Growth Potential for Growth Mindset Application in Mathematics Education: A Literature Review

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Background

Over the past 30 years, an abundance of research has emerged that suggests students' beliefs about their own intelligence can influence their academic performance. At the forefront of this research is Stanford psychologist Carol Dweck, whose best-selling book, *Mindset: The New Psychology of Success,* has helped to kick off a rethinking of how students learn, and how this new understanding can be utilized in the classroom. Backed by decades of research, *Mindset* lays out Dweck's implicit theory of intelligence (TOI) which categorizes individually held theories of intelligence into two categories; entity theory and incremental theory. Entity theory is the idea that intelligence is static and unchanging. This view holds that intelligence is an attribute gained at birth, comparable to one's height or natural hair color. You either have it or you don't. The incremental theory, on the other hand, holds that intelligence is malleable and changeable with practice, effort, and learning strategies. Incremental theorists view the brain as more of a muscle, something that can be exercised and grown.

The implications of the two mindsets are vast, since they can often determine *how* one approaches their learning. Those who hold the entity theory of intelligence are more likely to have what Dweck calls a *fixed mindset*; the believe that even while one may learn new things and gain abilities, intelligence remains static. Those with a fixed mindset are more likely to shy away from tackling challenging topics, such as math, believing that they aren't "math people," and thus are incapable of learning or mastering the topic. Conversely, incremental theorists are more likely to have a *Growth Mindset.* These individuals are far more likely to strive to learn new skills and achieve mastery of difficult subjects, paying less attention to natural abilities and giving more attention to the process of learning. The impact mindset has can be viewed as a cascade effect, such as in Figure 1. Mindset influences the perceived feasibility of a task, thereby influencing motivation, which can determine an entire range of actions. It should be noted that, while the discussion of growth and fixed mindset is often held in seemingly binary terms, mindset is very much a spectrum, and rarely does one fall squarely into one category or another.

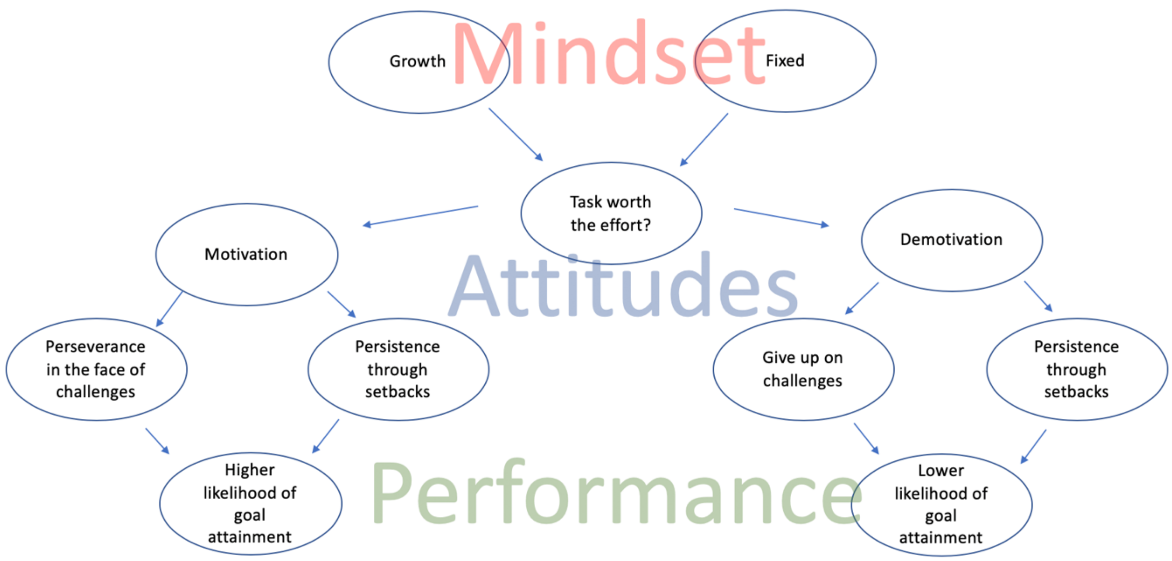

Figure 1

Introduction

Since Dweck's work began, there has been an abundance of research showing that mindsets can be a predictor of academic success (Sarrasin et al., 2018). Moreover, experiments have consistently shown that interventions regarding mindset or brain plasticity have led to improved academic outcomes across multiple categories including perceived ability, attitude, motivation, and achievement (Boaler, 2013). But while a bulk of the research is focused on theories of intelligence in general, there hasn't been a great deal of research looking at domain-specific theories of intelligence. In other words, are students' attitudes toward learning in general similar to their attitudes on learning mathematics? For instance, do students hold the same TOI for reading and mathematics? The phrase "I'm not a math person" is commonly heard, almost as a mantra, in academic and non-academic settings alike. Almost never heard, however, is the phrase "I'm not a reading person." Why should this be? And what can this tell us about growth mindset as it relates to specific subjects such as mathematics? These questions and observations offer a great opportunity to judge the impact of growth mindset since not being "a math person" is something most can relate to. The purpose of this review was to assess the state of knowledge on growth mindset to determine what, if any, effect of having or acquiring a growth mindset has on performance outcomes in mathematics. In the course of this review, three primary trends emerged. The first was how interventions impact students' growth mindset. An intervention is any controlled activity where brain plasticity and/or incremental theories of intelligence are introduced. The second was how growth mindsets impact attitudes toward academic work. The third relates to how those attitudes translate into academic outcomes.

Methods

To begin, I searched four primary databases; Google Scholar, ERIC, Pyscnet. The primary search terms were "implicit intelligence" and related synonyms, combined with "mathematics" and "achievement." Synonyms for incremental intelligence included "growth mindset," "fixed mindset," "mindset," "incremental," and "entity." I combined these terms with "and" to include variations with "mathematics," and "success" or "mathematics" and "achievement." The criteria for selected articles were as follows.

1. The article was peer reviewed.
2. The research (or a portion therein) in question was domain-specific to mathematics.
3. That the study utilized a quantitative measure of mindset using a validated questionnaire.
4. That the study performed a cross-sectional analysis, performed either an intervention with control group, or a longitudinal analysis (or a combination).

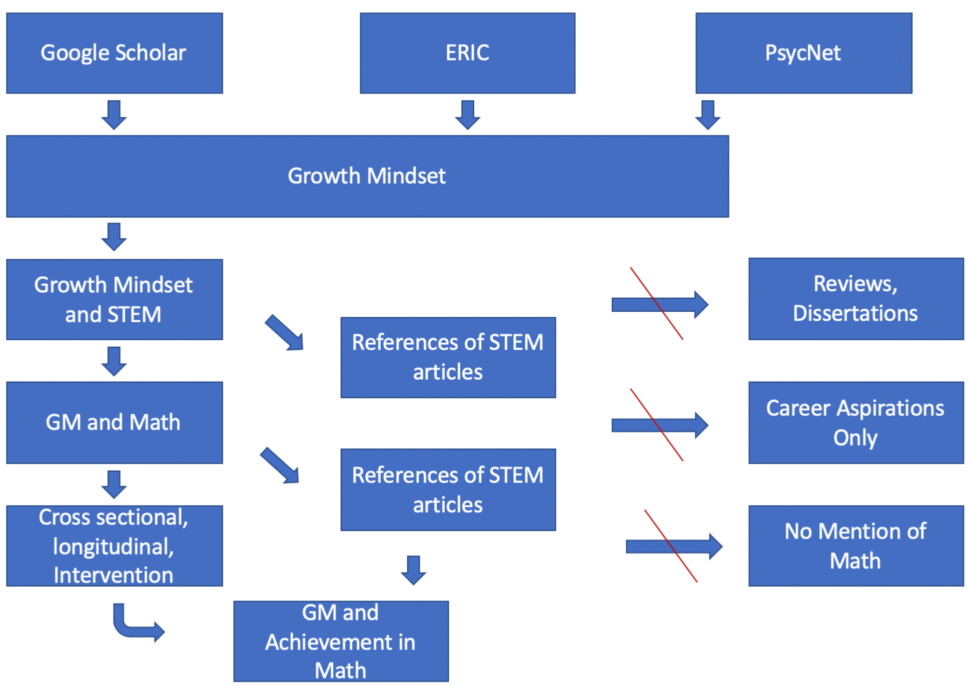

Figure 2

Thus, Master's thesis and PhD dissertations were discarded, as well as any papers that did not make specific mention of mathematics. In addition to the studies produced by a search of databases, several articles included in this study were produced by examining the references of the ones sourced from the databases. All age range/grade levels were considered, as well as country of origin. I excluded three articles because English versions of the entire text were unavailable. Of those three, two were of French origin, and one was of Chinese origin.

Discussion/Results

While the articles under review all looked at growth mindset and how it relates to performance in mathematics, the research all varies in scope and methods. Accordingly, the discussion of results in this review have been organized logically into three main categories that follow directly from the trends outlined in the introduction paragraph, as depicted in Figure 3 below.

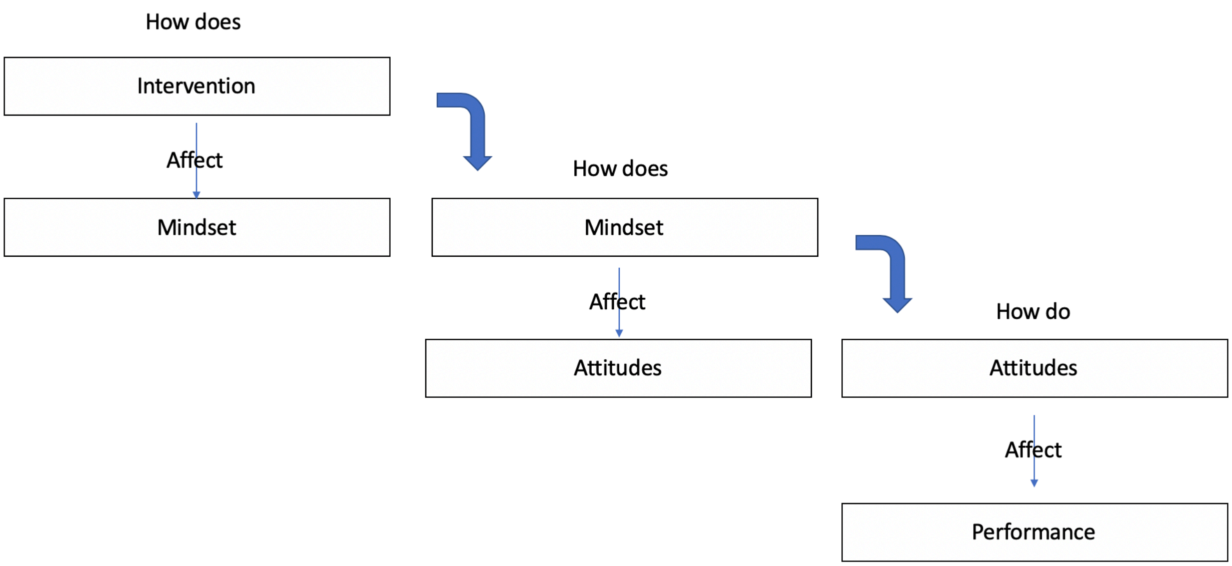

Figure 3

Thus, the methods for each category appropriately align with the goal of the research. For the *interventions*, groups of students were used in conjunction with self-reporting surveys and/or performance data, though data on student performance was not necessarily used. For the *attitudes* section, self-reporting surveys and questionnaires were the primary source of data. Finally, for *achievemen*t, which looks at performance outcomes, data was obtained from sources such as experimental tests or official grades along with self-reporting questionnaires.

Intervention's Effect on Mindsets

Three of the nine articles under review sought to determine whether or not interventions had a positive or negative effect on students' TOIs. Interventions ranged from open ended exercises to explicit educational instruction on the malleability of intelligence and/or neuroplasticity. All three studies concluded that interventions positively affected students' TOIs. In other words, students were found to hold incremental views on intelligence after being taught about the malleability of the brain and intelligence.

Stohlman et al. investigated whether open-ended problems led to increased growth mindsets among students. Over a period of four Saturday problem solving workshops, it was determined through the use of pre-intervention and post-intervention growth mindset questionnaires that students' beliefs of incremental intelligence did increase, thus the program showed statistically significant improvement of students' mindsets (Stohlman et al., 2018). Similarly, Blackwell, Trzesniewski, and Dweck (2007) showed a change such that students in the experimental group embraced an incremental theory of intelligence in comparison to the control group. In the Bettinger study of Norwegian high school students, three 45 minute sessions were administered. The first session measured baseline growth mindset in students, while the second provided students with information on brain plasticity and used specific metaphors such as "the brain is like a muscle that grows (Bettinger et al., 2017). As above, the results showed a "large and significant effect" on growth mindset post treatment.

In each of these studies, it was seen that the introduction of implicit TOIs had a positive effect on students' growth mindset. This is significant, since it implies that merely learning about brain plasticity and the idea that intelligence is malleable can change the way one thinks about intelligence. Next, we will look at how this change in mindset can affect student attitudes.

Implicit theories of intelligence's impact on effort, motivation, and persistence

The engine behind the effectiveness of Growth Mindset on one's performance is how a person's TOI affects the attitudes of the learner (Figure 1). For instance, if a person believes that effort, not ability, holds the key to learning math, this belief can determine their motivation and persistence, which will ultimately affect performance. Of the nine studies under review, two specifically addressed how math specific TOIs impact attitudes.

The Bettinger study was able to determine that student's belief in their ability learn was a positive indicator of persistence (Bettinger et al., 2017). However, the authors noted that, while they could identify the impacts of mindset, they were unable to determine whether positive changes in mindset came as a direct result of the intervention, or whether social pressure and norms contributed to the improvement. The Blackwell study was able to be more definitive, perhaps representing the strongest findings, as they relate to growth mindset's effects on student beliefs. Indeed, the research indicates that "adolescents who endorse more of an incremental theory of malleable intelligence also endorse stronger learning goals [and] hold more positive beliefs about effort" (Blackwell et al., 2017).

As Blackwell shows, it is specifically these attitudes which lead directly to improved academic performance in mathematics. ust as with domain-general mindset studies, we see an indication that mindset can indeed impact attitudes toward learning mathematics, and how that can lead to higher achievement.

Achievement

Of the nine studies under review five determined positive effects, two achieved mixed results, and two found no positive correlation.

Positive Results

Of the studies previously mentioned, Bettinger's results provide evidence that students' theories of intelligence are reliable predictors for perseverance, and that these beliefs are indeed malleable. In terms of improved performance, the students who received interventions were more likely to show improved effort in the first 10 questions of the math test administered. However, there was no correlation with increased effort among the first 20 questions, nor with the overall sample. The Bettinger study also observed that those who held a growth mindset during the pre-study were much less likely to benefit from the intervention, while those with the pre-fixed mindset benefited the most. This contrasts with the Blackwell study, which found that it was the students who already held a growth mindset that benefited most from the intervention.

Both Blackwell et al. studies observed statistically significant results. In the first, students entering junior high with fixed mindsets did not significantly differ from their growth minded counterparts. However, the study showed the two groups pulling apart over the next two years, with the growth minded students seeing steady increases in grades, while fixed minded students' grades remained flat or slightly declined. In the second study, the intervention measured a halt in declining grades among the experimental group, while the control group's grades continued to decline. In contrast to Bettinger, Blackwell found that it was the students with previously held growth mindset that benefited most from the intervention. Crucially, the study found that the interventions promoting incremental intelligence improved achievement motivation, a key factor, the researchers believe, in the halting of the declining grades, providing a connection between attitudes and performance. The Bostwick study focused specifically on mathematics, finding growth mindset to be positively associated with both academic engagement and achievement in mathematics.

Finally, two studies under review assessed gender disparities and math along with differences in growth and fixed mindset among boys and girls. While the question of gender was not a factor in this review, the results are nonetheless interesting, and have been included here since they offer an avenue of further research. Each found positive results associated with growth mindsets, but identified how mindsets affected boys and girls differently. For instance, while Good et al. found that boys had higher expectancy then females, they found that boys did not have higher grades than girls (Good et al., 2003). In fact, Good's results indicate that females with growth mindset often excelled more strongly in math. Degol et al. saw similar results, noting that lower expectancy beliefs did not correlate with lower grades, but observed that females may be more susceptible to fixed mindset due to lower expectancy (Degol et al, 2018).

Mixed Results

Gunderson et al looked at math specific TOIs as they relate to general TOIs and found significant differences (Gunderson et al, 2017). Interestingly, Gunderson shows that while math specific TOIs can be reliable predictors of motivation and achievement, reading and writing specific TOIs do not exhibit the same predictive power in motivation or grades. The Stohlman et al. (2018) study is an interesting case in that it was able to measure an increase in growth mindset as a result of the intervention which consisted of open-ended problems, but did not measure a correlation between the increase in growth mindset and the quality of solutions. The study notes that while the group's improvement in problem solving improved overall, the quality of solutions varied. While the study did identify a correlation between growth mindset and math achievement, the small sample size was not deemed sufficient to draw definitive conclusions.

No Correlation

Of the studies selected for review, two were unable to draw a correlation between growth mindset and increased mathematics performance. One study, conducted by Mills & Mills (2018), which attempted to teach growth mindset to low achieving college math students hypothesized that outcomes would improve. While they were able to draw no positive correlations, they were careful to point out that the study was limited in that the study was restricted to remedial math students at a single college. Thus, the authors warned that their results were not generalizable beyond the sample (Mills & Mills, 2018). And while Shively and Ryan were unable to conclude positive results in their cross-sectional study, they did find that those who held growth mindsets were more inclined to seek help, lending further evidence to the results of Dweck and others that incremental theorists are more likely to take proactive approaches in their learning (Shively & Ryan, 2013).

Conclusion

The aim of this review was to assess the value of math specific theories of intelligences as they relate to attitudes and performance in mathematics. While the literature on domain-general theories of intelligence is much more definitive in that it shows a high correlation of academic performance in general, the math specific results are far less conclusive. After controlling for variables such as gender and socio-economic status, the literature was able to show consistent success in improving mindsets among students of all ages. However, only moderate success improving achievement has been demonstrated by the literature under review. Though, given the small sample size of this review, there is likely much more to learn about the state of research as it pertains to growth mindset and mathematics achievement.

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