as evidence of a fixed mindset, I did not want to jeopardize the study and waited a while for the situation to resolve itself.

I did not use the exit tickets. Instead I opted for other means of gathering artifacts regarding mindset. I took notes when students came in to go over their tests and looked for such details as whether students looked to add the numbers in case I had made a scoring error in their favor or if they wanted to know how to answer a quotation that was marked wrong. If I worked with a student and the exchange held information regarding mindset I noted this down.

As the year went on I placed some quotes from the growth mindset oriented Coach Wooden on the board as well as some anecdotes of growth mindset successes (Mia Hamm, Thomas Edison, etc...) and occasionally a question to ponder about how they might think about things. I would sometimes offer an optional take home journal prompt which they could turn in if they liked. Each of these was an attempt to elicit qualitative data to help me to assess their mindset at that time in the course.

I interviewed many of my students at the end of the year (no bonus points were offered) asking questions such as these:

- Why did you choose to take this course?
- What will you take with you from this course now that you are almost finished with it? (Many students thought I wanted to hear about content and would tell me something about content. This could be a positive or negative comment regarding viewing the material as useful).
- Other than content what will you take from this course? (Most described that the group dynamics and the experience of doing real labs was new to their education and very powerful for them and they felt this would help them later in various areas of their life. Some mentioned that having learned how to organize and study or to ask others for help would be useful later).
- Can you recall and describe for me one experience of a really challenging problem or difficult experience you had in this class?
- How did you respond to this challenge? (Their answers from here led me to other questions to probe a bit as to what steps they had taken to solve the dilemma. For most a unit or homework problem or lab analysis were named).

- Are you glad you took this course or was it a waste of time?
- Is there anything else you would like to tell me or want me to know?

Many times I was puzzled by the apparent contradiction of students who worked very hard and yet made no progress. I was also puzzled by students who had seemingly really great attitudes saying frequently things like “You just have to work hard.” Or “I always expect the best of myself.” These seemed very growth mindset statements. However these same students might give up easily, whine when it got difficult or information wasn’t handed to them, or get angry and say they had not learned anything. Some of these students scored very high on the FCI as well as the other evaluations I gave them.

Later as we analyzed the essays and became even more familiar with the mindset characteristics, I began to see that these students were possibly parroting the comforting statements they had learned from coaches and parents. These are good statements indicative of admirable attitudes but I believe they can become rhetoric used to mask a fear of failure.

One last interesting piece of information from my part of the research is reported here and provides opportunity for further studies. St Edward can be a pretty high power institution. I use this phrase in the sense that I believe Dweck meant it when she discussed the higher percentage of fixed mindset persons to be found in ‘high power’ situations. St Edward frequently holds very successful CEO’s and sports figures up as models for the young men. Every year they have alum or contacts of alum come in to speak to the young men about success in the business world and in life. The institution intends to help the young men set high goals and develop strong character and work ethic. As a college preparatory school every student is expected to take challenging courses and to go on to college. This can put a great deal of pressure on the young men. Students in the AP classes have mostly been selected for the high level track and received the prestige of being ‘Max-Ad’³ students since they were freshmen. To be dropped from this level is to have failed. This is a tremendous amount of pressure for grades and success placed on this top track of students. Thus, the AP Physics class at St Edward is one of the courses where this ‘high power’ nature appears most strongly. Some students are now headed off to Brown, Carnegie-Melon, Harvard, Stanford, West Point, Yale, and other institutions of such standing. In this environment it is possible to find a ratio of fixed to growth mindsets move away from the 50-50 mix and favor the fixed mindset. (Aldous, 2008) While the students in the E&M class (2nd year physics) were varied in math ability and physics ability, the ratio of identifiable mindset to unidentifiable was 6 to 3 (67%) and 5 of those 6 were growth mindset students. In the interviews these second year students completed with me at the end of the year, every student but one reported that the learning experience was very challenging but also more important than any other single benefit to taking the class. This was a compelling reason to bring them back into the study as their data

³ Max-Ad is the St Edward name for “Maximum Advantage” a track which allows for the student to go into the top tier of courses.

had been taken the previous year when they began as first year mechanics students. In the spring of 2010, thirty students could have signed up for E&M but chose not to, some telling me at that time, they thought it would be too hard and too much work. A few of those professed a desire to be engineers. I was startled by the fact that once there was no real reason to take a difficult course in physics (they had one on their transcript already), the fixed mindset students appeared to be no longer interested in the pursuit of the study.

In the Mechanics AP classes (1st year physics) I had to exclude 24 of 36 students (67%) because I did not have 3 identical indicators of mindset. The scores of those 24 students contained contradicting indicators. Of the 12 students whose mindset could be determined, they were split precisely 6 growth and 6 fixed. Of these 12 students, 6 are eligible to sign up for E&M next year. The others are seniors and have left the school, to go on to college. From that pool of 6 students, 2 have chosen to go on to E&M and both positively identified as growth mindset students. The other 4 who elected not to take the class positively identified as fixed mindset students. The class next year will have 7 students in it. Of the seven, one is a new student for me. He is electing to take both AP Physics classes concurrently because as a member of the class of 2012, he can't have both curricula if he does not take both this year and he said he wanted to learn more physics and take more science. It seems reasonable to suspect that he may be a growth mindset student. The other 4 students for next year's E&M class were not able to be identified in this study in terms of their mindset but there are strong indicators that at least 2 of them are also growth mindset students.

Investigator 3 Results

Gain FCI

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	368.182	2	184.091	8.697	.000
Within Groups	2010.807	95	21.166		
Total	2378.990	97			

Table 10: ANOVA comparison of FCI raw score gains for strong-fixed, weak, and strong-growth mindset students of Investigator 3

The ANOVA test of FCI raw score gains of Investigator 3 (Table 10) compares three groups: strong fixed mindset, weak mindset, and strong growth mindset. The significance value $p=0.000$ indicates that the three groups, strong-fixed, weak, and strong-growth mindset are significantly different from one another.

Conclusion

Of the 147 students in this study, 99 were students in my modeling classes. I began this study believing that FCI scores would be low for students with a fixed mindset and high for students with a growth mindset. What I found was that fixed mindset students will achieve high post FCI scores if they have the math and science background and extrinsic motivation to do so. However many of the fixed mindset students may not have the background or the extrinsic motivation they do have is not sufficient motivation to allow them to achieve at high levels. FCI post scores and gains will be randomly distributed for students with a fixed mindset. On the other hand what is seen in our study is that students with a growth mindset tend to have post FCI scores and gains that cluster in the upper regions of a scatterplot. In other words, regarding gains in conceptual understanding in mechanics, there is a statistical advantage to having a growth mindset. If a student has a growth mindset that student has a greater likelihood of achieving greater conceptual understanding and thus has a greater likelihood of demonstrating higher overall gains on the FCI.

One of the reasons for the study was to determine if teaching the mindset and keeping students aware of the statistical advantage of a growth mindset might be worth the time and effort especially since classroom contact time is at a premium for most teachers. The study suggests that taking time to build such awareness will be a help to students. It suggests that the modeling method may be more effective for students who have the opportunity to build such awareness. I will make a greater effort in my classroom to educate my students to this theory and to offer more exposure to growth mindset thinking as a result.

Implications for further research

The implications for further research seem to be extensive. We will briefly outline some of them here.

While we attempted to prove that mindset can be a predictor of conceptual understanding in physics by using the Force Concept Inventory, we did not include in the scope of our research other assessment instruments. Other than qualitative evidence from the survey essays and the teacher observations and some anecdotal evidence provided in the interviews we did not assess student enjoyment or frustration level in the modeling physics classroom. We also did not measure the level of participation of students as it correlates with mindset. However the evidence suggests that students with a growth mindset would be more

Modeling promotes mastery goals. As the modeling curriculum is constructed during the course of the year, previously developed models are revisited in a progressive spiral. This leads to the development of problem solving strategies and deeper conceptual understanding. Studies in classroom structure indicate that engagement in learning increases not only time spent by students in learning but also in their persistence in the area of study. This student engagement is recognizable in participation in such problem solving strategies as modeling deployment activities or modeling labs. (Garner, 1990; Elliott and Dweck, 1988; McCombs, 1984). A number of the students identified as growth mindset students interviewed by Investigator 1 did mention specifically that they felt the [modeling] approach to learning helped them to learn the material in a way that was different and they identified that they were able to understand concepts more deeply. They identified that they had learned to think differently and felt more confident in their problem-solving abilities.

While we did measure student mindset, the goal of this study was not to attempt to change their mindset. We did do some limited teaching of the mindsets and did assess their mindset as they exited our courses but did not have an active plan or intention to sway their mindset. It would be interesting to study what percentage of students might be able to move towards a growth mindset using physics as the backdrop for the experiment as Dweck used junior high math students to study such trends. (Dweck, 2008; Aldhous, 2008; Blackwell, et al, 2007) Such a study would be extensive, involved and might be beyond the scope of possibility for research done by a full-time teacher with many other responsibilities in the minute to minute aspects of teaching. For teachers who may wish to begin to implement some of the mindset ideas Dweck's connection between the mindset theory and theories of self-efficacy and goal studies might be very helpful. This can be found summarized in a full color document online at <http://www.des.emory.edu/mfp/303/303dweck.pdf>. (Dweck, 1988). Other teachers during discussion after the presentation suggested sharing the list of common growth phrases and fixed phrases we used in the presentation, and these are now included in appendix D.

Research has found two other factors connected to this study of importance to science teachers. First, telling a child or student that they are “not a science person” gives the student the false belief that abilities are fixed. This then gives the student permission to not persist in following through on challenging science courses. (Dweck, 2008; Wigfield, 2000). Second, Dweck’s research shows that women and minorities may be more susceptible to the fixed mindset in the area of perseverance in science and math. The fixed mindset is connected with the low number of these populations in these fields of study. (Dweck, 2008)

Finally, as pointed out in the study at St Edward, it appears that beyond a greater probability of high conceptual understanding of forces, students benefit from a growth mindset in the choices they make regarding course selection. More students appear likely to take and persevere through challenging physics courses if they have a growth mindset. They appear to enjoy the experience of learning in these courses as well. Given the state of STEM education in this nation (Hestenes, 2010) it seems that such a correlation would be well worth researching.

Acknowledgments

This project has been challenging and rewarding. As we have studied the two mindsets we have each grown as teachers. It has changed the way we think about learning and adversity and as a result we work differently with our students. There are many persons who have helped us through this process. This research project could not have been completed without the assistance of many individuals. While they are too numerous to mention by name we do want to thank the following persons specifically:

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Appendix A:

Personal Beliefs Survey

Part I:

Please answer these survey questions about intelligence and personal qualities. You are asked to identify how much you agree or disagree with a statement. Circle 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”.

“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. Try to answer the prompt questions for each choice. Be as clear as you can, and use complete sentences.

- d. Identify 3-4 feelings you would have in this situation.
- e. 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 as 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.

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.

Interview

Photography: Jonathan Sprague

How successful you are depends on your mindset, not just luck or innate genius. Believing you can improve by practice, rather than thinking talent is fixed, makes all the difference, says psychologist **Carol Dweck**. She is launching software called Brainology, designed to help children trapped in the wrong mindset, and tells **Peter Aldhous** why her ideas trump the usual self-help approach.

Free your mind and watch it grow

You say that the key to success in life is to adopt a "growth" mindset as opposed to a "fixed" one. What do you mean by these terms?

People with a fixed mindset believe their basic qualities are carved in stone, so they are concerned about making their abilities look good. Those with a growth mindset believe their basic abilities can be cultivated through dedication and education. They are more concerned with stretching themselves. We've shown that a growth mindset orients you towards learning, whereas a fixed mindset makes you wary of challenges. If the learning involves risk of failure, those with a fixed mindset are more likely to pass it up.

Which of your studies most vividly demonstrates the power of these mindsets?

A year ago we showed how, if you know someone's mindset, you can predict how motivated they will be and the grades they are likely to get when they move to junior high school at the age of 12 or 13, when there is often a decline in grades. After a poor grade on an initial test, the students with fixed mindsets said that they would study less, try not to take that subject again - and consider cheating.

Why might a fixed mindset lead people to cheat?

Effort is seen as negative, and failures mean you lack ability. What's left? You can withdraw from that field of endeavour, but if you're required to pursue it, as in school, then maybe you will resort to other means.

Have you looked at how these mindsets operate at the level of brain activity?

We looked at the electrical activity in the brains of college students as they performed a difficult general-knowledge task, which showed whether they were entering a state of heightened vigilance. A second and a half after they typed in their answer to a question, they were told whether they were right or wrong. A second and a half after that, they were told what the right answer was. The students with the chronic fixed mindset entered a state of vigilance while waiting to learn whether they were right or wrong, and then that was that. But the students with the growth mindset entered a further state of vigilance while waiting to learn what the actual answer was.

Are people with a fixed mindset inevitably unsuccessful?

No. John McEnroe was one of the most talented tennis players ever and, despite his fixed mindset, he achieved great success. But he did not like to practise, he did not tend to address his weaknesses, and he often engaged in self-defeating tactics when he was losing. I can only imagine what he might have achieved if he'd had a growth mindset!

Are we born with one or other mindset?

I think there is some component that may be inborn. We know there are some kids who are very sensitive to mistakes and setbacks, while relatively impervious kids tear around the world come what may. However, we've also shown that environment can play a huge role

In a typical group of children starting school, what proportion is in each mindset?

We find that about a third of pre-school children have a fixed mindset and two-thirds have a growth mindset, except in very high-power environments like child day-care at an elite university's business school. These kids tend to have more of a fixed mindset. They worry more about mistakes and being disapproved of. Maybe they have more pressure put on them by their parents, or have been told they are brilliant. As children move on after pre-school, we find that more of them move into a fixed mindset, so we get a 50:50 split. In adults, it's about 50 per cent of each mindset, too.

What is your advice to parents who want to avoid trapping their children in a fixed mindset?

First, teach your child the growth mindset, and then praise effort, strategy and improvement. Do not praise intelligence and talent. This harms them.

How easy is it to influence people's mindsets?

We have shown that you can put college students in a fixed or growth mindset by having them read compelling scientific articles that support one view or the other. After the students read the articles, we gave them a difficult reading comprehension test on which they did poorly, and asked them afterwards: "Would you like to look at the tests of people who've done worse than you or better?" The students who had



read the articles supporting a fixed mindset chose to look at the work of people who had done worse. It made them feel better about themselves. But the students who had read the literature favouring the growth mindset overwhelmingly chose to look at the tests of people who had done better, so that they could learn new strategies. They also felt better about themselves

Could more be done to foster growth mindsets in school?

In our study of the transition to junior high, a control group was given extensive training using study aids. The experimental group got those study aids but they also got several workshops in the growth mindset. They were told that every time they stretch themselves, the neurons in their brain form new connections, and over time they get smarter. They were also taught how to put that into practice in their schoolwork. Their grades rebounded, while those of the control group continued to decline.

Your new computer program, Brainology, is based on these workshops. How does it work?

Kids follow two hip teenagers through the program. The students interact with these virtual characters and make study plans for them. But the basic framework is learning about the brain. They're told they can do things to make their brains work better. In that context they learn the growth mindset. Brainology is an owner's manual for the brain.

You say you used to have a fixed mindset. Where did that come from?

I was raised in an era when there was tremendous faith that IQ tests measured something inherent. My sixth-grade teacher seated us around the room in order of IQ and assigned every privilege and responsibility on this basis.

How did you change your mindset?

Through my work. When we discovered the mindsets, I thought: "How could I be doing this research and not taking up challenges?" As a result, I think my research became more adventurous. It was extremely difficult, initially, to study the mindsets, but I was ready to take on that challenge. Writing a popular book was also something I had never done before. My academic writing was clear and simple, but it had no personality. It was a matter of finding my speaking voice.

Do you have to put in constant effort to avoid slipping back into a fixed mindset?

Part of it is like flipping a switch, because you discover there is a new psychological way of being. But it takes a lot of effort, because you have immediate emotional reactions to things. You need to talk yourself back into a growth mindset at those points.

There are lots of self-help books urging us to adopt a positive attitude. How does your approach differ?

There's evidence behind it. Second, many of these books are lists of what you should do - have confidence and so on - but they don't reveal how you do that. I identify a core belief that creates a whole psychological world in which you might prefer to live. •

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Appendix C

Mindset Shorts

Mindset Shorts: Share your mindset examples for us each to use.

1. Calvin and Hobbes cartoon from “Mindsets Change the Meaning of Effort (Dweck, 2006 p. 40)

2. John Wooden: You aren’t a failure until you start to blame. What he means is that you can still be in the process of learning from your mistakes until you deny them. (Dweck, 2006 p. 37)

Reference: Wooden, John, with Steve Jamison. Wooden: A Lifetime of Observations and Reflections On and Off the Court. Lincolnwood, IL: Contemporary Books, 1997

3. In a study, seventh graders told how they would respond to a low test score in a new course. Some said they would study harder for the next test. Others said they would not bother to study. They said it would be a waste of time since they weren’t smart enough. College students who did poorly on a test were offered the opportunity of looking at other’s test answers. Some chose to look at test of those who did better than they had so they could learn the answers they did not already know. Others wanted to look at tests of those who scored worse than they did so that they could feel better about their scores. (Dweck, 2006 p. 35-36)

reference:

seventh graders: work done with Lisa Sorich Blackwell and Kali Trzesniewski

college students: work done with David Nussbaum

4. Jim Marshall, defensive player for Minnesota Vikings, scooped up a San Francisco 49ers fumble and ran it for a touchdown. Unfortunately he ran the wrong way and scored for the opposing team on national TV. He was devastated. The shame was overpowering. During halftime, he thought “If you make a mistake, you got to make it right.” I realized I had a choice. I could sit in my misery or I could do something about it.” Pulling himself together for the second half, he played some of his best football ever and contributed to his team’s victory. (Dweck, 2006 p. 34)

5. People in a growth mindset don’t just seek challenge, they thrive on it. The bigger the challenge, the more they stretch. Mia Hamm, the greatest female soccer player of her time says: “All my life I’ve been playing up, meaning I’ve challenged myself with players older, bigger, more skillful, more experienced - in short, better than me.” First she played with her older brother. Then at ten, she joined the 11 year old boys team. Then she threw herself into

the number one college team in the United States. "Each day I attempted to play up to their level ... and I was improving faster than I ever dreamed possible." (Dweck, 2006 p. 21)

reference: Hamm, Mia, with Aaron Heifetz. *Go for the Goal: A Champion's Guide to Winning in Soccer and in Life*. New York: Harper Collins, 1999, 3.

6. Michael Jordan was the hardest working athlete, perhaps in the history of basketball. He was cut from his high school varsity team. He wasn't recruited by North Carolina State, the college he wanted to play for. He wasn't drafted by the first 2 NBA teams that could have chosen him. When Jordan was cut in High School he began a disciplined practice regime. Every morning he left at 6 to go practice. At North Carolina University he was the hardest working player, constantly working on his weaknesses. Even at the height of his success and his fame - after he had made himself into an athletic genius - his dogged practice remained legendary. (Dweck, 2006 p. 86)

reference: Janet Lowe, *Michael Jordan Speaks: Lessons from the World's Greatest Champion* (New York: John Wiley, 1999).

7. Coach Wooden has a rule: "You have to apply yourself each day to become a little better. By applying yourself to the task of becoming a little better each and every day over a period of time, you will become a lot better." He didn't ask for mistake-free games. He didn't demand that his players never lose. He asked for full preparation and full effort from them. "Did I win? Did I lose? These are the wrong questions. The correct question is: Did I make my best effort?" If so, he says, you may be outscored, but you will never lose." He was not a softy. He did not tolerate coasting. If the players were coasting during practice he turned out the lights and left. "Gentlemen, practice is over." They had lost their opportunity to become better that day. (Dweck, 2006 p. 200)

8. Think about your hero. Do you think of this person as someone with extraordinary abilities who achieved with little effort? Now go find out the truth. Find out the tremendous effort that went into their accomplishment - and admire them more. (Dweck, 2006 p. 80-81)

9. Think of times other people outdid you and you just assumed they were smarter or more talented. Now consider the idea that they just used better strategies, taught themselves more, practiced harder, and worked their way through obstacles. You can do that too, if you want to. (Dweck, 2006 p. 81)

10. How do you act towards others in your lab group? Do you listen to their ideas? Do you ever reaffirm your status by demeaning others? Do you feel others are just judging you or are

they helping you to develop? Could you profit from the feedback you get? (Dweck, 2006 p. 137)

Appendix D

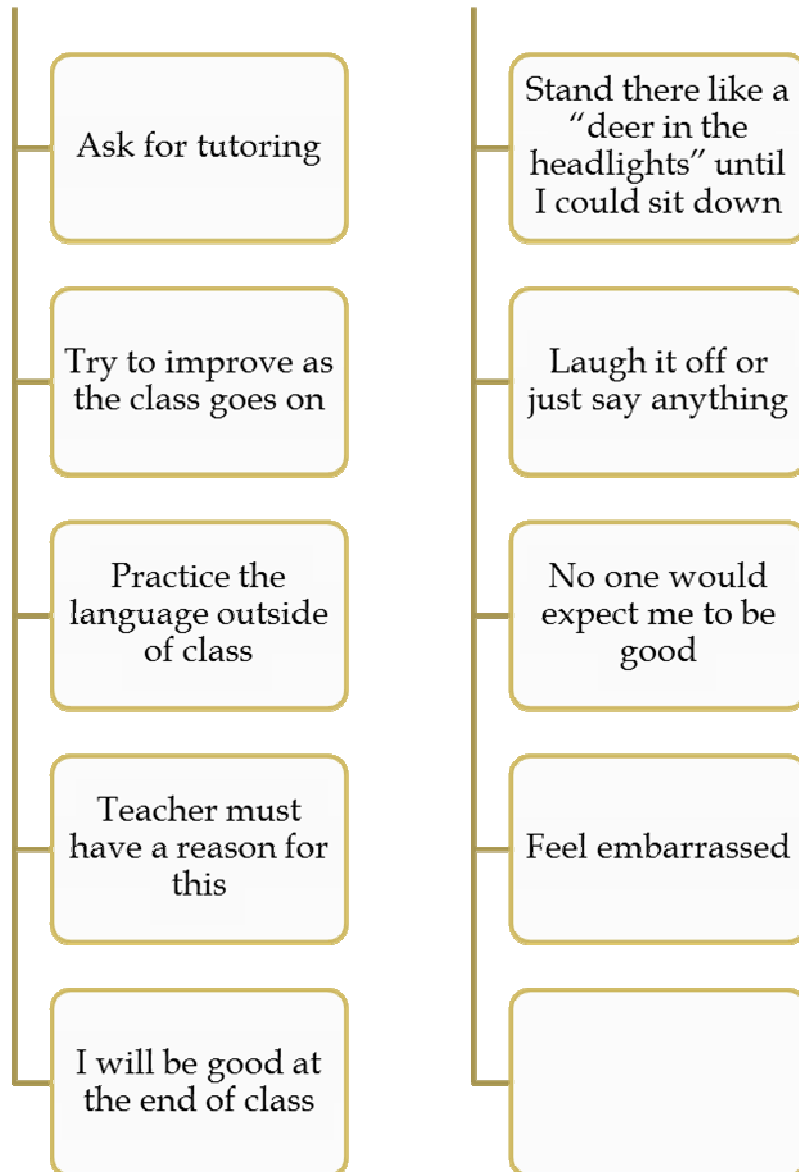
Trigger Words/Behaviors to assist in identifying mindset

Fixed	Growth
Frustrated	Excited
Angry	Enthusiastic felt good
Felt Stupid	This is fun
Felt bad	I'm learning
Didn't care	I can do this
Didn't want to do	This is great
Did not complete	I'm struggling but this is worth it
Did not attempt	This is interesting
This is stupid	It was hard but it was worth it
I'm not smart enough	Let me try that again
I'm not good enough	May I have help
I'll never get this	That practice really helped me
Head down/sleeping	This discussion really helped me
This is boring	Attentive
Why do we have to do this?	Asks question
Never	Yet

Growth Statements

Fixed Statements

Situation A: Language class – being called up front and asked to respond to questions



Situation B: Difficult math homework

Call a friend

See the teacher
so I could get it
done faster

Look up similar
problems/help
on the internet

Tell the teacher I
didn't
understand it

Re-read my
notes or book

I'm not the only
one with this
problem

Ask the teacher
for help in
morning

Feel
embarrassed

Feel excited by
the challenge

I tried my best

Situation C: Difficult day



Sample Scored Essays:

I would feel ~~trapped~~ out and ~~uncomfortable~~ standing up in front of the class. Having the teacher throw questions at me to which I ~~don't understand is frustrating~~. I would probably tell the teacher that I ~~don't know the answers~~. After that I would most ~~likely~~ slowly walk back to ~~my seat~~

$\frac{0}{3}$

Second Choice Situation _____:

- a. Identify 3-4 feelings you would have in this situation.
- b. Identify how you would respond.

A

(Situation B) In this situation I would get a ~~little~~ ~~scared~~ and nervous. I would probably ~~call someone~~ to see if they know how to do the problems or wait and ask the teacher if I could ~~have another~~ ~~explanation~~ and ~~one more day~~ to finish and ~~understand~~.

$\frac{4}{4}$

$\frac{8}{9} =$

I would be frustrated, embarrassed, and I'd quickly decide that I dislike that teacher. I would respond by trying to make something up, but I'd probably not make very much sense due to the fact that my mind is overcome with humiliation. I really dislike being called out. I'm not sure why, but I get embarrassed easily.

0
5

In situation A, I would feel overwhelmed and nervous because I would not be able to understand the questions, and I wouldn't want to look dumb in front of my class. I would also be bitter toward the teacher for putting me in this situation knowing I was new to the class. I would either respond by trying my best to answer the questions or explaining to her that I had no idea what she was saying.

I would feel angry because of all the stuff that has happened to me. I would also feel frustrated with myself. I would feel sad and down because ~~to~~ nothing seems to be going well. I would try to do something that would boost my energy or confidence by doing something I love and can't fail at. Or I would just go home and go to bed and forget about the day and try to move on.

I would be nervous because I do not know much about the language. I would be angry because the teacher is asking me questions that I know do not know how to answer. I would be frustrated because I wouldn't understand. I would also feel confused. I would try my best to respond with the little knowledge I have on the language then I would ask to go sit down if the questions were too difficult to understand.

I would wonder if I missed a part of the lesson or was not paying attention.

I would feel like I ~~have~~ ~~to~~ ~~have~~ to figure out how to do it.

I would feel ~~then~~ intrigued.

I would first try to think through the problem myself and see if there was anything I did understand.

OR

I would work w/ other students to see if we could figure something out.

5/5

I would be mad at the world. ~~and~~
~~want to relax by myself in my room.~~
 I would feel frustrated.
 I would be annoyed w/ myself ?

I would respond by spending some time
 alone to chill out and relax.

I would take extra steps like
 studying more, practicing more, going
 the speed limit to avoid getting
 myself in the same situation again.

I would be mad and disappointed that I was not prepared
 for my math homework, and I would be dissatisfied
 that I did not work harder in class to prevent
 struggling later on. I would do as much as I could
 on my own, and then seek out someone that can
 help me understand what is confusing me.

Teacher Observation Rubric:

Student	Trait 1- Perseverance does not quit easily in group problems or in HW	Trait 2- Unafraid to Learn - asks questions participates in discussions	Trait 3- Seeks Extra Help and goes over tests for understanding	Trait 4- Values understanding over points	Total
Fauli	1	1	2	1	1.50
Kelvin	1	1	2	1	1.25
Kelvin	1	1	1	1	1.00
Rutherford	2	2	1	4	2.75
Heisenberg	2	2	2	1	2.25
Einstein	2	2	1	2.5	2.38
Cavendish	2	2	1	2.5	2.38
Aristotle	1	1	1	1	1.00

Appendix E

Exit Ticket Guidelines and parameters:

Students and Teachers need to know the following:

Unit: Name of Unit being studied written here.

Rating of 1, 2, 3, 4 where:

1 is “strongly agree”, 2 is “agree”, 3 is “disagree”, 4 “is strongly disagree”

WHEN and HOW used

Students fill out one side of the sheet each week (three days a week). Each “ticket” lasts two weeks.

Before leaving class they are asked to complete the ticket of the day.

Whenever a student writes about a point of confusion, the following day they will have looked for a way to resolve the issue and written a quick response of the “answer” as well as how they resolved the issue: called a friend, practiced a HW problem, reread notes, paid attention to a WB problem or discussion, visited with a teacher or tutor, etc

Each teacher can decide how to collect the tickets, but should ensure that they don’t get lost by students or otherwise. It might be suggested that one collects tickets once a week to check that they’re being filled in and to make sure that students are being forthright.

Tickets will be returned to students before each unit test. They are allowed to review their tickets. At that time, they can take notes off their ticket but should not change their ticket.

Exit Ticket Template

Unit: _____ Name _____ Code _____

Level of Confusion: 1 2 3 4

An idea I still do not understand:

Clarification:

Source:

Unit: _____ Name _____ Code _____

Level of Understanding: 1 2 3 4

An idea I now understand:

Source:

Unit: _____ Name _____ Code _____

Level of Confusion/Understanding: 1 2 3 4

An idea I still do not understand/now understand:

Clarification and/or Source:

Appendix E

Interview/Blog Example Questions

Examples of interview questions which could be used for ticket prompts or journal/blog prompts. These prompts should be used as soon as possible after the event referenced so that student recall is high:

Sample 1:

On Unit ____ WS ____ . Pick out a question that you think was hardest.

Can you identify where you got stuck?

Can you remember what you did to fix the problem?

Sample 2:

When you were asked to present on your whiteboard, how did you feel?

Why do you think you felt that way?

Sample 3:

When you were trying to learn how to use logger pro (or Excel or other data analysis program), what did you do?

Sample 4:

When you struggled to make sense of your data and it was not going well, how did you deal with the difficulty?

Sample 5:

When you were faced with problem # ____ last night and it was really hard, what did you do to solve it?

Sample 6:

When you got your test back and looked at your grade what was your first thought? What about your second thought?

Sample 7:

When you got your lab report back and saw the grade, what was your first thought? What about your second thought?

Sample 8:

When you were trying to finish this lab and collect data and the experiment was not going well or the sensors were not easy to operate how did you deal with the difficulty?

Sample 9:

Do you think you were an effective member of your group today? Why or why not?

Appendix F

Interview Excerpts from Investigator 1

(The following are a 7 samples of interview responses from my students. The interviews were selected because they expressed so clearly the two different mindsets. The first 3 are from the AP E&M class. The next 3 are from AP Mechanics class. The last one is from regular level physics. Bold text means the word was emphasized by the responder).

Sample Interview I

I1: You had all the science you needed yet chose to take AP E&M. Why?

Heisenberg: I “definitely wanted to ‘step it up’....felt I needed a challenge. Last year regular level [chem] was not challenging. Junior year I moved up to honors English. I regret freshman year. I did not start strong. Sophomore year a change began to surface. I was getting motivation from **new** ideas...engineering, biology, and geometry.

I1: What do you think you will take with you?

Heisenberg: Answers of how things work. That didn’t mean plugging numbers into formulas...it was different. Lab experience – helpful to answer concepts. If I see an experiment it’s **mine**...like the 2 objects rolling down the ramp...you know - the one where the wood is solid and the metal is just a hollow ring.

I1: I know this class was not easy for you and you came in quite often to go over tests and ask questions. You even took AP Chem concurrently. What did you do when something was really difficult? How did you handle that?

Heisenberg: well, ...ask the teacher. And I asked other kids.

I1: Like who?

Heisenberg: (Names 2 students who have very different working styles), to get different viewpoints. That usually helped.

I1: Anything else?

Heisenberg: Most people take the test to get it over with. I want to know what I got wrong to know how to fix it so if I see it again...what bothers me is probably it is stupid

I1: Your answer you mean?

Heisenberg: Yes – but when I was actually confused – if I looked at it and asked then I would remember what my mistake was...my pre-calc teacher. [I would have] one wrong [on the test]. She’d actually say ‘You did good’. **‘But I got that one wrong! Why?’**

I1: So your teacher is happy with your work and you aren’t. Have you always been that way?

Heisenberg: No. Sophomore year, when things got interesting that’s when I started to go back over tests...

Sample Interview II

I1: So why take this course? You didn’t need it. It’s your senior year, this is really hard.

Pauli: I’ve never done anything easy. Exciting – always pushed to do better...enjoy trying to make myself better. I’m sort of like in competition with myself.

I1: Sometimes I see you were not happy with yourself when you missed an idea. What did you do when something was difficult to understand?

Pauli: Frustrating. I’d push myself harder – to get to the point where I was with the rest of the class. Most of the time I’d revisit the material, talk to other students in the class...sometimes I’d use the textbook.

I1: What will you take away from this class?

Pauli: It was a difficult challenge. The material...thinking through very different ideas. I was using different parts of my brain....just the experience that I learned something so hard.

I1: So which mindset do you think fits you better?

Pauli: ...I’m not big on ‘I accomplished this or that’ – knowing I experienced this or that is more important to me...

Sample Interview III

I1: You almost dropped this course. You were afraid you couldn't do it. Why did you decide to stay?

Galileo: To challenge myself – I'm going to be a business major, so no immediate benefits. [very matter of fact] I don't think the content will be useful– [very matter of fact] I don't think I'll pass the [AP] test...

I1: It was not easy for you at all. How did you handle the tough stuff?

Galileo: Well, the book was really complicated. I used the net a lot. It was frustrating but I kept pushing, kept going. You know - I was using you and other people for help.

I1: All that work – was it worth it? Looking back, are you glad you did it?

Galileo: I was able to hold good grades – it was worth it. Mostly how you earned it – understood the material; maybe I will use it. It was definitely learning something different and it will give me confidence for the next tough task.

I1: So you think you'll take something away with you?

Galileo: Oh yeah. The challenge. How to study. Lab work. Just work ethic. The learning process. I never had to do that before. It's always good to have more education. It can't hurt. I'm not sure how, but somewhere down the line it will help.

Sample Interview IV

I1: Why take this class? Why not just take physics?

Aristotle: Needed another AP. Had to take physics...might as well do AP Physics.

I1: So, do you have any regrets?

Aristotle: Oh yeah. – tough course. I didn't feel like I learned much it was really confusing.

I1: But you had one of the really high scores on the national test we took. You got a 26. The average score is much less than that. What about that?

Aristotle: Yeah I was surprised by the test score. I was proud of it, but didn't think I had learned it. I mean the basic physics I got, but the more intense stuff I didn't get.

I1: Do you think you'll take anything away from this course?

Aristotle: Yes. Well the basic stuff. But I'm not intending to take physics. I'm more inclined to Biology than chemistry or physics. I'm more receptive to that stuff.

I1: What about things that are not content. Do you think you'll take anything else away with you?

Aristotle: No...nothing. I had lots of trouble with the calculus stuff. [Aristotle is referring to the kinematics graphs at the beginning of the course. No calculus was used at that time]. You shouldn't be allowed to take this course without calculus. [Aristotle was in the highest level of pre-calculus offered at St Ed's when he took this course]. It's just way tougher to understand without the calculus. The other guys [that already had calculus] they knew shortcuts and it was easier. We only had one option.

Sample Interview V

I1: AP Physics did not seem easy for you. Are you happy you chose to take AP Physics?

Rutherford: Happy? Yeah – not sure how well I did on the AP test but I learned a lot.

I1: What will you take away from this course?

Rutherford: It puts things in a different perspective.

I1: You experienced that?

Rutherford: Yeah...what causes things. It's logical.

I1: So cause and logic...you like that

Rutherford: Yeah. We looked at data ourselves and then shared it instead of the teacher telling you. I'm sure I'll have to do that later...learning figuring things out on our own. I liked the experimenting.

I1: Do you think it is possible to expand your intelligence?

Rutherford: Uh...I don't really know – like some people naturally have it but anyone can work hard and get better and learn more.

Sample Interview VI - (Note: This student earned a 25 on the FCI. The student also demonstrated anger and frustration on at least 4 memorable occasions when his grade of A was in jeopardy of moving to A- but never seemed interested in discussing material at depth or spending more than a few moments on any one problem. One time he was very frustrated and stated that students had been given no idea how to solve a problem. The problem was assigned after Unit 8 Uniform Circular Motion, including the Universal Law of Gravitation extension. The problem asked students to determine how long it would take for the earth to circle the sun).

I1: Why did you take AP Physics instead of the easier course?

Mendeleev: It looks better for college...I took the course and my cumulative GPA will get a boost. I want to go to a top level university.

Mendeleev: Well I practiced time management during the football season in terms of it being a challenge. I thought it was equal to the other AP courses about the same difficulty and work load.

I1: Was there ever a time that you found the material a challenge?

Mendeleev: The course work was easy – the work itself - I was never confused – I understood everything.

I1: You never had a time you needed to dig deeper?

Mendeleev: No

Sample Interview VII – (I worked very hard with this regular level physics student on a regular basis. He worked very hard, but mostly seemed to simply copy things down that I or others said. When I question him, he seems to not be able to answer himself without great and careful prompting. I sometimes run out of time and have to simply remind him of things we said in class or earlier together. His FCI gain was zero, and I was disturbed by the failure that I felt I shared with him).

I1: You work so hard – that is very impressive.

Kepler: Oh. Thank you.

I1: Do you ever consider any of the ideas about mindset?

Kepler: What's that?

I1: (I explain)

Kepler: Oh. No. My parents – they have just taught me I need to get things done. They ask me, "What do you need to do?"