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A SENSE OF POSSIBILITY: CULTIVATING PERSEVERANCE IN AN URBAN MATHEMATICS CLASSROOM

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Abstract This study explores promotion of perseverance on mathematics tasks in an Algebra II class. Influences of interventions on perseverance are investigated through qualitative action research. Students' beliefs about their own mathematical ability are traced through a pretest, intervention, and posttest over the course of the school year. Observation data, surveys, and students' written comments were analyzed to identify how students' beliefs shape their reactions to challenges in mathematics, as well as how these beliefs might be influenced through mindset interventions. Findings suggest that interventions can influence students' mindsets toward challenge, and may impact tendency to persevere in the face of adversity in mathematics. This study bridges the gap between nascent research and praxis, suggesting that brief interventions hold promise in supporting underserved students toward mathematical tenacity.

Keywords: perseverance, mathematics, grit, non-cognitive, mindsets, action research

Introduction

Students who withdraw from mathematics in secondary years close doors to economic access and career opportunities (Schoenfeld, 2002). Those without quantitative skills face limited access to higher education and higher-paying jobs. Although encouraging persistence into higher mathematics is a clear imperative of schools, the factors contributing to mathematical attrition are complex. In examining the reasons students desist in mathematics, many researchers have concluded that the culprit cannot be intellectual ability alone (Wechsler, 1943; Duckworth & Allred, 2012).

Researchers are increasingly turning to non-cognitive factors, such as perseverance, to explain differences in academic performance (Duckworth, 2006; Duckworth, 2009;

Duckworth, Peterson, Matthews, & Kelly, 2007; Lepper, Ross, & Lau, 1986; Rosen, Glennie, Dalton, Lennon, & Bozick, 2010; Shechtman, DeBarger, Dornsife, Rosier, & Yarnall, 2013). Researchers at the University of Chicago called academic perseverance "a critical factor for students' long-term educational attainment" (Farrington et al., 2012, p. 9). Of course, school performance is a result of myriad factors. However, the ability to persist on problems—in the face of confusion and complexity—is essential for success and advancement in mathematics (Dweck, Walton, & Cohen, 2011).

Literature Review

This tendency to persist may have psychological roots. Carol Dweck's epochal work has demonstrated a clear connection between mindsets that students hold and academic behaviors affecting achievement (Dweck, 1986; Dweck & Leggett, 1988; Dweck et al., 2011; see also Oyserman, Bybee, & Terry, 2006). She proposes two distinct mindsets held by students: fixed-intelligence and malleable-intelligence. Students with a fixed-intelligence mindset "readily pass up valuable learning opportunities if these opportunities might reveal inadequacies or entail errors—and they readily disengage from tasks that pose obstacles," because of fear that struggle on obstacles reveals a limited amount of intelligence (p. 3). Students with a malleable-intelligence mindset, even those with low confidence in their intelligence, tend to stick with difficult tasks, believing that their intellectual abilities can be increased. Additionally, these students tend to attribute poor academic performance to poor showing of effort, rather than to intelligence or ability (Dweck, 2000). In other words, students equipped with the knowledge that ability can grow tend to exhibit effective strategies in the face of challenge; while students who are unaware of this fact may believe success is not possible, and consequently give up. In fact, students often *equate* working hard with inability (Dweck & Leggett, 1988; Bandura, 1986). This has serious detrimental consequences for many students as mathematics increases in complexity.

Wilson and Linville (1985), in a classic study, identified and challenged another important mindset—beliefs that students do not belong. In this study, struggling freshmen were shown videos of interviewed upperclassmen describing their transitions to college, and attributing their poor performance to temporary causes, such as lack of familiarity with college classes. The purpose was to expose students to the idea that struggles were not indicative of a lack of innate ability. The interviewees described that their early poor grades improved over time. One week after the intervention, students in the treatment group outscored students in the control group on practice GRE questions. A year later, students in the treatment group had higher GPAs than the control group (Wilson & Linville, 1985).

No matter how intelligent an individual is, at some point she will encounter a mathematical challenge. Success in mathematics requires more than ability. It requires sustained hard work in the face of frustration. Although the research illuminating best practices to promote perseverance in math is limited, some studies have shown advances in facilitating productive mindsets through brief interventions (Dweck, 1986; Diamond & Lee, 2011; Blackwell, Trzesniewski, & Dweck, 2007; Yeager & Walton, 2011). The literature suggests that mindsets and beliefs are a crucial factor in how students react to difficult academic tasks.

Methodology

Research Questions. Despite apparent consensus on the impacts of mindsets on perseverance, much remains unknown about whether these mindsets and their related behaviors might be malleable. Farrington and colleagues (2012) highlight that many claims about non-cognitive factors have little or no research literature to inform educational practice. Drawing on the above literature, I designed this study to fill a gap in the present body of research. Researchers have not directly examined methods for cultivating perseverance in a high school mathematics classroom, despite increasing calls for in-classroom practices to foster this attitude. This study aimed to explore three interventions to help students persevere on challenging mathematics problems. This project sought to answer: How do mindset interventions influence secondary mathematics students' behavior on mathematics tasks? How do mindset interventions influence secondary mathematics students' attitudes toward challenging tasks?

Methods. This study took place in a public school in New York City where the previous year only 32% of students attained the Math College Readiness Standard (NYC Department of Education, 2013). The student body is 99.5% Black or Hispanic, and 100% of students qualify for free/reduced lunches. The study focused on one Algebra 2 class of 18 students. As I observed these students over a school year, in field notes I commonly recorded low engagement and a tendency to withdraw effort before tasks were complete. For example, on October 22, at 8:41am I noted, "Cervando has had his head between his hands, staring at his paper since 8:30. He looks very frustrated." (For the purposes of this study, all participants have been given pseudonyms.) Entries such as this led me to choose this class as my case study.

Data Sources. Data came from three sources: (a) a survey, administered both before and after the interventions (Appendix A); (b) a field journal of observation notes; and (c) students' written comments during intervention lessons. Multiple data sources offered "differing vantage points from which to view the research question and the data generated" (Anderson, Herr, & Nihlen, 2007, p. 152). I conducted observations of the entire class-period three days per week for the majority of a school year, recording notes in my field journal each time.

Survey questions were designed to measure students' confidence in mathematical ability, beliefs about the nature of intelligence, and reactions to struggle in mathematics. The survey was comprised of 15 items with a Likert-type range of responses and open-ended items. The survey provided baseline information on students' thinking about effort and perseverance.

In addition to the 15 ranged-response questions, I included three open-ended questions. One fill-in-the-blank read "complete the equation: 'intelligence = ____% effort + ____% ability'" (Dweck, 2000, p. 62). This question implicitly indicates that both components are present in intelligence. Dweck (2000) used responses to this question to determine students' theories of intelligence. Students who hold a malleable theory of intelligence will put more weight on effort, while students with a fixed theory of intelligence will complete the equation with more weight on ability

Another open question asked, "Which statement do you agree with more: 'When I have to struggle on a math problem for a long time, I see it as an opportunity for learning' or 'When I have to struggle on a math problem for a long time, I see it as proof that I'm not good at math'? Why?" This question was devised to illuminate students' reactions to and thoughts about struggle within mathematics. These questions shed light on students' feelings about challenging mathematics and beliefs about the nature of intelligence.

Additional data comes from three interventions—lessons of five- to ten-minutes that I taught during a unit on logarithms. The first lesson provided data in the form of field notes, in which I documented salient features of students' discussion throughout the lesson and in observations following it. Data from the second and third lessons included students' written responses to the lesson in addition to field notes.

Observations recorded on an observation protocol accompanied data from the interventions, to specifically connect observed behavior with reflections related to the literature. The protocol provides space for my observations side-by-side with reflections (Anderson, Herr, & Nihlen, 2007). I described student behavior, documenting time and duration of described behavior, and made reflections connected to the literature.

As I documented the amount of time spent on problems, I specifically recorded behaviors of *returning to* or *quitting* problems students had not yet succeeded at and noted when students kept working if classmates had given up. I recorded comments and conversations, in tandem with observed behaviors as students worked on problems. This allowed me to connect any mindset-revealing comments with perseverant behavior exhibited. Some of these observations were descriptive, requiring no inference on my part, but others necessitated my making a judgment call (e.g., The student seems frustrated) (McKnight et al., 2000). To mitigate the subjectivity of my descriptions, I defined a set of criteria for identifying perseverant behavior prior to conducting observations (Appendix B).

Data Analysis. In my initial phase of data analysis, I read the student surveys twice to process the data (McKnight et al., 2000). I analyzed comments on open-ended items using an iterative (alternating emic/etic) approach (Tracy, 2013). I examined student comments line-by-line, using the vocabulary of the participants themselves to assign phrases that captured the essence of each (Strauss & Corbin, 1998). In my secondary cycle of coding, I critically analyzed identified codes, and synthesized them into hierarchical categories (Tracy, 2013). I coded my observation notes with the same iterative approach. An iterative analysis includes reflection on the literature as well as the active project, repeatedly revisiting the data, connecting it to literature, and refining insights (Srivastava & Hopwood, 2009). I followed this same process with all written data. Finally, I organized data chronologically to see changes from beginning to end (Kawulich, 2004). This afforded me a glimpse into students' perseverant behavior and attitudes over the course of the school year.

Interventions. After giving the initial survey, I designed three interventions. The goal was threefold: (1) to show that struggle in mathematics is not a unique experience; in fact, many successful mathematicians had to persevere through periods of confusion; (2) to show students that intelligence is malleable; (3) to boost students' self-regulatory skills through a goal-setting exercise.

In the first intervention, in line with Wilson and Linville's work (1985), students were taught that struggle is a natural and temporary part of learning. When students experience difficulty, they are more likely to work hard if they can attribute their difficulty to part of learning rather than to personal inability (Yeager & Walton, 2011). Students in this study were shown a video of successful college graduates telling personal stories. One graduate told of experiencing confusion while learning logarithms. She noted that her 11th grade teacher told her that she was terrible at math, and that she shouldn't take any more math. She described her decision to do what she liked although it was hard for her at that time, rather than listen to her teacher. The story ended with a note of hope—she graduated cum laude with a degree in mathematics. Another graduate stressed that the mistakes she made in the course of learning logarithms helped her learn. She related wondering if she had what it took at times. This intervention targeted students' sense of capability and belonging, showing that challenges are common in mathematics.

The second intervention followed in the footsteps of Blackwell, Trzesniewski, and Dweck (2007), who found that middle school students who were taught that the brain grows similar to muscular growth showed significant increase in achievement for the duration of the school year. Students read an article by Blackwell (2002), describing the brain's process of growing as difficult tasks are worked on. The article concluded with the message that learning makes you smarter.

Intervention three was modeled after work by Duckworth, Kirby, Gollwitzer, and Oettingen (2013). Students were asked to visualize a desirable goal regarding this course. They elaborated this goal on paper, along with obstacles that might arise. Duckworth and colleagues (2013) found that the conjoint mental imagining of a desired future with the real obstacles could turn wishes into "strong commitments with subsequent goal striving and goal attainment" (p. 6). Students wrote a detailed description of their goal, potential hurdles, and how they intended to overcome these hurdles.

Results

On the survey given at the beginning of the unit, a portrait of students' mindsets began to emerge. There were several answer trends that signified counterproductive mindsets. On the item "When I have to work hard at math, it makes me feel like I'm not very smart" one-third of students selected "agree" or "definitely agree." Researchers have shown that students who think having to work hard throws their intelligence into question tend to quit when tasks become difficult (Dweck, 2000; Dweck & Leggett, 1988). Of greater concern, one-third of the students answered "disagree" or "strongly disagree" to the prompt "When I fail to understand something, I become discouraged to the point of wanting to give up." Additionally, only 50% of students said they agree or definitely agree with the statement, "I try very hard in math, even after experiencing failure."

Question 17 posed the dualistic, "Which statement do you agree with more: 'When I have to struggle on a math problem for a long time, I see it as an opportunity for learning' or 'When I have to struggle on a math problem for a long time, I see it as proof that I'm not good at math'? Why?" Although a majority of students tended to agree with the first statement, six students did not see struggle on math in this productive light. Four students said they agreed with the second statement more than with the other. An additional two students were unsure which statement they agreed with more. A salient theme arose within the responses of students who agreed more with the second statement: belief that being bad at math was insurmountable, even inextricably bound with identity. Janet describes her experience:

I agree with the fact that when I find something really hard I get discouraged because I feel like maybe I'm not cut out for math. And I feel like maybe I can learn this but maybe I can't. I feel like this because throughout my whole life of school I've always struggled with math. As she points out, these feelings did not arise in high school; rather, years of schooling experiences have left her wondering if she is "cut out for math."

Valerie acknowledges a similarly debilitating mindset in her comment, "I agree with the second statement because I try really hard to understand a concept and if I still don't understand it must be something in my system isn't compatible to math." While she describes trying really hard, it is clear that she attributes her frustration to inability, to something in her "system." As found by Licht and Dweck (1984), this attribution of failure to students' very *identity* will often preclude continuation of effort in the face of challenge. One student identified *when* she agrees with this statement—when she sees other people not struggling yet she is. "I agree with the second statement because I do feel like am bad at math [*sic*] mostly when I struggle and see other people not struggling." This contrast between herself and others implies a belief that she is not as able as her peers.

As I observed this class over a school year, in my field notes I recorded off-task chatting and students appearing frustrated to the point of giving up. I commonly observed students putting their heads on their desks when they got stuck on math. For example, on October 22, at 8:50 am I noted, "Josue—who has completed two math problems in 35 minutes—raises his hand. 8:52 am: The teacher hasn't seen him; he gives up and puts his head back down."

Intervention #1. In the first lesson, students connected the graduates' stories to the idea of intelligence being a combination of effort and ability. One claimed, "Effort matters more than anything else. If you put in effort it will pay off." When another student disagreed, arguing, "If you are not gifted with this ability you won't be able to do it," he was quickly contradicted by Alejandro, "It's not like I was born knowing how to do two plus two; I had to work at it." These comments reflect the divergence also present on the pre-intervention survey.

Two days later, 16 students stayed on task; however, I noted the behavior of two students who gave up almost immediately. Cervando was staring for eleven minutes, then I wrote, "8:59am- Cervando lays his head down." I also observed Alejandro looking at his neighbor's work, without lifting a pencil. These descriptions highlight two students who were not persevering through confusion on mathematics. In coding my notes from the observations between the first intervention and the next, I noticed that many of the frustrated behavior codes (e.g. "covers face," "loudly sighs and crosses arms") were associated with multi-step problems.

Intervention #2. After reading the article, students were asked to write down their reactions. Some of the content of the article was new to students. Kimberly wrote, "I think I agree and am surprised because I never thought that making mistakes was getting you smarter [*sic*]." She considers the learning value of making mistakes, which could be a beneficial takeaway for her future encounters with challenging mathematics (Blackwell et al., 2007; Dweck, Walton, & Cohen, 2011).

Even though it was not the most common notion in students' comments, the central message of the article emerged three times—intelligence as a malleable rather than congenital entity. Two students tied this idea to specific actions. Josue elaborated:

> I completely agree with what the author says about this because while you're watching TV, some other student is revising what they learned in class, you'll think that they were just born smart, and you'll let yourself down and it'll be difficult to get by that.

Additionally, two students focused on the concept of the brain as a muscle. Marcos wrote, "I believe that it was interesting to know that my brain is lifting weights as I learn. I wonder if my brain could get 10% heavier." Three students specifically named effort or challenging oneself as a means for increasing intelligence. Michael's comment captures the theme, "I do believe that we as people choose to get smarter. Like in the article said, 'When we challenge our self than [*sic*] our brain cells grow!' Which this can expand our intelligence." These students affirmed a mindset that putting forth effort on challenges will lead to greater gains in intelligence.

A week after the second intervention, I observed students working consistently, consulting notes and asking peers questions throughout class. One logarithm word problem took two students 11 minutes to complete, which was notably longer than the time spent on problems documented on previous observations (the maximum to this date was 7 minutes).

The next day, students were asked to work independently for four minutes before asking for help. On my observation protocol, I wrote, "8:25 am - All but two students are actively looking through notes to determine mistakes on quiz." As soon as independent work time was over and students were allowed to ask those seated around them for help, those two joined the rest of the class in work. My next note reads, "8:29 am – All students now asking peers to explain and continuing engaging with logarithms." Only once during that period did I note that one student quit working. Most notably, at 9:15 am I recorded, "Not one student gave up on the 'Bringing it all Together' problem, an 8-step word problem. All have been reading, working, and asking questions of peers for a solid ten minutes." In the week following the second intervention, students stuck with work even when it required searching for help in multiple places in order to understand, and even when students publicly acknowledged being confused. Observation data and students' written response data converge to provide evidence that perseverance indeed increased after this intervention.

Intervention #3. The most commonly described obstacle to students' goal attainment on the third intervention was lack of effort. Janet, for example, wrote, "Being lazy might get in the way because I might be overwhelmed." An additional obstacle, described by three students was a noisy home. Bianca wrote, "One thing that might get in the way is my house, my house in generally is really, really, really loud and there's always people coming in and out, really hard to concentrate in an area like this." Four students cited a lack of focus; Michael, in a typical response, stated, "I get distracted, and I don't really like to study." Also to this prompt, three other students described struggling with mathematics. For example, Valerie responded, "Some teachers tell me I can't because I need sertain [*sic*] type of math classes in my previous years that I was struggling with." Overall, these comments show that students saw insufficient effort, insufficient focus, external factors, and struggle with mathematics as potential impediments. What stands out is that students saw achieving their goals as within their control: a matter of greater effort or greater focus.

The final prompt asked students to write an action they could take to overcome their obstacle and achieve their goal. Responses matched the roadblocks listed on the previous prompt. Ten students' answers referenced the amount of time one spends studying. In a typical comment, Maria answered, “Put time in studying and ask question [*sic*].” Four students wrote about focusing in spite of noisy or distracting surroundings. For example, Alejandro answered, “What I can do is just lock myself in my parents room [*sic*] and study independently.” The emphasis on time spent studying or working on math—spoken of by more than half the students—shows that students believe keeping up their efforts over time will result in goal achievement. In analysis of students’ comments overall, what stands out is that no student mentioned lacking mathematical ability: a contrast to data from the initial survey.

Post-intervention Survey. Comparison of data from the post-intervention survey to the pre-intervention survey showed notable shifts in mindset. On the pre-intervention survey, one-third of the class answered “definitely agree” or “agree” to the prompt, “When I have to work hard at math, it makes me feel like I’m not very smart.” On the post-intervention survey, *no* students selected “definitely agree,” and only two agreed. Kimberly, who admitted at the beginning of the unit that she felt bad at math, initially answered, “definitely agree” to this question, but changed her answer to “disagree” following the interventions.

The prompt, “Effort won’t do much for you if your ability level isn’t high,” received 4 fewer “neither agree nor disagree” answers. As evidenced by Tables 1 and 2, “disagree” and “definitely disagree” were the most common answers on the post-intervention survey. The change here indicates that students began to see effort as a potential catalyst for success. This emphasis on effort over ability is precisely what Dweck (1986) identified as increasing striving toward goals. If students believe the possibility of achievement rests upon effort rather than ability, they are much more likely to persist.

Table 1: *Pre-intervention Survey, Question 3: "When I have to work hard at math, it makes me feel like I'm not very smart."*

Answer	*n*	Percent of Total
Definitely agree	1	6%
Agree	5	28%
Neither agree nor disagree	2	11%
Disagree	8	44%
Definitely disagree	2	11%

Table 2: *Post-intervention Survey, Question 3: "When I have to work hard at math, it makes me feel like I'm not very smart."*

Answer	*n*	Percent of Total
Definitely agree	0	0%
Agree	2	11%
Neither agree nor disagree	2	11%
Disagree	11	61%
Definitely disagree	3	17%

Question 10 measured a similar mindset: "My mathematical ability grows with hard work." Prior to the interventions, 28% of students neither agreed nor disagreed with the statement, and 6% definitely disagreed. After interventions, 100% of students agreed or definitely agreed with the idea that mathematical ability grows with hard work.

Table 3: Pre-intervention Survey, Question 10: "My mathematical ability grows with hard work"

Answer	*n*	Percent of Total
Definitely agree	4	22%
Agree	8	44%
Neither agree nor disagree	5	28%
Disagree	0	0%
Definitely disagree	1	6%

Table 4: Post-intervention Survey, Question 10: "My mathematical ability grows with hard work"

Answer	*n*	Percent of Total
Definitely agree	8	44%
Agree	10	56%
Neither agree nor disagree	0	0%
Disagree	0	0%
Definitely disagree	0	0%

The fill-in-the blank equation, "intelligence = _____% effort + _____% ability," was also written with the intent that it would reveal whether students' conceptions of intelligence tended toward a fixed or a growth mindset. However, four students left the question blank on one or both surveys, and an additional three students gave nonsensical answers such as "intelligence = 100% effort + 10% ability." Of the answers that summed to 100, four showed a change that placed more emphasis on effort than ability at the end of the unit. The majority (*n* = 7) answered the same as on their pre-unit surveys. Although most students' answers remained static or only changed negligibly, this question showed a slight change for a small number of students, for whom this might make a difference since exerting effort no longer threatens intelligence (Dweck, 2007b). If these students continue to strive when problems become tougher now that they believe the difficulty is not due to lack of ability, they are more likely to be successful in mathematics.

In addition to the questions measuring mindset, some questions asked students to report their own behavior. Question 6 read, "When I fail to understand something, I become discouraged to the point of wanting to give up." Post-intervention, three fewer students agreed or definitely agreed with the statement.

Table 5: Pre-intervention Survey, Question 6: "When I fail to understand something, I become discouraged to the point of wanting to give up."

Answer	*n*	Percent of Total
Definitely agree	3	17%
Agree	5	28%
Neither agree nor disagree	4	22%
Disagree	4	22%
Definitely disagree	2	11%

Table 6: Post-intervention Survey, Question 6: "When I fail to understand something, I become discouraged to the point of wanting to give up."

Answer	*n*	Percent of Total
Definitely agree	1	6%
Agree	4	25%
Neither agree nor disagree	3	19%
Disagree	7	44%
Definitely disagree	1	6%

These results show that even as the work increased in challenge level, students were less inclined to become discouraged to the point of wanting to give up.

Responses to the question, "Even if understanding a math concept took hours of study, I would keep working at it" reveal consequential changes on every answer. The majority of those who initially neither agreed nor disagreed with the statement selected definitely agree or agree on the post-intervention survey. These shifts were consistent with students' responses throughout the interventions. Jaime, for example, identified a strategy for achieving his goals as "study during the weekends until understanding the notes." His behavior across my observations was consistent with that of a conscientious worker, but his comments began to indicate a more deliberate effort to persevere in achieving his goals. This question's results are harmonious with students' comments and behavior in class.

Table 7: Pre-intervention Survey, Question 12: "Even if understanding a math concept took hours of study, I would keep working at it."

Answer	*n*	Percent of Total
Definitely agree	2	11%
Agree	7	39%
Neither agree nor disagree	5	28%
Disagree	1	6%
Definitely disagree	3	17%

Table 8: Post-intervention Survey, Question 12: "Even if understanding a math concept took hours of study, I would keep working at it."

Answer	*n*	Percent of Total
Definitely agree	4	22%
Agree	8	44%
Neither agree nor disagree	2	11%
Disagree	3	17%
Definitely disagree	1	6%

Two-thirds of the class definitely agreed or agreed with the statement after the interventions, contrasted with half of the class prior to intervention. Not only have more students displayed a belief that hard work for a time will result in goal attainment, on this question more students also confirmed a willingness to act on that belief.

Another prompt that showed noteworthy changes was "I am a hard worker." As evidenced by the data, students were much more likely to select "agree" or "definitely agree" with the statement after the interventions. Since hard work is implied in perseverance (Farrington et al., 2012), this finding is consistent with students' increased perseverance as observed throughout the unit.

Table 9: Pre-intervention Survey, Question 13: "I am a hard worker."

Answer	*n*	Percent of Total
Definitely agree	2	11%
Agree	7	39%
Neither agree nor disagree	7	39%
Disagree	2	11%
Definitely disagree	0	0%

Table 10: Post-intervention Survey, Question 13: "I am a hard worker."

Answer	*n*	Percent of Total
Definitely agree	4	22%
Agree	10	56%
Neither agree nor disagree	4	22%
Disagree	0	0%
Definitely disagree	0	0%

Similarly, on the pre-intervention survey, 50% of students agreed or definitely agreed with the statement "I try very hard in math, even after experiencing failure." Post-intervention, 67% of students agreed or definitely agreed with the statement, and no students disagreed or definitely disagreed.

Analysis of open-ended questions further indicated changes in mindsets. Question 17 read, "Which statement do you agree with more: 'When I have to struggle on a math problem for a long time, I see it as an opportunity for learning' or 'When I have to struggle on a math problem for a long time, I see it as proof that I'm not good at math'? Why?" On the pre-intervention survey, four students agreed more with the second statement, and two were unsure. On the post-intervention survey, one student disagreed with both statements, one student left the question blank, and 16 students indicated that they agreed more with the first statement. Coding of students' comments allowed three primary themes to emerge: (a) a view of persistent effort (e.g., "If you are not good at something you have to keep on trying to get it right.") as the most successful strategy when struggling with math; (b) a view that struggle increases learning; and (c) the view that struggling should trigger escalated effort.

Persistent Effort. Four students expressed a view that persistent effort will be beneficial when struggling with a math problem. Nayle responded, "I agree with the first statement, because if I give up on an equation I'm not learning how to work through a problem." Magaly explained:

I agree with the quote 'when I have to struggle on a math problem for a long time I see it as an opportunity for learning' because if your [*sic*] struggling with a math problem, obviously more help is needed for the concept and if more help is needed, more studying will get done increasing the understanding level of the math problem.

Struggle is How Learning Occurs. Six students' responses expressed a view that learning comes from struggle. Bianca, in a typical comment, said, "[I agree more with] the first one because either or – struggling means learning." It is noteworthy that she wrote on her pre-intervention survey, "The second statement, 'When I have to struggle on a math problem for a long time, I see it as proof that I'm not good at math' because its [*sic*] easier to believe."

Struggling Should Trigger Escalated Effort. Six students described a view that they should increase effort when faced with a math problem on which they struggle for a long time. For example, Yessenia wrote, "For the first one, I agree with it the most because if you were to try harder, it'll show results." Similar student responses included, "think harder on the problem," and "pay more attention." Kimberly commented, "The first one because I pay more attention towards the mini-lesson when I see that I'm having trouble." Kimberly, by contrast, wrote on her pre-intervention survey, "I agree with the second statement because I do feel like am bad at math mostly when I struggle and see other people not struggling."

Other revealing responses include Janet's answers from the pre- and post-intervention surveys. Before the interventions, she agreed with the second statement and described herself as "not cut out for math." Following the interventions, she wrote, "I agree with the first one," acknowledging "but sometimes it can be difficult." Although still maintaining that mathematics can be difficult, she no longer agreed that struggle meant proof she was bad at mathematics. Additionally, Valerie, who claimed at the beginning of the unit, "I try really hard to understand a concept and if I still don't understand it must be something in my system that isn't compatible to math," wrote on the post-intervention survey,

> "I agree more with the first statement because if you don't know something very well, then you obviously have the opportunity to learn more about it. It's just up to said person if they want to learn more or not."

These students, who initially viewed struggle on math as proof they were not good at math, began echoing the views encouraged by the interventions—that struggle is an opportunity for learning and with perseverance success is possible.

Discussion

These findings allow me to suggest some particular experiences that may support students' perseverance in secondary mathematics classrooms. Findings reveal insights into how students drew upon malleable intelligence theory, stories of others' successful struggles in mathematics, and a goal-setting exercise as they encountered challenges in mathematics. I argue that three brief interventions influenced students' perseverant behavior and mindsets toward difficult mathematics. As an example, on the initial survey, forty-four percent of students referenced discouragement and wanting to give up when they had problems with understanding the material. However, as students began to frame struggle as part of the growing process, and intelligence as malleable, they began exhibiting more perseverance in class, in addition to responding with more perseverant statements about challenging mathematics.

Mindsets Impacted. A close look at the nature of students' responses to questions about their mindsets suggests that for those students who viewed struggle on math as proof they were not good at mathematics, these interventions may have provided an alternate narrative. The interventions, I contend, allowed students to see this struggle as productive, thereby enabling them to grapple with mathematics without questioning their intelligence.

Students' Feelings about Challenging Tasks. Congruous with students' evolving mindsets, students' feelings about challenging tasks were also shifting throughout the study. Students were less likely to feel that they were not very smart when they had to work hard at math, as reported on the survey. They also self-reported less discouragement when they fail to understand something. Moreover, students began expressing the belief that challenge augments learning. By the end of the unit, no student saw having to struggle with math for a long time as proof that she is bad at math. This can have substantive consequences for students' mathematical achievement (Blackwell et al., 2007).

Perseverance Promoted. Observation data showed a marked improvement in perseverance over time. Across the school year, I documented observed behaviors including: continuing to work on a problem on which students have experienced failure before, continuing to work on a problem which takes longer than the previous problems to complete, and completing a problem that requires more than five steps to complete. The volume of perseverant behaviors documented increased from an average of 12 per week to 27 per week at the end of the study. My observation data indicates, in keeping with students' self-reported behaviors, that these behaviors increased after the interventions. Since many topics in mathematics take time and tenacity to understand, this could expand students' future achievement trajectories.

Implications

This study suggests that even brief interventions may foster the mindsets that can enable students to persevere despite mathematical challenges. Although a few researchers have focused on the effects of specific interventions, this study highlights how three accordant interventions may impact students' perseverance in a secondary mathematics classroom. Results from this study suggest that teachers should attend to students' mindsets in building supportive classroom environments. These findings will help practitioners make decisions in implementing similar interventions in their own contexts.

Although this study provides empirical evidence that students' feelings and behaviors toward challenging mathematics may be influenced through interventions in this particular context, researchers should further investigate interventions across an array of settings and with diverse students, to enable practitioners to leverage this research in everyday practice. Replication of this study in multiple contexts would enable educators to adapt the interventions for specific settings. Educators need research-based methods for supporting academic mindsets and academic perseverance in praxis.

This work explored effects of interventions within the context of one unit; researchers should also examine lasting effects as students show progress longitudinally. This study's participants were students of color with low socioeconomic status—subgroups that historically trail in mathematics achievement; future research should explore the potential for similar interventions to affect achievement gaps.

Limitations

At the same time that I report new insight into how perseverance may be fostered through mindset interventions, I also recognize limitations of this study. First, my presence may have changed the dynamic of the classroom. McKnight and colleagues (2000) describe this phenomenon: "The subjects may attempt (consciously or unconsciously) to increase behaviors they believe the observer desires and to decrease undesirable behaviors" (p. 77). In other words, I may have changed the situation simply by observing it.

Additionally, students may have become more perseverant in part because as the year went on, they practiced working self-sufficiently and experienced success. Thus, they had seen that hard work paid off in passing grades. Although direct references to growth of ability seem to stem from the interventions, it is probable that perseverant behavior resulted from multiple factors. Interviews of students to gain insight into subjects' perspectives on the effects of interventions would be a profitable exploration for future research.

Conclusion

As perseverance surfaces in the field of non-cognitive academic skills, a new challenge is raised: empowering students on the margins without shifting the blame for achievement gaps onto their shoulders. Often, as educators, we know that if students would work harder, they could succeed. A natural conclusion, then, is that they underperform because they are lazy or do not care. As the literature makes clear, however, students who cannot see the possibility of success—either because they believe their ability level is fixed, they do not belong in mathematics, or that failure at one task precludes success in the course—may be being crippled by fixed mindsets. As I conducted the literature review for this study, these beliefs were exposed as important factors in shaping students' experiences in mathematics classrooms. As I analyzed data from this study, it became evident that students' mindsets may be responsive to interventions as well. Students who initially thought they were not cut out for math began to internalize and express the importance of trying hard after failure. They then identified factors within their control—framing success as graspable. Students answered questions about struggle with mathematics in noticeably more tenacious terms. Rather than blaming students for not working hard enough, this study provides evidence that students can rise to the challenge and even change mindsets when teachers attend to these mindsets.

About the Author

Samantha Marshall is a Ph.D. student at Vanderbilt University. She earned her B.S.E. in mathematics from Oklahoma Christian University, and her M.A. in Curriculum & Teaching from Teachers College, Columbia University, with a concentration in mathematics. She has taught high school math in a variety of settings, from Oklahoma to New York. Most recently she served as an instructional coach, crafting and leading professional development for pre-service and in-service teachers in Tennessee and Mississippi. Her interests center around issues of equity: classroom environments and tools that foster equitable mathematics learning, and how in-service teachers' supports become influential in their work. Email: samantha.marshall@vanderbilt.edu

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Appendix A: Student Survey

	definitely agree	agree	neither agree nor disagree	disagree	definitely disagree
1. I feel confident about my ability in mathematics.	○	○	○	○	○
2. You have a certain amount of intelligence, and you really can't do much to change it.	○	○	○	○	○
3. When I have to work hard at math, it makes me feel like I'm not very smart.	○	○	○	○	○
4. If you're not very good at math, working hard won't make you good at it.	○	○	○	○	○
5. If you have to work hard on some problems, you're probably not very good at them.	○	○	○	○	○
6. When I fail to understand something, I become discouraged to the point of wanting to give up.	○	○	○	○	○
7. Effort won't do much for you if your ability level isn't high.	○	○	○	○	○
8. No matter how hard it gets, I will succeed in Algebra 2.	○	○	○	○	○
9. The harder you work at math the better you will be at it.	○	○	○	○	○
10. My mathematical ability grows with hard work.	○	○	○	○	○
11. Everyone has a hard time with something in math; it doesn't mean they won't be successful.	○	○	○	○	○
12. Even if understanding a math concept took hours of study, I would keep working at it.	○	○	○	○	○
13. I am a hard worker.	○	○	○	○	○
14. When the math I am studying is difficult, I try harder.	○	○	○	○	○
15. I try very hard in math, even after experiencing failure.	○	○	○	○	○

16. Complete the equation: intelligence = ______% effort + ______% ability.

17. Which statement do you agree with more: "When I have to struggle on a math problem for a long time, **I see it as an opportunity for learning**" or "When I have to struggle on a math problem for a long time, **I see it as proof that I'm not good at math**"? Why?

18. Do you plan to take another math course after Algebra 2?

Additional comments:

Appendix B: Criteria for Identifying Perseverant Behavior

Observed Behavior 1	Student continues to work on a problem on which (s)he has experienced failure before
Observed Behavior 2	Student continues to work on a problem which takes longer than the previous problems to complete
Observed Behavior 3	Student continues to work on a problem which seems to frustrate him/her
Observed Behavior 4	Student comes back to a problem on which (s)he has previously given up
Observed Behavior 5	Student completes a problem that requires more than five steps to complete
Observed Behavior 6	Student continues to work on a problem on which classmates have quit