Mindset towards mathematics: The effects of growth mindset interventions on math anxiety

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Abstract: Many students are faced with math anxiety which can affect their working memory, which in turn can tamper with their ability to effectively problem solve. In the current study, the effect of three growth mindset interventions: self-assessments, increased group collaboration, and low floor, high ceiling math tasks, had on math anxiety, math achievement, math self-efficacy, and growth mindset were explored. There were 96 honors geometry students from a rural high school in Southern Maryland that participated in the following study. Students completed a pre-/post-Likert scale survey to measure their sense of self-efficacy, growth mindset, and math anxiety. Math achievement was measured by comparing the average scores of five students' homework scores pre-/post-intervention. Throughout the intervention, students participated in increased group work, completed a short self-assessment on days when new content was introduced, and low floor, high ceiling math tasks. After the implementation of the growth mindset activities, there was no significant difference in students' growth mindset (*p-value* = 0.45) and math anxiety (*p-value* = 0.87), and there was a significant change in math self-efficacy *(p-value* = 0.00) and math achievement (*p-value* = 0.00). Qualitative data indicated that students felt both more capable and more confident in their math ability following the implementation of the growth mindset activities. The results support that teachers should consider incorporating self-assessments, increased group collaboration, and low floor, high ceiling math tasks into their classrooms to increase student math self-efficacy, growth mindset, and math achievement.

Introduction and Justification

Math anxiety impacts how capable a student feels about their ability to solve math tasks, and therefore impacts their math achievement (Klee et al., 2021; Park, Ramirez et al., 2014; Ramirez et al., 2016; Skaalvik, 2021). In order to successfully show an understanding of mathematical concepts, students need to problem solve to demonstrate their thinking process. An apprehension of trying to apply a new math concept and experiencing a sense of failure can prohibit a student from problem solving. In my honors geometry math classroom, I have frequent interactions with a student who appears to have high levels of math anxiety. Whenever they raise their hand, it is not because they have a specific question, but because they "don't know how to do anything." This student not only believes they are incapable of completing the math task, but they are also fearful of failure. Trying the math task and making a mistake will be a negative judgment of the student's intelligence; they would rather not try at all.

Math anxiety has been defined as worry, fear, or apprehension towards mathematics (Huang et al., 2019; Park et al., 2014). When actively worrying about a math task, math anxiety resides in the working memory of the brain, where reasoning and decision-making take place. This leaves limited room in the working memory to process the current math task (Klee et al., 2021). By decreasing math anxiety, students will have a greater ability within their working memory to problem solve, which will lead to an increase in math achievement. In addition to being negatively associated with math achievement, math anxiety is also negatively associated with math self-efficacy. Self-efficacy is one's belief that they are capable of producing a desired outcome (Bandura, 1997). If a student does not feel capable of completing a math task, they will feel apprehensive about even attempting to complete the task. Increasing a student's growth mindset can help increase self-efficacy (Lee et al., 2021).

Growth mindset is the belief that talent and knowledge can be developed with hard work. In contrast, a fixed mindset is the belief that talents are unlearned and cannot be developed with hard work (Dweck, 2016). Students who have a fixed mindset in math believe that no matter how hard they try, they will not have the talent and skills they will need to be successful. Students with a growth mindset in math believe that if they keep trying, they will eventually be successful. Self-efficacy and growth mindset have a positive association (Lee et al., 2021; Huang et al., 2019). In order to increase math achievement within the math classroom, students need to transform their fixed mindset into a growth mindset, strengthen their self-efficacy, and decrease their math anxiety.

There are current studies that investigated how math anxiety and/or growth mindset interventions impact elementary aged students (Klee et al., 2021; Lee et al., 2021; Ramirez et al., 2016), but there is no current research that looks at the impact of math anxiety and growth mindset interventions on high school students. In this study, an investigation on how the implementation of three growth mindset interventions will impact math anxiety, growth mindset, self-efficacy, and math achievement was conducted. The results of the study can help direct other educators on how to recognize and approach the growth mindset within their classroom. In the next section, existing research on math anxiety, growth mindset, and math self-efficacy, and three growth mindset interventions used in the current study are explained in greater detail. I will then introduce the research questions on how I believe growth mindset interventions will impact the math classroom.

Literature review

The intentions of the current study were to use the relationships between growth mindset, math self-efficacy, and growth mindset interventions to increase growth mindset and math achievement. First, an explanation of growth mindset is provided, including some common misconceptions about growth mindset, as well as the differences between growth and fixed mindset (Dweck, 2015; Dweck, 2016). Next, there is a detailed description of self-efficacy and its relationship with student learning. After this, there is an explanation of the goals and benefits of growth mindset math interventions, including a description of the three interventions that were implemented into the classroom for the current study: writing self-reflections/self-assessments, group work collaboration, and low floor, high ceiling math tasks. To conclude the literature review, there is a presentation of the research questions and purpose statement for the current study.

Growth Mindset

Carol Dweck (2015), most saliently known for her research in growth mindset theory, defines students' beliefs of their own ability with two terms: growth and fixed mindset. With a growth mindset, students believe that they will be able to achieve a learning goal if they persevere in the face of a challenge. In contrast, students with a fixed mindset believe that their ability is innate and they will not be able to be successful, no matter how hard they try. A common misconception of growth mindset theory is the belief that students either have a growth mindset or a fixed mindset. In reality, Dweck believes that everyone is a combination of both growth and fixed mindset. In order to continue with growth mindset beliefs, humans have to actively work against fixed mindset thoughts (Dweck, 2015). In her *TedTalk* on growth mindset, Dweck discusses the word "yet." Growth mindset in students is about their current ability, what they cannot accomplish yet, and what plan they develop to persevere and further grow their abilities (Dweck, 2014).

In the face of a challenging math task, students will respond to the stressor with the three steps of stress. First, they will recognize the task is difficult. Second, they will think of potential responses to the math task. The third step would be to execute the responses they create (Carver et al., 1989). Students will cope with the difficult math task in two different ways: students with low math anxiety will use active coping and attempt to utilize different problem solving strategies, whereas students with higher math anxiety are more likely to utilize restraint coping strategies, including waiting until an answer is provided to them, and problem avoidance (Ramirez et al., 2016; Skaalvik, 2018). Students with a growth mindset also utilize active coping strategies as they persevere to solve challenging math tasks. A student with a fixed mindset who believes that their ability is up for judgment, is more likely to avoid attempting the problem (Dweck, 2014).

In the book *Mathematical Mindsets*, Jo Boaler (2016) discusses the importance of growth mindset by explaining the value of making mistakes. Everytime a mistake is made within the math classroom, the brain forms a new synapse, as making mistakes is a learning experience. In addition, students with a growth mindset are more likely to be aware of their mistakes, and will be more likely to reflect on their mistakes and try alternative strategies to reach the correct answer (pp. 11-12). As educators, we need to relay the message to students that mistakes are not a bad depiction of intelligence. In fact, educators should be mindful of all messages about growth mindset and ability they are sending their students. Teaching practices can both implicitly and explicitly deliver messages to students about their teacher's stance on ability and their intelligence (Liu Sun, 2018; Seaton, 2017). In the discussion of the literature on growth mindset interventions, I will introduce how teaching practices can be changed to deliver growth mindset messages.

Self-Efficacy

Albert Bandura (1997), the renowned psychologist behind self-efficacy, defined self-efficacy as one's belief that they are capable of producing a desired outcome. In addition to this definition, several variations of the definition appear throughout research, including the belief that one can perform actions to lead to the desired outcome (Lee et al., 2021), and math self-efficacy being perceived confidence in math (Huang et al., 2019). All three definitions share the common theme of the belief in one's capability of reaching a particular learning goal. Both vicarious experiences and observations have a strong influence on one's self-efficacy. In the math classroom, students will be more self-efficacious after observing models who persevere in the face of failure and find alternative solutions. Coping models will also increase self-efficacy if they are able to show students how they deal with difficult math tasks, and how to go about using different strategies (Bandura, 1997). Students who view success through vicarious experiences are more likely to experience increased self-efficacy after they view their peers struggle and reach success (Klee et al., 2021). In the discussion of the literature of group work collaborations, I will expand on the benefits of peer interactions in self-efficacy.

Connection between Growth Mindset and Self-Efficacy.

A link has been established between math anxiety and self-efficacy (Martin et al., 2017; Klee et al., 2021). One reason for this link is the perceived control students feel they have over various math tasks (Klee et al., 2021). In addition, when constructing and testing the COPE strategy inventory, Carver et al., (1989) found a positive association between optimism, feelings of being able to do something, and self-esteem. Students feel more self-efficacious (and less math anxious) when they feel they are capable of being able to complete a math task. When faced with a challenging math task, students need to hold a growth mindset and have a high sense of self-efficacy. Students need to feel that they are capable of changing their current abilities if they keep persevering (growth mindset), and they need to feel capable of having the skills needed to produce the final learning outcome (self-efficacy). The positive association between self-efficacy and growth mindset (Huang et al., 2019; Lee et al., 2021) furthers the call to implement growth mindset interventions to potentially increase self-efficacy, growth mindset, and math achievement.

Growth Mindset Interventions

The main goal of growth mindset interventions is to change how a student approaches challenging math tasks in order to help avoid a fixed mindset from overtaking a student's growth mindset (Casad et al., 2018). The interventions work towards having a mastery-goal oriented environment over a performance-goal oriented environment. A mastery achievement goal is one where there is a focus over understanding the material over grades and how others may perceive ability. In contrast, a performance-oriented goal has a focus on how others perceive ability and on the outcome, which can be displayed in the classroom setting through either the final grade or the correct answer (Klee et al., 2021). A positive association has been found between mastery-goals and both active coping strategies and math achievement (Skaalvik, 2018). To help increase mastery-goals within the classroom, focus should be placed on student learning and comprehension over grades on assignments (Boaler, 2016; Klee et al., 2021; Liu Sun, 2018). All students need to be held to high expectations. Holding students to different standards sends the unintentional message that some students are more capable of success than others. In addition, students should spend time working on open-ended math tasks that require students to think critically, problem solve, and think/reflect about tasks and concepts (Abaziou, 2018; Boaler, 2016; Liu Sun, 2018). Throughout this investigation into growth mindset interventions, I have found studies that looked at writing self-reflections/self-assessments, group work collaboration, and low floor, high ceiling math tasks in elementary, middle, and college classroom settings (Lee et al., 2021; Martin et al., 2017; Park et al., 2014; Skaalvik, 2018), but there has been little research surrounding high school classrooms. I am hopeful that the current study will find that the three chosen interventions will help decrease math anxiety and increase growth mindset, self-efficacy, and growth mindset.

Writing Self-Reflections, Self-Assessments.

Self-reflections and self-assessments within the math classroom are opportunities for students to check in with where they are in their learning, and how they can improve. Written self-check-ins can come in several forms within the math classroom, including expressive writing, checklists, and prompt and answer templates. The benefits of writing self-reflections and/or self-assessments within the math classroom has been well documented including a decrease in math anxiety (Park et al., 2014), and an increase in self-efficacy, self-regulation, problem-solving skills (Martin et al., 2017), and autonomy (Boaler, 2016; Boaler, 2018; Martin et al., 2017). Boaler (2018) discusses the Assessment for Learning Model which holds three key components: "Where students are now, Where they should be, and How to get there" (p.1). Self-assessment can utilize these three components, encourage growth in learning, and de-emphasize the importance of performance. By incorporating written self-reflections/self-assessments into my classroom, I hope to increase self-efficacy, growth mindset, and math achievement as well as decrease math anxiety.

Group Work and Collaboration.

Group work allows students to work with their peers and share ideas, strategies, and experiences. An increased effect on self-efficacy has been found through group work due to an increased opportunity for success and mastery experiences (Klee et al., 2021). Student collaboration has also been shown to be a useful tool to allow students to help their peers gain understanding through student-to-student teaching (Boaler, 2016). Through my intervention, I hope to scaffold increased peer interactions for students so they can have more positive vicarious and mastery experiences within the math classroom (Bandura, 1997).

Low Floor, High Ceiling Math Assignments.

Low stake assignments, or low floor, high ceiling assignments, provide all students with the opportunity to start and work on a problem without the pressure of following a specific algorithm to reach the correct answer. Low stake assignments provide a focus on mastering a concept instead of performance. Low floor, high ceiling (LFHC) assignments encourage proficiency with conceptual understanding, and utilize the eight mathematical practices that are supported by the Common Core State Standards (NCTM, 2014). The eight mathematical practices all support incorporating growth mindset within the math classroom, and especially helping students to make sense of problems and persevere in solving them (Mathematics Practice 1), model with mathematics (Mathematics Practice 4), and construct viable arguments and critique the reasoning of others (Mathematics Practice 3). Through low floor, high ceiling math tasks, group work, and self-assessment, these standards can be met in the math classroom. When using low-risk math tasks, all students in the classroom are able to demonstrate what they know, and are able to preserve their problem solving (NRICH, 2019). Including low floor, high ceiling math tasks in the math classroom was also found to increase student engagement, and demonstrates high expectations to all students (Boaler, 2016; Liu Sun, 2018). Low floor, high ceiling math tasks have been introduced into high school math classrooms by other teachers and have shown an increase in growth mindset and perseverance (Abaziou, 2018).

Purpose Statement and Research Questions

The purpose of this study was to examine whether or not the growth mindset interventions, writing self-assessments/self-reflections, group work and collaboration, and low floor, high ceiling math tasks had an impact on math anxiety, growth mindset, math self-efficacy, and in turn, math achievement. The research questions that guided my study were:

Will the implementation of writing self-assessments/self-reflections, group work and collaboration, and low floor, high ceiling math tasks:

1. Create any change in math anxiety?
2. Create any change in math self-efficacy?
3. Create any change in growth mindset?
4. Create any change in math achievement in the classroom?

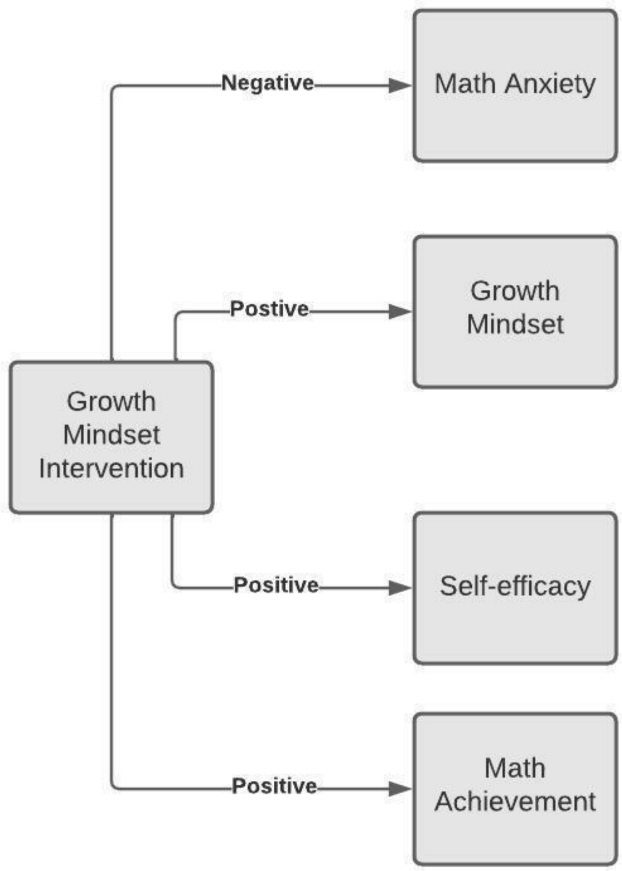

Figure 1: Predictions of results from implementing Growth Mindset Interventions

Methods

Participants

The study was conducted in a 9th grade honors geometry classroom at a public high school in Southern Maryland. The sample was pulled from five sections of honors geometry, resulting in the total number of participants being 96 students. Of those students, 42 were male and 54 were female. Seven students were economically disadvantaged, three had an Individual Education Plan (IEP) and eight students had a 504 Plan.

Intervention

Throughout the study, there was an increased use of self-assessment in the classroom. Students completed homework reflections (see Appendix B) on the days where a new concept was introduced. In this reflection, students answered the following questions: 1. What was the main idea you learned today? 2. What are you struggling with or what do you have questions about? 3. How could the ideas from today's lesson be used in the real world? and 4. What are you going to do to continue practicing and understanding the new concept? In addition, several opportunities for low floor, high ceiling math tasks (see appendices D and E) were included. Here, all students could participate in every activity, and could make connections to the content currently being explored in the geometry classroom. Throughout the time of the intervention, students had additional time for collaboration through increased think-pair-shares and time for group work.

Data Collection

In order to collect data for this study, a mixed methods approach was used to collect data both quantitatively and qualitatively in order to better gauge the effectiveness of the growth mindset intervention. Quantitative data was collected through a fifteen question Likert scale (see Appendix A) that had five questions measuring math anxiety (Carey et al., 2017), growth mindset (Dweck, 1999), and self-efficacy, (Bandura, 2006) respectively. The questions on the scale were adapted from previous scales with the help from a professor who has previously published research in this field. The survey was conducted pre- and post-intervention to investigate whether there were any changes in the ratings. In addition, averages on the five homework assignments pre-and post-intervention were compared to identify any change in math achievement. Qualitative data was collected through open-ended surveys students completed at the end of the intervention. The survey asked students questions regarding their math anxiety, growth mindset, and self-efficacy (see appendix).

Table 1:

Research questions and data sources

Research Question	Data Source 1	Data Source 2
Will the implementation of writing self-assessments/ self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in math anxiety?	Open-ended survey	Math Anxiety Likert Scale
Will the implementation of writing self-assessments/ self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in students' growth mindset?	Open-ended survey	Growth Mindset Likert Scale
Will the implementation of writing self-assessments/ self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in students' math self-efficacy?	Open-ended survey	Self-efficacy Likert Scale
Will the implementation of writing self-assessments/ self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in math achievement in the classroom?	Average of the scores of 5 process grades pre-intervention	Average score of 5 process grades post-intervention

Data Analysis.

A two-sample *t-test* assuming unequal variances was used to look at the data collected in the pre-/post-Likert scale. Three *t-tests* assuming unequal variances, one for self-efficacy, growth mindset, and math anxiety respectfully were conducted to assess differences following the integration of increased self-assessments, increased group collaboration, and low floor high ceiling math tasks. A two-tailed paired *t-test* was conducted to compare student math achievement on homework assignments. Qualitative data collected from the four open-ended survey questions students responded to was coded to look for common themes surrounding students' growth mindset, self-efficacy, and math anxiety. The data was collected anonymously and 88 students participated in the open-ended survey.

Validity Concerns.

The Likert scale questions were reviewed by an overseeing professor in the educational studies department. When analyzing the growth mindset Likert scale questions, reverse scoring was done to ensure that the results of the *t-test* provided accurate results.

Results

Will the implementation of writing self-assessments/self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in math anxiety?

After the implementation of growth mindset interventions, there was a nonsignificant change in students' math anxiety (*p-value* = 0.87). As shown in table 2, the bayes factor (0.17) shows there is substantial evidence supporting the null hypothesis. The mean score on the pre- and post-Likert scale was a 2.7 suggesting that the students did not feel very anxious both before and after the growth mindset interventions were introduced. Looking at the qualitative data, question three (see Appendix C) asks students to identify a problem-solving strategy they could use the next time they are given a challenging math problem on a math quiz. From the 88 students who answered the question, five common problem-solving strategies emerged, including: skipping the problem and going back to it later (13%), think back to notes and examples done in class (18%), try different strategies (14%), break the problem down into steps (16%), and reread the problem to see what it is already asking for (10%). Results yield that students in the honors geometry class already demonstrated a low math anxiety prior to the start of the intervention. In addition, students were able to provide problem solving strategies they use when faced with a challenging problem suggesting that students are able to successfully attempt to process and solve challenging math problems without math anxiety impacting them.

Table 2:
T-test results: Comparing Math Anxiety

	n	*M*	*p*	*BF*
Pre	84	2.7	0.87	(1/6.071746) = 0.17
Post	94	2.7		

Will the implementation of writing self-assessments/self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in math self-efficacy?

Following the intervention, there was a significant change in students' math self-efficacy (*p-value* = 0.024). Cohen's d (0.365169) confirms there was a small/medium effect level supporting a positive change in self-efficacy. Students answered an average of 0.23 higher on the post-Likert scale than they did on the pre-Likert scale demonstrating a higher confidence level in mathematics (see table 3). The open-ended survey data source further investigated students' opinions on any change in math confidence through question one (see Appendix C). Out of the 88 participants of the open-ended survey, 22 students (25%) said that the growth mindset interventions did not make them feel any more confident, while 66 students (75%) felt that their confidence had increased throughout the intervention or did not change. Three of the students who said that their confidence did not change explicitly stated that this was because "I've felt confident in my abilities since day 1". From the 66 students who mentioned an increase or no change in their confidence, group work/collaboration was mentioned seven times, the transformation project (see Appendix E) was mentioned 23 times, and low floor, high ceiling activities, such as Desmos, were mentioned three times. Of the 22 students who felt none of the growth mindset activities over the three week period made them feel more confident, only one student explicitly expressed a feeling of lowered confidence. "I feel less confident doing the transformations project since it was a new format, but other than that I don't think too much else had an impact". Although this student expressed a lowered confidence level because of the format of the transformations project, the other growth mindset encouraging activities did not bother this student. Overall, it appears that the implementation of growth mindset enhancing activities increased students' self-efficacy. Out of the students who completed the open-ended survey, 75% felt their confidence was increased or unchanging following the increased use of self-assessments, group collaboration, and low floor, high ceiling math tasks.

Table 3:
T-test results: Comparing Math Self-Efficacy

	n	*M*	*p*	*d*	*BF*
Pre	84	3.74	0.024	0.365169	1.767534
Post	94	3.97			

Will the implementation of writing self-assessments/self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in growth mindset?

The implementation of growth mindset interventions into the honors geometry classroom produced a nonsignificant change in students' growth mindset (*p-value* = 0.45). The interpretation of the bayes factor (see table 4) furthers that there is substantial evidence for the null hypothesis. In the open-ended survey however, question four (see Appendix C), asks students to assess any change in their capability to do geometry after the implementation of growth mindset promoting activities. Of the 88 students, 59 (67%) felt they were more capable in doing geometry, four students felt they were already capable prior to the intervention, one student felt less capable, and 20 students felt no change in their capability to do geometry following the growth mindset intervention. The one student who felt less capable specifically mentioned feeling "less capable after doing a desmos because it doesn't tell you if you are right or wrong". This does not allude to every growth mindset intervention decreasing this student's sense of capability, just the Desmos low floor, high ceiling activities. Although the quantitative data did not result in a significant *p-value,* the qualitative data suggests an increased sense of capability in completing math tasks following the implementation of self-assessments, group collaboration, and LFHC math tasks.

Table 4:
T-test results: Comparing Growth Mindset

	n	*M*	*p*	*BF*
Pre	84	2.00476191	0.45	1/6.107408 = 0.16
Post	94	2.01170213		

Will the implementation of writing self-assessments/self-reflections, group work and collaboration, and low floor, high ceiling math tasks create any change in math achievement in the classroom?

The results from the implementation of growth mindset promoting interventions yield a significant change in students' math achievement (*p-value* = 0.00). Cohen's D (d = 0.92) helps classify the implementation of growth mindset interventions as having a large effect size. The average of student's homework scores on the five homework assignments pre-intervention was a 0.71, while the average of the five homework assignments post-intervention was a 0.88 showing a nearly 17% improvement. The interpretation of this result yields that a positive change in math achievement is produced following use of self-assessments, increased group work, and LFHC math tasks in the geometry classroom.

Table 5:
T-test results: Comparing Math Achievement

	n	*M*	*p*	*d*	*BF*
Pre	96	0.709	0.000	0.921947	3828073
Post	96	0.877			

Students' opinion on self-assessment

Question two of the open-ended survey (See Appendix C) explicitly asked students to voice their opinion on the self-assessment growth mindset intervention. On the three days where new content was introduced, students completed four homework reflection questions to reflect on the new math concepts introduced that day (See Appendix B). Of the 88 students who completed the open-ended survey, 56 of the students "liked self-reflecting because it helped me get an understanding on what I needed to work on in order to get to my best ability" and "liked the concept of self-reflecting because it helps me and my teacher know what to improve on." In addition, five students felt "indifferent to self-reflection" and, six students felt "like I said the same thing every week. Not much changed therefore I didn't like it". Nine students felt that "trying to come up with a good answer that would fit what you're looking for," and "trying to connect it to real life" was difficult (question three on the self-assessment, see Appendix B). Finally, 18 students expressed disinterest in self-reflecting for several different reasons including, "they were just another annoyance to do", "If I did already understand the subject, then it could be very hard to try and reflect", and "They don't make me feel any better or worse about what I've learned". Only one student noted that they felt self-reflecting does not do much “aside from make me feel less about my ability to perform in math class”. Although this is concerning in regards to the student’s amount of growth mindset or math self-efficacy, the student went on to say “the self reflections make me feel no more motivated than before” hinting at a different issue also including math motivation. Overall, the majority of students indicated a positive opinion towards the self-assessment intervention.

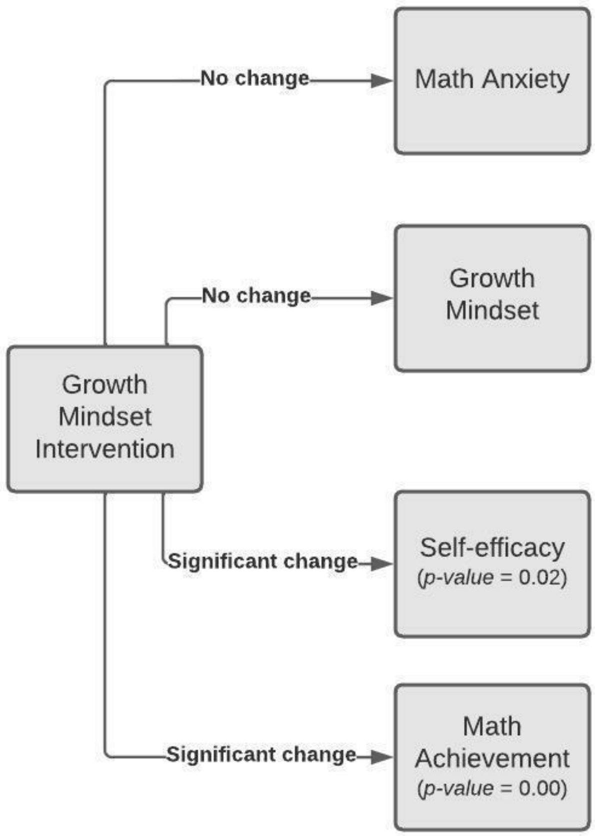

Figure 2: Results from implementing Growth Mindset Interventions

Discussion

Both the quantitative and qualitative data findings for math self-efficacy and math achievement aligned with the findings in previous research. Even though the quantitative data regarding growth mindset and math anxiety does not reflect previous research, qualitative data supports the previous findings on the topic. In the current study, the interpretation of results regarding students' self-efficacy showed a positive increase in both the quantitative and qualitative data. Overall, students felt more confident in their ability to do math following self-assessments, increased group work, and low floor, high ceiling math tasks. Although the quantitative data did not allude to any change in students' growth mindset, 67% of the students who reported on the sense of capability felt their math capability increased throughout the intervention, suggesting growth mindset in students also increased. This aligns with previous research on self-efficacy, growth mindset, and the correlation between self-efficacy and growth mindset (Huang et al., 2019; Lee et al., 2021). Students did not demonstrate any significant change in math anxiety following the growth mindset interventions. An explanation of this finding could be that the students already had a low math anxiety prior to the start of the math intervention. A reason for this could be the sample population including five sections of honors geometry. Results of previous research found that a higher math anxiety could prevent students from adequately problem-solving (Ramirez et al., 2016). Each of the 88 students who participated in the open-ended survey were able to successfully name an effective problem solving strategy they could use when faced with a challenging problem. The current study aligns with previous research on the relationship between math anxiety and the ability to effectively problem solve (Park et al., 2014). In addition, the results of previous research yield that students with a lower math anxiety have more room in their working memory to problem solve, increasing their math achievement (Huang et al., 2019). Students in the current study demonstrated a significant change in their math achievement following the implementation of growth mindset interventions, increasing their overall homework average of five assignments by almost 17%. This does not align with previous research as students' math anxiety did not demonstrate a significant change. However, it is important to note that the current study was implemented in a short, three week stand alone unit on geometric transformations, spanning the entire intervention period. In addition, the intervention finished at the end of the third marking period of the school year. Both the content and the timing of the intervention could be contributing factors to an increase in math achievement. After analyzing both the qualitative and quantitative data, it seems that incorporating self-assessments, increased group collaboration, and low floor, high ceiling math tasks is an effective strategy for increasing student math self-efficacy, growth mindset, and math achievement.

Conclusions and Implications

The purpose of this study was to see if implementing self-assessments, group work/collaboration, and low floor, high ceiling math tasks into the math classroom would create any change in students' math anxiety, math self-efficacy, growth mindset, and math achievement. It was found that, while there was no significant difference in students' math anxiety and growth mindset, there was a significant change in students' math self-efficacy and math achievement. Qualitative data shows students felt more confident and more capable in their math abilities following the implementation of different growth mindset enhancing interventions, suggesting an increase in math self-efficacy (math confidence) and growth mindset (capability). When asked about activities done throughout the three week period that made them feel more confident, students mentioned group work, interactive low floor, high ceiling math tasks such as the transformation project (see Appendix E) and Desmos as tools that helped increase confidence. The majority of students also expressed a liking towards self-assessing. Several students expressed a dislike of the questions being too generic. In the future, questions could be aligned closer with the math concepts being taught that day.

Limitations

The current study was only conducted in honors geometry classes. Students in this course started off with a low math anxiety, which limited the impact growth mindset interventions could have to alleviate math anxiety. The second limitation of this study was the time period in which it took place. The growth mindset interventions were completed over a three week period in January. The three week period was a relatively short time frame to change perceptions on math confidence and math ability that have been formulating for the past nine years of the students' education.

Implications

Results from the current study suggest that growth mindset interventions such as self-assessment, low floor, high ceiling math tasks, and increased group work positively impact students' growth mindset, self-efficacy, and math achievement. Future educators should continue to explore how growth mindset interventions can help increase students' math confidence, sense of capability, and math achievement within the math classroom.

In the math classroom, math anxiety prohibits students from effectively problem solving and therefore impacts their math achievement (Klee et al., 2021). Previous research has shown that math anxiety is negatively associated with math self-efficacy (Lee et al., 2021), and self-efficacy has a positive association with growth mindset (Martin et al., 2017). The current study was able to support that growth mindset interventions does help increase students self-efficacy, growth mindset, and math achievement. The study's results did not yield any significant change to math anxiety due to the students already having a low sense of math anxiety. Future research should be conducted in other high school classrooms, perhaps with a mixture of honors and on-grade level classes, to see if the results from this study can be replicated. The math classroom should not be a place where students feel that making a mistake is a sign of failure. Students should be confident in their ability to persevere in the face of a challenging math problem. Mistakes are simply a learning opportunity to help students grow.

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Appendix A

Pre/Post Likert Scale

Geometry Survey

How do you agree or disagree with the following statements:

1. I can solve math problems that look different than the examples in class.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

2. I can do well in geometry.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

3. I can understand new concepts in geometry.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

4. I can describe geometry concepts to a classmate.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

5. I am a capable geometry student.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

6. To be honest, you aren't able to change your ability in the math classroom.

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

7. You have a certain amount of math ability and you can't do much to change

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

8. No matter who you are, you can significantly change your math ability level.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

9. You can change your math talent ability considerably through hard work.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

10. You can learn new things, but you can't change your basic math ability.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

How Anxious do you feel during the following situations:

11. Watching the teacher work out a geometry problem on the board.

	1	2	3	4	5	
Not really anxious	◯	◯	◯	◯	◯	Extremely anxious

12. Having to complete a worksheet by yourself.

	1	2	3	4	5	
Not really anxious	◯	◯	◯	◯	◯	Extremely anxious

13. Being given geometry homework with a lot of difficult questions.

	1	2	3	4	5	
Not really anxious	◯	◯	◯	◯	◯	Extremely anxious

14. Listening to the teacher talk for a long time in geometry.

	1	2	3	4	5	
Not really anxious	◯	◯	◯	◯	◯	Extremely anxious

15. Starting a new topic in geometry.

	1	2	3	4	5	
Not really anxious	◯	◯	◯	◯	◯	Extremely anxious

Appendix B

Daily Homework Reflection

Honors Geometry

Name:____________________
Date:_____________________
Period:_____

GEOMETRY

1. What was the main idea you learned today?

2. What are you struggling with or have questions about?

3. How could the ideas from today's lesson be used in life?

4. What are you going to do to continue practicing and understanding the new concept?

Appendix C

Open-ended survey questions:

1. Were there any geometry class days/geometry activities done in the past three weeks that made you feel more confident? What were they, if any, and why did they make you feel this way?

2. Over the past three weeks, we began self-reflecting on days where we learned new content. What did you like/not like about self-reflecting?

3. If you are given a challenging problem on the next math quiz, identify a strategy you could use to solve the problem.

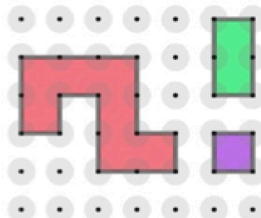
4. Do you feel any more/less capable in doing geometry after trying the different activities and assignments over the past few weeks?

Appendix D

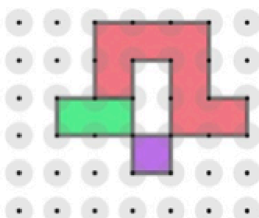
Example of a Low Floor, High Ceiling Math Task

Reflecting Squarely

The three pieces below can be fitted together to make shapes with at least one line of symmetry.

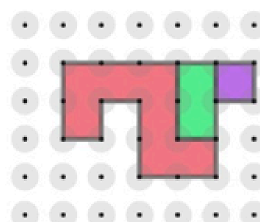


The vertices of each piece must lie on grid points, and you must not overlap two pieces.



The pieces must be placed edge to edge, so this is not allowed.

This arrangement does not satisfy the criteria because the shape does not have a line of symmetry.



Can you find all possible solutions? (There are more than six.)

Appendix E

Below is the product description and grading checklist for the Transformation students created as their summative assessment for the unit.

Honors Geometry
Pd: _____

Name:_______________
Date:_______________

Transformations Project

Directions: **Score: _____ out of 81**

To demonstrate your understanding of the different types of transformations and their properties, you are going to create a **Geometric Transformations Reference Guide** to use as a study resource. Requirements for each section of your guide as described below.

Notes:

***** Reminder: Follow ALL Directions and SHOW ALL WORK**

Make sure your Reference Guide is Neat and Follows the Organization of the requirements listed below. **(5 pts)**
Make sure you have your pages in this order. Staple your review packet in the upper left corner. **(1 pt)**
**Graphs MUST be made using graph paper and then glued onto the appropriate page. DON'T FORGET TO LABEL ALL COORDINATES.
USE RULERS to make sure your lines are straight.** **(2 pts)**

Page 1: Title Page (red paper) (8 pts)

- ☐ Title at the top of the page: **Geometric Transformations Reference Guide** (1 pt)
- ☐ Write the definitions of image, preimage, and Isometry (3 pts)
- ☐ Graph of a transformation of your choice (cut and paste graph from graph paper) (2 pts)
- ☐ Write the rule for the transformation you graphed (1 pt)
- ☐ At the bottom of the page: Name, Period, Row (1 pt)

*Write in marker on **this page only**, so you can clearly see what you have written.*

Page 2: Translations (light pink paper) (22 pts)

- ☐ Title at the top of the page: **Translations** (1 pt)
- ☐ Define Translation in your own words (1 pt)
- ☐ Using the translation $T_{(5,-2)}$, find the following images and preimages:
  - ☐ Image of A (4, 7)
  - ☐ Image of B (3, -2)
  - ☐ Preimage of C ' (4, 3)
  - ☐ Preimage of B ' (3, -2) (8 pts)
- ☐ **On the same graph**, graph preimage of △ABC : A (1, 2), B (4, 4). C (4, 2), and graph the image: A' (-5, 3), B'(-2, 5), C (-2, 3) (2 pts)
- ☐ Write a rule for the translation shown in the graph (2 pts)
- ☐ **On a new graph**, Given the rule (x, y) → (x - 2, y + 4), graph the image and preimage of Δ ABC (You choose the starting coordinates for Δ ABC). (2 pts)
  - ☐ Confirm your coordinates are correct by finding the image coordinates algebraically (6 pts).

    A (,) → A' (,)
    B (,) → B' (,)
    C (,) → C (,)

Page 3: Reflections (yellow paper) (21 pts)

- ☐ Title at the top of the page: **Reflections** (1 pt)
- ☐ Write the coordinate rules for:
  - ☐ Line of reflection: X-axis
  - ☐ Line of reflection: Y-axis
  - ☐ Line of reflection: Y= - X
  - ☐ Line of reflection: Y= X (4 pts)
- ☐ **On the same graph, graph the image and preimage of the transformation.** Reflect Δ ABC in the X- axis when the preimage coordinates are: A (1, 2), B (4, 4), and C (3, 1). (4 pts)
- ☐ **On a new graph,** Reflect Δ ABC in the line X = 2 when the preimage coordinates are: A (- 1, -3), B (2, - 4), and C (3, 0). (4 pts)
- ☐ **On a new graph,** Reflect Δ ABC in the line Y = X when the preimage coordinates are: A (-3, 3), B (-3, 0), and C (0, 2). (4 pts)
- ☐ **On a new graph,** Find the coordinates of point C on the x-axis so AC + BC is a minimum. A (-1, 4), B (6, 3) (4 pts)
- ☐ Staple any used patty paper onto the back of this sheet.

****Show ALL work****

Page 4: Composite Transformations (light blue paper) (22 pts)

- ☐ Title at the top of the page: **Composite Transformations** (1 pt)
- ☐ **On the same graph**, graph the preimage of segment CD, C (2, -5), D (4, 0). Complete the following glide translation:
  1. Translation: (x, y) → (x, y - 1)
  2. Reflection: in the Y- axis. (5 pts)
- ☐ **On a new graph,** graph the preimage of Δ PQR. P (2, 4), Q (6, 0), R (7, 2). Graph the image of Δ PQR after the following composition of transformations:
  1. Translation: (x, y) → (x - 5, y - 3)
  2. Translation: (x, y) → (x - 1, y + 4) (7 pts)
- ☐ **On a new graph,** plot the points for Δ ABC. A (-2, 2), B (-4, 2), C (-4, 5). Reflect in the Y- axis, then reflect over line X = 5. Write a TRANSLATION rule for Δ ABC → Δ A" B" C".

A (-2, 2)	A' (,)	A" (,)
B (-4, 2)	B' (,)	B" (,)
C (-4, 5)	C' (,)	C" (,)

Rule: (x, y) → (,) (9 pts)

****REMINDER: Show ALL work****