Mindset
and
the Middle School Math Student

By

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Abstract

Mathematics classrooms in Montessori schools use Controls of Error to allow students to receive immediate feedback. However, not all students use them effectively. Why do some students use them and others choose to ignore them? A factor could be mindset. Students tend to have a growth mind-set (the incremental theory of intelligence) or a fixed mind-set (the entity theory of intelligence). A middle school teacher compared student mindset with control of error use, homework percentage and time spent on independent practice on a math app. Data was collected from 50 Pre-Algebra students in an urban Montessori middle school during the spring semester of 2014-15 using a student questionnaire, student data and teacher observations. Analysis of the data indicates that students with a growth mindset are moderately correlated with higher control of error use, more time spent on a math app, and higher homework turn-in rates.

Introduction

Every Montessori teacher has the goal of giving feedback to students in a timely manner. To get the students to actually do the work is another objective. The availability of controls of error in a Montessori classroom can be an effective way of achieving both of the goals. But why do some students rarely check their work? Why do others use them effectively, receiving the feedback on their own so they are ready to move on to new topics? In the fall of 2013-14, my first year as a Montessori teacher, I decided to study the use of controls of error in my Pre-Algebra classroom. Using controls of error was a new idea to me. I had used answer keys before but there was something different about these Montessori controls of error to which I wanted to pay attention. I found it hard to believe that students could use them effectively but felt that if they could, it would give students much more “control” over their learning. I administered an end of year survey to measure the students’ attitudes toward the controls after a year of using them. Figure 1 shows the most interesting data points:

End-of-Year Control of Error 2013-2014 Survey

1) I use the controls to check my work after I finish an assignment.
   70% Agreed or Strongly Agreed
2) I like to use a control to help me figure out how to do an assignment I don’t understand.
   70% Agreed or Strongly Agreed
3) Sometimes I use the control to check every few problems to make sure I’m doing the work correctly.
   68% Agreed or Strongly Agreed
4) I’d rather ask a teacher for help than try and figure it out on my own with the control.
   47% Agreed or Strongly Agreed
5) I just use the controls to copy the work.
   84% Disagreed or Strongly Disagreed
6) I’ve seen my classmates just copy the work from the controls.
   50% Agreed or Strongly Agreed
7) I like using the controls because I like to know if I am doing my math correctly.
   70% Agreed or Strongly Agreed
8) I learn more because I correct my own work.
   62% Agreed or Strongly Disagreed
9) I like using a control because it shows me what I’m doing wrong so I can fix it.
   82% Agreed or strongly agreed
10) It’s good that there is more than one control for each work, on the wall and in the control binder.
   88% Agreed or strongly agreed

Figure 1: End – of- Year 2013-14 Control of Error Survey

I was pleased that most students used the controls and understood how they help students learn from their mistakes. I was also glad that almost everyone agreed that having two places to find the controls was an improvement. It also interested me that more than half the students still would rather have a teacher help them than try and figure it out on their own. Maria Montessori wrote, "The first aim of the prepared environment, as far as it is possible, is to render the child independent of the adult." It was a hard first year, convincing the students that they can be come more self-sufficient. Many days, the only way to get many students to do any work was to sit down next to them and work side by side. I hope that as they get older and more confident and comfortable in their own mathematical skins they will be willing to try more on their own. Some of my students are so used to being unsuccessful in mathematics that they have never realized it is okay to make mistakes…and as I learned during my research this year, necessary.

Thus I decided to continue my action research this year with student use of Controls of Error. After reading many studies, I began to focus on student mindset, in other words, their belief in their own intelligence. I agree with many researchers that those students who have intrinsic motivation to learn and in addition possess an incremental theory of intelligence, or growth mindset, are those who are more successful in school. I chose to examine whether these are the same students who are more likely to use controls of error properly in my Pre-Algebra classroom. The other data sets I examined, homework percentage and Buzz Math minutes, are two additional aspects of my class that involve student motivation. Buzz Math, is an interactive, independent Math application students use on their iPads.

As I began formulating my action research, I set out to answer the following questions:

1) Are students' mind-sets related to use of controls of error?

2) Are students' mind-sets related to completing homework?

3) Are students' mindsets related to independent use of an iPad Math app?

Literature Review

Controls of Error

In a Montessori classroom controls of error are part of the prepared environment a teacher readies for her students. Dr. Montessori herself describes their purpose in her treatise, <u>The Absorbent Mind</u>.

> "Control of Error" is any kind of indicator which tells us whether we are going toward our goal or away from it…We must provide this as well as instruction and materials on which to work. The power to make progress comes in large

> measure from having freedom and an assured path along which to go; but to this must also be added some way of knowing if, and when, we have left the path. (Montessori 93)

The controls of error are the ways that students evaluate their own work without teacher's intervening in this part of the learning process. "All the crosses made by the teacher on the child's written work…only have a lowering effect on his energies and interests" (Montessori, 1964, p. 245). Much Montessori material incorporates controls of error within itself. Feedback from the teacher is unnecessary. The controls of error in many middle school classrooms are answer keys with or without worked out solutions for assigned work. Students are able to see their own mistakes (Lillard, Montessori: The Science behind the Genius, p.175). Dr. Montessori taught her teachers that correcting mistakes comes from within the child's own observation of mistakes in the work. The materials a child works with should make it obvious when mistakes are made. Many are self-correcting (Lillard, 2007, p. 278). Use of materials like "Versatiles" and "Pre-Algebra with Pizzazz" puzzles are such examples from middle school classrooms.

The classic Montessori classroom also runs without rewards and grades. When controls of error are used correctly in a Montessori classroom, students have no incentive to cheat (Lillard, 2007, p.180). They use them with classmates to compare their work with the control, deciding whether or not they are ready to move forward or to ask for a mini-lesson.

Intrinsic vs. Extrinsic Motivation

In 2012 the Center on Education Policy at George Washington University compiled a list of four major factors that researchers agree affect student motivation: Competence, Autonomy, Interest, and Relatedness. Schools bend over backwards trying to develop ways to motivate students. However, in a 2006 survey 70% of dropouts said they were unmotivated when asked why they dropped out of high school (Bridgeland, Dilulio, & Morrison, 2006). Thus in a middle school classroom, it is imperative to develop a curriculum and ambiance that appeals to the innate workings of adolescent development. The overall pedagogy of schools adhering to the Montessori philosophy contains these important components as goals.

Students in Montessori classrooms have been shown to have more intrinsic motivation towards learning (Rathunde & Csikszentmihaly 2005). Because of the freedom of choice they have in many aspects of their learning they are more motivated to learn for the sake of learning. They have no need for extrinsic rewards because they are autonomous learners. Montessori teachers develop students that are autonomous learners by creating communities of learners that root for each other, promoting the mantra, "Everyone does better, when everyone does better."

Researchers have shown many other positive trends in Montessori schools as well. At the end of elementary school, Montessori students wrote more creative essays with more complex sentence structures, selected more positive responses to social dilemmas and reported feeling more of a sense of community at their school (Lillard & Else-Quest, 2006). Students who were given cognitive and organizational autonomy support had high motivation to complete tasks, finishing because it was important to the students, not because they would get in trouble if they didn't (Hwee Ling Koh & Frick, 2010). Montessori schools benefit from a central theme that organizes and focuses all of its practices. They emphasize student self-direction and intrinsic motivation (Rathunde, 2005). Studies also confirm that Montessori students have high self-regulation and academic performance which foster positive work habits and again, intrinsic motivation (Ervin, Walsh & Mecca, 2010).

Fixed vs. Growth Mind-sets

How students view their intelligence can influence their motivation in school. Why does a student bother checking their work with a control of error? Many feel that it is because students have an incremental view of their intelligence also known as a growth mind-set. They know they have more to learn and that mistakes are challenges from which to learn (Blackwell Trzesniewski & Dweck, 2007). If a student has a fixed mind-set, a belief that knowledge is something they either have or don't have, that student has lower motivation to learn than one who has a growth mind-set, a belief that knowledge is an amount that can change and grow (Dweck, 2010). With a fixed mindset, students who think they know the mathematics material would not bother to check for errors because they assume their answers are correct. With a fixed mindset students who think their answers are wrong won't necessarily check their answers either because they think, "Why bother. I'll never get it anyway."

However, students' self-perception of their ability may be inaccurate, resulting in students' lack of effort in mathematics. Teachers need to applaud effort more than achievement. In one study, students did seem to be committed to the incremental view, growth mind-set, of their intelligence by affirming that anyone can be good at math if they put their mind to it (Sullivan & McDonough 2007). In another study student performance on standardized tests improved by learning skills that foster a growth mindset to battle the anxiety that can come with stereotype threat faced by females and students of color (Good, Aronson & Inzlicht 2003). Similarly students in Montessori schools understand that although work can be hard, with practice and by working with the materials they will come to understand the concepts (Ervin 2010). The most eye-opening insight involves the need for students to make mistakes in mathematics. When students grapple with figuring out a problem and correcting mistakes, new synapses are formed in their brain. These connections cause the brain to grow. If students are not challenged in math, their brains stop growing and the chance for development stops (Boaler 2013).

Conclusion of the Literature Review

Researchers agree that motivation is a difficult subject to pinpoint. Montessori schools seem to be in the correct position to help students develop intrinsic motivation to learn. The meaningful work that Montessori schools strive to provide "can also teach students to love challenges, to enjoy effort, to be resilient, and to value their own improvement" (Dweck September 2010). Researchers also agree that students who possess a growth mind-set and as a result believe that they can get smarter have a better success rate in schools. Dr. Montessori developed the idea that controls of error allow students to self-monitor their learning.

Research Design, Methodology and Data

This research took place at an urban public Montessori middle school in the Midwest during the 2014-15 school year. The school population consists of approximately 500 students. The participants in my research were the 50 seventh grade students in my two sections of Pre-Algebra. They were categorized as not proficient in Mathematics based on their sixth grade MCA III standardized test scores.

As I read the many articles for my literature review, I became more and more intrigued by the idea of how one's mindset affects the learning process. I decided to focus my research on determining my students' mindsets and seeing if they were at all related to how the students used the controls of error. The four sets of data I analyzed were the mindset score on a questionnaire, the number of days of control of error use out of ten observation days, the number of minutes of Buzz Math use this year and the third quarter homework percentage. See Appendix B for the sets of data.

To determine the mindset students possess, they were given a questionnaire adapted from one that Carol Dweck published in her article: Mindset: The new psychology of success *(2006)*. (See Appendix A) The students read 20 statements that reflected growth or fixed mindset. They responded with whether they strongly agreed, agreed, disagreed, or strongly disagreed with the statement. The statements were assigned point values. If the statement was a fixed mindset statement, the point values were: 0 points for Strongly Agree, 1 point for Agree, 2 points for Disagree, 3 points for Strongly Disagree. If the statement was one that reflected a growth mindset, the point values were: 3 points for Strongly Agree, 2 points for Agree, 1 point for Disagree, 0 points for Strongly Disagree. Students with a total of 60-45 points possess a strong growth mindset. A total of 44-34 shows students with a Growth Mindset with some fixed ideas. A total of 33-21 show students with a Fixed Mindset with some growth ideas. A total of 20 – 0 shows students with a strong Fixed Mindset.

Figure 2 gives a powerful visual to the results of the mindset questionnaire.

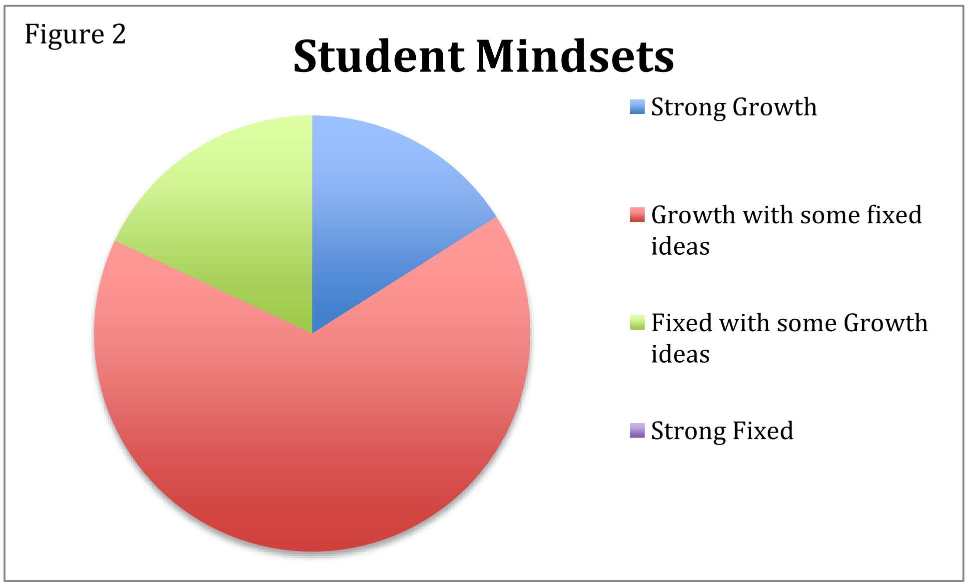


Figure 2: Student Mindsets

The overwhelming majority of students in my classes have a growth mindset with 16% having a strong growth mindset. When I examine who are the specific students who have the strong growth mindset, they are all hardworking students in class, though not all earn the highest scores on assessments or highest grades in class. The students with the fixed mindset interestingly hold some growth ideas in their beliefs as well. During the school year I intentionally spoke to growth mindset and the real probability of improving your intelligence through focused hard work on correcting and understanding one's mistakes. I wonder if any of these conversations had any impact in the mindsets of these students. I was pleased that no one held to a solid fixed mindset, which in a class full of students who are not proficient in math would be a difficult view to push past to be successful.

In order to gather data on control of error use I observed my students' use of controls of error during class work time. I observed a total of 10 work periods. This is not easy since I am the sole teacher in the room and often occupied with giving mini-lessons during work time as well. But I made a point to be seated in a position where I could easily see the board where the controls of error are posted. When students came to check the controls of error, I simply placed a tally next to the student's name when they approached the board to compare their work with a control of error. Some students came to check their work many times during the class period. They tend to be the students who need more assistance and/or assurance and are using the controls of error to check frequently throughout the time they spend on an assignment. Other students only check after they complete an assignment. They tend to be students who feel pretty confident about their work. Still others rarely check their work. I tallied every time a student came to the board. In the end students were identified as control users whether they used it once or 5 times during the class period.

Figure 3 illustrates the distribution of the number of days students used the controls of error. Interestingly, no one used them during every observation day and

3 students never checked them at all. Otherwise there is wide variety in how often students check their work. The median is 4 and the mean is 4.5, less than half of the possible times. It is a trimodal set of data with the modes being 7, 5, and 1.

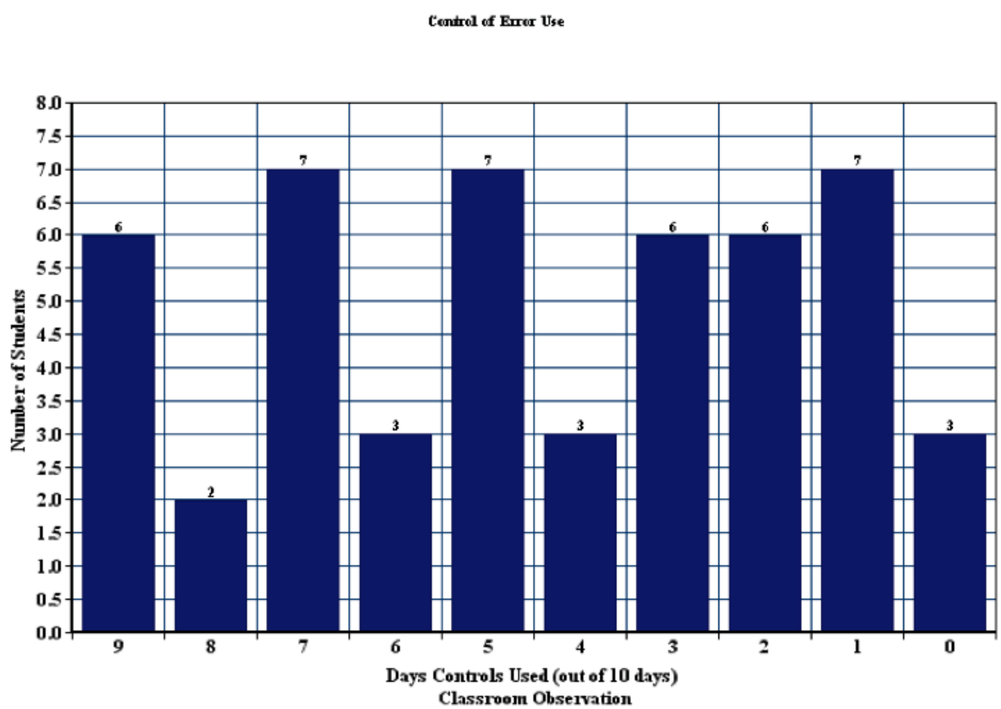
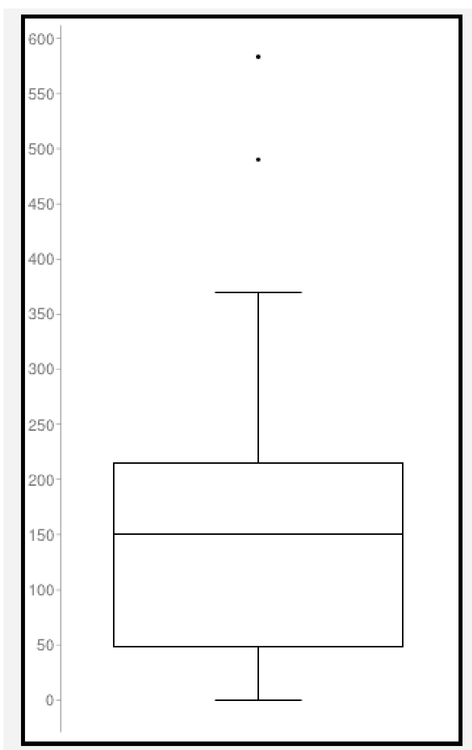


Figure 3: Student use of controls of error

This year another learning tool that was introduced to all students was the iPad. An application that my math students use is Buzz Math. It allows me as a teacher to assign specific tasks to the whole class or to individual students. In my class it was never a task for which the student received a grade or any points. It was an additional way students could practice concepts that we were currently working on, concepts that they needed to review or, for those who wanted to work ahead, concepts that would be coming in the future. Students could work on the task at home or in class when finished with the day's class work. As the year went on, I realized that student minutes on Buzz math would be another set of data I could use. I collected the total number of minutes from the administrative section of the teacher page from October through March.

As illustrated by the outlier points in Figure 4, two students worked significantly more than their classmates on Buzz Math. The upper 50% of students logged many more minutes than the lower half. These increased minutes were possible only because these students elected to work on Buzz Math outside of class.

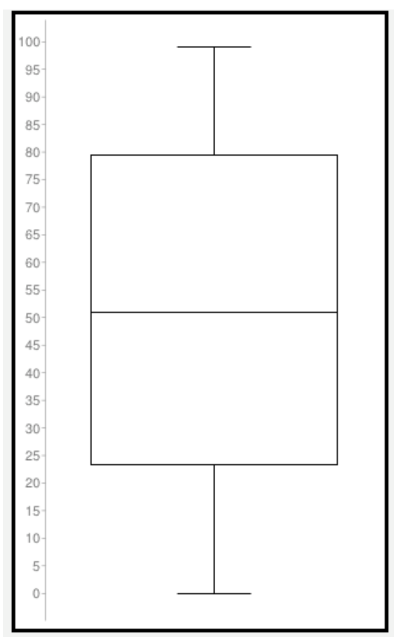


Student Minutes Spent on Buzz Math

Outliers: 583, 493
Maximum: 583
3rd Quartile: 215.25
Median: 150
1st Quarter: 48.75
Minimum: 0

Figure 4: Minutes spent by students on Buzz Math

The last set of data I examined was my students' homework percentages for third quarter. In my class students receive a weekly homework assignment. The controls of error for this assignment are also posted in the room throughout the week. This way, students can receive feedback on their work early in the week and ask for mini-lessons if needed. Students only receive full credit if they show their work, use the control and correct their mistakes. In reality, most students do not complete their homework regularly. There are probably many factors that determine students' ability and motivation to do their weekly homework. One may be that homework is only 8% of the overall grade. Those who do it may also often have a strong parental push to complete it. I began to wonder if the students' mindset factored into their motivation to do homework as well.



Student Homework Percentage

Maximum: 98
3rd Quartile: 79.5
Median: 51
1st Quartile: 23.25
Minimum: 0

Figure 5: Student homework percentage

Findings

Once the data was gathered I wanted to see if there were any positive correlations between a student's mindset score and the other 3 sets of data. In statistics the correlation coefficient describes the strength and direction of a linear relationship. The values of this coefficient, usually designated as *r*, range from -1 to 1. When studying the relationship between variables depicting real world data rarely are correlation coefficients have values of -1 or 1. Arriving at these values would mean that the points lie precisely on a straight line. When looking at how the points fall in Figures 6 through 8, an uphill tendency is noticeable especially when comparing the lower mindset scores with the high end scores. The middle points are much more random. So I expected the coefficents to be positive but far from 1.

Figure 6 illustrates how students' Control of Error use relates to their mindset scores. They are moderately correlated at 0.47.

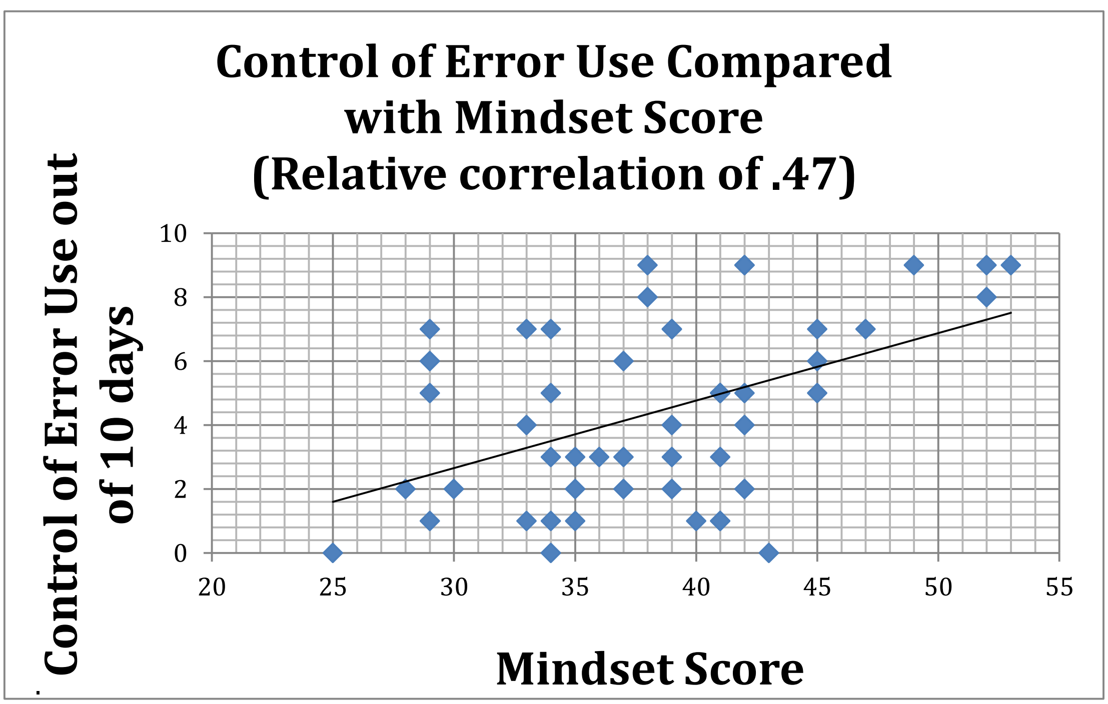


Figure 6: Control of error use compared with mindset score

Students with a strong growth mindset use the controls most days to check their work. Some students with stronger fixed ideas use them just as often. The students represented by the points in the middle, those with mindset scores of 34 - 44, all had a large range of control of error use.

Figure 7 illustrates how students' minutes on Buzz Math and their mindset are related. They are moderately correlated at 0.42.

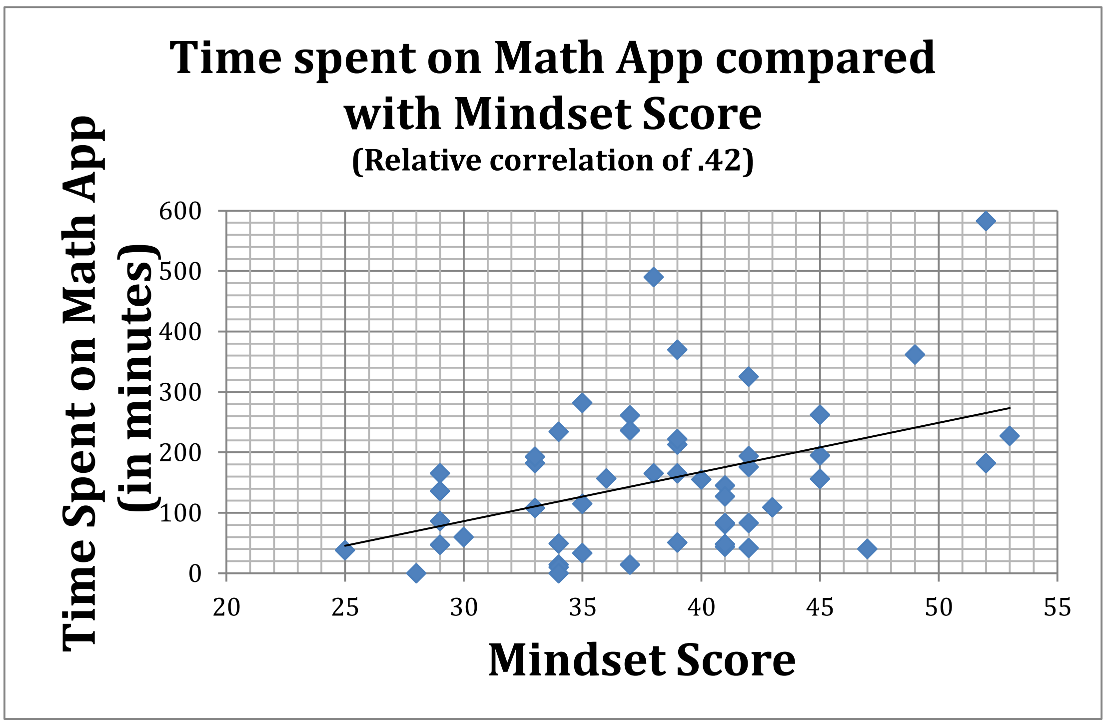


Figure 7: Time spent on math app compared with mindset score

Again the students with stronger growth mindsets tend to work more on Buzz Math and the students with more of a fixed mindset tend to work on it less. I made the decision to not eliminate any of the student data, although I know some students had lost their iPad for a period of time or had problems with their account.

Figure 8 shows how students' homework percentage and their mindset scores relate.

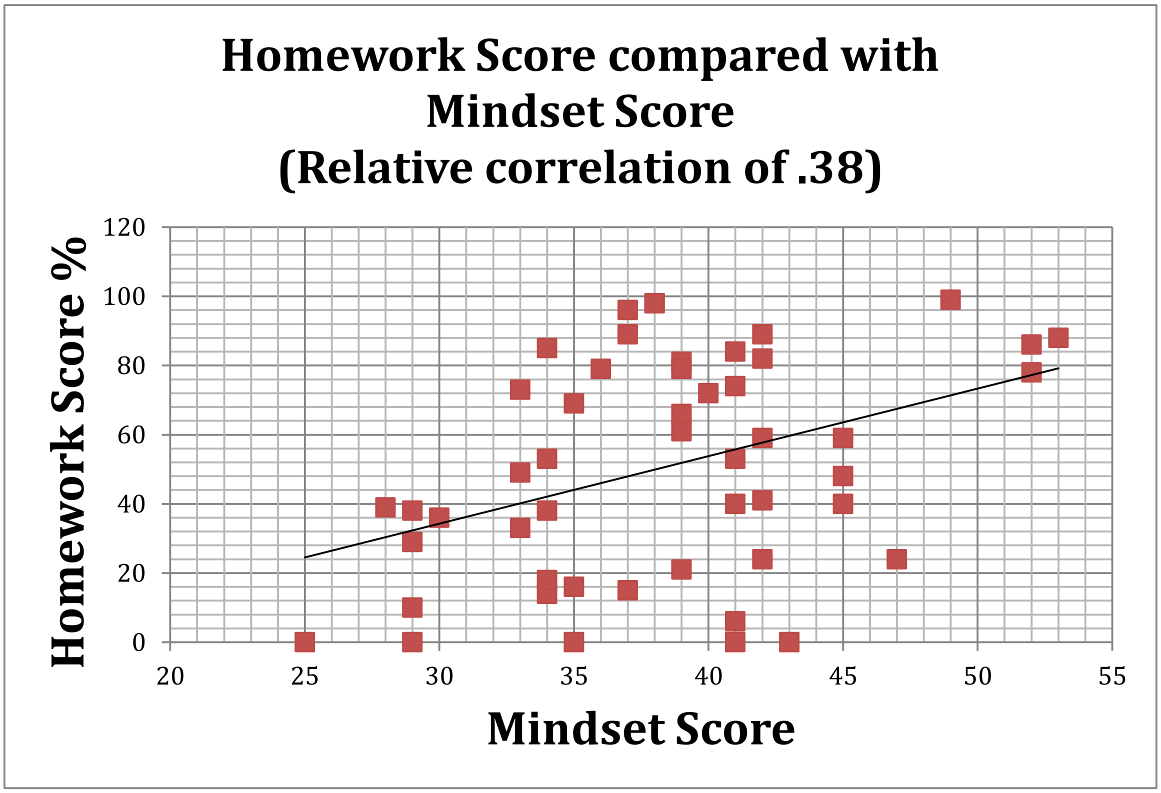


Figure 8: Homework score compared with mindset score

The two variables have a moderate correlation of .39. It is interesting to me that the students with the four strongest growth mindset scores have high homework percentages However the next four strongest have under 60 % for homework. The students with low mindset scores definitely have low homework percentages but so do many other students with higher mindset scores. As discussed earlier, there are many other variables that may factor in students' ability and willingness to do homework well.

In looking at the relationships with many classroom activities, namely controls of error, a practice Math app, and homework, I see that students having a strong growth mindset tend to do more homework, do more independent work on Buzz Math and use the controls. However I see this research as only the beginning. More research still needs to be done in all three of these areas.

While I observed my students as they worked, I had new insights. First of all, I was grateful that this research forced me to sit back and observe my students at work. As a Montessori teacher it is one of the techniques I should use on a regular basis to monitor the learning of my students. In reality, it is a very difficult teacher task for me to implement. As the only adult in my classroom, I am multi-tasking constantly as I teach mini-lessons, listen to questions, reinforce positive behaviors and redirect the negative behaviors. I need to do more training of my students so they understand that sometimes my job is just to watch and listen. It is amazing what a teacher can observe and learn when she is paying attention.

Future Action

As I look to the upcoming school year, I am even more convinced that encouraging a growth mindset in students will bring improved results in learning, in motivation to learn and in standardized test scores. I look forward to incorporating changes in my classroom.

To begin the school year, I will have the students take the mindset survey during opening week and have them calculate their own mindset score before we have any conversation about mindset. I would be interested in having the students revisit the questionnaire at the end of the school year to see if there is any shift in attitudes after the work we do.

I will also incorporate mindset work into two Montessori aspects of class, shelf work and seminar. I will create shelf work on Mindset, including videos to watch, and articles to read and scenarios to categorize as depicting growth or fixed mindset. I will also have Socratic seminar on Carol Dweck's article, "Even Geniuses Work Hard" during the first quarter. The dialogue among the students during seminars is always engaging and leads to powerful insights and thoughts to refer back to throughout the year.

I am also going to make the growth students show in math class more obvious to them by returning to pretests and posttests. This year I stopped administering pre-assessments to my students on each of the learning targets because of the time that they took to administer and correct. When students took an assessment this year, it was then the first measure they had of how far they were along the proficiency continuum. For most a retest was usually in order. In the past I had always focused on the growth a student made from knowing nothing on a pretest, to knowing something on a posttest, and finally to knowing it all or most on the retest. By eliminating the pretest students lost the opportunity to celebrate the many stages of growth while learning a concept. In concert with this I will continue to offer students multiple opportunities to improve by offering mini-lessons, making students complete test corrections, retake an assessment and teach their classmates.

I will continue to provide controls of error in multiple locations in my room, for both homework and shelf work. Students are starting to realize the benefit of their availability and that it is not cheating to use them. They are recognizing that they are useful to check multiple times during the work period. I want to continue to start focusing more on what students should do if the control of error does not provide them with the necessary assistance to understand mistakes or misconceptions. I would like more students to request mini-lessons, from me or a classmate, and acknowledge that it is okay to need to spend more time on a concept and to work harder to clarify it.

Buzz Math will also continue to be a part of my classroom but I will continue to investigate other apps on the iPads that might engage students who are not motivated to work on Buzz Math. The extra practice that students had from Buzz Math will hopefully pay off with increases in their standardized test scores.

In conclusion, I relish the idea of working to instill growth mindset strategies into my future students' outlook on learning mathematics and life in general. I continually remind myself to keep my growth mindset as I encounter obstacles in my path as a teacher, parent and learner. As hard as mistakes, criticism and setbacks are to endure, it is necessary to listen and learn from them in order to grow and move forward.

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APPENDIX A

What's your Mindset?! NAME _________________

Read each statement. Then tell how you feel about each by writing **SA, A, D** or **SD** in the box next to each statement.

SA – Strongly Agree **A** – Agree **D** – Disagree **SD** – Strongly Disagree

1) Your intelligence is something about you that you can't change very much.	
2) No matter how much intelligence you have, you can always change it quite a bit.	
3) You can always substantially change how intelligent you are.	
4) You are a certain kind of person, and there is not much that can be done to really change that.	
5) You can always change basic things about the kind of person you are.	
6) Musical talent can be learned by anyone.	
7) Only a few people will be truly good at sports – you have to be "born with it."	
\8) Math is much easier to learn if you are male or come from a culture who values math.	
9) The harder you work at something, the better you will be at it.	
10) No matter what kind of person you are, you can always change substantially.	
11) Trying new things is stressful for me and I avoid it.	
12) Some people are good and kind and some are not – it's not often that people change.	
13) I appreciate when people like parents, coaches or teachers give me feedback about my performance.	
14) I often get angry when I get feedback about my performance.	
15) Everyone is capable of learning.	
16) You can learn new things but can't really change how intelligent you are.	
17) You can do things differently but the important parts of who you are can't really be changed.	
18) People are basically good but sometimes make terrible choices.	
19) An important reason I do my school work is that I like to learn new things.	
20) Truly smart people do not need to try hard.	

Adapted from: Dweck, C.S. (2006) Mindset: The new psychology of success. New York: Random House Inc.

Appenndix B

	Mindset score	Controls	Buzz Math	Homework %
Name	60	10		100
DV	53	9	227	88
KHC	52	8	182	86
MC	52	9	583	78
ML	49	9	362	99
CG	47	7	40	24
FM	45	6	262	48
SW	45	5	195	59
BW	45	7	156	40
MA	43	0	109	0
DY	42	5	176	59
YH	42	9	325	89
CH	42	2	42	24
CT	42	4	194	41
VY	42	9	83	82
KC	41	1	44	6
AR	41	5	81	74
AL	41	5	48	84
DM	41	5	83	0
SY	41	3	145	53
MM	41	1	127	40
BB	40	1	155	72
CV	39	3	370	81
RW	39	7	165	21
TJ	39	4	213	66
DavM	39	2	222	61
PY	39	7	51	79
KV	38	8	165	98
SP	38	9	490	98
BE	37	3	261	89
OJ	37	2	14	15
NP	37	6	236	96
EW	36	3	157	79
SA	35	1	33	0
LX	35	3	282	69
DamM	35	2	115	16
TV	34	1	14	14
DG	34	3	10	18
AG	34	7	49	85
BH	34	5	234	53
NJ	34	0	0	38
TL	33	7	108	73
AM	33	1	182	33
MY	33	4	193	49
EH	30	2	60	36
AF	29	5	136	0
AGH	29	6	86	38
MR	29	7	165	29
KS	29	1	47	10
JC	28	2	0	39
AH	25	0	38	0