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Growth Mindset and the Makerspace Educational Environment

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Abstract

This action research project has studied the impact of implementing strategies in a Makerspace on increasing grit in students. The study has been conducted in two fifth grade classes in a mid-western suburban elementary school. During the study, students completed four different Makerspace design challenge activities. Data was collected from Angela Duckworth's grit survey to establish a baseline of student grit. Documentation of strategies used was collected through an inventory students completed after each design challenge. The data was used to identify changes in grit scores from students' initial survey results to their final survey results. Student's survey results were then compared to the total number of strategies used throughout the design challenges. The research data indicated that there was no correlation between the total number of strategies used and an increase in individual grit score. Identifying a tool, or resources to teach and foster grit in students may be increasingly important as grit has been identified as one of the most reliable factors in determining one's success and capacity for academic, professional, or personal success.

Keywords: Makerspace, Makerspaces, growth mindset, grit, maker mindset

On any given day, you may walk into the maker classroom and what you see or hear may be unexpected. Through the hustle and bustle of the classroom, you will observe students working, sketching their ideas, iterating their designs, or bringing their designs to fruition. Students will be heard making statements such as, “I can do this.” or, "I saw what another group was doing, and I think we could make changes and it could work." Phrases like these are commonly heard from students possessing a growth mindset. Students sharing these statements believe that through hard work, they can accomplish any goals. Students with a growth mindset and grit possess the ability to innovate, iterate, and create, cycling through that process without giving up.

Through our years of experience in a fifth-grade classroom, we have found that when confronted with a challenging problem, some students tend to see the challenge as overwhelming or insurmountable. Students’ academic success is hindered by their fixed mindset. Students unwilling to attack a challenge seem to lack the strategies necessary to move from a fixed mindset to a growth mindset. We hope to determine the extent to which the strategies afforded by implementing a Makerspace in the upper-level elementary classroom fosters a growth mindset in students.

The research will have taken place in a large elementary school in an affluent suburban neighborhood in the Midwest. The research will have been conducted in two fifth grade classrooms. Classroom "A" is a class of 24 students. 96% of the students are white/Caucasian, and 4% of the students are African-American. The teacher of the classroom identified as "A" will have completed nine years of teaching experience. Classroom "B" is a class of 25 students, 79% of which are white/Caucasian, 16% Asian, 8% African. The teacher of classroom "B" will have completed 14 years of teaching experience.

The classroom teacher's experiences as well as the observation of student's performance in challenging hands-on tasks show a disconnect between student aptitude and standardized scoring ability. Students need to find a way to excel in the face of difficulty and challenge.

Students' success beyond their formal education demands they possess both the knowledge and skills to be successful (Laursen, 2015). Duckworth (2013) and Steiner-Adair (2013) noted one dominant characteristic many top performing students must have is the mindset to persevere, otherwise known as grit. The best performing and most successful students possess the knowledge and skills of collaboration, problem-solving, grit, perseverance, tenacity, and self-control (Duckworth, 2013).

In classrooms across the country, students with the highest IQs do not inevitably have the top scores and grades, some students with lower IQs are often some of the best performers (Duckworth, 2013). The students that are the best performers possess soft skills; grit, perseverance, tenacity, self-control and the ability to collaborate and problem solve (Laursen 2015). Dougherty (2013) calls to action educational reform to foster the maker mindset supporting the growth and development of students physically, mentally and emotionally. Dougherty (2013) refers to Dweck's growth mindset as aligning to the 'can do' attitude of the maker mindset.

Mindsets

Dweck (2010) identified two mindsets people possess and believe about themselves; people either have a fixed or growth mindset. Individuals with a fixed mindset believe that one is born with a specified amount of intelligence and that one will maintain their baseline intelligence throughout their life (Dweck, 2010). Not only do they believe they have a certain degree of intelligence, individuals believe they are born with or without certain inherent talents (Laursen,

2015). These mindsets are established early on in life. Students with a fixed mindset do not seek effort in the unknown and challenging, because they believe “if you have the ability, everything should come naturally” (Dweck, 2010, p. 17). This belief leads students to think they lack talent and intelligence and that others will perceive them as lacking intelligence when met with academic challenges (Dweck, 2010). Fixed mindset students place value in looking smart above all else (Dweck, 2010). Instead of recognizing their weaknesses and using opportunities to strengthen them, students with a fixed mindset try to conceal these weaknesses from others and will go to great lengths to do so (Dweck, 2009). Their desire to learn becomes less important than proving their intelligence therefore, students will seek out and do tasks that “will prove their intelligence and avoid ones that might not” (Dweck, 2007, p. 34). Students will try to hide their mistakes or deficiencies instead of trying to correct them (Dweck, 2007). Fixed mindset students "don't handle setbacks well, they feel it calls their intelligence into question if they have to work hard they feel dumb, become discouraged or defensive if they don't succeed right away." (Dweck, 2010, p.17).

Dweck (2010) also finds that people with a growth mindset hold the belief that intelligence is related to experience and the tenacity to learn. Growth mindset students believe that they can conquer any challenge in front of them with adequate time, tools and guidance (Dweck, 2010). Students view challenging work as an opportunity to learn and grow (Tough, 2012). These students with a growth mindset believe that through dedication and effort they can develop their talents (Laursen, 2015). They believe that their intelligence can be developed and therefore “seek out learning, develop deeper learning strategies, and strive for an honest assessment of their weaknesses so that they can work to remedy them” (Dweck, 2009, pg 9). Students with a growth mindset enjoy learning, even when it is hard, and are resilient in the face

of obstacles (Dweck, 2007). When students with a growth mindset meet obstacles, they remain involved, try new strategies, and use all the resources at their disposal to learn (Dweck, 2010). Dweck (2009) found that students with a growth mindset, academically outperform their peers with fixed mindsets.

Students' mindsets can be changed, and if they are changed, it can promote resilience (Yeager & Dweck, 2012). Teachers can foster this change in a variety of ways. One way would be by directly teaching students about the different mindsets (Dweck, 2010). Another way to foster the change is through praise (Dweck, 2010). The type of praise and encouragement teachers give students can help create a classroom culture that is supportive of a growth mindset (Dweck, 2007). Dweck (2010) states that

> "praising students for the process they have engaged in the effort they applied, the strategies they used, the choices they made, the persistence they displayed, and so on-yields more long-term benefits than telling them they are "smart" when they succeed" (p. 18).

Teachers need to focus on the strategies taken to achieve growth (Laursen, 2015). This framing will help students to be prepared to use those strategies the next time they are confronted with a similar challenge (Dweck, 2007). If teachers praise students' intelligence instead of giving process based praise, students get a short burst of pride, but it is then followed by many negative consequences and puts students into a fixed mindset (Dweck, 2007).

Teachers presenting meaningful learning tasks give students a clear sense of progress which leads to mastery and fostering a growth mindset (Dweck, 2007). These tasks allow students to see themselves able to do or understand something that they couldn't before, giving them a sense of improvement because of their efforts (Regalla, 2016). These situations provide

an opportunity for teachers to praise the student's efforts that led to progress and improvement as well (Dweck, 2010).

Grit

One quality that most successful and high achieving people possess is grit (Bashant, 2014). Grit is defined as "passion and perseverance for very long-term goals" (Duckworth, 2013, 3:02). Grit involves working hard toward challenges, "maintaining effort and interest over the years despite failure, adversity, and plateaus in progress" (Bashant, 2014, pg. 14). Duckworth (2013) found, through her many studies identified in her book *Grit: The Power of Passion and Perseverance*, that grit is a predictor for success. It is a better predictor for success in college than the SAT or IQ tests according to Bashant (2014). Duckworth (2013) also asserts that grit can be taught. Teachers can teach students how to be grittier by helping them understand that when they struggle it is okay to feel confused, and that making mistakes or taking a long time to complete a task isn't a sign of failure, but instead a normal part of the learning process (Laursen, 2015). Duckworth (2013) developed the grit scale which gives a numerical value to answers on a questionnaire to determine how gritty one is.

Makerspaces

Maker Media (2013) defines makerspaces as learning environments that develop the physical and mental capacity of students allowing them to develop new skills, seek challenging projects, and find opportunities preparing themselves for their future. Makerspaces and the Maker movement in an educational environment are potentially revolutionary approaches to teaching, learning, and thinking (Maker Media, 2013). Dougherty (2013) is focused on the institution of education creating a space where kids have the opportunity to make. Makerspaces provide the users with the assets necessary to advance their do-it-yourself attitude and move

toward personal fabrication (Peppler, Halverson, & Kafai, 2016). Dougherty (2013) defines a makerspace as a "physical mash-up of different places that allow makers and projects to integrate different kinds of skills" (p. 2). These makerspaces share a resemblance to the traditional shop classes, home economics, art studios, and science labs (Dougherty, 2013).

The maker movement is founded in the theory of constructionism, developed by Seymour Papert, as hands-on learning through the construction of things (Kurti, Kurti, & Fleming, 2014). Martinez (2013) identifies that Papert's theory was rooted in the process of actively making something physical. Papert (1991) asks for the type of innovation that can and will produce a radical change in the ways children learn. Constructionism could lead to deeper learning and knowledge (Papert, 1991). In Papert's theory of constructionism the learner must actively be involved in the process of making something shareable. (Martinez, 2013). Constructionism is the learning theory that most strongly resonates within makers, the maker movement, and maker education (Martinez, 2013). Papert's life's work has been to create tools, theories, and learning environments to inspire children to build through their firsthand experiences (Martinez, 2013). Constructionism can be simplified as the application of the Piagetian constructivist learning principles into a hands-on learning environment (Kurti, Kurti, & Fleming, 2014).

Swiss psychologist and epistemologist Jean Piaget developed the theory of constructivism. With constructivism, the learner constructs knowledge internally. That knowledge is based on personal experience and schema (Martinez, 2013). Knowledge does not result from passively receiving information. Piaget believed the learner needed to undergo an internal process of sense-making for learning to take place (Martinez, 2013). In Piaget's ideal constructivist environment, the line between learner and instructor becomes blurred (Kurti, Kurti, & Fleming, 2014). Peppler, Halverson, and Kafai (2016) assert that "the Maker Movement

offers an opportunity to reach across the divide between formal and informal education and encourage formal spaces to think informally and have informal spaces to think like formal learning environments" (p. 7). The blurring of lines is evident in the maker movement where learning by making, tinkering and engineering is consistent with Piagetian theories (Martinez, 2013). Constructivism is a well-established theory of learning indicating that people actively construct new knowledge by combining their life experiences with previous knowledge (Martinez, 2013). In maker education and makerspaces, teachers act as guides and develop an inquiry-based approach developing the student's thinking and learning process (Kurti, Kurti, & Fleming, 2014). Constructivism suggests that knowledge is not delivered to the learner by an outside source, such as a teacher, but constructed inside the learner's mind (Martinez, 2013). Piaget's focus to teachers is to provide a learning environment to develop students' experiences and expand their personal schema (Martinez, 2013). Students will be building not based on directions or directives but from their background knowledge to develop something new, unique and necessary in a makerspace (Maker Media, 2013). The maker movement is a way to celebrate the expanse of the students' experience that Piaget calls for and the virtues Papert believed all children should have (Martinez, 2013). Makerspaces expand the experiences of constructivism as well as the virtues of constructionism (Martinez, 2013).

Martinez (2013) claims makerspaces and the maker movement may represent our best hope for reigniting education. Makerspaces and the maker movement develop the educational experiences that link making to the formal concepts of scientific theory, and the process of discovery and exploration (Martinez, 2013). Makerspaces achieve the pairing of formal theory and discovery by introducing novel tools and advanced design practice driving student inquiry and a desire to find new ways of thinking (Maker Media, 2013). Kurti, Kurti and Fleming (2014)

go on to determine the effective use of educational makerspaces form the basis for a new paradigm in education. Makerspaces, by design, spark a revolution in learning where students can learn through exploration, failure, and success (Kurti, Kurti, & Fleming, 2014). Makerspaces foster curiosity, tinkering, and iterative learning, which in turn leads to deeper thinking and reflective questioning (Maker Media, 2013). Makers take a chance, give something a try, take things apart and attempt things the original product designers did not even intend (Dougherty, 2013). The makerspace learning environment highlights students with enthusiasm for learning, self-confidence, and the ability to collaborate (Kurti, Kurti, & Fleming, 2014). Makerspaces develop students' determination, independence and creative problem solving, and establish an authentic process of preparation for the real world by simulating the iteration process (Kurti, Kurti, & Fleming, 2014). Educational makerspaces develop this kind of thinking and learning by being failure tolerant (Kurti, Kurti, & Fleming, 2014). Makerspaces are an initiative that seeks the development of self-motivated, self-directed learners (Maker Media, 2013). Dougherty (2013) implores education to "encourage more young people to explore, create, discover and make in their way" (p.1).

Maker Mindset and Grit

Growth, collaboration, and grit are encouraged in makerspaces by establishing challenges beyond the natural ability of any single individual within the task (Kurti, Kurti, & Fleming, 2014). Making is about developing one's full potential (Maker Media, 2013). Dweck's growth mindset ties into the mindset of a maker, Dougherty (2013) claims that Dweck's growth mindset has a *direct* connection to the maker mindset (Maker Media, 2013). The challenges presented should be more than any single individual can solve on their own, or possess all the skills to complete (Kurti, Kurti, & Fleming, 2014). Effective educational makerspaces are designed to

embrace the power of collaboration, and the collective knowledge the group members (Kurti, Kurti, & Fleming, 2014). Regalla (2016) calls for educational time for play, exploration, iteration, reflection and sharing to encourage deeper learning. Makerspaces are designed to foster each student's full capacity, for creativity, confidence, and collaboration (Maker Media, 2013).

Makers have a can-do mindset (Maker Media, 2013). The Maker movement creates an experience that develops the Maker mindset, a growth mindset, that encourages us to believe that makers can learn to do anything (Maker Media, 2013). The makerspace environment fosters enthusiasm for learning, student confidence and natural habits of collaboration (Kurti, Kurti, & Fleming, 2014). At the center of the maker experience, is the iterative process of learning where prototypes are made, feedback is gathered, and the process is shared with others creating a powerful learning experience (Regalla, 2016). Educational makerspaces are the ideal environment to foster independent exploration and a place for students to become independent thinkers (Kurti, Kurti, & Fleming, 2014). Regalla (2016) finds making as an opportunity for students to foster their instincts when they imagine, question, and play with ideas to create something new and find new ways of creating.

Students with the ability to learn how to learn will find few limits in their futures and develop a deep sense of confidence and intellectual passion (Kurti, Kurti, & Fleming, 2014). Makers are enthusiasts who play to learn, tend to be unafraid to error, and possess a growth mindset, as they will find ways to reiterate and move beyond the mistake (Maker Media, 2013). Kurti, Kurti, and Fleming (2014) find makerspaces as a way to empower students to become experts in new technologies and tools. A significant advantage of student empowerment is that there are always more students than teachers. The maker mindset encourages students to become the experts and share their learning in the role of teacher (Kurti, Kurti, & Fleming, 2014).

Makers explore what they can do and are always learning as they explore (Maker Media, 2013). Making develops the character traits including grit, creativity, curiosity, open-mindedness, persistence, social responsibility and teamwork among others (Maker Media, 2013; Dweck, 2010; Duckworth, 2013). Dougherty (2013) asserts that fostering the maker mindset through education is a way for learning to focus on the whole of the learner, as making is truly a creative process that requires all of a student's knowledge and ability.

Conclusion

The best performing and most successful students possess the knowledge and skills of collaboration, problem-solving, grit, perseverance, tenacity, and self-control (Duckworth, 2013) to be successful students must have a growth mindset, the ability to persevere, also defined as grit (Steiner-Adair, 2013). Dweck (2009) found that students with a growth mindset, academically outperform their peers with fixed mindsets. Making develops the character traits including grit, creativity, curiosity, open-mindedness, persistence, social responsibility and teamwork among others (Maker Media, 2013; Dweck, 2010; Duckworth, 2013). The Maker movement develops the Maker mindset, a growth mindset that encourages makers to believe that they can learn to do anything (Maker Media, 2013) and represents our best hope for reigniting education (Martinez 2013)

To what extent do the strategies afforded by implementing a Makerspace in the upper-level elementary classroom foster a growth mindset in students?

Description of the Research Process

Students were administered Duckworth's grit survey (2012) to complete individually at the beginning of the school year. The surveys were scored according to Duckworth's 12-point grit scale. The scores determined the students' grittiness at the start of the school year. The

results of the survey were withheld from the students to be sure that when they took the survey at the end of the research, their final scores were not influenced.

The classrooms each have technology devices, tools, supplies, and space devoted to the process of making as well as Makerspace design challenges. The physical space of the classrooms has been arranged to ensure that all of these things are visible and usable for all students at any time throughout the research.

The first Makerspace design challenge the students completed was Tapigami. Students were presented a slideshow that introduced them to the art of Tapigami. The slideshow covered picture and video examples of Tapigami, the core shapes used for tape construction, a mini tutorial on how to get started rolling and combing tape structures, and the classroom expectations of the project. The slideshow also covered the process and expectations of the students' Makerspace journal that they completed for each of the activities.

Students were then prompted to brainstorm an idea of something to create using the art of Tapigami that represented a personal interest. Students sketched this idea in their Makerspace journal. Once their designs were approved, they were then given a roll of masking tape to begin creating their piece. Students were given approximately 40 minutes of uninterrupted work time. Students shared their artifacts at the end of the process. After sharing, they completed the last two parts of their reflection in their Makerspace journal. These parts included sketching their final artifact, and writing down the changes they made as well as the difficult parts they had to solve.

Completion of the students' reflective journaling lead into the Makerspace Mindset Survey. In her book *Makeology: Makerspaces as Learning Environments, Kylie Peppler* identified strategies that challenge student thinking, and align with the mindset of a maker. These strategies

are used when students are faced with challenges that may be beyond their current level of skill or understanding. The Makerspace Mindset Survey is a tool devised by the classroom teachers conducting the study to flush out the strategies students used to track their process as they move from their first design to their completed artifact. Students completed the survey reflecting on what strategies they accessed when struggling. Reflection on the process was designed to have students look at what they did when meeting challenges. The limited directive allowed for students to iterate in different ways and through reflection see which mindset strategies they turned to when facing a challenge.

The second task students completed was the Paper Airplane Challenge. Students were introduced to the challenge through a slideshow presentation. The presentation included the expectations for the project, details of the challenge, and determination of the challenge winner. The prompt students were given was to design and create a paper airplane that can carry maximum cargo, and glide ten feet through the upper ⅓ of a doorway. Pairs of students were given a piece of construction paper, tape, and as many pennies as they needed. Students were given time to sketch their planned plane with cargo location. Once they had sketched, they built their aircraft and tested them. Students attempted to fly their planes through the target area with maximum payload, determining success at the end of the work time

Students returned to their Makerspace journals after the challenge. Students sketched their final artifact and described the challenges they met and the strategies they used to overcome those challenges, as well as any changes in design. Lastly, they again completed the Maker Mindset Inventory.

The focus of the third challenge was conductivity, circuitry, and binary computer inputs using Makey Makey. Students started with a slideshow presentation that included watching a

tutorial and videos of different input devices people have created and used. Students then followed the printed directions on how to set up the Makey Makey in small groups. In order to determine if materials conducted electricity and worked as an input for the computer, students were given a variety of materials to try with the Makey Makey. Some of the materials included a variety of foods, plastic toy pieces, metal coins, and other materials found around the classroom. The students chose what they wanted the inputs to control from a list of links. Some of the these included a web-based piano, Pac-Man, ping pong, and Guitar Hero. After each group had set up their Makey Makey, they toured the classroom to observe and try using all of the other inputs.

During the next Makey Makey Makerspace activity, students were prompted to brainstorm and sketch an idea in their Makerspace journal for an input device, recording all materials necessary to create their input device. They also noted if they were creating their input device to be used with any specific programs or games. Students had to get their sketch approved and then gather the materials necessary before beginning to construct their input device. Once the students built their input devices, they tested them and iterated if required. Upon completion of the design process, students sketched their final artifact and described the challenges they met and the strategies they used to overcome them as well as any changes in design. At the end of the challenge, students presented their input devices, quickly shared their process, and then got to test other people's input devices. Finally, they completed the Maker Mindset Inventory.

The fourth challenge focused students into rapid prototyping and the use of Littlebits microelectronics. Students were introduced to the process through a slideshow presentation. The focus of the presentation detailed the two elements of this maker design challenge. In phase one of this challenge, the students were asked to follow the guidelines outlined in one of the rapid prototyping challenges included with the Littlebits guides. Students were given multiple bits and

bit combinations and all the tools and supplies they would need to construct a simple circuit. The circuit and the provided materials combine to build one of the various suggested prototype builds from the kits. This experience with the circuitry and build process was necessary to complete the task in phase 2 of the Littlebits challenge.

The second phase of the slideshow presentation challenged students to use the Littlebits and the process of rapid prototyping to design and build an element that could be included in a haunted house. Students were specifically grouped in small groups of 4-5 students to complete this task. The groupings of the students were based on the data from the Makerspace use log. Students who had logged numerous sessions in the Makerspace were spread out through the groups to have making experience in as many groups as possible. Students were granted access to a multitude of various supplies that could be used in the construction process. Students were also allowed access to the entire collection of Littlebits to guide their planning process toward completion of the design challenge. Again, students first sketched their build plan to guide their reflective piece later in the process. Students were given 30 minutes of time to plan out their element and 1 hour and 30 minutes to construct the actual artifact. This process forced the students into making quick decisions and focused their efforts on the outcome of the project rather than the aesthetics. Completion of the task was determined by the functionality of the final artifact. Once finished, students went back to their Makerspace Journal to document their final artifact as well as reflect on the process and describe the challenges they met and the strategies used to overcome them. Students also noted changes in their design from their first iteration to completion of their artifact. Lastly, students completed the Maker Mindset Inventory.

Students were given permission to work with the tools and equipment from each of the challenges outside of the challenge activity time. Students were required to log their time and

activity, providing their name and task they focused on. Time in the Makerspace was unstructured and available upon completion of other curricular assignments. This time varied based on the student's personal drive and freedom within their daily schedule.

Upon completion of all Makerspace challenges, students were re-administered Duckworth's 12-point grit survey again to determine if their scores increased. Initial and final scores were then shared with students to reflect on their levels of grit.

Analysis of Data

Data was collected from each student through Angela Duckworth's Grit survey (Duckworth, 2007). Forty-eight (48) students total from two different fifth grade classrooms filled out the grit survey at the beginning of the research period establishing a baseline grit score on a five point scale. The girt survey followed the structure of a Likert Scale with the middle value identifying students as being moderately gritty. Students' scores for each of the 12 statements were then added together and divided by 12 as the total number of statements to determine a student's "grit score." Students' scores determined their individual level of grittiness with an overall rating of 5 being extremely gritty and a one being not at all gritty (Duckworth, 2007).

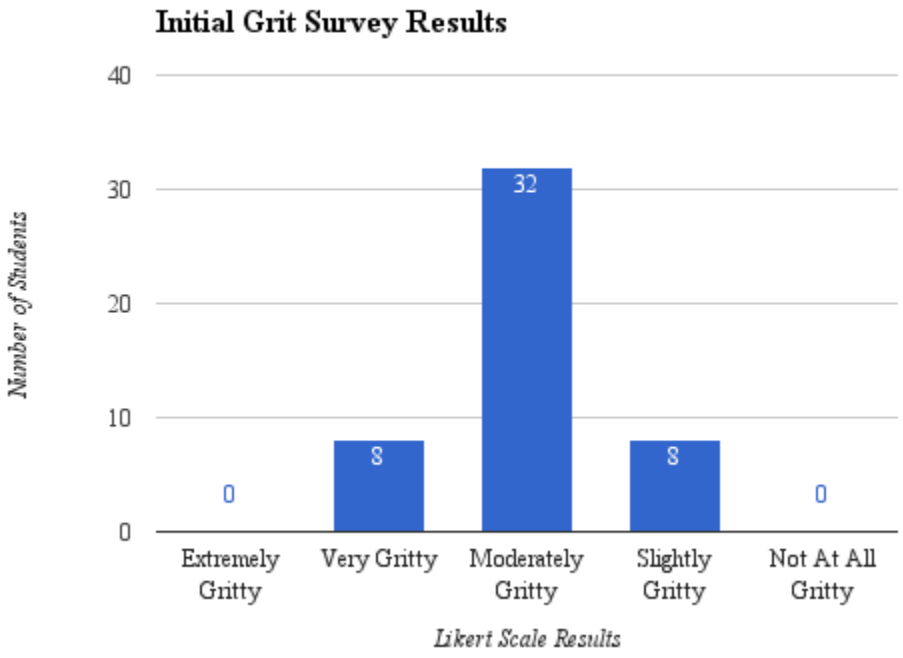

Figure 1 Number of students in each grit category.

Results of the initial grit survey detail that 32 of the 48 students averaged between 3.0 and 3.9 being identified as moderately to very gritty. Eight of the 48 of the students surveyed scored themselves between 4.0 and 4.9 self-identifying as very gritty based on the self-assessment. Therefore, 40 of the 48 total scores were at a score of 3.0 or higher. This group of students identified themselves as being at least moderately gritty based on Angela Duckworth's 12 point grit survey. Only eight of the 48 students scored themselves below the moderately gritty threshold of 3.0 on the grit scale. These students self-identified as being slightly gritty based on the grit survey.

The results indicated that 83% of students in their formative years identified themselves as being at least moderately gritty. 16% of the students in the survey group self-identified as being only slightly gritty per their initial grit scores on the grit survey.

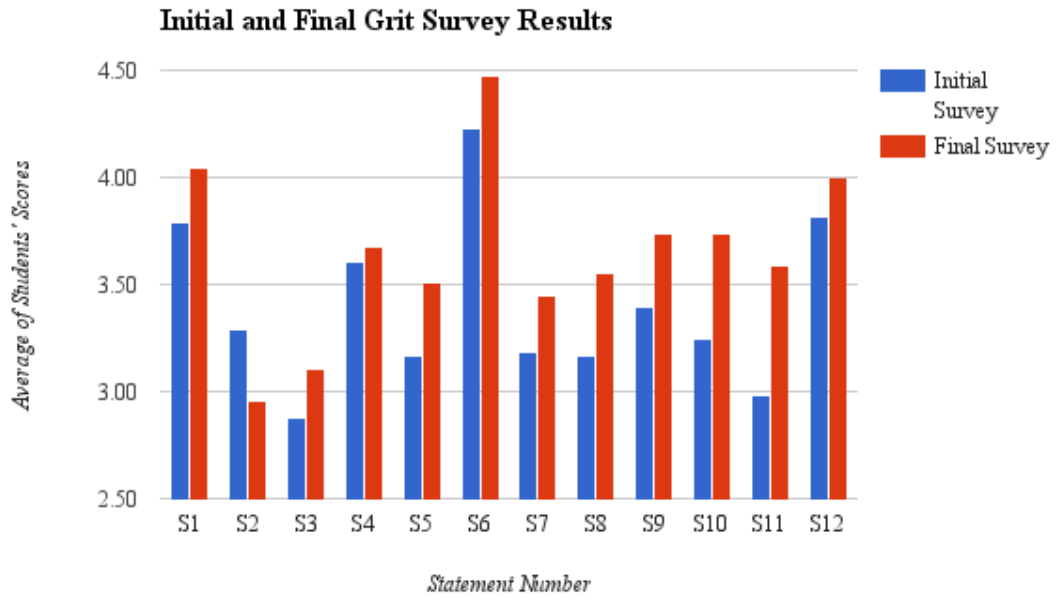

Figure 2 Comparison of grit survey question scores from initial to final survey.

Figure 2 shows that the average score for each statement increased from the initial to the final survey except for the 2nd statement. On the initial survey statement S3, "My interests change from year to year." was the lowest scoring statement with an average of 2.88 points. The statement S2 "New ideas and projects sometimes distract me from previous ones." was the lowest scoring on the final survey with an average of 2.96 points for the 48 students surveyed. Students self-assessed an overall average score indicating signs of moderate grittiness. 33.3% of the students surveyed saw themselves as only slightly gritty or not at all gritty when it comes to new ideas and projects distracting them from previous ones.

In contrast to the lowest scoring statement, the highest scoring statement, "I am a very hard worker," yielded results that frame students' thinking regarding the efforts they put forth in the actions and activities in their school and personal lives. 89.5% of students surveyed identified themselves as very gritty or extremely gritty when self-assessed as a hard worker. "I am a very hard worker," was the highest scoring statement on both the initial and final survey. Only 6% of

students surveyed identified with statement S6, “I am a hard worker” as not being like them at all.

Maker Mindset Survey

Throughout the four activities students participated in, each student used an average of 15 strategies when encountering challenges. Students reported 123 strategies used throughout the Tapigami design challenge. Students used a total of 139 strategies during the paper airplane design challenge, while they reported using a total of 160 during the Makey Makey design challenge. The final activity, designing with LittleBits, had a reported total of 179 strategies used. In total for the four design challenges, students used a total of 601 combined strategies to meet their goals for each challenge. Each subsequent activity reported a higher total number of strategies used than the previous activity. Each time a strategy was used in an activity by a student, it counted toward the total strategies used. Students may have utilized the same strategy in more than one activity tabulating its usage each time used. This method of calculation allowed us to credit the total strategies used and account for the variance in the types of tasks students complete in each of the design challenges.

The strategy most commonly utilized was, “I brainstormed a different way to make it work.” This was most commonly used strategy in each of the four activities accounting for 22% of the total strategies used. Some of the design challenges lent themselves well to specific strategies therefore, the strategies varied. The least used strategy, contacting an expert, accounted for less than one percent of the total strategies used. The low usage of this strategy was expected as the activities didn’t require this strategy. The next strategy reportedly used the least was “I asked a teacher or adult.” We believe this to be underreported by students as seeking help from a teacher seemed to occur more times than was reported by either class. The structure of the

feedback outlined by Carol Dweck guides the teacher to respond with formative feedback. Formative feedback is done to help the students guide their learning and discovery toward the solution. These two factors may have been in conflict as we analyzed the results from this question.

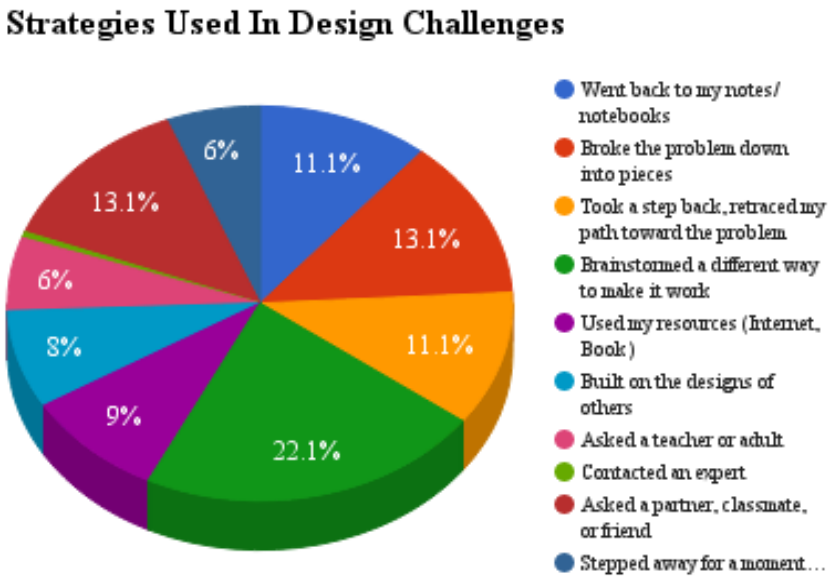

Figure 3 Breakdown of strategies used by students throughout all design challenges.

Final Grit Survey

The average grit score on the initial grit survey was 3.40 points identifying students as being somewhat gritty, while the average grit survey score on the final survey was 3.65 points identifying students as somewhat gritty trending toward gritty. Students identified themselves as somewhat gritty to very gritty on the final grit survey. Students increased an average of 0.25 points from initial to final grit score. The overall average student grit score showed a gain in grit. 65% of the surveyed students made gains, 29% of the students surveyed showed a decrease in grit score, and 6% of the students reported no change from initial to final grit score. The average

gain was 0.47 points for the students who made gains. Of the students who showed a decrease in grit, the average decrease was 0.40 points.

Students who increased by more than 0.50 points on the grit survey used ten or more strategies accounting for 25% of students surveyed. Students whose grit score increased used an average of 14 strategies. Students whose grit score decreased used an average of 17 strategies over the course of the four activities. It is imperative to note that students whose grit score decreased, used on average, more strategies than the average number of strategies used by students whose grit increased. This data shows through the course of our study that there is not a positive correlation between an increased number of strategies used and an increase in grit score. 10% of students used ten or more strategies and their grit score still dropped by more than 0.50 points.

Makerspace User Log

Due to lack of time with establishing beginning of the school year routines, the students in the classrooms had an inadequate amount of, if any, opportunities to use the makerspace independently. Therefore, we chose to disregard the data from the makerspace user log. Even in the extremely limited student usage, we could not provide any evidence or link between the time spent in the Makerspace and an increase in overall grit score.

Student framework of their thinking in regards to self-assessed grit scores helped us to understand the basic mindset of the students at the outset of the research process. Moving students to the point of growth on the survey was challenging based on their high personal assessment at the beginning of the process.

Action Plan

The culmination of our research shows that students in our fifth-grade classrooms possess a high level of initial grit and therefore the experiences afforded to them from the strategies of a classroom Makerspace may or may not increase a student's' grittiness. Results did not show connections between the number of strategies used in a Makerspaces or makerspace activities and an increase in grit. The research data support a connection between students' average grit score increase and time spent doing Makerspace activities.

In order to make the connection between the strategies afforded by Makerspace activities and an increase in grit stronger, we would like to implement for a longer period. Our data alone shows that we cannot predict if time would be a positive or negative indicator of grit growth connected with strategies used. Student journaling of their thinking process may indicate growth in grit better than only recording the number of strategies used in the process. Further research focused on increasing time and focus on editing and revising the initial design and changes made to it may prove increased growth in grit. Students may be able to articulate the processes and the thinking aligned with the growth of grit that naturally develops outside of a list of predetermined strategies.

We intend to continue to incorporate makerspace activities into our classrooms, but also plan to incorporate activities that are increasingly challenging and span more time. Extended time combined with an increase in the challenge level of makerspace activities could require the depth of grit we seek for our students to achieve. We also plan to allow more time for students to plan, reiterate, build on previous designs, and reflect at the end of the activities. We see the greatest potential in proving grit growth, in the students' reflection and use of strategies identified by the students through their experience. Reevaluation of the students' grit scores will take place at the end of the school year.

Hands on, challenging experiences push students' thinking beyond the known and expand the strategies they use in their understanding and learning. We believe that if all classrooms had a makerspace, there is a greater potential for an increase in grit than would occur in classrooms that do not afford students the experience of a makerspace. We also believe, based on our research that students' grit would increase and be maintained if they had access to Makerspaces and Makerspace activities each year. Students who are continuously exposed to such experiences would be able to have a greater base of resources to draw from expanding their available strategies. Further, long term research would have to be conducted to determine if this perceived outcome would be attainable and as impactful as we as a research team believe it could be.

There are many potential topics for future investigation. Some of the topics include the following:

1. Do the strategies listed in the Maker Mindset Inventory accurately match the expectations, structure, and challenge of the activities? The strategies we used were identified by Kylie Peppler in Makeology (2016) to help frame students thinking when taking on a design challenge.
2. Do the strategies we focused on actually foster grit in the activities?
3. Do students need to use different strategies to increase grit? As long as they are utilizing a strategy, even if it is often the same strategy, is there an increase in grit?
4. Is there a correlation between specific strategies used and an increase in grit?
5. Is there a correlation between the number of strategies used per individual design challenge and increase in grit score?

Because Makerspaces are a relatively new topic to study, there is much more research that could be done. Future research may provide additional insight on the benefits of Makerspace

activities and connection to students' grit. Furthermore, identifying a tool, or resources to teach and foster grit in students may be increasingly important as grit has been identified as one of the most reliable factors to determine one's success and capacity for academic, professional, or personal success.

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Appendix

12- Item Grit Scale

Directions for taking the Grit Scale: Please respond to the following 12 items. Be honest – there are no right or wrong answers!

1. I have overcome setbacks to conquer an important challenge.
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

2. New ideas and projects sometimes distract me from previous ones.*
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

3. My interests change from year to year.*
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

4. Setbacks don't discourage me.
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

5. I have been obsessed with a certain idea or project for a short time but later lost interest.*
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

6. I am a hard worker.
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

7. I often set a goal but later choose to pursue a different one.*
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

8. I have difficulty maintaining my focus on projects that take more than a few months to complete.*
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

9. I finish whatever I begin.
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

10. I have achieved a goal that took years of work.
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

11. I become interested in new pursuits every few months.*
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

12. I am diligent.
   - ❑ Very much like me
   - ❑ Mostly like me
   - ❑ Somewhat like me
   - ❑ Not much like me
   - ❑ Not like me at all

Scoring:

1. For questions 1, 4, 6, 9, 10 and 12 assign the following points:
   5 = Very much like me
   4 = Mostly like me
   3 = Somewhat like me
   2 = Not much like me
   1 = Not like me at all

2. For questions 2, 3, 5, 7, 8 and 11 assign the following points:
   1 = Very much like me
   2 = Mostly like me
   3 = Somewhat like me
   4 = Not much like me
   5 = Not like me at all

Add up all the points and divide by 12. The maximum score on this scale is 5 (extremely gritty), and the lowest scale on this scale is 1 (not at all gritty).

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