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Speaking to the Numbers: Impacts of Growth Mindset on Student Mathematics and Achievement

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Abstract

The purpose of this study was to determine if an increase in teacher growth mindset language and practices positively impacted students' mindset and mathematical achievement. This study took place in a suburban public school. Twenty-one fifth grade students' mathematics data were collected as part of this study. At the beginning of the academic year, students were administered a mathematical growth mindset survey. During a mathematical unit involving mathematical operations with percentages, taught near the end of the academic year, students' mathematics journals, mathematics unit pre- and post- assessments, and a teacher reflection journal were collected. The results showed that students increased in their performance in pre- and post- mathematics assessments after receiving instruction centered in growth mindset language and practices. The results of this study indicate that growth mindset-centered language and practices may help increase student achievement. Implications for the results, including this study's limitations and further research are discussed.

Keywords: growth mindset, mathematics, achievement, productive struggle

Much like the small train chugging its way up the steep mountainside, believing we can achieve something is often half the battle. Unfortunately, in many of today's schools, classrooms are full of little engines desperately trying to make their way up mountains with the added obstacles of poverty, homeless/highly mobile populations, learning disabilities and family stress to name a few. While schools are not able to take away the obstacles in students' lives, teachers and school communities are working to teach students the skills to have the metacognition to overcome them. The following study sought to understand how a focus on growth mindset instruction might help students develop a growth mindset that might increase achievement.

This study took place in a fifth-grade classroom in a suburban area of the Midwest area of the United States. The classroom had 23 students, though data was collected for 21 students. The school population is comprised of 40% White students, 30% Black/African American, 13% Hispanic/Latino, 4% Asian, 1% American Indian and 12% who identify as two or more races. The percentage of students who qualify for free or reduced lunch is 55%. Of the 21 students for whom data in this study was collected, almost 24% of the students receive special education services. None of the students in the classroom are identified as meeting the criteria for receiving gifted and talented services. The classroom was a cluster, grouped together due to lower-performing in mathematics and reading. From their prior experience in mathematics, they were often apprehensive, if not avoidant, of mathematics instruction.

From the beginning of the school year, most of the students appeared to be disengaged with mathematics instruction. Students would often use negative self-talk during mathematics instruction, around the lines that that mathematics was too difficult or that mathematics was just too boring. When confronted with a multi-step problem, requiring problem solving skills or strategies, students would first seek out the help of an educational assistant or myself. When students were able to identify the steps and strategies needed to solve a difficult mathematical problem, they sought out validation from special education assistants or me instead of using self-regulated strategies. For example, students might run up to me with their paper, ask, “Is this right?” but not be able to articulate how or why they were right. When students were incorrect in their solution, they defined themselves by their failure with statements like, “I’m just not good at math,” or “it’s easy for (other student in class), he’s good at math.” Learned helplessness seemed to be a common factor in most of the students’ experiences in mathematics. It became clear that most, if not all, of the classroom exhibited signs of fixed-mindset in the area of mathematics.

Infusing growth mindset language and practices involved explicit teaching on brain processes and functions (such as how information is received, stored, and accessed). This also included a shift in teacher behaviors including using growth mindset-centered feedback when conferring with students, recognizing and celebrating when students used growth mindset-centered language, and communicating with parents regarding growth mindset practices that could be used at home. The research attempts to investigate the impacts of growth mindset language and practices on student mathematical achievement and mindset.

Review of Literature

Research into the literature on growth mindset and mathematics indicated that often the adults or models in children’s lives play a large role in forming students’ perceptions of their abilities, their mindset, and their achievement in mathematics (Diemer, Marchand, McKellar, & Malanchuk, 2016; Hendy, Schorschinsky & Wade, 2014; Park, Ramirez, & Beilock, 2014; Schmidt, Shumow, & Kackar-Cam, 2015). From the kinds of praise students hear to the ways teachers address the anxiety students face in mathematics, the literature indicates that there is an important link between the actions of teachers and adults in children's lives and how students build their mathematical mindsets (Diemer et al. 2016, Hendy et al. 2014, Park et al. 2014, Schmidt et al. 2015).

Student Beliefs in Mathematics

In addressing underachievement in mathematics, it is vital to begin with what students believe about their competency in mathematics. Anxiety in mathematics can intrude in students' ability to work competently in mathematics and have a negative correlation with grades in mathematics in school-age children (Diemer et al., 2016; Hendy et al., 2014; Park et al., 2014). According to Hendy et al., (2014) anxiety in mathematics involves negative feelings such as "tension, confusion, and frustration when attempting to solve math problems," (p. 1225). The mindset and beliefs around an individual's ability to perform a mathematical task are often more of a determinant of the success in completing such a task rather than low numerical skills (Park, Ramirez, & Beilock, 2014). In their study, Park et al. identified a group of students as either high math-anxious or low math-anxious. Students wrote freely describing their anxiety before a mathematics exam for seven minutes or waited quietly. High math-anxious individuals who were asked to write expressively before their mathematics exam performed much greater than their fellow high math-anxious counterparts who were asked to wait quietly before the exam (Park et al., 2014). Researchers in this particular study hypothesize that writing expressively helps reduce anxiety, thus improving working memory which is necessary for completing mathematical tasks (Park et al., 2014). Expressive writing allows students to make the connection between how they feel about a task (their anxiety) and their beliefs in their mathematical abilities (Park et al., 2014).

Students’ beliefs about their mathematical ability, the value of a given mathematical task, and achievement are connected (Diemer, Marchand, McKellar, & Malanchuk, 2016). In their study, Diemer et al. found that relevant mathematics instruction, meaning instruction that connected to what students use or might use in their everyday lives fostered positive beliefs of mathematics among African American students (p. 1220). Diemer et al. believed that a possible reason for students' lowered beliefs in their ability in mathematics might stem from the idea of expectancy-value theory, the belief that what students learn in mathematics will or will not help them later on in their immediate or long-term goals. In this case, the more relevant a teacher made mathematics instruction to students' immediate or long-term goals, the more students believed in their ability to perform the mathematical task.

While expectancy-value theory was one hypothesis for college students' negative beliefs in mathematics in their study, Hendy et al. (2014) also postulate that there may be at least two other theories explaining negative student beliefs in mathematics. Self-efficacy theory suggests that even if students believe that the mathematical behaviors will help them, they are still not able to do those mathematical behaviors (Hendy et al., 2014). For example, a student knows it is useful to ask a teacher for support in gaining clarity on a difficult task, but prior negative experiences in asking for help create anxiety that prohibits the student from asking for help. On the other hand, the health-belief model suggests that even though the value of performing a mathematical behavior is obvious to an individual, the perceived barriers in completing said behaviors inhibit a person's ability to do the mathematical behavior (Hendy et al., 2014). All of the studies investigated in this literature emphasized the role teachers play in shifting student beliefs about mathematics, either positively or negatively.

Growth Mindset

Much of students' beliefs around their abilities in mathematics stem from a specific kind of mindset – fixed or growth (Robinson, 2017). If an individual has a fixed mindset, they believe that they are born with a set amount of intelligence and abilities; these are unchangeable. However, a person with a growth mindset believes that their abilities can be developed and improved over time. Robinson suggests that by explicitly teaching growth mindset concepts including neuroplasticity – that the brain is malleable and can adapt over time, positive self-talk, normalization of mistakes and failure, entire classrooms can shift their culture to that of a growth mindset (Robinson, 2017).

Building on Robinson's idea of using an intervention to explicitly teach the concepts around growth mindset, Schmidt et al., (2015) found that not only teaching growth mindset concepts, but consistent teacher modeling of growth mindset practices helps foster a classroom rich in growth mindset. In their study, Schmidt et al. studied two 7th grade teachers implementing an intervention called Brainology – a web-based program designed to teach students about growth mindset. While both teachers self-reported that they regularly use growth mindset teaching practices, one teacher regularly used growth mindset practices by encouraging students to work through challenges, guiding students to success through careful questioning rather than directing students to complete tasks, and encouraging effort more than achievement. The teacher who regularly modeled growth mindset practices helped students identify strategies when they were challenged and fostered more independence with her students (Schmidt et al. 2015). The other teacher, though she felt she regularly used teaching practices aligned with growth mindset, was quick to help students without encouraging them to discover strategies, spent much of her time recording information and did not develop a sense of agency amongst her students (Schmidt et al. 2015). Student achievement in science as assessed after the Brainology intervention, and the students in the classroom with the teacher who regularly modeled growth mindset greatly outperformed their counterparts who had the other teacher. While both teachers used Robinson's approach to directly teaching concepts around growth mindset, only the teacher who regularly modeled practices aligned with growth mindset fostered a classroom rich in growth mindset.

Teacher Language and Its Impact

In America, many elementary teachers are female (Shapiro & Williams, 2012). However, most female elementary teachers self-report having high anxiety in the area of mathematics instruction (Shapiro & Williams, 2012). In their study, Shapiro and Williams (2012) found that teachers with high anxiety in mathematics instruction can negatively impact students of the same gender in math achievement. Perhaps one reason teachers with high anxiety in mathematics result in decreased student achievement in mathematics might be due to the questions teachers ask. High math-anxious teachers, wanting to get through the math lesson quickly, may not be asking higher-level questions that lead to deeper understanding. When a teacher asks questions that promote deeper conceptual understanding ("How did you decide to use that strategy?") versus closeended questions ("What is the product of a x b?), students will gain deeper understanding. Open-ended questions rooted in growth mindset (effort vs. ability) will "lead to persistence and broader learning." (Johnston, Ivey, & Faulkner, 2011, p. 233). High-anxious mathematics instructors may not feel as comfortable in generating the types of open-ended questions that lead to deeper mathematical thinking and reasoning.

In addition to asking deep, thought-provoking questions, Kamins and Dweck (1999) examined the role that teacher criticism and praise has on student mindset. In their study, Kamins and Dweck role-played different scenarios with a group of kindergartners who were creating block towers. In the first scenario, children were given either person criticism ("I'm disappointed in you"), outcome criticism ("That's not the right way to do it because it's messy"), or process criticism ("The blocks are crooked and in one big mess. Maybe you could think of another way to do it?") (Kamins & Dweck, p. 838). In the second group of scenarios, children were given praise, again either person-centered ("I'm very proud of you"), outcome-centered ("That's the right way to do it"), or process-centered ("You found a good way to do it. Can you think of other ways to do it?") (Kamins & Dweck, p. 842). Whether the feedback was criticism or praise, the same results happened each time. When the researcher used person-centered feedback, children were less likely to show persistence, reported lower ratings of their product, and showed helpless reactions when they were presented with setbacks later in the study. This research builds on earlier work from Dweck (1998) in studying fifth graders' responses to praise. This earlier study focused on understanding the role praise for ability (fixed mindset) versus praise for effort (growth mindset).

Similarly to the Kamins and Dweck study, Mueller and Dweck (1998) found that when students were praised for their intelligence, "(it) seemed to teach children to value performance even when following their information-seeking interests whereas praise for (effort) seemed to lead children to value learning opportunities." (p. 49). Mueller and Dweck also found that praising children for their intelligence (e.g. *You are so good at math*), led to a contingent self-worth, indicative of fixed mindset, which can lead to lower achievement (1998). Dweck suggests providing praise for effort (e.g. *You worked really hard on that problem*), to help foster a growth mindset, instead. Praise rooted in effort leads the child to believing that it is not the ability but the productive struggle that leads to achievement.

Conclusion

When students have lowered expectations and beliefs in themselves as mathematicians, they lose before they begin. The role of the teacher as a model for positive beliefs in mathematics can be a key factor in helping students achieve success. In teaching with confidence, modeling a growth mindset, and using careful language during questioning, praise, and criticism, the teacher creates an environment that is conducive to learning and improving achievement in mathematics.

Methodology

To begin to answer my action research question, I met with my school's fifth grade professional learning community (PLC) to discuss needs in mathematics as a grade level. As a grade level, we determined that mindset, specifically fixed mindset, appeared to be a major hurdle for our students. From these PLC discussions, fifth grade teachers created a survey identifying four hypothesized concepts surrounding mathematics and mindset – students' feelings towards mathematics, perceived value of mathematics in their lives, how students coped with mathematical struggle, and how students persevered given mathematical struggle. Growth mindset, and changing students' mathematical beliefs, became a focus of weekly grade level PLC team meetings. From weekly PLC meetings, teachers discussed the importance of communicating about growth mindset to our students and their families in creating meaningful mindset shifts.

Parents were given information about growth mindset and mathematics, via online and written communication at the beginning of the school year and with monthly updates in the form of class newsletters. Then, parents were given permission forms (Appendix A) for the collection of data on achievement and growth mindset for the purpose of action research. Permission for data inclusion in this action research project was requested only from my class, not the other grade level classrooms, though collaboration with other fifth grade level teachers helped in creating the Mathematics Mindset survey used as a pre- and post- assessment for this action research project.

Following the fifth-grade level PLC team's initial meeting a Mathematics Mindset survey (Appendix B) was created. The purpose of this survey was to determine a baseline for students' feelings and beliefs surrounding mathematics. At the beginning of the academic year, students were administered the Mathematics Mindset survey. This survey was administered again at the end of the academic year, to gauge how students' mathematical mindsets had shifted after a year with growth mindset language incorporated daily into mathematics instruction. From the four hypothesized areas of concern, the PLC grade level team created a survey, with a question relating to each of the areas identified, with a total of four questions. The PLC grade level team then identified four responses students could choose from, with each response indicating a different level of growth mindset. These answer choices were given a score between a 1, indicating a low level if not absence of growth mindset, to a 4, indicating a higher level of growth mindset.

During the first week of instruction for the school year, students engaged in direct instruction of growth mindset and cognitive processes that occur during learning. Direct instruction included daily lessons for a period of five days that lasted approximately 30 minutes each lesson. Students learned how different parts of the brain respond during the acquisition of new information, for example that neural pathways become deeper and stronger with repeated exposure. Students also learned about famous failures, or athletes, leaders, and public figures who experienced failure but succeeded by using traits that are indicative of growth mindset. During these lessons, students were exposed to the power of the word *yet*, the idea that while success might not come today, it can come tomorrow. Daily lessons also included read-alouds that foster a growth mindset, such as *Your Fantastic, Elastic Brain* by JoAnn Deak (2010). Then, throughout the year, growth mindset-centered language such as, "Your neural pathways are getting stronger!" was frequently used by both teacher and students.

While growth mindset-centered language was an important part of mathematics instruction throughout the academic year, during one unit of mathematics taught near the end of the academic year, involving percentages, several pieces of data were collected to determine how growth mindset-centered language impacted student achievement. At the beginning of each mathematics unit, students were administered a pre-test identical to the post-test of the unit to gauge students' improvement throughout the chapter. For the purposes of data comparison, one assessment administered from a mathematics unit at the beginning of the academic year, prior to growth mindset instruction, on the topic of data analysis is compared to an assessment from a unit taught near the end of the academic year on the topic of percentages.

Teacher reflection journals (Appendix C) were recorded daily after mathematics instruction occurred during the two-week unit on percentages. The goal of teacher reflection journals was to determine when and how often the teacher and students used growth mindset-centered language during whole group mathematics lessons. Teacher reflection journals also recorded whether or not students met the desired performance and learning objectives for daily mathematics lessons, successes, challenges, and connections teacher and students made to growth mindset during instruction.

During the independent or partner work portion of mathematics lessons, students were given Problem of the Lesson journals. Problem of the Lesson journals (Appendix D) involved more challenging, multi-step mathematical problems related to the day's mathematics lesson objectives. Student journals were scored using a mathematical mindset rubric (Appendix E). Students were given the opportunity to complete Problem of the Lesson problems independently, with a partner, or with a small group, however students wrote the reflection portion of the journal independently.

Midway through the percentages unit taught near the end of the academic year, students worked with partners to create a Mid-Point quiz common practice throughout the academic year. To create the Mid-Point quiz, student partner groups would reflect on the mathematical content they had learned thus far in the unit, use a class-generated work bank including words that consistently were used during that mathematical unit, and create a question relating to the mathematical concept being studied for their peers to answer. This Mid-Point quiz (Appendix F) was then administered to students.

Finally, after instruction on the unit was completed, students completed a post-test, identical to the pre-test given at the beginning of the unit. The data from students' post-test was compared with their pre-test score to see how students' achievement increased during the unit.

At the conclusion of the academic year, students completed the survey from the beginning of the year, Mathematics Mindset survey, to see how student mindset in mathematics had changed over the year with the intervention of regular growth mindset-infused language.

Analysis of Data

Growth mindset-centered instruction occurred through the entirety of the academic year. One survey, designed to assess students' growth mindset in the context of mathematics, was administered at the beginning and end of the academic year. During one particular unit that occurred near the end of the academic year, data was gathered through student work in student mathematics journals and a student-created formative assessment. Finally, achievement and growth from pre- and post-assessments of mathematical units that occurred during the beginning and end of the year were compared.

Mathematics Mindset Survey Results

The aim of the Mathematics Mindset scale was to assess student mindset and beliefs in conjunction with mathematics. The Mathematics Mindset survey was administered at the beginning of the academic year (pre-assessment) and again at the end of the academic year (post-assessment) to gauge how students' mindsets changed and developed over the course of the academic year. In coding responses, I sought to ascertain whether a student had more growth of fixed mindset in mathematics. In terms of this survey, responses that indicated a connection to growth mindset were coded with either a score of 4, indicating a high level of growth mindset, or a 3 indicating an emerging level of growth mindset. Responses indicating a fixed mindset, or the belief that mathematical abilities are innate and that mistakes are "bad," were coded with either a 2 or a 1. Responses coded with a score of 2 indicated a fixed mindset progressing towards a growth mindset. Responses coded with a score of 1 indicated a fixed mindset. Students were surveyed with four questions, each designed to assess student mindset in different components of mathematics instruction and learning.

The first question on the survey was designed to assess students' feelings towards mathematics. Figure 1 compares students' responses from the beginning to the end of the year. A response of "I am not excited to do math" was coded with a 1 and a response of "I'll do math only because my teacher tells me to" was coded with a 2, indicating a fixed mindset. A response of "I like to do math because I like to learn new things in math" was coded with a 3 while a response of "I see math as a challenge and challenges are exciting to me," was coded with a 4, indicating a growth mindset. Students who were in the level 2 category, fixed mindset shifting toward growth mindset, appear to have made that shift during the school year, as the number of students in this category decreased, the number of students in categories three and four increased.

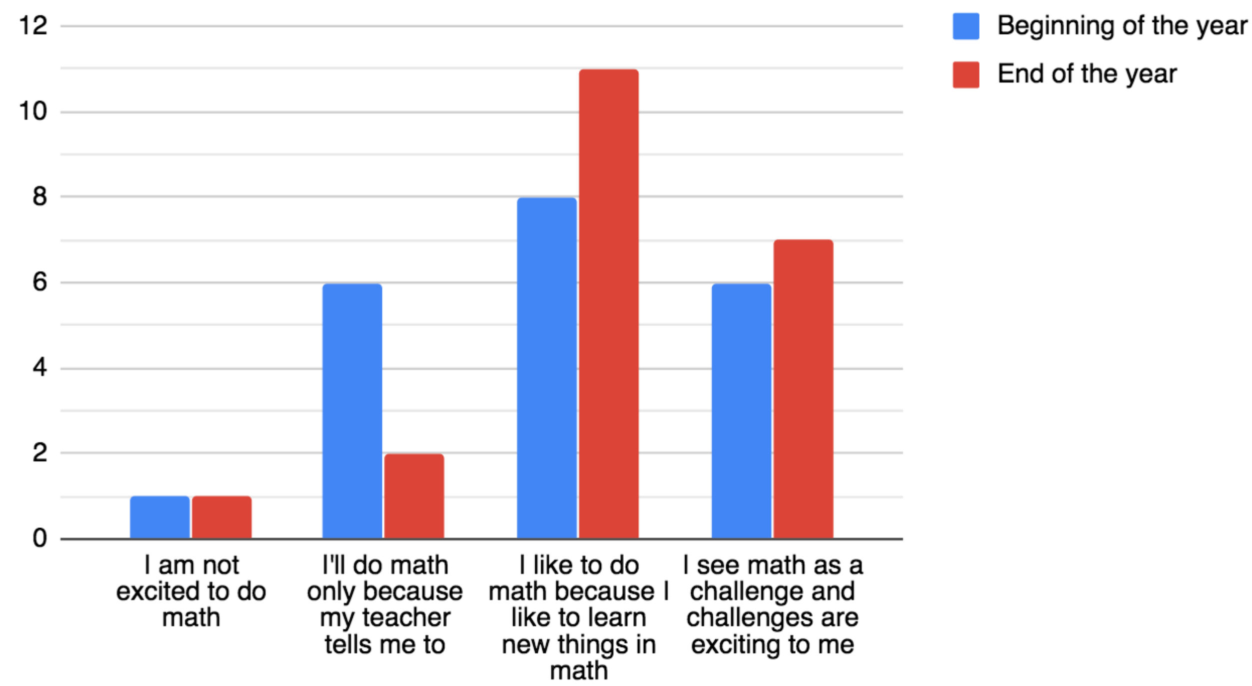

Figure 1. "How do you feel about math?" survey results, comparison of beginning and end of year responses.

At the end of the academic year, 48% of responses indicated a shift toward growth mindset, increasing by one or levels of growth mindset response. Of the remaining students, 28% did not indicate any change and 24% decreased in their growth mindset response. One student who increased from a level 2 to a level 4 response shared how he felt about math and his future goals during small group math instruction. He stated, “It’s like, math isn’t just a worksheet - it’s logical. When I’m working at NASA one day, I’m not gonna have a paper in front of me that’s like, ‘What’s 4,000,000 x 10?’ I’ll have real problems to solve. And I won’t have a teacher to help me. I’ll have to figure it out for myself. I might not get it the first time, but if I keep trying different things, I can do it.” This student made a dramatic transformation in his approach to solving challenging mathematical problems throughout the academic year. At the beginning of the academic year, if other students found a solution for mathematical problems before him, he would join a teacher-led small group. His demeanor in teacher-led small groups was often passive; he would not share or offer suggestions during small group work. Throughout the year, he seemed to begin to understand that there are often multiple ways to attack a mathematical problem. He was more comfortable with taking longer than others on solving mathematical problems; he compared his achievement to his prior experience rather than to other students' achievements.

The next question in the Mathematics Mindset survey assessed students' ability to cope with intellectual struggle. In Figure 2, we see that the number of students who use higher levels of growth mindset when confronted with a difficult problem increased from the beginning of the year to the end of the year.

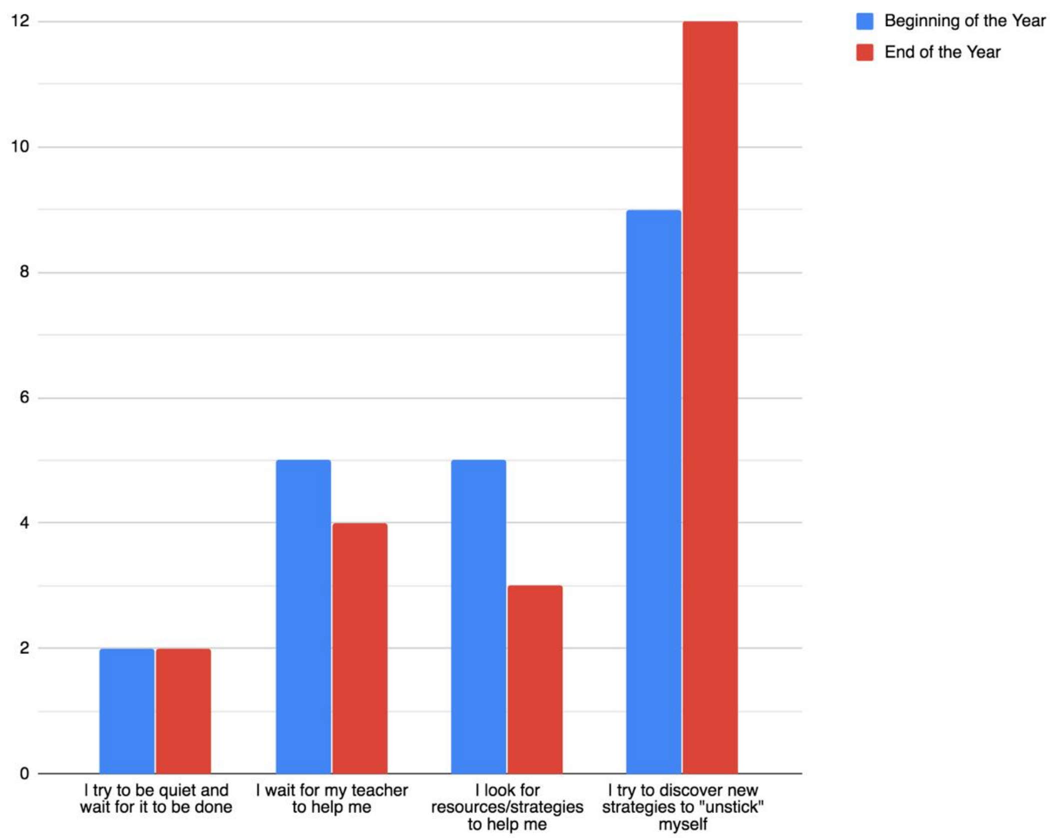

Figure 2. "When I'm stuck on a difficult mathematical problem..." survey results, comparison of beginning and end of year responses.

At the end of the academic year, over 57% of the class reported that they felt empowered to discover strategies to solve problems instead of seeking assistance from teachers or avoiding the task.

After a more challenging mathematics lesson involving multiple step, real world application of knowledge of percentages, a student reflected on how it felt to complete a challenging problem on her own. “It’s like, when I run the mile it wouldn’t be fair if I got to ride my skateboard for half of it. It would get me there faster, but I wouldn’t really be faster or stronger. It’s the same if (my teacher) gives me the answer. I would get the right answer but my brain wouldn’t be faster or stronger.” This was a common theme in student math journals – connecting fitness and the physical body to “stronger brains.” During whole group mathematics instruction, there were often connections to physical activity or fitness and productive struggle. One particular visual was also mentioned in student journals, “the Tank” (Appendix G). During mathematics instruction, I shared how growth mindset impacted my physical fitness work. One tool I use during exercise is “the Tank,” a heavy exercise sled used for high intensity interval training. Students were shown how weight can be added to the Tank as well as increasing or decreasing resistance. I shared that the first time pushing the Tank was very easy because there was little resistance, but when resistance was increased it became very difficult. I shared that when I pushed the Tank across the room the first time, it was very easy and I was proud of how strong I must have been that I pushed it so quickly. Then, when my physical trainer increased the resistance it took far more effort, but at the end I was proud of how hard I worked to get there and felt even stronger than I had been before. This resonated with students, and it seemed to help them gain a better grasp of how effort is connected to growth mindset. When given the prompt, "Math is like…." one student replied, "Math is like the Tank. If it's easy, it's not good enough for you. If it's hard, it makes you tougher." The visual of the Tank remained in the classroom throughout the academic year. Students referenced it during mathematics, but also during literacy, social-emotional lessons, and preparation for their upcoming middle school transition.

The third question, "How I use math in real life…" in the Mathematics Mindset survey was designed to assess students' beliefs in how mathematics is involved in their lives.

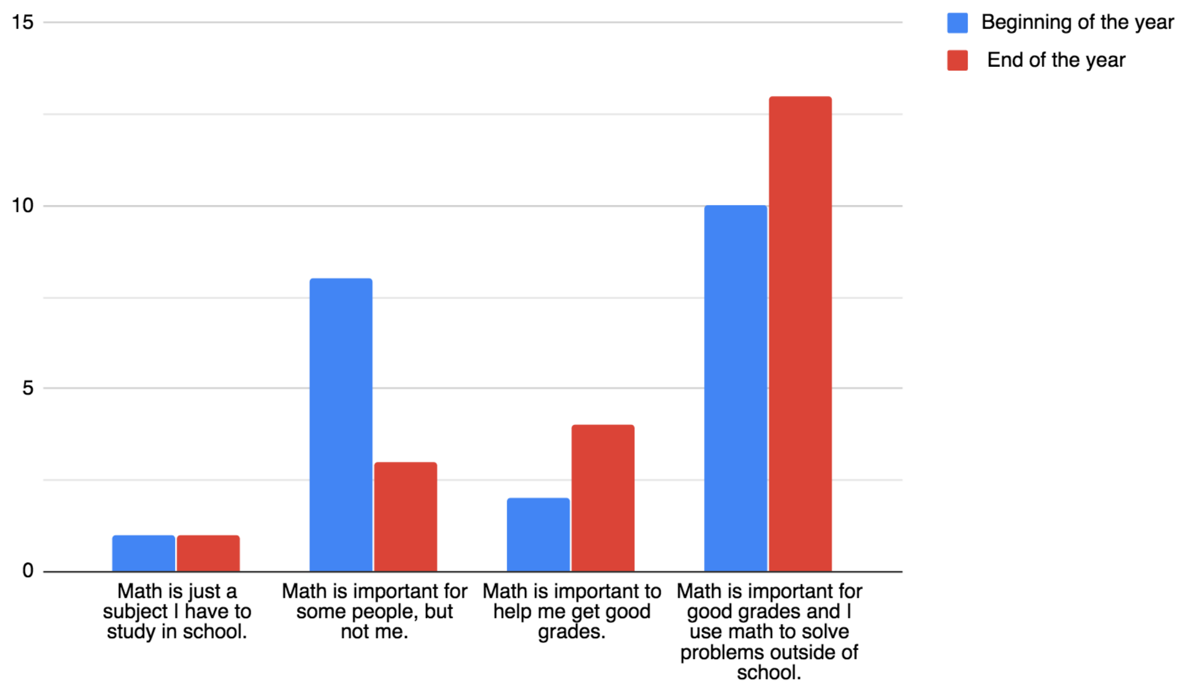

Figure 3. "How I use math in real life... " survey results, comparison of beginning and end of year responses.

In Figure 3, five students (24%) who initially responded with a score of one or two changed their responses to either a progressing or high growth mindset response. In his mathematics journal, one student remarked that, "I see math a lot more. I find how many XP (experience points) I need to get to move to another level (in my video game).

I feel really smart when I can add up huge numbers in my head. I couldn't do that before." The five students who shifted from lower growth mindset responses to responses with a score of 3 or 4 joined the majority of their classmates. Most students, even at the beginning of the year, understood that mathematics is important to them. In Figure 4, question three is the only question where the majority of the class stayed the same in their response from the beginning to the end of the year.

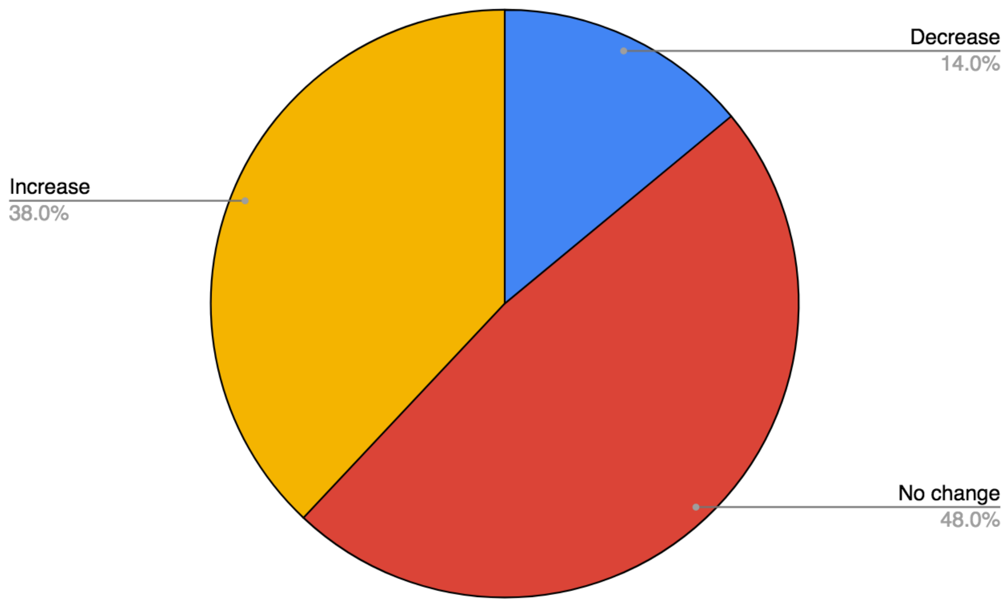

Figure 4. Increase, decrease, and stagnation in students' growth mindset responses, "How I use math in real life...".

The final question of the Mathematics Mindset survey assessed how students coped with confusion in mathematics. In Figure 5, students who gave themselves a rating of three or four indicating growth mindset decreased from the results in the beginning of the year. One student, who dropped from a score of a 4 to a 2 reported that confidence in public speaking was part of what prevented her from asking questions during mathematics lessons. "Well, if I have a question other people do too. I don't like talking in class, and most of the time someone else will just ask it." This shows that perhaps it isn't the student's mindset, but confidence in speaking in public or with peers that prevented her from asking questions when they were stuck.

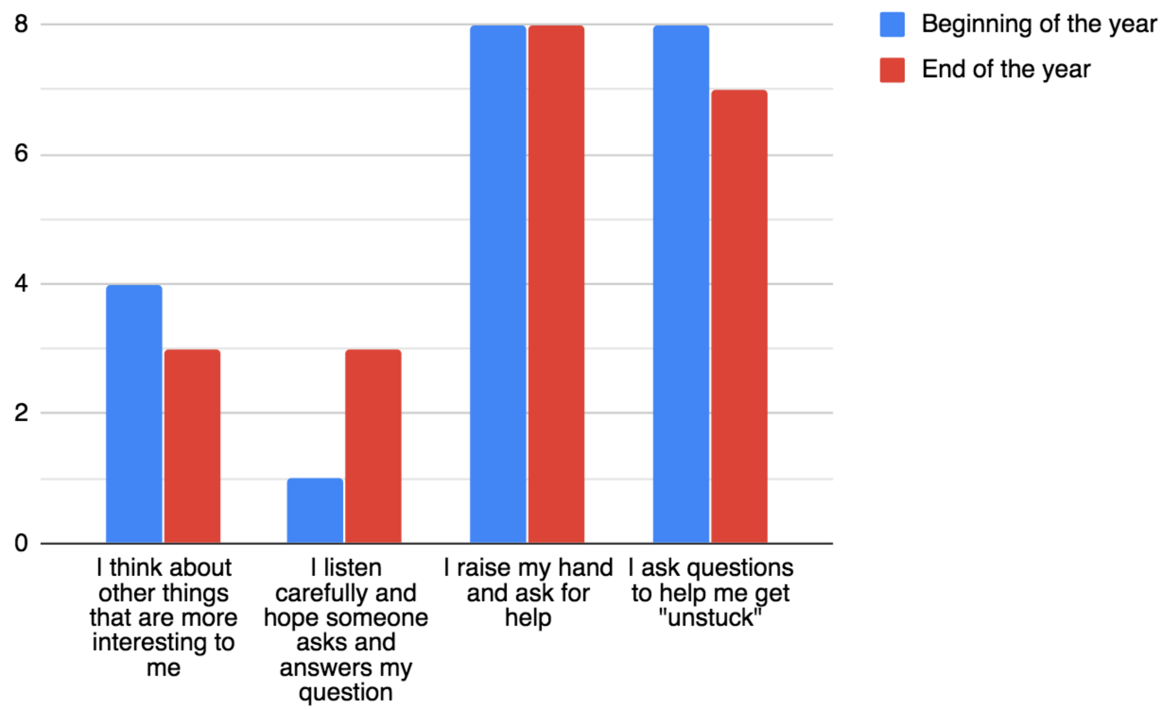

Figure 5. "If I don't understand..." survey results, comparison of beginning and end of year responses.

Finally, students' survey results were averaged – one average for their results at the beginning of the year and another average for their results at end of the year. From these surveys, 62% of the class increased their score, indicating a shift toward growth mindset.

Student Mathematics Journals

While growth mindset language was targeted as an intervention throughout the course of the academic year, during one particular unit students' mathematics journals were collected and scored using a mindset rating scale for data collection purposes. The aim of assessing student mathematics journals was to gauge student achievement and proficiency along with growth mindset practices throughout a mathematics unit.

As with the Mathematics Mindset survey, students were given a score between one to four, with one indicating a low level of growth mindset language and practices and four indicating high levels of growth mindset practices. In order to receive a score of four, students were required to show evidence of multiple strategies for problem solving.

In Figure 6, overall the class performed lower on the rubric scale. This may be due to the fact that students did not show evidence of multiple strategies being used. Students often answered the difficult mathematical problem correctly, but rarely offered other solutions to their answer or elaborate on why and how their answer was correct. The question students solved and responded to in Journal 3 (Appendix E) was the most challenging, requiring students to use multiple steps and procedures in their responses. One student simply responded with, “I don’t know.” When questioned about their response, the student reflected that, “If I look around and see other people getting it, then I know I can eventually find the answer. But with that problem nobody was getting it. If nobody gets it, then it doesn’t matter (what I do), I won’t either.” This student, while shifting in and out of growth mindset practices throughout the year, showed that the group dynamic of a classroom’s approach to perseverance and productive struggle, are very important in creating growth mindset in students.

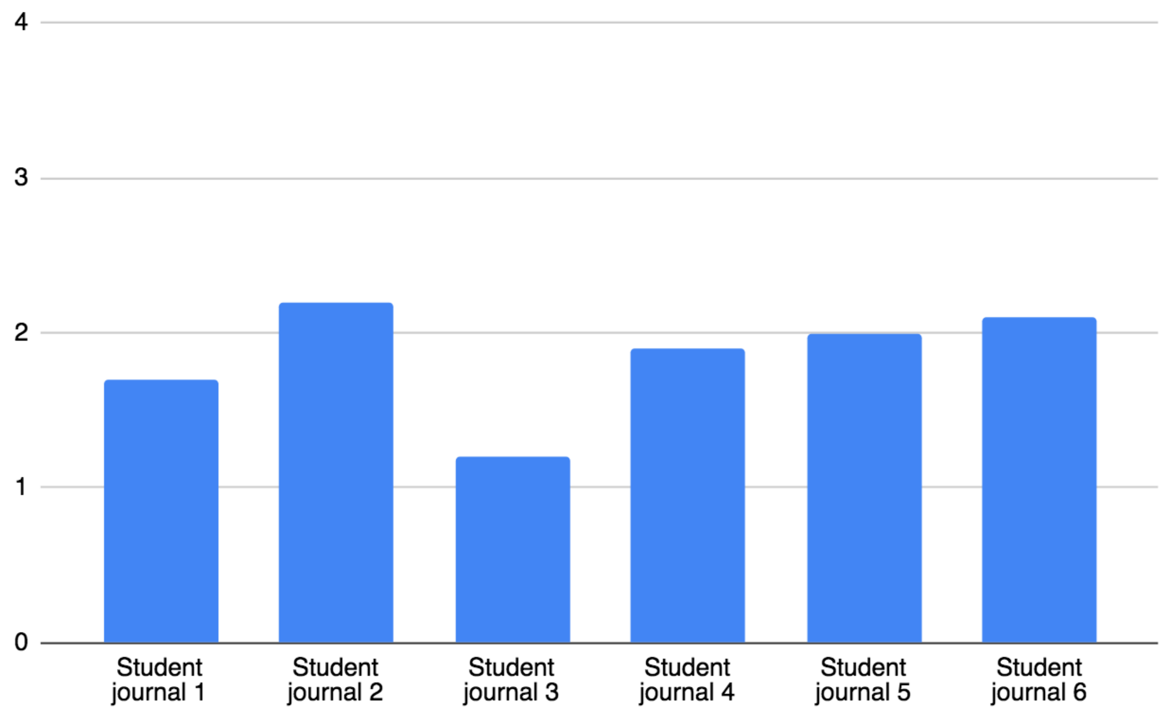

Figure 6. Class averages for student math journals, as assessed by growth mindset rubric

Mathematics Chapter Assessments, Beginning and End of Year

At the beginning and end of each mathematics chapter (unit), students completed an identical pre- and post- assessment. The aim of the pre- and post- assessments was to identify growth throughout the given mathematics chapter. Students met in small groups to reflect on their pre-test score and set goals for their post-test. They discussed common errors, and set individual goals for improvement. For the purpose of data comparison, one unit assessment administered at the beginning of the school year, before growth mindset instruction took place, is compared to another unit assessment administered near the end of the academic year.

In Figure 7, the pre-assessment from the beginning of the year had a low mean (10%), median (0), and mode (0). At the conclusion of this particular assessment, students increased from their pre- to their post-assessment. The mean of these tests increased 17%, from 10% to 27%. The median and mode both increased from 0% to 25%. The pre-assessment data from the unit measured near the end of the school year, after regular, intentional use of growth mindset language and practices during instruction, had a mean, median, and mode at or lower than 25%. Students' scores increased more than they had at the beginning of the year. The mean of the tests increased from 37%, from 22% to 59%. The median of the tests increased from 25% to 63% and the mode increased from 13% to 63%.

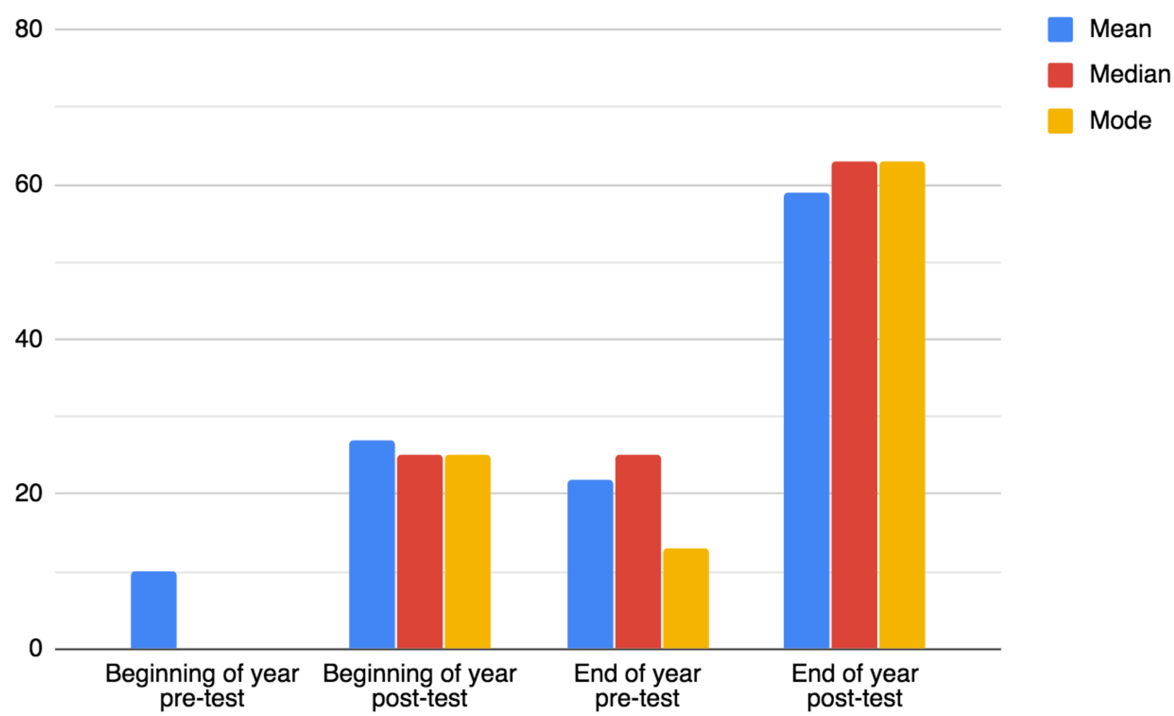

Figure 7. Comparison of achievement and growth of pre- and post- assessments from the beginning of the year, before growth mindset instruction, to the end of the year, after growth mindset instruction.

Midway through each mathematics unit, students were asked to create a formative assessment for their peers. Each student created a mathematical question about the concept or skill they had studied. In Figure 8, we see that students appear to have a strong grasp of the mathematical content according to the student-created formative assessment. This student-created formative assessment had a mean of 84%.

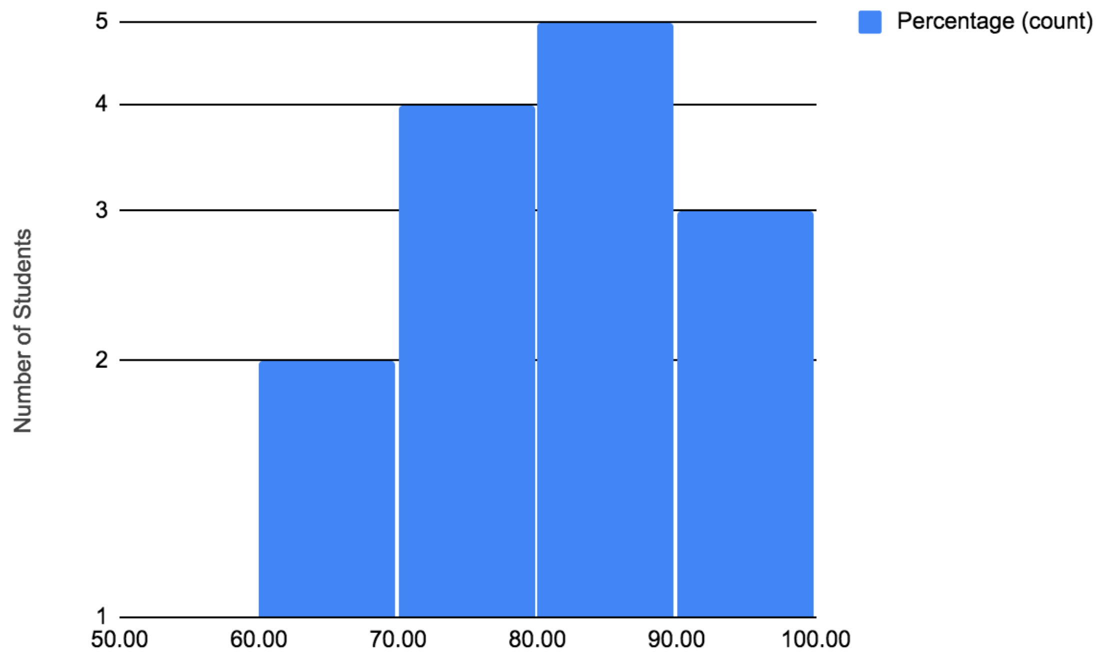

Figure 8. Individual scores by percent on student-created formative assessment - percentages unit.

As growth mindset language and practices in the classroom were implemented, there was an increase in student achievement, based on pre- and post- assessments, as well as the mid-unit formative assessment. However, the confounding point of data are the student mathematics journals. The mathematics journals indicated that students were not yet using the deeper thinking and processes that occur with consistent growth mindset practices. Furthermore, while students increased in achievement from pre-assessments, they did not achieve what is determined as “proficient,” still scoring lower than an average of 60% on post-assessments.

Action Plan

This study shows that students who received instruction from a teacher with purposeful growth mindset language and practices increased their mathematical achievement and mindset, as measured by pre- and post- assessments from the beginning of the year compared to the end of the year. Teacher growth mindset language and practices included visualization with connections to physical challenges and fitness, growth mindset anchor charts, and growth mindset-centered language during whole and small group mathematics instruction. The increase in growth mindset and mathematical achievement is one piece of a much larger puzzle.

While students showed a small increase in growth mindset as measured by the Mathematics Mindset survey, work should be refined on the survey to give a more thorough picture of where students' mindsets are in mathematics. In reflecting on student survey results, four questions seems insufficient to gain a picture of where students are in their mathematical mindsets. Further, instead of four response choices, it might be more beneficial for students to use a scale from 1 – 10 with increasing degrees of growth mindset as students might feel limited by the four response choices. The Mathematics Mindset survey was limited due to the restrictive number of response choices and questions. Similarly, assessing student mindset through student mathematic journals was also limiting.

The intended goal of grading student mathematic journals as assessed by the growth mindset rubric was to identify how students showed their mathematical thinking through written work. Students did not always write growth mindset language and practices in their own written work. Because mindset involves internal processes and does not always require written work, the growth mindset rubric is not necessarily indicative of the mathematical cognitive processes that took place in solving a mathematical problem. Students may have found multiple ways to find their answer in their minds, without recording their process. Assuming students were able to engage in productive struggle while completing mathematic journal problems is one part of the equation. During whole group instruction, it was clear that not all students were willing to engage in productive struggle while challenging mathematic problems.

While some students were able to engage in productive struggle, use growth mindset practices, and solve very challenging mathematical problems. However, many students in the class fell back into learned helplessness and were unable or unwilling to attempt more challenging mathematical operations and problems. Even though many students fell into learned helplessness when confronted with frustration-level mathematics problems, almost all of the students were able to see that growth mindset is not isolated to the classroom, and made important connections.

An important real-life connection many students identified with in whole group discussions was that of growth mindset and physical fitness. What I happened to bring up during a discussion, a personal struggle with the exercise tank and physical therapy following a knee surgery, seemed to be the connection students needed to understand what growth mindset meant. Students instantly connected with experiences following a broken bone, working on a sports teams, or even skateboarding. With the connection of physical exertion, what you physically are or are not capable of, and growth mindset, students seemed to understand that achievement is not always based on what you can do compared to other people, but rather what you can do compared to yourself. They seemed to be able to make the connection that while something may be difficult now, through effort it may be possible tomorrow.

A powerful connection for growth mindset at the school I work at can be forged between classroom teachers and physical education teachers. During the academic year, I frequently discussed growth mindset lessons in the classroom with my students' physical education teacher. When students needed to collect data for physical fitness testing, the physical education teacher began by reviewing growth mindset and comparing one's success to oneself – not to what other people do. In following years, I hope to collaborate further with other specialist teachers in creating growth mindset connections across domains such as art, music, or physical education.

It was also helpful to see that adults, in this case their teacher, also face failure and have to work towards success. While early growth mindset lessons in the beginning of the academic year were about famous failures – important people who faced adversity and overcame it – what might be more powerful is for students to see examples of people they have connections with and hear about times they have used a growth mindset. In future years I plan to engage families and community members in sharing their growth mindset stories. In my classroom, I plan to have students begin the year with a growth mindset interview. In this interview, they will meet with someone in their family or community and ask questions about failure, persistence, effort, success, and goal-setting. This will be followed by sharing the stories they curate. In this way, students' voices and experiences will be infused into growth mindset from the very beginning of the year.

Because mindset takes years of practice to develop, I would be very interested to see what a looped classroom might look like in their development of growth mindset. If a class were followed through several years, with the same teacher utilizing consistent growth mindset language and practices, I imagine that students' growth mindset practices and beliefs would evolve and become stronger each year. Consistency in developing growth mindset is absolutely critical.

Finally, as I continue to refine my practice, I hope to include more growth mindset language and practices in how I provide feedback to students. Feedback is highly impactful in student achievement, and I wonder if the feedback I provided to students on assignments and tests were as representative of the growth mindset language I used in whole group teaching.

While the beginning of the academic year and my research were focused on achievement, it became clear that what I really sought was for students to develop a growth mindset. For students to achieve, they need to be able to have the skills to persevere, think abstractly, engage in productive struggle, and seek to continually improve. If achievement in mathematics is the only goal, then the reward may be short-term. With an intervention in math fact fluency, students may be able to improve their mathematics facts. This is necessary for growth – but will they have the skills in order to look at a triangle and solve for a missing angle? Will they be able to set and maintain a budget given constraints? Not necessarily. It is for this reason that developing a growth mindset in learners became more of a focus in my research than simply achieving higher. Mindset should be an important component of mathematical instruction, as it empowers students to become strategic, mathematical problems.

I hope that the findings of my research encourage other teachers to take time to teach a life-skill students desperately need – growth mindset. As one of my students mentioned in an interview, teachers will not always be next to students to help them. Students need to be able to use a growth mindset to push them towards finding a solution to problems they will inevitably encounter.

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Appendix A
Impact of Teacher Language on Student Math Mindset and Beliefs
Parental Permission Form

April 16, 2018

Dear Parents,

In addition to being your child's fifth grade teacher, I am a St. Catherine University student pursuing a Masters of Education. As a capstone to my program, I need to complete an Action Research project. I am going to study your child's beliefs about math because I want to see if the language I use during teaching will help build more positive beliefs in math.

In the coming weeks, I will be having students record their thinking in math as a regular part of my math instruction. All students will participate as members of the class. In order to understand the outcomes, I plan to analyze the data obtained from the results of this activity such as a math belief pre and post assessment, math journal entries and pre and post mathematical chapter assessments to determine how students' attitudes and beliefs in mathematics evolve. All strategies implemented and assessments given are part of normal educational practice.

The purpose of this letter is to notify you of this research and to allow you the opportunity to exclude your child's math belief pre/post assessments, journal entries, and pre and post mathematical chapter assessments from my study.

> If you decide you want your child's data to be in my study, you don't need to do anything at this point.
>
> If you decide you do NOT want your child's data included in my study, please note that on this form below and return it by April 30, 2018. Note that your child will still participate in the math reflections and journaling, but his/her data will not be included in my analysis.

In order to help you make an informed decision, please note the following:

- I am working with a faculty member at St. Kate's and an advisor to complete this particular project.
- Risks to students involved in this study are minimal. Benefits of participating are that students could improve metacognition during mathematical problem solving and develop more positive beliefs in mathematics.
- I will be writing about the results that I get from this research. However, none of the writing that I do will include the name of this school, the names of any students, or any references that would make it possible to identify outcomes

connected to a particular student. Other people will not know if your child is in my study.

- The final report of my study will be electronically available online at the St. Catherine University library. The goal of sharing my research study is to help other teachers who are also trying to improve their teaching.
- There is no penalty for not having your child's data involved in the study, I will simply delete his or her responses from my data set.

If you have any questions, please feel free to contact me, sarah_rodriguez@rdale.org. You may ask questions now, or if you have any questions later, you can ask me, or my advisor Dr. Gunpinar, ygunpinar@stkate.edu, who will be happy to answer them. If you have questions or concerns regarding the study, and would like to talk to someone other than the researcher(s), you may also contact Dr. John Schmitt, Chair of the St. Catherine University Institutional Review Board, at (651) 690-7739.

You may keep a copy of this form for your records.

______________________________ ________________

Sarah Rodriguez Date

OPT OUT: Parents, in order to exclude your child's data from the study, please sign and return by April 30, 2018

I do NOT want my child's data to be included in this study.

______________________________ ________________

Signature of Parent Date

Appendix B
Mathematics Mindset Survey

1. Who is your math teacher?
2. How do you feel about math?
   a. I am not excited to do math
   b. I'll do math work only because my teacher tells me I have to
   c. I like to do math because I like to learn new things in math
   d. I see math as a challenge and challenges are exciting to me
3. When I'm stuck on a different problem, I…
   a. Try to be quiet and wait for work time to be done
   b. Wait for my teacher to help me
   c. Look for resources and/or use strategies to help me
   d. Try to discover new strategies to "unstick" myself
4. How I use math in "real life"
   a. Math is just a subject I have to study in school
   b. Math is important for some people, but not me
   c. Math is important to help me get good grades
   d. Math is important for good grades; I use math to solve problems outside of school
5. If I don't understand, I…
   a. Think about other things that are more interesting to me
   b. Listen carefully and hope someone else answers or asks my question
   c. Raise my hand and ask for help
   d. Ask questions to help me get "unstuck"

Appendix C
Teacher Reflection Journal

Date:	Unit/Lesson:
Students' Learning Goal: (Will know)	Students' Performance goal: (Will do)
What strategies did I provide for the students to process information?	What strategies did I provide for students to share information?
What connections did students make to growth mindset during the lesson?	What connections did I make to growth mindset during the lesson?
What successes did students have during the lesson?	What challenges did students have during the lesson?
Did students meet their learning goal?	Did students meet their performance goal?
Additional Notes:	

Appendix D
Sample Student Mathematics Journal

In a survey of the most popular types of coffee sold by a cafe, *latte* received 42% of the votes, *espresso* received $\frac{3}{25}$ of the votes and *ice blended* received 0.46 of the votes. Order the types of coffee from the most popular to the least popular.

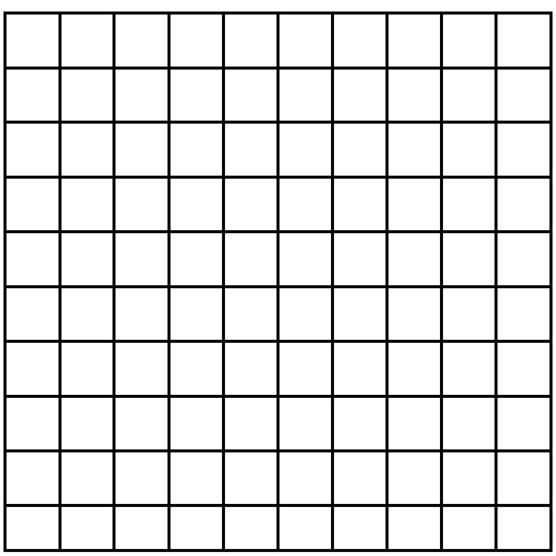
Appendix E
Mathematic Journal Rubric

1	2	3	4
Student does not answer the math question and offers no reflection OR student answers the math question but offers no reflection on how they found their answer	Student answers the math question and writes notes in a few words, vaguely explaining how they found their answer.	Student answers the math question and explains why they chose the strategy they used and/or why the strategy works.	Student answers the math question and explains how they found their answer. Student offers a thoughtful explanation of their strategy and can explain how it works to others. Student identifies “problem areas” where they had a difficult time but persevered

Appendix F
Midpoint Quiz

1. What is 78% written as a decimal?
2. What is 57/100 written as a percentage?
3. What is 88 out of 100 written as a decimal, percent, and fraction (in lowest terms)?
4. Out of 100 pieces of candy, Jaydon ate 36 pieces. What percent of the candy did he eat?
5. 51% of the boys played video games. There were 100 boys, how many of them played video games?
6. If I make 70% of my basketball shots, how many shots out of 100 did I miss?
7. What is 108/100 written as a percentage?
8. What is 80/10 written as a percentage?
9. What is 72/10 written as a percentage and a decimal?
10. Turn 9/20 into a percentage.
11. 100 kittens in total were lost. She found 36% of them. How many more kittens are left?

12.) Shade in 24 boxes in the grid below, then answer the following questions:



a.) What percent of the boxes are shaded? _________________________

b.) What percent of the boxes are unshaded? ______________________

Appendix G
"The Tank" visual