

GROWTH MINDSET AND DESIGN THINKING IN THE MIDDLE SCHOOL SCIENCE  
CLASSROOM

by

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## TABLE OF CONTENTS

1. BACKGROUND AND INTRODUCTION .....	1
Introduction.....	1
Background.....	1
Context of Study .....	2
Focus Questions .....	5
2. CONCEPTUAL FRAMEWORK.....	6
Introduction.....	6
Developmental Importance of Middle School.....	6
Incremental versus Entity Theory of Intelligence.....	7
Growth Mindset and its Benefits for Students .....	8
The Importance of the Growth Mindset in the Science Classroom .....	14
Design Thinking and the Science Classroom .....	16
Design Thinking and the Growth Mindset.....	18
Conclusion .....	20
3. METHODOLOGY .....	21
Overview.....	21
Participants and School Description .....	21
Treatments.....	23
Instruments.....	26
Data Collection Instruments – Mindset Assessment Toll and Student Interviews .....	27
Data Collection Instruments – Self-Reflection .....	30
Data Collection Instruments – Design Thinking Behaviors Rubric .....	30
Conclusion .....	32
4. DATA AND ANALYSIS.....	33
Results.....	33
Research Question 1: Does instruction in design thinking strategies increase the level of growth mindset in eighth grade science students? .....	34
Change in MAT Score for the Experimental and Control Groups .....	34
Change in Mindset Category Designation .....	37
Research Question 2: How does the initial mindset impact student display of design thinking behaviors during novel problem solving? .....	44
Self-Reported Confidence Ratings and Mindset Category Designation.....	44
Observed Design Thinking Skills and Mindset Category Designation .....	46

TABLE OF CONTENTS CONTINUED

5. CLAIM EVIDENCE AND REASONING .....53

    Claims From the Study .....53

    Value of the Study and Consideration for Future Research .....58

    Impact of Action Research on the Author .....59

REFERENCES CITED.....63

APPENDICES .....67

    APPENDIX A: Instructional Review Board Exemption .....68

    APPENDIX B: Introduction to Design Thinking Lesson.....70

    APPENDIX C: Density Curiosity Project Slideshow Template and Grading Rubric .....75

    APPENDIX D: Platform Project Assignment Sheet and Grading Rubric.....80

    APPENDIX E: Mindset Assessment Tool and Scoring Rubric.....84

    APPENDIX F: Student Interview Questions Pre- and Post-Treatment.....87

    APPENDIX G: Design Thinking Behaviors Rubric.....90

## LIST OF TABLES

Table	Page
1. Description of treatments, goals associated with each treatment and timelines .....	26
2. Data triangulation matrix .....	27
3. Descriptive statistics of pre-treatment and post-treatment scores for experimental and control groups .....	35
4. Pre-treatment and post-treatment mindset category distribution for experimental and control groups.....	38

## LIST OF FIGURES

Figure	Page
1. Illustration of the characteristics of fixed mindsets and growth mindset from Carol Dweck’s “28Mindset Works” organization.....	10
2. Design thinking process steps from the Meadowbrook School .....	16
3. Pre-treatment and post-treatment MAT scores for experimental ( $n=47$ ) and control groups ( $n=8$ ).....	35
4. Change in MAT scores from pre-treatment to post-treatment implementations for the experimental ( $n=47$ ) and control groups ( $n=8$ ) .....	37
5. Change in mindset category designation for the experimental ( $N=47$ ) and control ( $N=8$ ) groups. ....	39
6. Comparison of change in MAT score based on the pre-treatment mindset category for the experimental ( $n=47$ ) and control groups ( $n=8$ ).....	40
7. Magnitude of change in MAT score within pre-treatment mindset category designations for experimental ( $n=47$ ) and control groups ( $n=8$ ).....	42
8. Self-reported confidence rating on use of design thinking skills based on pre-treatment mindset category designations .....	45
9. Observed design thinking skills based on pre-treatment mindset category designations .....	48
10. Observed groups of design thinking skills based on pre-treatment mindset category designation .....	49
11. Student ability to explain how their design supported the needs of their stakeholder based on pre-treatment mindset category designation .....	50

## ABSTRACT

Individuals who possess a growth mindset believe that they can improve their abilities over time thanks to hard work, learning from mistakes, and practice. Those who are growth-minded perceive challenges and mistakes as opportunities to learn and stretch their thinking. Possession of a growth mindset is a framework that is correlated with a host of positive outcomes in both the academic and personal lives of students. One potential way to promote this growth mindset is in teaching design thinking strategies. Design thinking is a system for creative problem solving that emphasizes curiosity, learning from experience, and perseverance as the keys to developing effective solutions. The values of design thinking mirror the qualities of a growth mindset and the purpose of this paper was to investigate whether there was a connection between these two frameworks.

To investigate this question, I taught a four week design thinking unit through the topic of physical oceanography. The level of growth mindset of students was assessed with a Likert style survey before and after the design thinking curriculum. Student volunteers were also interviewed after both implementations of the mindset assessment survey. A control group of eighth grade students, who covered the same physical oceanography topics but did not experience design thinking instruction, also completed the two administrations of the mindset survey. Additionally, for the experimental group, students self-reported levels of confidence with design thinking skills after completing their first design challenge. Furthermore, a Design Thinking Behaviors Rubric was used to observe students as they participated in their final design challenge.

The data show that there was a positive correlation between design thinking instruction and student mindsets. The mindset score of the experimental students showed a significant, positive increase over the control group's change in mindset score between the pre- and post-treatment administrations of the survey. On the other hand, the results do not reveal any patterns about how students' initial level of growth mindset influenced their ability to display design thinking skills.

## BACKGROUND AND INTRODUCTION

### Introduction

The purpose of this action research (AR) was to investigate whether a connection existed between instruction in design thinking skills and a student's level of growth mindset. I was specifically curious about whether teaching design thinking skills to my eighth grade science students would cause an increase in their level of growth mindset. I also investigated how a student's initial level of growth mindset impacted their ability to demonstrate specific design thinking behaviors. A growth mindset is a powerful tool that students can use to navigate challenges throughout their academic careers. Design thinking is an effective system to utilize to develop innovative solutions to complex problems. The goals and objectives of these two frameworks mirror each other and the benefits they offer to students are correlated with many positive academic and socio-emotional qualities. Design thinking is a big part of my science classroom and if teaching this skill is correlated with an increase in students' mindsets, then I will have evidence that I am able to provide students with tools for success in both their academic and social worlds through this teaching method.

### Background

I teach eighth grade science at Cary Academy (CA) located in Cary, NC. The 2021 – 2022 academic year was my first year teaching at this independent school. CA is comprised of grades 6 – 12 with a student population of 785 students. The middle school contains grades 6 – 8 and has 310 students, and the upper school includes grades 9 – 12 and holds 475 students. The average classroom size is 16 students throughout the school. Fifty-five percent of the student body identifies as students of color and 45% of students identify as white. The cost of middle

school tuition at CA is \$27,720 and the school prides itself on a robust financial aid program, offering over \$2 million in aid each year.

The mission of the school is captured in four key words – Discovery, Innovation, Collaboration, and Excellence. Indeed, CA is dedicated to living its ideals of sparking curiosity to question assumptions, encouraging bold and creative strategies to forge new realities, nurturing strong local and global interactions, and recognizing that excellence is found in the meaningful growth from the dedicated pursuit of individual and shared goals. Academic learning and personal evolution are equally valued and connected at this school.

CA is a community of deeply motivated, talented, and hardworking learners. Over the past 12 years I have had the opportunity to teach in independent schools throughout New England with similarly steadfast student populations. These students are a joy to teach because they value the relationships established in such tight-knit communities and eagerly invest themselves in their schoolwork. They think creatively, dig into real-world applications of class concepts, and collaborate effectively to solve problems. Even so, this is also a population of students who often rigidly hold themselves to very high standards with regard to academic achievement and can experience mental health challenges due to this pressure to succeed.

### Context of Study

Throughout my years of teaching seventh and eighth grade science, I have observed my students experience self-esteem setbacks, engage in negative self-talk, become more risk-averse, and have strong emotional reactions to perceived failures in my classroom. For example, a poor grade on an assessment, a mistake on a lab, an error during a design challenge, or a miscommunication in a project have all triggered significant adverse reactions from my students.

I have observed students fall into negative spirals following these experiences and extensive coaching was required in order to get these students to bounce back from their errors. Students tend to view a single poor grade or piece of constructive feedback from a teacher as a global judgment about their abilities as a scholar rather than helpful information about their current state of mastery that can be used to continue to grow their learning.

I noticed that this pattern led to hesitation or avoidance of risk taking in class for fear of failure. Students also demonstrated significant signs of anxiety around graded assignments such as assessments or lab reports. Both manifested as over-studying, over-preparing, and asking for clarification multiple times to confirm that they were on the right track. On the other hand, I have also observed students that travel in the opposite direction. Here, they throw their hands up and declare that they “just aren’t good at science” when they experience a challenge in my class. These students frequently moved into a negative cycle of low-test grades, greater frustration with open ended tasks, and more helpless response strategies to setbacks. This speaks to the unique challenge in science classrooms where students have a binary view of their abilities in this subject – they are either “science people” and they must be consistently perfect or “not science people” and have no hope of improving their capacity in this area of study.

It is my aspiration to help these students change their perspective about learning, effort, and making mistakes. I want to support my students as they build resiliency in the face of setbacks, reinforce their self-esteem, and promote confidence in their belief about their abilities in science. I feel privileged to work with middle schoolers at such critical moments in their development as both scholars and people and I want to encourage a greater sense of self-efficacy in my students.

In order to start to accomplish this goal, I investigated the potential for a connection to exist between the development of a growth mindset in my students and the process of design thinking. Possessing a growth mindset means that a person believes that they can improve their abilities over time thanks to hard work and practice. Those who are growth-minded view challenges and mistakes as opportunities to learn and stretch their thinking. Conversely, individuals with fixed mindsets believe that intelligence and abilities are set and there is no opportunity to improve on these facets of a person's being. As such, mistakes and challenges are viewed as threats and the fixed mindset person places value on getting the correct answer rather than the process of learning. Significant research has shown the benefits of teaching students growth mindset strategies in connection with confidence, academic achievement, and risk taking.

My research focused on investigating these mindset levels through the lens of design thinking, which is a method of creative problem solving. Design thinking is a perfect encapsulation of the growth mindset because this thinking strategy emphasizes curiosity and perseverance as the keys to developing effective solutions to problems. Design thinking does not expect students to begin a problem as experts or develop a perfect solution on the first try. Rather, the process of design thinking is all about approaching each problem with inquisitiveness, identifying what one knows and what information one needs to research, learning from experience, and persisting through challenges in order to create better outcomes for real-world problems. Design Thinking is truly the growth mindset in action. I suspected that there was a relationship between these two aspects and I was interested in learning more about that possible connection. I also aimed to investigate whether there was a directional correlation between these variables - was it the initial mindset that influenced a student's design thinking abilities or was it learning about design thinking skills that impacted a student's level of growth

mindset?

This research was important to my school, because CA takes pride in fostering the personal growth and development of their students. CA's learning philosophy consists of eight key statements that explain the school's values with regard to teaching and learning and several of these statements echo the goals of the growth mindset and design thinking. Namely, Statement 1 – learning is an iterative and interdependent process, Statement 2 – taking risks, embracing struggle, and developing resilience are essential to deep and life-long learning, and Statement 3 – individuals must develop self-awareness as learners and take ownership of their learning. These three claims were all deeply connected to the goals of my research. As such, my focus on these developmentally important questions had the potential to contribute to helping my school understand more about its progress in carrying out the goals of its learning philosophy and mission.

### Focus Questions

My focus question was, Does instruction in design thinking strategies increase the level of growth mindset in eighth grade science students?

My sub-question included the following:

1. How does the initial mindset impact student display of design thinking behaviors during novel problem solving?

## CONCEPTUAL FRAMEWORK

## Introduction

In order to investigate the potential connection between design thinking skills and the growth mindset, five lines of research were pursued. These avenues included: the importance of the middle school years in developing problem-solving skills, the psychological underpinnings of the growth mindset, the benefits of the growth mindset, the specific relationship between the goals of middle school science learning and the growth mindset, and possible connections between design thinking and the growth mindset.

### Developmental Importance of Middle School

Academic work begins to take on new challenges during the middle school years; learning becomes more demanding and greater effort is required to continue to succeed (Blackwell, 2002; Grant & Dweck, 2003). Inferential thinking is emphasized, rather than the rote memorization of earlier years, and this enhanced complexity matches with students' burgeoning abstract thinking abilities thanks to the maturation of brain functioning during this time of life (Semrud-Clikeman, 2010). However, if students have not been previously exposed to curricula that has taxed their abilities in their elementary years, this shift to higher order thinking in middle school can be a discordant experience.

Students frequently encounter their first academic failure in middle school due to the increasingly complex curriculum and heightened workload. When initially faced with academically rigorous assignments and multifaceted concepts, these students do not initially have the skill sets to overcome these hurdles and must be taught both the skills necessary to move forward productively as well as how to manage the disappointment that comes with failing for the first time (Blackwell, 2002; Grant & Dweck, 2003). This means that the adolescent years

are a critical point in the development of coping strategies for middle school students when they are faced with difficult obstacles and personal failure in the classroom. How students learn to manage these challenges and whether they choose to implement effective or ineffective strategies has major implications for their academic futures (Blackwell et al., 2007).

### Incremental versus Entity Theory of Intelligence

The psychological underpinnings that enable some students to thrive and others to flail when confronted with an academic challenge relates to the way that those students perceive their intelligence and abilities. Some students hold the belief that intelligence is a malleable aspect of a person that can be developed over time. On the other hand, others believe that intelligence is an unchanging facet of a person's traits that cannot be altered. The first type of student possesses what is known as an incremental theory of intelligence and the second student possesses an entity theory of intelligence. This worldview has been shown to have significant impacts on student academic achievement and socioemotional wellbeing (Blackwell et al., 2007).

In the literature review by Yeager and Dweck (2012), the authors point out that when a student possesses an entity theory of intelligence, they tend to interpret academic challenges or lower grades as an indication that they lack intelligence and that they may be viewed as "dumb" by their peers and teachers. This can lead to these students choosing to shy away from challenges in order to avoid these negative feelings and decreased resilience in academic settings. Conversely, students who possess an incremental theory of intelligence embrace challenges and demonstrate enhanced resilience in the classroom.

The review goes on to say that a student's theory of intelligence not only shapes their perspective on scholastic challenges, but it can also impact their learning goals, the value that

they place on the importance of effort, their level of self-efficacy, their attribution of setbacks, and resilience in the face of these setbacks. Students who possess an incremental theory are eager to learn, possess a firm understanding of the connection between effort and success, believe that they will ultimately be able to succeed, recognize that a setback requires a reevaluation of their strategies, and that they must apply themselves more effectively to a setback in order to overcome the challenge (Yeager & Dweck, 2012).

On the other hand, students with an entity theory of intelligence are more concerned with looking smart and not failing at tasks. They also feel that effort is a signal of weakness and that failing at a task means that they are incompetent. This can cause them to give up, become defensive, or consider cheating when they think about how to overcome a challenge. Clearly, possessing an incremental worldview arms a student with a mindset that views school as a landscape of opportunities to learn, grow, and stretch one's thinking, whereas the entity theory represents a world of threats and constant assessment of whether one is good enough. Undoubtedly, the former is a viewpoint that we should encourage and actively foster in our students, especially during the developmentally important years in middle school.

### Growth Mindset and its Benefits for Students

One popular educational method of fostering an incremental theory of intelligence in students is through Carol Dweck's framework of the growth mindset (2006). In her work, Dweck contrasts an incremental theory or growth mindset with an entity theory or fixed mindset by explaining,

Believing that your qualities are carved in stone - the fixed mindset - creates an urgency to prove yourself over and over. If you only have a certain amount of intelligence, a certain personality, and a certain moral character - well, then you better prove that you have a healthy dose of them. It simply wouldn't do to look or feel deficient in these most basic characteristics ... There's another mindset in which these traits are not simply a hand you're dealt and have to live with, always trying to convince yourself and others that you have a royal flush when you're secretly worried it's a pair of tens. In this mindset, the hand you're dealt is just the starting point for development. This growth mindset is based on the belief that your basic qualities are things that you can cultivate through your efforts. (pp. 6-7).

The differences between these two mindsets is further illustrated by Figure 1.

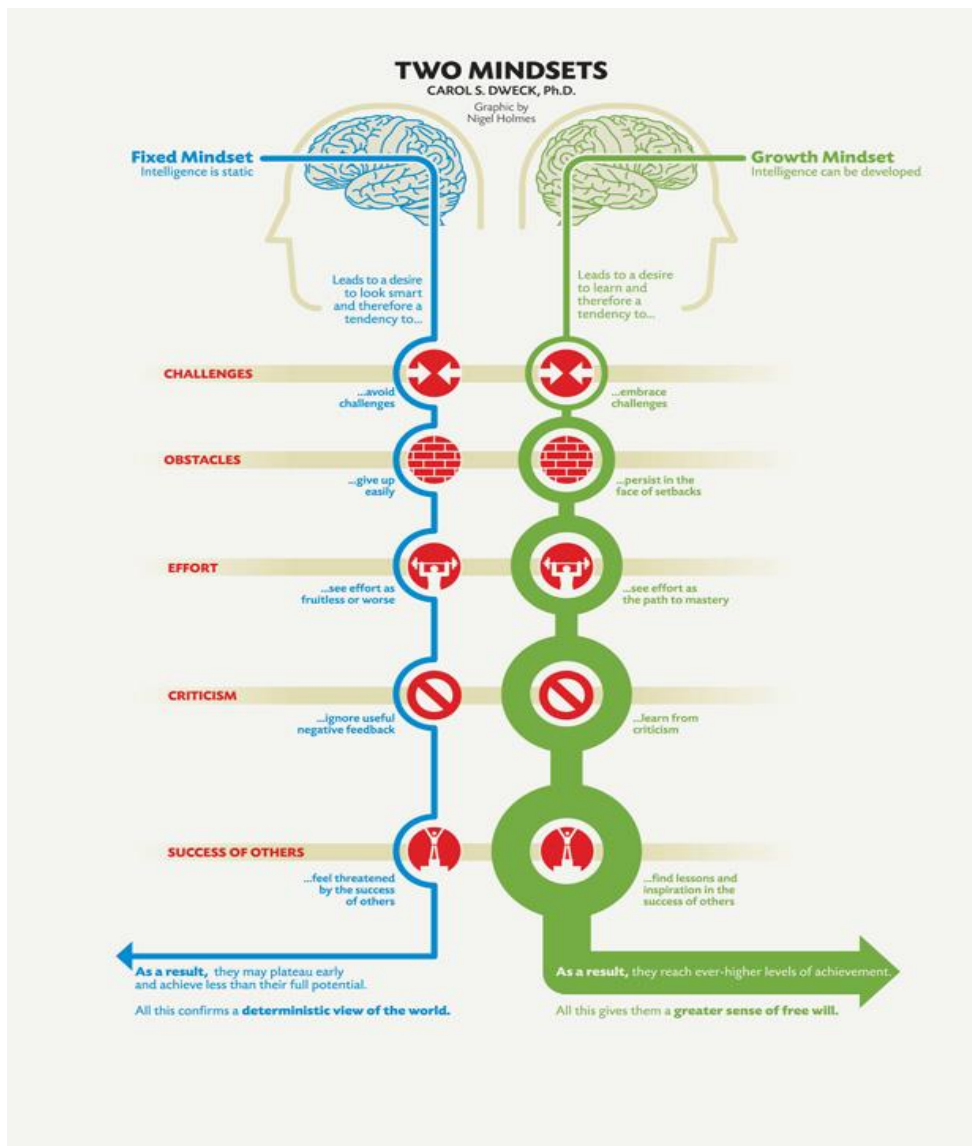


Figure 1. Illustration of the characteristics of fixed mindsets and growth mindset from Carol Dweck's "Mindset Works" organization (2006). Graphic by Nigel Holmes.

The most powerful assertion of this framework is that students can develop this growth-oriented perspective when they are presented with information and evidence that shows that intellectual abilities can be developed over time through hard work and practice (Dweck, 2006). Several studies attest to the positive impact that a growth mindset intervention can have on both

cultivating a growth-oriented perspective in students and a corresponding improvement in academic performance (Blackwell et al., 2007; Donohoe et al., 2012). One of the most popular and effective intervention programs is “Brainology,” which was developed by Carol Dweck (2012) through her Mindset Works Program. The main goal of this curriculum is to show students how their brain can become stronger with effort and practice through activities, interactive direct instruction, and sharing the results from brain science. Additionally, students are introduced to “healthy habits, study techniques, self-regulation strategies, and other essential non-cognitive skills that help them to become confident and effective learners.” By combining these actionable skills with the knowledge that intelligence and abilities can be improved through hard work and practice, the Brainology program helps students’ mindsets evolve towards a more growth-oriented, flexible worldview. This shift in mindset is also correlated with higher academic achievement levels in both the classroom and on standardized tests (Blackwell et al., 2007; Donohoe et al., 2012; Dweck, 2014; Jones et al., 2010).

Possessing a growth mindset is also correlated with a host of additional positive outcomes including enhanced motivation to take on challenges, improved self-efficacy, a more positive belief about effort and effort-based strategies in response to failure, and increased resilience in the face of setbacks (Bandura et al., 1996; Bedford, 2017; Blackwell et al., 2007; Donohoe et al., 2012; Dweck, 2006; Jones et al., 2010; Stipek & Gralinski, 1996; Yeager & Dweck, 2012; Yeager et al., 2016).

In one study conducted by Blackwell, Trzesniewski, and Dweck (2007), the researchers applied a growth mindset intervention treatment to middle school students in a math class. The researchers discovered that teaching a malleable theory of intelligence was successful in enhancing students’ motivation in math class and halted an achievement decline in the class.

Furthermore, when the researchers followed up with this same cohort of students two years later, they discovered that these growth-minded individuals still outperformed students who held a more entity theory of intelligence. The authors also found that student motivation was a mediating variable between mindset and achievement, which led them to conclude that when a student possessed an incremental theory of intelligence, that student also held more positive motivational beliefs, which related to improved academic performance. The authors further identified these reports of increased motivation based on evidence from teacher observations of students placing a heightened emphasis on effort and enhanced student interest in learning in other contexts.

To investigate the unique challenges of the science classroom, Bedford conducted a similar study in 2017. Many students identify themselves in binary terms about whether or not they are STEM students. Bedford points out that this often has to do with the fact that task value, or the personal importance of the content and skills in a particular class, has crucial repercussions with respect to student motivation in particular subjects. Frequently, students do not see the value in science concepts nor do they feel a connection to the topics being taught. As a result, motivation can decrease in science classes, especially as topics become more complex and abstract. However, Bedford discovered that a 10-week growth mindset intervention was successful in increasing the motivation of student learning in science. This finding shows the specific positive impact that cultivating a growth mindset ethos can have in the science classroom.

Another key aspect of the growth mindset is how it shapes the way that students react to academic setbacks. To investigate this, Nussbaum and Dweck conducted a study in 2008 that examined how students with fixed mindsets and growth mindset responded to setbacks. Students

were first randomly assigned articles that promoted either a growth or fixed worldview. They were then given a speed-reading task in which they were set up to fail. Upon receiving news of their failure, students were then asked to review four out of eight strategies from fictitious students in order to compare their personal performance to others who had completed the same task. Participants who read the fixed mindset article chose the approach of downward comparison and self-esteem repair. In other words, these individuals chose to build back their self-esteem by comparing their performance to those who did worse. Conversely, participants who read the growth mindset article selected a method of upward comparison and examined strategies connected to higher scores as a way to learn how to improve. In the two subsequent experiments in this study, this pattern repeated itself. Fixed mindset individuals responded in a defensive manner to failure and growth mindset individuals responded with tactics aimed at increasing their ability.

These findings have important implications for how middle school students can tackle tasks in school. Overall, even if a student possesses a fixed mindset/entity theory of intelligence they can be given information and taught strategies to help them shift to a growth mindset/incremental theory of intelligence. Studies show that possessing this growth mindset sets students up for a host of positive outcomes in the classroom, like increased motivation, productive responses to failure, and greater academic achievement. This mindset is beneficial across subjects and grades, but it can be especially beneficial in the middle school science classroom.

### The Importance of the Growth Mindset in the Science Classroom

The ideals of the growth mindset are highly compatible with the learning goals of the Next Generation Science Standards (NGSS). These are a series of science learning milestones that progress in step with student cognitive development over the course of their academic career developed by the National Research Council in 2013. The NGSS stresses scientific thinking, evaluation of evidence, and application of science skills as key goals for science learning rather than the rote memorization of facts and content heavy curricula from the past. Indeed, they represent a trajectory of learning where students aim towards mastery of skills and concepts over time, layering additional information and nuance as they progress through school. This mastery is earned through active learning, synthesis of data and content over time, and with effort.

Within the NGSS standards are the Science and Engineering Practices (SEP) and this aspect is particularly closely tied with the growth mindset. The SEP are a series of eight statements that represent skills and habits that students will need to implement in order to become fully scientifically literate citizens. The NGSS (Lead States, 2013) points out the primacy of these practices when they say,

students should not only ‘know’ science concepts; but also, students should use their understanding to investigate the natural world through the practices of science inquiry, or solve meaningful problems through the practices of engineering design....The Framework uses the term “practices,” rather than “science processes” or “inquiry” skills for a specific reason: We use the term “practices” instead of a term such as “skills” to emphasize that engaging in scientific investigation requires not only skill but also knowledge that is specific to each practice. (p. 1).

As students move through their grade levels, they engage with each practice as it simultaneously “grows in complexity and sophistication across the grades” (Lead States, 2013, n.p.). This mirrors the growth mindset process of increased capacity with effort and time. Rather than expecting students to grasp and memorize all aspects of the SEP in one shot, the NGSS has created a developmentally appropriate timeline where students are able to cultivate their facility

with these practices and apply this understanding to comprehend concepts and, as a result, engage more deeply in the process of doing science.

Moreover, another significant growth-oriented component of the NGSS is its emphasis on ensuring student understanding of the Nature of Science (NOS). NGSS clearly states that,

science is the pursuit of explanations of the natural world, and technology and engineering are means of accommodating human needs, intellectual curiosity, and aspirations. One fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge. Indeed, the only consistent characteristic of scientific knowledge across the disciplines is that scientific knowledge itself is open to revision in light of new evidence (Lead States, 2013, p. 2).

Science and engineering as disciplines are both growth-oriented fields in the way that they rely on new information and novel ideas to amend and improve theories and designs. A more fixed perspective would mean that scientists and engineers become entrenched in outdated notions, refuse to acknowledge innovations, or accept new information. As a result, our society would suffer. The NOS is an epossible model for the growth mindset, because it represents tangible evidence of the powerful, positive impact that such a framework can have on solving problems in the real world.

### Design Thinking in the Science Classroom

There are many methods employed to teach these aforementioned science skills, but the process of design thinking is one of the most effective ways for students to engage with the Science and Engineering Practices, the Nature of Science, and the growth mindset in the science classroom. In essence, design thinking is a human-centered process of creative problem solving that asks students to develop innovative ideas, integrate the needs of people, and utilize the possibilities of technology. (IDEO U, 2021; Yeager *et al.*, 2016). It can be represented by a cycle of five steps – Understand, Define, Imagine, Prototype, and Try as shown in Figure 2 below.

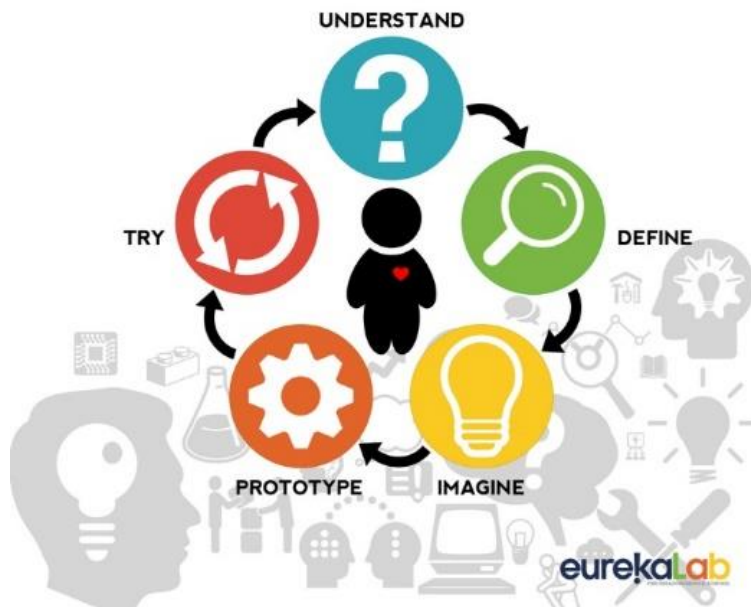


Figure 2. Design thinking process steps from the Meadowbrook School of Weston located in Weston, MA.

In the first step, Understand, problem solvers begin by interviewing stakeholders and conducting research in order to comprehend the full scope of a problem. From here, students move on to the Define phase, where they utilize the information from the Understand phase to identify the particular needs of the user and specific aspects of the problem that they are trying to solve. Next, they progress to the Imagine Phase where they brainstorm as many solutions as possible. They then rapidly prototype a subset of their ideas or designs in the fourth phase, Prototype. Finally, students present the prototypes of their initial solutions to the user in the Try phase and they receive feedback on their designs. Based on the guidance from these feedback sessions, students might return to any point in the cycle in order to improve their solutions to better meet the needs of their user (Meadowbrook School, 2017).

The concrete skills that are employed to solve these problems can be found in the SEP. The iterative nature of design thinking activities helps connect this framework to the NOS as

well as the growth mindset. One study conducted by Lilly, McAlister, Fick, Chiu, and McElhaney in 2022 helped connect the dots between the SEP and engaging in design challenges. They explored how students can be supported in their progress toward mastery on the SEP's by engaging in a design challenge to reduce their school's water runoff. In this design thinking project, students were asked to execute many of the SEP's, such as computational thinking, engineering, and model making in order to find success on this assignment. This study reported successful techniques to support student achievement across the SEP's through this design-based assignment.

### Design Thinking and the Growth Mindset

The design thinking process helps students understand and practice applying feedback as it was originally intended to be used in the classroom. Research into effective feedback has identified that the goal of feedback is to give targeted instructions to help students become aware of their own abilities in class and then turn that awareness into productive action to grow their scholastic capacity. Growth minded individuals tend to welcome feedback and use the information to continue to develop their abilities. Fixed mindset individuals, on the other hand, tend to become defensive and perceive the feedback as a threat or judgment about their intelligence (Forsythe & Johnson, 2017). This framing means that fixed mindset individuals are less able to access the helpful information contained in the feedback and lose out on the opportunity to progress in their abilities. The process of design thinking puts this feedback framework into practice in the way that it asks students to continually seek comments on their ideas and designs through testing and interviews. It then offers a clear demonstration of the positive effect that applying targeted feedback to ideas can have by supporting students as they develop effective solutions.

Moreover, feedback can also help bolster another aspect of the growth mindset, which is the way that students respond to setbacks. Students with fixed mindsets often demonstrate a helpless response to setbacks. Here, they view their failure as a measure of their innate ability and conclude that they are not smart or capable in a particular task. This is coupled with lowered expectations for what they can achieve as well as a negative affect. Conversely, students with a growth mindset display a mastery-oriented response to setbacks in which they re-evaluate on their chosen strategy, keep the expectations that they set for themselves, maintain a positive attitude, and continue to work to overcome the challenge (Kamins & Dweck, 1999).

Viewing effort as a key to success is a hallmark of the growth mindset whereas those with fixed mindsets view effort as evidence of deficiency in ability rather than a tool to deeper understanding and greater achievement (Blackwell et al., 2007; Donohoe et al., 2012). Design thinking helps reinforce this connection, because it provides students the chance to practice receiving and implementing feedback, which results in their ability to develop a successful solution to a problem. Design thinking helps students see the clear line between the value of effort in the science classroom and achievement in the form of an effective solution. This experience reinforces a mastery-oriented response to setbacks, which promotes the development of a growth mindset.

Indeed, setbacks abound and are encouraged in the process of design thinking. The emphasis on rapid testing and prototyping ideas sets students up to discover errors in their thinking or barriers to success early on in the problem-solving process, so that they are well equipped to develop ways to overcome these obstacles and achieve their ultimate goal. Another key design thinking component that supports the development of a growth mindset is that it encourages risk taking despite the possibility of failure and setbacks. The classroom should feel both safe enough for students to take a chance with a new idea and challenging enough to push students so that they have to think outside the box and take risks (Ingram, 2017). Design challenges are excellent opportunities for practicing the skills associated with risk taking in the growth mindset.

Further, design challenges are authentic tasks in which students must collaborate to solve an engineering problem or develop a solution to a real-world issue. This type of assignment has high task value for students, which encourages deeper student engagement (Bedford, 2017; Eccles & Wigfield, 1995). These are also tasks that present complex problems that require

multifaceted solutions, which will help ensure that my classroom is challenging enough to push students to take risks. Finally, the iterative nature of design challenges helps to break down the notion that some people are better at science than others. Not only does iteration allow students to make many mistakes and learn from these mistakes in order to improve their design, but it also takes away the belief that some students must be intrinsically good or intrinsically bad at science and engineering (Oshin et al., 2021). This will help tackle the unique binary thinking about student abilities in STEM classrooms in both directions – relieving pressure from students who feel that they should always “be good” at science and reducing anxiety for students who feel that they are “not good” at science.

### Conclusion

The skills associated with design thinking and the experience of design challenges all work to promote growth-oriented perspective and habits of mind in the science classroom. Specifically, design thinking can bolster a mastery-oriented response to setbacks and a productive acceptance and implementation of feedback. All of which mirror the Nature of Science and trajectory of Science and Engineering Practices outlined in the NGSS.

## METHODOLOGY

### Overview

The purpose of my action research project was to investigate the possibility of a connection between the development of a growth mindset in eighth grade science students and design thinking instruction. Significant amounts of research demonstrate the benefit of developing a growth mindset on adolescent academic performance and confidence. Further, evolution of growth-oriented worldviews is directly linked to twenty-first century skills. Design thinking is a key skill that I teach in my classroom and it seems that the problem-solving strategies within the system of design thinking mirror the important qualities of a growth mindset. As a result, my focus research question aimed to assess whether there was a connection between these two frameworks in my classroom. Additionally, I considered the direction of the connection between mindsets and design thinking skills – did learning and practicing design thinking skills impact a student’s mindset or was it the initial mindset that impacted how students implemented design thinking skills?

### Participants and School Description

The study involved all four of my grade eight sections, three of which had 17 participating students and one had 16 participating students. There were a total of 26 biological males and 41 biological females in my classes. Thirty-four of my students identified as students of color and 33 of my students identified as white. Among all of these classes there were six students who received support for a variety of learning challenges. All experimental students were between the ages of 13 and 15 years. Additionally, there were two control classes of grade eight students, one class of 18 and one class of 17, who did not receive design thinking

instruction during their units on density and buoyancy. Of these control students, there were 20 biological females, 15 biological males. Twenty-five students identified as students of color and eight students identified as white. All control students were between the ages of 13 and 15 years and three students received support for learning differences.

Participation in my data collection methods was optional for all of these students. From my science sections that received instruction in design thinking skills, 47 students chose to participate in data collection. Of these students, 17 were biological males and 30 were biological females. Additionally, 27 students identified as students of color and 20 identified as white and all students in the experimental group were between the ages of 13 and 15 years. Eight students in my colleague's class, the control group, volunteered to participate in my data collection. Of these students, seven were biological females and one was a biological male. Four students identified as students of color, four students identified as white, and all students were between the ages of 13 and 15 years. Two students in the control group received support for learning differences.

Cary Academy is an independent school located in Cary, North Carolina. The school is divided into a middle school (grades 6-8) and an upper school (grades 9-12). There are 785 students in total at the school and there is a 9:1 student to teacher ratio. The middle school science curriculum weaves concepts from biology, chemistry, physics, geology, ecology and incorporates sustainability themes throughout each grade level. The title of my eighth grade curriculum this year was "The Water Planet" and we examined water through the lens of chemistry, physics, life science, ecology, and human anatomy throughout the year.

I have been teaching middle school science for the past 12 years at independent schools in New England and now, in North Carolina. I have taught life science, physical science, and

Earth science topics as well as implemented direct instruction in the Science and Engineering Practices outlined in the NGSS. To support my knowledge of design thinking I have attended multiple conferences to hone my skills in instructing this content through the Nueva School in California, the MIT Edgerton Center in Massachusetts, and District C in North Carolina. I have also had the opportunity to participate in a year-long, one-on-one coaching relationship with the Design Thinking and Project Based Learning Coordinator at my former school in Boston, MA. Additionally, I have four years of experience delivering Carol Dweck's Brainology Curriculum to seventh grade students and guiding my students as they work to cultivate their own, unique levels of growth mindset through lessons, reflection activities, and long-term projects. All of these experiences have set me up to create and run this design thinking curriculum and evaluate student levels of growth mindset.

### Treatments

In order to investigate the research questions, a four-week series of lessons about design thinking, density, and buoyancy, was implemented in the experimental group. The control group of students reviewed the same science content, but did not receive instruction or practice in design thinking skills. Additionally, while the control group did complete two projects about density and buoyancy, these were more traditional, guided inquiries about the topics rather than design-based challenges. The research methodology for this project received an exemption by Montana State University's Instructional Review Board and compliance for working with human subjects was maintained (Appendix A).

The action research was conducted from the second week of January 2022 to the second week of February 2022. To plan and develop this lesson series, I collaborated with Sue Fisher, a

former colleague from the Meadowbrook School in Weston, MA. Sue is the Eureka Lab Coach and is a specialist in design thinking and project based learning. Sue's expertise in design thinking and science education was invaluable as we worked together during the fall and winter to create this four-week unit. She helped me develop the introductory design thinking lesson as well as coached me as I incorporated the major themes from density and buoyancy into the subsequent design thinking projects.

To begin, students in the experimental group received direct instruction in the steps of design thinking, heard stories about real-world examples of each step of the design thinking cycle, participated in two mini-design challenges, and watched a TED Talk on the power of design thinking (Appendix B). Following this, students combined their newly acquired design thinking skills with their understanding of density in the Density Curiosity Project (Appendix C). In this assignment, students were challenged to design an original investigation into a topic connected to density about which they were curious. For example, students assessed the ingredients and relative densities of popular sodas and sports drinks and how increased salinity impacted the movement of water in wind driven currents. Students used design thinking skills and their understanding of density to prototype procedures and iterate on their experimental designs to develop a reliable test. Students reported their findings and reflected on the effectiveness of their procedures in a slideshow format. The intended audience for these presentations was next year's eighth grade students. The goal of this was to ensure that these future eighth graders could learn from this collected knowledge and advance the research into these curiosity topics.

The eighth grade students in the experimental group then learned about forces and buoyancy through hands-on inquiry and mini-lectures. This led to the culminating project for this

unit – The Platform Project (Appendix D). In this assignment, students worked to understand the current state of our supply chain crisis and the traffic jam of containers and cargo ships at our nation’s ports. Students then identified a stakeholder connected to this problem and collaborated to design a floating storage platform to support the needs of their stakeholder. For example, students selected small business owners as their stakeholder and designed small, moveable platforms that could dock next to ships and hold the cargo containers specific to the small businesses. Another example was in service of truck drivers and students designed floating barges to ferry trucks with empty chassis to the ships so that cargo could be loaded directly onto the trucks. Table 1 summarizes the treatment timeline for my class.

Table 1. Treatment timeline.

Treatment Name	Goals	Treatment Description	Time
Introduction to Design Thinking	<ul style="list-style-type: none"> <li>• Introduce students to design thinking</li> <li>• Provide students with real world examples of design thinking in action</li> <li>• Give students the opportunity to practice design thinking skills</li> <li>• Offer reflection time for students to process this new information</li> </ul>	<ul style="list-style-type: none"> <li>• Students received direct instruction about Design Thinking and Design Thinking Skills through a presentation that outlined the steps of the Design Cycle, defined the skills, and shared real-world stories about organizations and individuals that used the skills effectively.</li> <li>• Students engaged in the Build a House mini-design challenge as a way to practice building empathy with their user.</li> <li>• Students participated in the Spaghetti-Marshmallow Tower Challenge as a way to practice prototyping and iterating.</li> <li>• Students watched Tom Wujec's TED Talk about the Spaghetti-Marshmallow Tower Challenge.</li> <li>• Students engaged in a debriefing conversation at the conclusion of this lesson.</li> </ul>	One, 75 minute class period
Density Curiosity Project	<ul style="list-style-type: none"> <li>• Apply design thinking skills to a content area</li> <li>• Practice iteration and prototyping</li> <li>• Work to consider the needs of the user when designing a final product</li> <li>• Reflect on their progress and understanding of design thinking skills</li> </ul>	<ul style="list-style-type: none"> <li>• Students worked in groups to design and run original investigations about the density of a substance of their choosing.</li> <li>• Students reported their findings so that next year's eighth graders can continue the original research.</li> <li>• Students engaged in personal reflections about their use and confidence in implementing design thinking skills.</li> </ul>	Three, 75 minute class periods
Storage Platform Project	<ul style="list-style-type: none"> <li>• Practice all steps of the design cycle</li> <li>• Engage in research to understand the needs of a user</li> </ul>	<ul style="list-style-type: none"> <li>• Students worked to understand the traffic jam taking place at our nation's shipping ports.</li> <li>• Students identified a stakeholder connected to the problem for whom they could work to develop a solution.</li> <li>• Students designed, tested, and iterated floating storage devices created specifically to serve the needs of their user.</li> </ul>	Three, 75 minute class periods

### Instruments

To assess each component of this project, I utilized four main lines of evidence – the Mindset Assessment Tool, student interviews, student self-reflections, and teacher observations. The data collection instruments used to assess these areas were elected to establish credibility,

validity, and reliability in my investigation. Several of these strategies were modeled after earlier studies (Bedford, 2017; Blackwell et al., 2007; Donohoe et al., 2012; Dweck, 2014) as well as design thinking based organizations (Stanford D. School, The Nueva Design School, and IDEO). Further, these instruments allowed me to capture data from a variety of perspectives and time periods throughout this study. Table 2 summarizes my data collection methodologies.

Table 2. Data triangulation matrix

Research Question	Data Sources		
	1	2	3
Does instruction in design thinking strategies increase the level of growth mindset in eighth grade science students?	Mindset Assessment Tool	Design Thinking Behaviors Rubric	Interview Responses
How does the initial mindset impact student display of design thinking behaviors during novel problem solving?	Mindset Assessment Tool	Design Thinking Behaviors Rubric	Reflection Responses

#### Data Collection Instruments - Mindset Assessment Tool and Student Interviews

A modified Mindset Assessment Tool (MAT) (Appendix E) was used to evaluate both of my research questions. This tool was based on Carol Dweck’s 2012 “Mindset Assessment Profile Tool” and the “Patterns of Adaptive Learning Scales (PALS)” implemented by Midgley et al. (2000). This Likert Scale survey assessed students’ level of growth mindset by measuring students’ rating from *Strongly Disagree* to *Strongly Agree* in response to 20 different statements. The MAT was implemented before the design thinking lesson, in order to assess baseline levels of growth versus fixed mindsets in my students, and then administered again at the conclusion of the design thinking project in order to determine whether there was a change in the mindset of my students. The MAT was administered via Google Forms and responses were exported and organized into an Excel File. This survey was optional for my students. Forty-seven students in the experimental group and eight students in the control group participated in the surveys.

Upon collecting the data, students' scores were tallied on a scale of 0 – 90 and each child was sorted into a mindset category based on this score. The highest level of growth mindset was the Strong Growth Mindset (SGM) category and it contained students who scored 68-90 on their MAT. The next category was called Growth Mindset with Fixed Ideas (GMFI) where students who scored 46-67 on their MAT were placed. The third category was the Fixed Mindset with Growth Ideas (FMGI) and it contained students who scored 23-45 on their MAT. The category with the lowest level of growth mindset was the Strong Fixed Mindset (SFM) and students in this group scored 0-22 on the MAT. The results from both the pre- and post-MAT were analyzed through box plots and bar graphs in order to show the change in both MAT score as well as mindset category for both the individual students and between the experimental and control groups over the course of this four-week design thinking curriculum. Additionally, I ran descriptive statistics (mean, median, mode, and quartiles) on the data sets in order to identify trends between the control group and experimental group as well as between individual student's pre- and post-treatment scores. Further, a one-tailed, two sample t-test was run in order to compare the means of the control and experimental groups and assess the significance of the difference between the raw scores of these two groups.

Following both pre- and post-MAT implementations, I conducted interviews with 13 student volunteers. Eleven of these students were in my experimental group and two were in the control group. Nine students were biological females and four were biological males. One student received support for a learning difference. Seven of these volunteer students identified as students of color and six of the volunteer students identified as white. The goal of these student interviews was to gain additional understanding about student motivations, perspectives, and experiences that could have informed their ratings on the MAT. This layer of nuance was used to

help me identify common themes in my students' experiences and provided insight into their results on the MAT as well as their mindset category designations. Students elected to participate in these 15-minute interviews that took place during morning break and study hall periods. I used a standard set of six questions during the first round of interviews following the delivery of the pre-treatment MAT (Appendix F). These standardized questions were selected to address different statements on the MAT that inquired about students' level of growth versus fixed perspective on a person's abilities and a person's innate characteristics.

During the second round of interviews after the post-treatment MAT, I asked students to elaborate on questions where their rating changed, plus five standardized questions about design thinking (Appendix F). The questions about MAT ratings asked students to talk about why they think their rating changed and how they felt about each of these MAT statements. The design thinking questions asked about students' understanding of design thinking, connections between a different class or their life outside of school and design thinking, and their level of enjoyment and confidence with design thinking in science class.

Student responses to questions were captured on Excel spreadsheets and sorted into pre- and post-treatment MAT administration tabs. Then, each student's pre- and post-treatment MAT score plus their change in MAT score was added to the spreadsheet. This allowed me to compare specific responses to questions between the experimental group and the control group, between mindset categories, and between changes in MAT scores - whether students' MAT scores increased, decreased, or stayed the same. The quotes were used in the Data and Analysis section and attached to specific results as a way to underscore the evidence and put the numbers into context. Furthermore, quotes were also used in the Claim Evidence and Reasoning section to bolster claims and ground the numeric conclusions in student experiences.

### Data Collection Instruments – Self Reflection

At the conclusion of the Density Curiosity Project, students were asked to reflect in their journals about their overall level of confidence with design thinking and then to identify which specific steps of the design thinking process they felt most and least confident about. Students rated their confidence on a scale of 1 (not at all confident) to 5 (super confident) and then wrote a sentence explaining each rating. To analyze these results, I matched their overall confidence ratings as well as the confidence ratings connected to each step in the design thinking cycle with each student's pre-treatment mindset category in order to look for patterns between their initial level of growth mindset and facility with particular aspects of the design thinking cycle.

### Data Collection – Design Thinking Behaviors Rubric

The Design Thinking Behaviors Rubric instrument (Appendix G) was based on the Stanford D.School Design Thinking Rubric and developed in collaboration with the Dean of Faculty, Martina Green, at Cary Academy. It listed a series of behaviors that could be observed when students were engaged in design thinking challenges. The observed behaviors were broken down into 4 categories that described the students' behaviors at the start of the work block and at the end of the work block. Students were first coded on whether they exhibited "Define" behaviors or "Imagine" behaviors at the beginning of the work block. If students showed "Define" behaviors, then they quickly came to consensus around their stakeholder, their design for their platform, and their strategy to build their prototype. If students showed "Imagine" behaviors, then they spent a longer time discussing ideas about who their stakeholder should be, contemplating the design for their prototype, and considering their building strategy.

Once students began building their platforms later in the work block, their behaviors were coded as either “Prototype” or “Try” behaviors. Students who were coded with “Prototype” behaviors were ones who spent time carefully constructing a single prototype and then tested their design once their platform was fully built. On the other hand, students who showed “Try” behaviors were those who tested their platforms frequently and iterated the structure of their design based on these tests. The observer watched for behaviors and then tallied each instance that a behavior was observed. Additionally, in order to assess whether students could perform the “Understand” phase, the observer asked each group if they could explain how their platform design supported the needs of their stakeholder. Furthermore, she also wrote down qualitative observations while students were working.

This rubric was used during Day Two of the Platform Project when students were engaged in defining their problem and building and testing their platforms. During this class, Martina Green observed each of my four sections of eighth graders for 30 minutes to assess their demonstrated design thinking skills. She then totaled up the tallies and wrote up specific observations of each class section. To analyze these results, I assessed the frequency that each behavior was observed on the rubric. Additionally, I matched the written observations about behaviors with each student and then looked for patterns between the initial mindset category and the observed design thinking skills. The results were analyzed through a bar graph to compare behaviors and mindset categories.

### Conclusion

The data collection methods outlined in this section provided a multifaceted approach to analyzing my results. I was able to incorporate conversations with students, observations from a

veteran teacher, student personal reflections, and vetted assessment tools. I also examined student facility with design thinking and their growth mindset status at different points in time and collaborated with two faculty mentors as I worked to analyze my findings. These data allowed me to effectively respond to each research question in order to examine possible connections between the growth mindset and design thinking in my eighth grade science students.

## DATA AND ANALYSIS

### Results

My primary research question was - Does instruction in design thinking strategies increase the level of growth mindset in eighth grade science students? To investigate this question, I administered a pre-treatment Mindset Assessment Tool (MAT) Survey that categorized each student's level of growth mindset. Students in the experimental group then experienced a four-week unit on density and buoyancy that was based in design thinking. Students in the control group also received a four-week unit on density and buoyancy, but did not engage in design thinking instruction. Following the conclusion of this unit, a post-treatment MAT was administered to all students and changes in MAT score and mindset category were assessed.

My second research question was - How does the initial mindset impact student display of design thinking behaviors during novel problem solving? To assess this question, I compared student's initial mindset category to their self-reported confidence in design thinking skills following their first design challenge. I also compared this same mindset category to the results from the Design Thinking Behaviors Rubric which was utilized during the second design challenge. These comparisons were made in order to see if there was a pattern between the baseline level of growth mindset possessed by a student and display of specific design thinking skills and confidence.

Research Question1: Does instruction in design thinking strategies increase the level of growth mindset in eighth grade science students?

Change in MAT Score for the Experimental and Control Groups. To answer my main research question, I evaluated the results of pre-treatment and post-treatment MAT scores for individual students and compared the results between the control and experimental groups using descriptive statistics. These results indicated that students in the experimental group, who participated in the design thinking curriculum, experienced both an overall positive increase in their individual mindset scores and a larger, positive increase than the control group.

The average score on the MAT for the experimental group during the pre-treatment MAT was 68.33 and the average score for the control group was 69.25 (Table 3). Both scores place the average for each cohort of students into the Strong Growth Mindset (SGM) category, which is the highest level of growth mindset, with the control group having a slightly higher average score. When examining the data on a box plot, we can see that the boxes are both overlapping and similar in size (Figure 3). We can also note that the control group has a slightly higher median score (72) as compared to the experimental group (68). This indicates similar variability in the pre-treatment scores of the control and experimental groups. It is therefore reasonable to conclude that there are not large differences in the baseline levels of mindsets of the two groups.

Table 3. Descriptive statistics of pre-treatment and post-treatment mindset assessment tool scores for experimental ( $n=47$ ) and control groups ( $n=8$ ).

	Mean Score	Minimum Score	First Quartile	Median Score	Third Quartile	Maximum Score
Pre-treatment Experimental Group ( $N=47$ )	68.33	44	64	68	73.25	84
Post-treatment Experimental Group ( $N=47$ )	71.19	45	66	71.5	78.25	88
Pre-treatment Control Group ( $N=8$ )	69.25	54	67.75	72	74.25	78
Post-treatment Control Group ( $N=8$ )	67.5	44	63	69	74.75	81

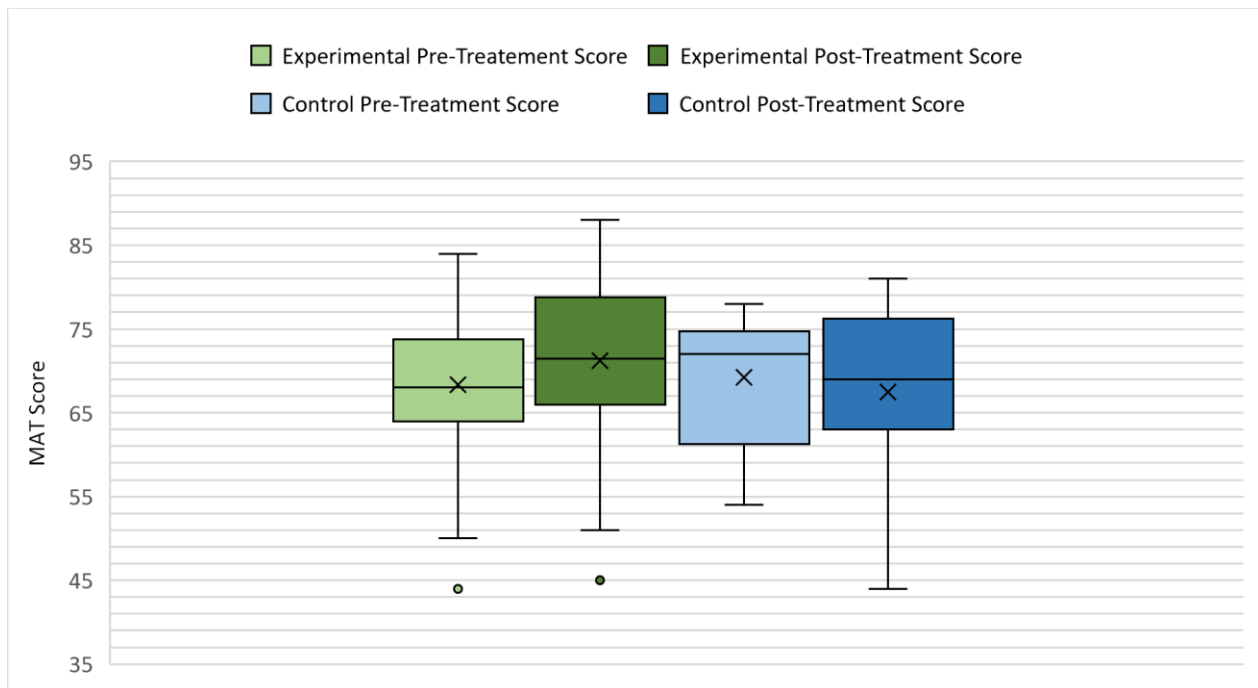


Figure 3. Pre-treatment and post-treatment mindset assessment tool scores for experimental ( $n=47$ ) and control groups ( $n=8$ ).

At the conclusion of the treatment, the average score for the experimental group increased by 2.86 points to a value of 71.19. On the other hand, the control group's average score decreased by 1.75 points to a value of 67.5. In this case, the experimental group's average

remained in the SGM category, but the control group's average slipped into the Growth Mindset with Fixed Ideas (GMFI) category, which is the second highest level of growth mindset.

In looking over this graph, we can also see that the median for the experimental group increased from 68 to 71.5, which indicated an overall increase in the MAT scores for the experimental group between the pre-treatment and post-treatment administration of the MAT. Conversely, the median for the control group decreased from 69.25 to 67.5, which represented an overall decrease in the MAT scores for the control group between the pre-treatment and post-treatment administration of the MAT. Further, there appeared to be more variation in the post-treatment MAT scores for the control group as the box for the post-treatment scores for the control group is larger than the box representing the post-treatment scores for the experimental group. These data suggested that the treatment can have the effect of increasing the level of growth mindset of eighth grade science students.

If we compare the change in MAT scores between the control and treatment groups from pre-to post-MAT administration, we can observe that 75% of students in the experimental group experienced a positive increase in their mindset score after engaging in design thinking skills (Figure 4). On the contrary, the results for the control group are less consistently positive. Fifty percent of the students in the control group experienced a decline in their mindset score whereas the other fifty percent of students experienced an increase in their mindset score.

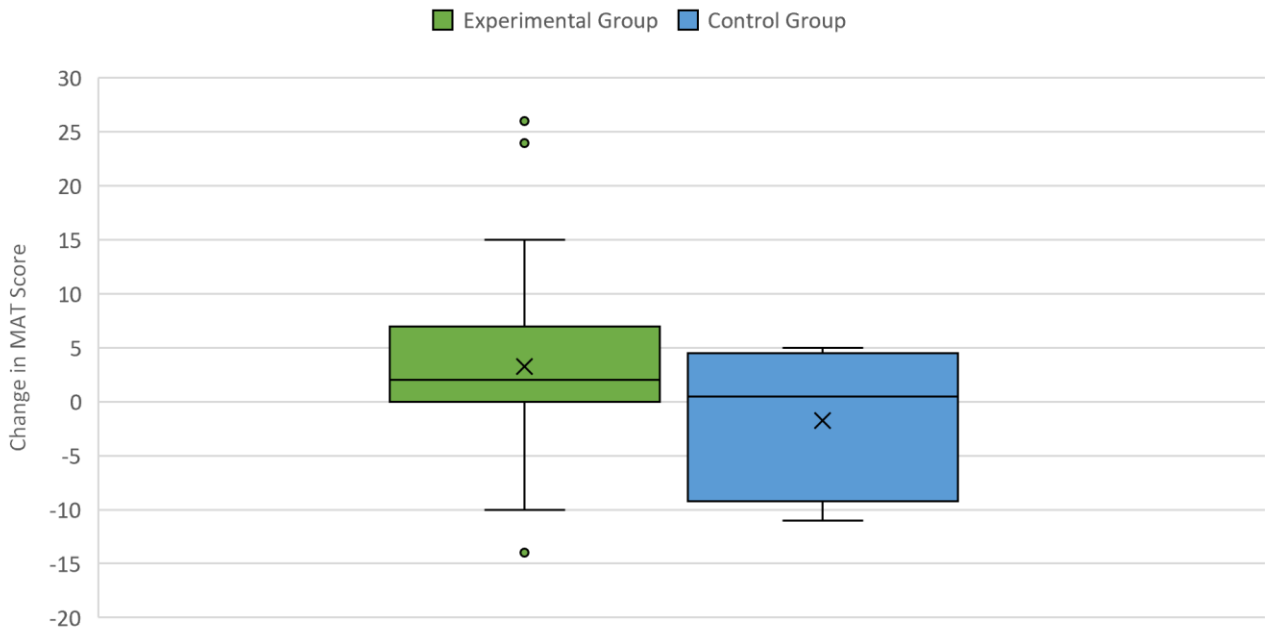


Figure 4. Change in mindset assessment tool score distributions for the experimental group ( $n=47$ ) and control group ( $n=8$ ).

A single tailed, two sample mean t-test was also run on this change data. The t statistic was -1.49 and the p value was 0.042, which indicated a significant difference in the pre- and post-treatment change scores of the experimental group as compared to the control group. Taken together, the spread of the data and the t-test results are additional evidence to bolster the claim that the treatment had a positive impact on increasing the mindset scores of eighth grade students.

Change in Mindset Category Designation. The score that a student earned on the MAT correlated with a specific mindset category. A higher score on the MAT represented a stronger level of growth mindset whereas a lower score on the MAT represented a more fixed mindset. Students who earned 68-90 points were placed into the Strong Growth Mindset Category (SGM), which was the highest level of growth mindset. The next mindset grouping contained students

who scored 46-67 points in the Growth Mindset with Fixed Ideas (GMFI) category. If students earned 23-45 points, they were placed into the Fixed Mindset with Growth Ideas (FMGI) category. Finally, if students scored 0-22 points, they were placed into the Strong Fixed Mindset (SFM) category. The results from the pre-treatment and post-treatment MAT administrations for the control and experimental groups are described in Table 4 and Figure 5.

Table 4. Pre-treatment and post-treatment mindset category distribution for experimental and control groups

	Strong Growth Mindset (Score Range 90-68)	Growth Mindset with Fixed Ideas (Score Range 67-46)	Fixed Mindset with Growth Ideas (Score Range 45-23)	Strong Fixed Mindset (Score Range 22-0)
Pre-treatment Experimental Group ( <i>n</i> =47)	26 (55%)	20 (43%)	1 (2%)	0 (0%)
Post-treatment Experimental Group ( <i>n</i> =47)	34 (72%)	12 (26%)	1 (2%)	0 (0%)
Pre-treatment Control Group ( <i>n</i> =8)	6 (75%)	2 (25%)	0 (0%)	0 (0%)
Post-treatment Control Group ( <i>n</i> =8)	4 (50%)	3 (37.5%)	1 (12.5%)	0 (0%)

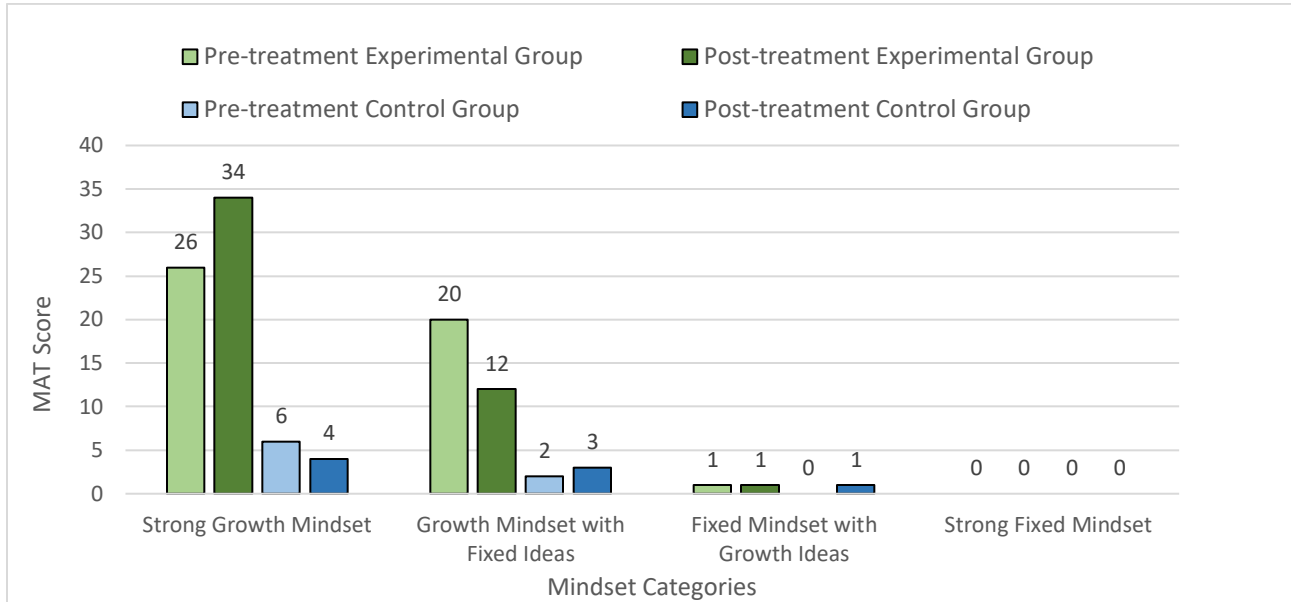


Figure 5. Change in mindset category designation for the experimental ( $n=47$ ) and control groups ( $n=8$ ).

In looking across student data, we first observe that no students in the experimental or control group earned scores to place them in the SFM category. Additionally, only one student in the experimental group was in the FMGI category based on their pre-treatment MAT score. The majority of students in the control and experimental groups were in SGM and GMFI categories for both the pre-treatment and post-treatment administrations of the MAT.

The experimental group ( $n=47$ ) showed a 30% increase in students scoring in the SGM category between the pre- and post-treatment administrations of the MAT. This change in SGM resulted in a 40% decrease in students scoring in the GMFI category, because students increased their score so much that they moved out of this lower mindset category designation. These data represented a positive shift towards a stronger level of growth mindset in the experimental group. There was no change in the number of students who scored FMGI in the experimental group.

Conversely, in the Control Group ( $n=8$ ), there was a 33% decrease in students who scored SGM, a 50% increase in students who scored GMFI, and a 100% increase in students who

scored FMGI. These data represented mixed results in how students changed in their mindset categories for the control group. The fact that we did not see a clear pattern in the control group, but saw a clear, positive change of students moving from GMFI to the higher level of mindset category of SGM underscores the same takeaways from the examination of the MAT score change between the control and experimental groups – the data indicated a positive connection between design thinking instruction and the development of a growth mindset.

The next layer of analysis examined the direction of change in student’s MAT scores within their mindset category designations (Figure 6). Here, students were organized into their initial mindset category based pre-treatment MAT score and the change (increase, no change, decrease) in student’s MAT score during the post-treatment implementation was assessed.

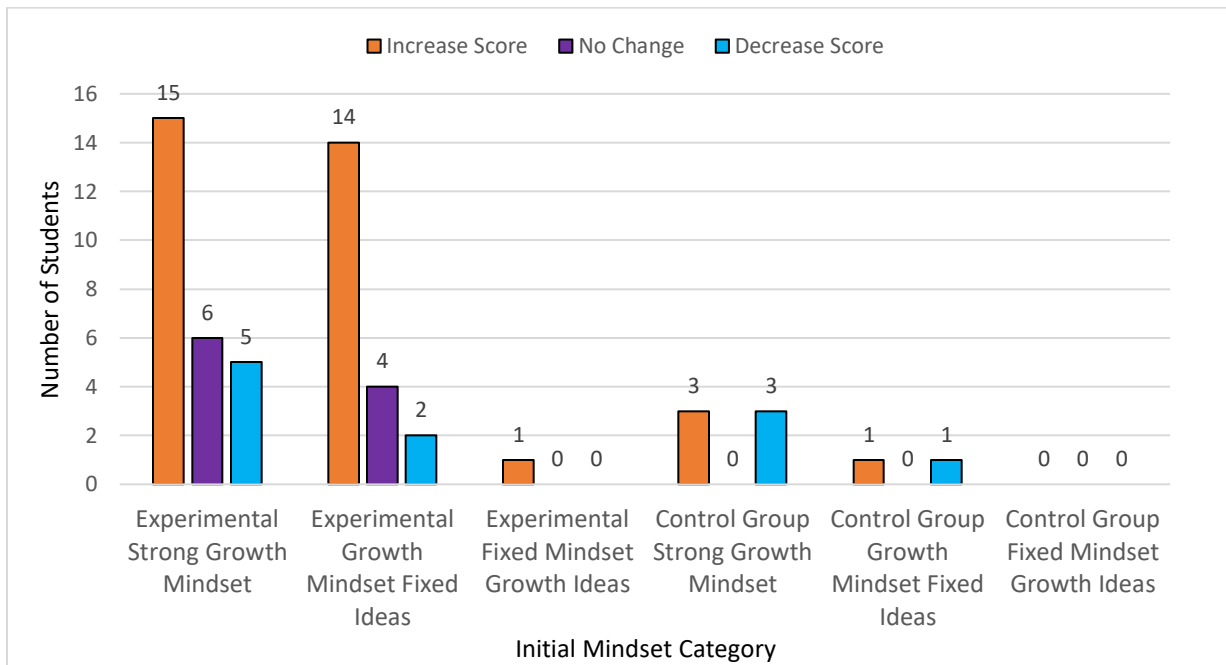


Figure 6. Comparison of change in mindset assessment tool score based on the pre-treatment mindset category for the experimental ( $n=47$ ) and control groups ( $n=8$ ).

In the experimental group, we can see that the majority of students increased their MAT scores in all mindset categories. Fifty-seven percent of students with an initial SGM valuation

increased their score, 23% SGM students experienced no change in their score, and 19% of SGM students decreased their score. In the experimental GMFI category, 70% of students increased their score, 20% of GMFI students experienced no change in their score, and 10% of GMFI students showed a decrease in their score. The single student in the FMGI category increased their score as well.

In the control group SGM category, 50% of the students increased their score, 0% of the students experienced no change in their score, and 50% of the SGM student decreased their score. The same pattern repeated itself for control students in the GMFI category – 50% increased their score, 0% experienced no change in their score, and 50% decreased their score. It was clear that a higher percentage of students in the experimental group experienced a positive change in their MAT score than the control group regardless of mindset category designation. These results bolster the claim that there seems to be a positive connection between experiencing design thinking skills and the development of a growth mindset.

An examination of the magnitude of the previously described changes in MAT score for students based on their initial mindset category designation provides more nuanced information about how students' mindsets were impacted by design thinking instruction (Figure 7).

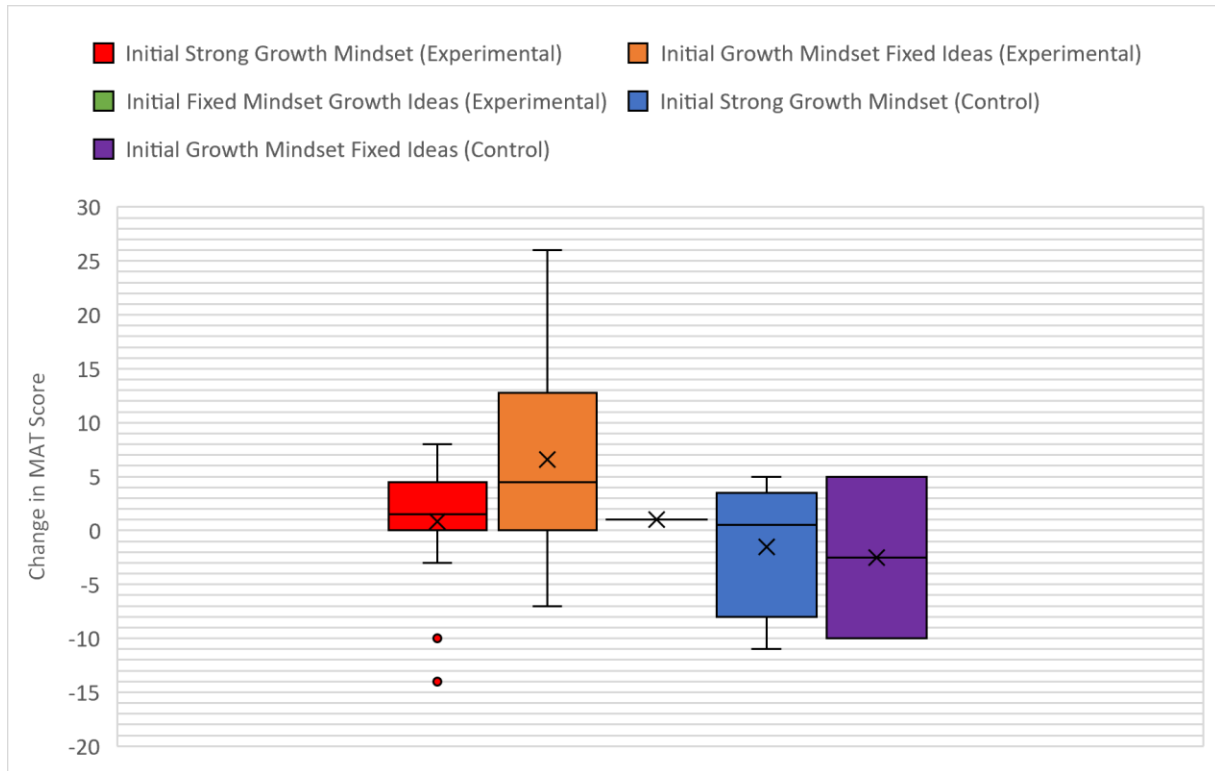


Figure 7. Magnitude of change in mindset assessment tool score within pre-treatment mindset category designations for experimental ( $n=47$ ) and control groups ( $n=8$ ).

In the experimental group, the median score change for eighth graders in the SGM category was an increase of 0.52 points, the median score change for students in the GMFI category was an increase of 6.6 points, and the median score change for the single student in the FMGI category was an increase of one point. For the control group, the median score change for eighth graders in the SGM category was a decrease of 1.5 points and the median score change for students in the GMFI category was a decrease in 2.5 points.

If we combine the information from Figures 5, 6, and 7 we can understand the connection between change in MAT score and corresponding change in mindset category designation. In the experimental group, there were 26 students who initially scored SGM on the pre-treatment administration of the MAT. As SGM was the highest level of mindset category, no students from

this group changed category toward a higher level of growth mindset, but three students, or 11%, moved down a mindset category to GMFI. Of the 20 students who initially scored GMFI during the pre-treatment implementation of the MAT, 11 students (55%) increased their MAT score enough to change their mindset category to SGM. Four GMFI students (20%), did not change their score enough to change their mindset category and no GMFI student decreased in their mindset category. While the single FMGI student did increase their score, this was not enough to increase their mindset category.

The changes in mindset category that eighth grade students in the experimental group experienced were overall toward a higher level of growth mindset classification. Notable among the changes was that over half of experimental students with an initial GMFI score improved their score to move to the SGM category on the post-treatment MAT. Further, only three students out of the 47 experimental students reduced their mindset score enough to change mindset categories. Taken all together, this evidence supports the claim that exposure to design thinking may have a positive impact on students' mindsets.

During the initial round of student interviews, those individuals who scored in the SGM category shared about their motivations around hard work and its connection to intelligence. One student reported that she felt more motivated when work was harder. She said, "When I struggle with a topic, I want to work on it more, not less." Another student described feeling, "excited by the big challenge" of complex tasks. Further, another SGM student stated that, when work makes her think hard, she "can't stop until she knows the answer."

Students in the GMFI category reported similar motivation to work hard, but this motivation was tempered by a desire to also be successful. For example, when asked about their responses to Statement 16 on the MAT (I often have negative emotions (Frustrated, angry, sad,

etc.) when I get feedback about my performance or work), the GMFI identifying students tended to agree with that statement more than the SGM students. These GMFI students specifically cited feeling judged by feedback and that they had a hard time accepting criticism of their ideas. One GMFI student shared that feedback is hard “to accept that someone else wants to change what you already have your heart set on.” Conversely, students in the SGM welcomed feedback and identified that even though constructive criticism may sting when first received, their final product will be better. One SGM student described an experience of receiving feedback during a rehearsal for the spring concert, “When I got that negative feedback, I was upset in the moment, but I also knew that it was going to help me work toward a better performance. After the performance is over and it went well, that’s when you appreciate that negative feedback, because looking back on it, if you didn’t hear it when you were practicing, the final performance would not have been as good.” This perspective stood out as a distinguishing characteristic between SGM and GMFI individuals.

Research Question 2: How does the initial mindset impact student display of design thinking behaviors during novel problem solving?

Self-Reported Confidence Ratings and Pre-Treatment Mindset Category Designation. To answer this question, I first compared student self-reported confidence ratings about their capacity for design thinking skills with their initial mindset to see if there was a correlation between these variables (Figure 8). Students rated their level of confidence in their ability to implement design thinking skills on a scale of 1 (not at all confident) to 5 (very confident) and reported these confidence ratings after they had completed the Density Curiosity Project.

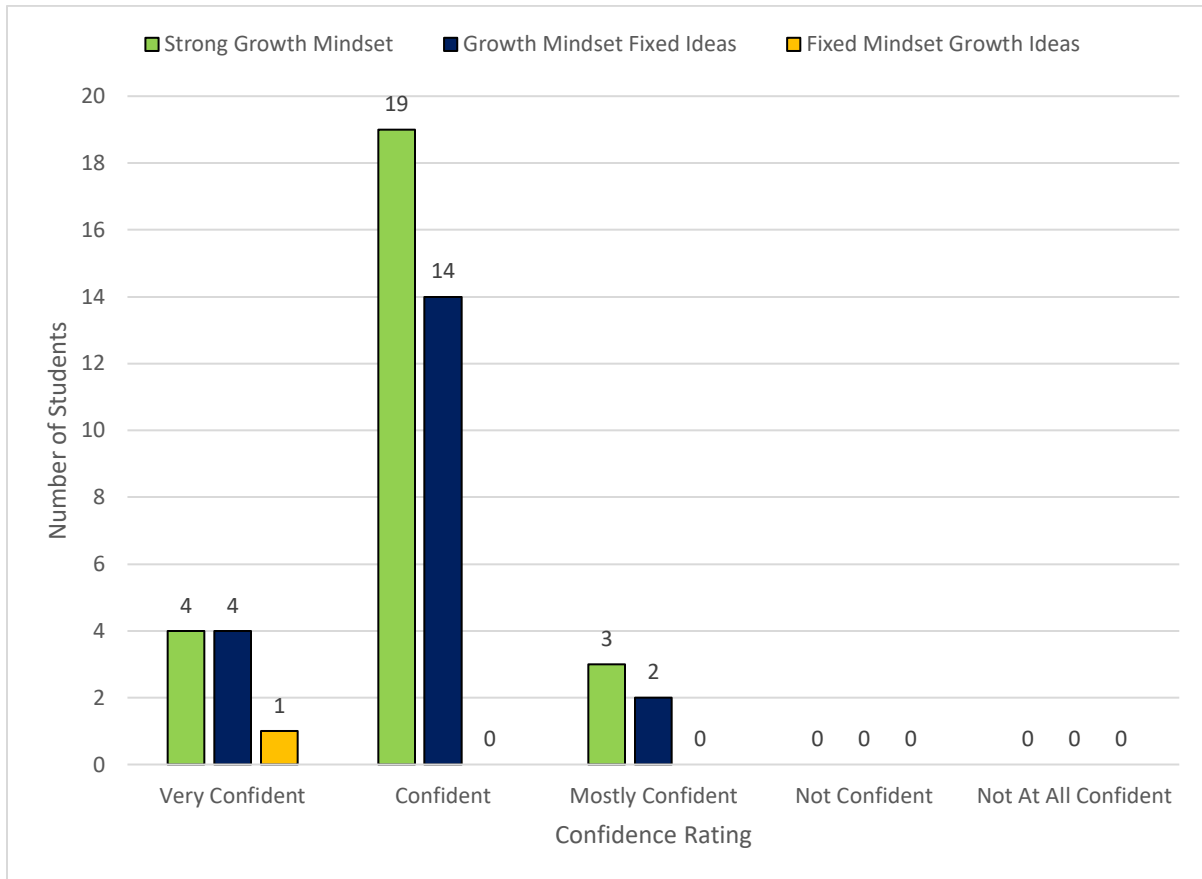


Figure 8. Self-reported confidence rating on use of design thinking skills based on pre-treatment mindset category designation.

The average score across all eighth grade students in the experimental group was 4.12, which is in the “Confident” category. Overall, 19% rated themselves as “Very Confident,” 70% rated themselves as “Confident,” and 10% rated themselves as “Mostly Confident.” This meant that no students ranked themselves below a 3 in confidence, which suggests that all eighth graders felt comfortable and capable in their ability to implement design thinking skills following the Density Curiosity Project.

Of the 26 students in the SGM category 7% were Very Confident, 62% were Confident, and 31% were Mostly Confident. Of the 20 students in the GMFI category, 20% of the students were Very Confident, 50% of the students were Confident, and 30% of the students were Mostly

Confident. The single FMGI student rated themselves as Confident. In looking over these ratings, no clear pattern between initial mindset category and confidence in design thinking skills emerges. However, it can be deduced that all eighth graders felt more confident than not in their ability to implement design thinking skills regardless of their initial mindset category.

Indeed, this confidence was echoed during my student interviews with students. Many students commented on how design thinking was helpful in promoting their understanding of class concepts and they could easily identify which steps in the process most resonated with them. One SGM student explained that she loved, “prototyping, because it is a physical product out of your imagination and it really helps you visualize the idea. Also, you can look for mistakes or changes and that is really helpful too.” Another student in the GMFI initial mindset category shared that prototyping helped them, because they are an “over thinker and I will come up with either too many good solutions or not enough good ones and I have a hard time narrowing down. But having specific design thinking steps helps break that cycle and helps me move forward with my ideas.”

#### Observed Design Thinking Skills and Pre-Treatment Mindset Category Designation.

Another way to investigate this sub-question was to examine teacher observations from the Design Thinking Behaviors Rubric. My Dean of Faculty, Martina Green, visited each of my classes during Day Two of the Platform Project and observed the students working during a 30-minute work block. She coded the students’ behavior using the Design Thinking Behaviors Rubric and also wrote down qualitative observations. Additionally, she asked each group if they could explain how their platform design supported the needs of their stakeholder. These lines of observations helped identify which design thinking skills students were implementing.

The Design Thinking Behaviors Rubric looked at four categories of behaviors that described two aspects of students' approach to design thinking. The first was to code whether students exhibited "Define" behaviors or "Imagine" behaviors at the beginning of the work block. If students showed "Define" behaviors, then they quickly came to consensus around their stakeholder, their design for their platform, and their strategy to build their prototype. If students showed "Imagine" behaviors, then they spent a longer time discussing ideas about who their stakeholder should be, contemplating the design for their prototype, and considering their building strategy.

The next task was to code whether students demonstrated "Prototype" or "Try" behaviors as they began to investigate materials and build their platforms. Students who were coded with "Prototype" behaviors were ones who spent time carefully constructing a prototype and tested their design once their platform was fully built. On the other hand, students who showed "Try" behaviors were those who tested their platforms frequently and iterated the structure of their design based on these tests (Figure 9).

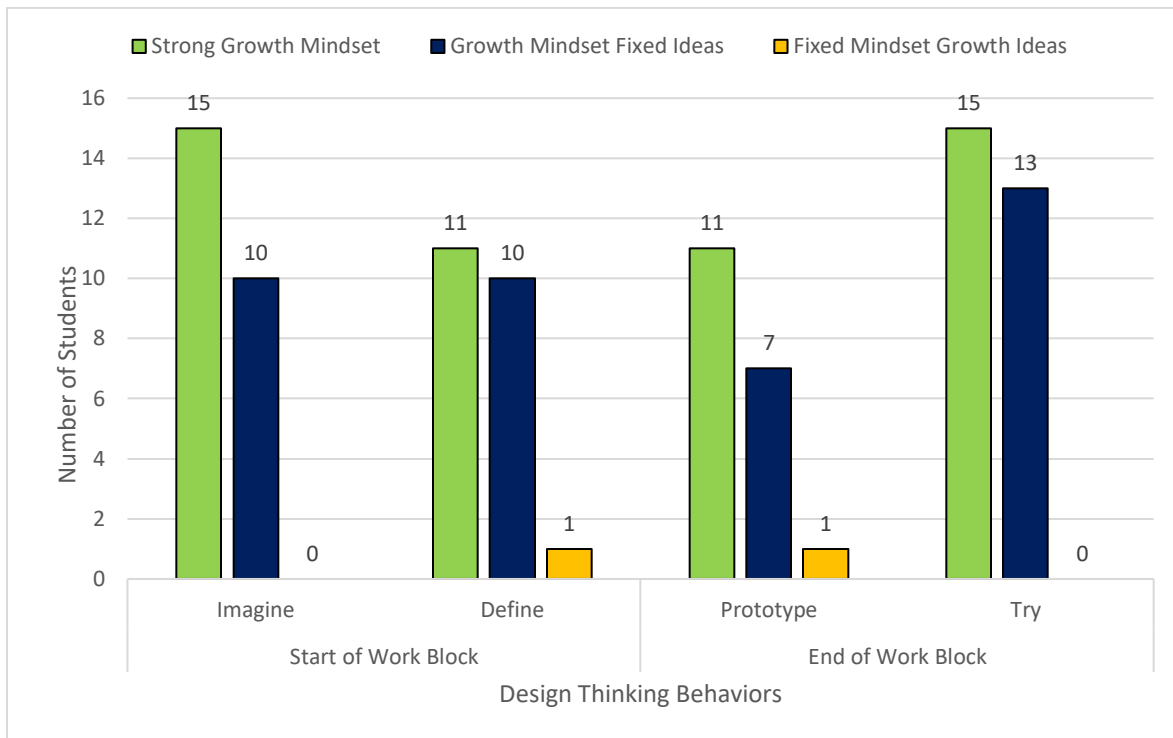


Figure 9. Observed design thinking skills based on pre-treatment mindset category designation

When starting out on a design challenge, students with a pre-treatment mindset category of SGM are slightly more likely to engage in Imagine behaviors (58%) than Define behaviors (42%).

Students with a pre-treatment GMFI mindset category are equally likely to engage in Imagine (50%) and Define (50%) behaviors at the start of a design challenge. The single FMGI student demonstrated Define behaviors at the start of their design challenge. When students move onto constructing their designs, SGM students are slightly more likely to implement Try behaviors (58%) than Prototype behaviors (42%). GMFI students were also more likely to engage in Try behaviors (65%) than Prototype behaviors (35%). The single FMGI student displayed Prototype behaviors during the building phase of this design challenge.

These codes were then put together to form four Design Thinking Skill Groups of student design thinking behaviors – Define/Prototype, Define/Try, Imagine/Prototype, Imagine/Try in

order to determine if there was a connection between the skills demonstrated in each phase of the design challenge and pre-treatment mindset (Figure 10).

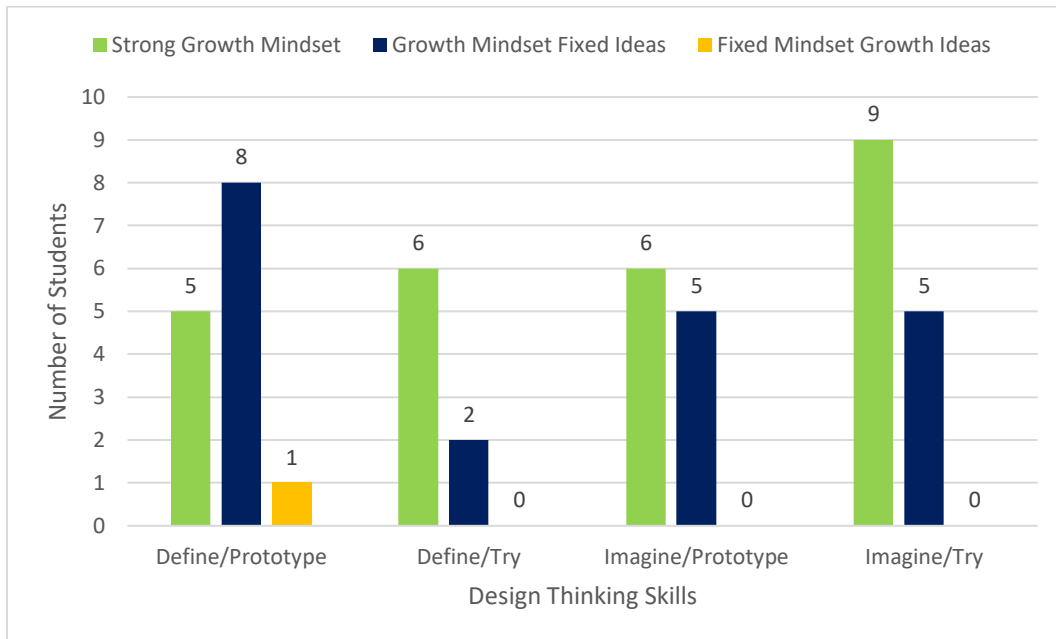


Figure 10. Observed groups of design thinking skills based on pre-treatment mindset category designation

The most frequently observed design thinking behavior for the SGM category was Imagine/Try (35%). The two next most commonly observed design thinking behaviors for the SGM category were Imagine/Prototype (23%) and Define/Try (23%). The least observed design thinking behavior for SGM was Define/Prototype (19%). These results suggest that students with an initial mindset category of SGM are slightly more likely to engage in the Imagine/Try combination of skills.

Conversely, the most frequently observed design thinking behavior for GMFI was Define/Prototype (40%). Next, there was again a tie for the two second most observed design thinking behaviors for GMFI, Imagine/Prototype (25%) and Imagine/Try (25%). The least observed design thinking behavior for GMFI was Define/Try (10%). These results suggest that

students who have an initial mindset category of GMFI are slightly more likely to engage in Define/Prototype behaviors when engaging in design challenges. Additionally, the single FMGI student's observed design thinking behavior was Define/Prototype (100%), however, there this single data point is not enough evidence to draw a conclusion about a pattern for this initial mindset category and observed design thinking skills.

In addition to observing the skills of Define, Imagine, Prototype, and Try, Martina also looked for evidence of behaviors connected to the "Understand" skill of design thinking. In order to assess this, she asked each group if they could explain how their proposed design worked to serve the needs of their chosen stakeholder (Figure 11).

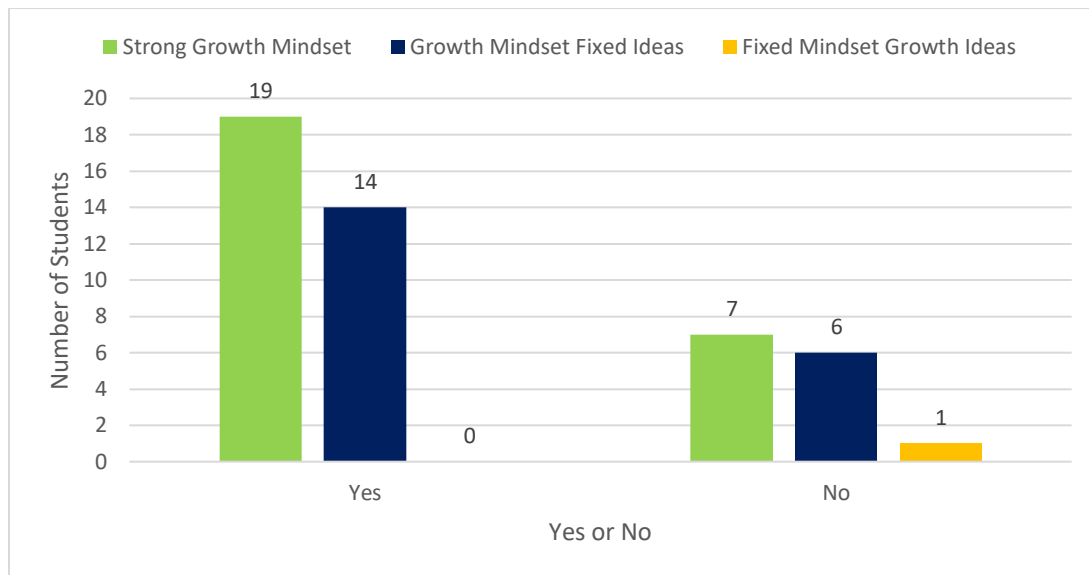


Figure 11. Student ability to explain how their design supported the needs of their stakeholder based on pre-treatment mindset category designation

Overall, 73% of students with an initial mindset category of SGM were able to answer this question in the affirmative, but 27% of SGM students were not able to correctly respond to this question. Additionally, 70% of students with an initial mindset category of GMFI were able to answer this question, but 30% of GMFI students were unable to explain how their design met the

needs of their stakeholder. Finally, the single FMGI student was unable to accurately respond to the question. This shows us that the majority of eighth graders were able to successfully demonstrate “Understand” behaviors during a design thinking assignment, but this does not reveal any patterns between how the initial mindset category of students impacts their ability to implement “Understand” behaviors.

During the second round of student interviews, eighth graders were able to articulate their thoughts about design thinking and identify the specific skills within the framework that most resonated with them. Of the 11 students in the experimental group who were interviewed, all responded positively to the question, “What do you think about “Design Thinking” and your experience with design thinking projects?” Students talked about how much they enjoyed this type of assignment and how it supported their understanding of class material; “It’s super fun! I like how hands-on it is and how it applies to the real world. It is much easier to visualize the concepts that way.” Another student shared that she liked it because, “you are able to imagine anything and don’t have to think too much. You can just allow ideas to flow and then test those ideas out. It is OK if it doesn’t work out because you can always try again.”

They were also able to identify which steps of the design thinking process most resonated with them. The majority of interviewees, six students, said that Prototyping was the step that they enjoyed and understood the most. This step was described as both the most fun and most practical. One eighth grader reported that, “Prototyping is my favorite, because it is the actual doing. If I am imagining ideas that’s great, but the actual, physical building of the idea is the best part.”

The next most frequently cited skill was Try and three students chose this skill. It was described as the most crucial step by students who selected it as their top choice. One student

shared that it was, “the most important, because you don’t know if your platform is going to work until you try it. Everything falls on this.” Finally, Understand and Imagine were each selected by one student as their preferred step. The student who selected Understand talked about how they used this step to reduce their anxiety about new assignments. They said, “When you first hear about a new project it sounds like a lot of work and that stresses me out. But once I break it down, I realize that it isn’t as bad as I thought it was going to be.” The student who nominated Imagine as their favorite step explained that she loved seeing “all of the different ways that people have to solve problems.” It is clear that eighth graders, regardless of their initial mindset category, were able to grasp the goals of design thinking and connect to all skills in this process.

## CLAIM EVIDENCE AND REASONING

Claims From the Study

My data suggested that design thinking instruction can have a positive impact on the level of growth mindset possessed by my eighth grade scientists. The experimental group of students earned a higher overall average change in score on the post-treatment MAT than the control group. Additionally, 75% of the experimental students increased their MAT score as compared to only 50% of the control group who increased their scores. A one-tailed, two sample t-test also revealed a significant difference (0.042) in the change of scores between the control and experimental groups. Furthermore, a larger number of students in the experimental group increased their MAT score enough to move into the highest level of mindset category, Strong Growth Mindset (SGM). On the other hand, students in the control group tended to decrease their scores and more students moved out of the SGM category into a lower level of growth mindset, the Growth Mindset Fixed Ideas (GMFI) category. Taken together, these results bolster the claim that the treatment may have had a positive impact on increasing the mindset scores of eighth grade students.

One reason that we could have seen this positive change in mindset for the experimental students is because the process of design thinking mirrors the central tenant of the growth mindset as outlined by Dweck in 2006. Namely, that a person can grow their intelligence and abilities through hard work and practice. In design thinking, the process of constructing prototypes, testing designs, and iterating on those designs based on feedback represents the same process as shifting a person's intelligence. In other words, a person can augment their solutions through practice and hard work just as they can augment their intelligence as outlined in the

growth mindset. Similarly, the study conducted by Blackwell, Trzesniewski, and Dweck in 2007 showed that when students are presented with the idea that intelligence is malleable, the researchers saw an enhancement in student motivation in class. This key piece of information is the reason that growth mindset interventions are effective at increasing student mindsets. Similarly, design thinking shows students that their ideas and prototypes are malleable and that they can revise their plans and enhance their solutions thanks to testing and iteration. This connection, when explained to students, could have been the reason we saw the corresponding increase in the level of growth mindset in my eighth graders.

An additional benefit to design thinking that could help us understand the positive connection revealed in this project could be explained by Bedford's 2017 research and the investigation conducted by Eccles and Wigfield in 1995. In these studies, the authors provided evidence to support the fact that task value, or the personal importance of the content and skills in a particular class, has a powerful impact on student motivation and perseverance in the face of setbacks, both of which are associated with the growth mindset. When students do not see the value in a task, they are less motivated to dig into the challenge. Conversely, when students feel a personal connection to content or an assignment, they are more likely to actively engage with that task.

Design thinking-based assignments tend to have high task value thanks to the real-world connections and student choice associated with each assignment. In this study, students had a choice in their investigation topic for the Density Curiosity Project as well as their stakeholder and design for the Platform Project. Additionally, the authentic audience of rising eighth graders in the Density Curiosity Project and the very real problem of the supply chain issue at shipping ports in the Platform Project provided genuine connections to life beyond the walls of the

classroom. These two aspects increased the task value of the design thinking challenges, which would have also increased student motivation and willingness to push through setbacks. Perhaps it is this high task value that could have also contributed to the positive connection between design thinking and the development of a growth mindset.

A final element that should be considered when interpreting the results of the first research question of this paper is the idea of feedback. Several studies have highlighted the positive impact that quality feedback can have on student performance and confidence (Forsythe & Johnson, 2017; Kamins & Dweck, 1999). This is underscored by the way that growth-oriented individuals view feedback and effort as keys to success. Indeed, those in possession of a growth mindset perceive effort and feedback as valuable tools to use to gain better understanding and greater achievement (Blackwell, Trzesniewski, & Dweck, 2007; Donohoe, Topping, & Hannah, 2012).

Design thinking echoes this connection, because students are often asked to alter their design plans based on information and feedback from the user, new research, or test results in order to develop the best solution possible. In other contexts, students might view this type of constructive criticism as disapproval of their prototypes and, consequently, as a personal failure. The way that design thinking recontextualizes feedback is not in terms of a failure; rather, design thinking helps students reframe these experiences as helpful information to empower them to make their final design effectively meet their user's needs. This system is all about growth, viewing challenges as opportunities to learn, and perceiving feedback as information to assist in reaching goals. This reframing of feedback and effort within the context of a high task value assignment could help us understand the results of this study.

When it came to Research Question Two, determining whether a student's initial mindset impacted their ability to demonstrate design thinking behaviors, no clear patterns emerged. Overall, experimental students in all mindset categories rated themselves on average as "Confident" in their ability to carry out design thinking skills. Students in all mindset categories were uniformly distributed through the confidence ratings. This suggests that initial mindset does not impact a students' belief in their ability to carry out design thinking skills.

One reason for the high confidence ratings for students could be explained by Ingram's article from 2017. Here, the author reported that in order for students to feel successful in a classroom, assignments must feel both safe enough for students to take a risk with an original idea and challenging enough to push them to think outside the box. Since this design thinking curriculum was taught within science concepts about which students felt confident in their understanding, this self-assuredness could have translated into their high self-reported confidence ratings after their first design thinking project. The overall level of confidence in content and classroom could have superseded any impact from the initial mindset.

We also do not see a clear pattern when we consider how the initial mindset category impacted observed design thinking behaviors. The skill of Understand is the first step in the design thinking cycle and eighth graders were asked to demonstrate this skill by explaining how their design met the needs of their chosen stakeholder to the observer. The majority of students in the experimental group were able to successfully demonstrate this skill (70%), while the minority of students (30%) were unable to successfully connect the features of their design to how it could assist their stakeholder. These students represented both the SGM and GMFI categories, which meant that, overall, both categories of mindset were able to understand the needs of their stakeholder and demonstrate this understanding to the observer. Slightly more

GMFI students (30%) than SGM students (27%) were unable to perform this skill and the single FMGI student was also unable to demonstrate their understanding of the needs of their stakeholder. These differences are too small, however, to draw a firm inference on whether initial mindset impacts a students' ability to demonstrate the design thinking behavior of Understand.

Students were also assessed on their ability to demonstrate additional design thinking behaviors during a design challenge. Eighth graders were observed during the second day of the Platform Project and their behaviors were classified into four different categories. At the start of the design period, students demonstrated either Imagine behaviors or Define behaviors. Then, as they progressed to constructing their platforms, they were coded as showing Prototype or Try behaviors. These two categories were then combined to identify students as showing Imagine/Prototype, Imagine/Try, Define/Prototype, or Define/Try behaviors. No clear pattern between the pre-treatment mindset category of students and any of these behaviors emerged. Students in all mindset categories demonstrated each of these behaviors with similar frequencies. Therefore, the takeaway was that eighth grade students were indeed able to demonstrate design thinking skills, but they do not do so based on their level of growth mindset in this context. It is clear that students were able to follow directions and carry out the steps of design thinking, but it is unclear how this behavior correlates with their initial level of growth mindset.

Previous studies have shown the effectiveness of growth mindset interventions that last approximately 10 weeks (Bedford, 2017; Blackwell, Trzesniewski, & Dweck, 2007; Donohoe, Topping, & Hannah, 2012; Dweck, 2006; Yeager & Dweck, 2012; Yeager et al., 2016). While in this study, we did see an overall positive impact on the development of a growth mindset after four weeks of instruction, we did not see specific patterns in the development of individual

design thinking skills. The fact that we observed demonstration of all of the skills plus the fact that students felt confident in their ability to carry out design thinking skills, suggests a global understanding of the ethos of design thinking, but not the detailed comprehension of the individual steps within this system. Additionally, student demonstration of design thinking behaviors was only observed one time during this study. If students had the opportunity to practice design thinking skills for a longer period of time and multiple observations of their behavior were taken, it might be possible to observe differences in the approaches that students with different initial mindsets might have taken. All in all, the four-week unit and single observation were likely not enough time for students to master and develop preference for specific design thinking behaviors.

#### Value of the Study and Consideration for Future Research

We know that the personal and academic development that occurs in middle school is of critical importance for student identity and learning strategies. It is during these years that students begin to understand themselves as learners and develop scholastic habits as well as personal characteristics. The more we can understand about how to promote a growth mindset in our students, through direct instruction around mindsets and also through our subject-based curriculum, the more we can support the goals of graduating capable problem solvers and scientifically literate citizens who are able to persevere through challenges and adapt to the rapidly changing pace of society in order to find success.

Therefore, the observation of a positive connection between design thinking instruction and the development of a growth mindset in the eighth grade science students in my classroom this year provides ample opportunities for further inquiry. It would be interesting to see how a

longer design thinking unit might impact student mindsets. The study described in this paper was only conducted over a four-week period and positive results were still captured. A longer-term study where students learn about design thinking and engage in design challenges over a greater period of time would certainly be intriguing. A larger sample size or a longitudinal study over multiple years of the same students would also be worthy investigations.

Additionally, this study was unable to uncover how a student's initial mindset category impacted their ability to demonstrate design thinking skills. A different approach to measuring the relationship between these two variables could reveal insights into student understanding and application of design thinking skills. Much like practicing metacognitive reflection after learning novel information, being able to understand how one's mindset influences one's ability to implement a new skill could greatly aid students on their journey toward mastery with their design abilities.

#### Impact of the Action Research on the Author

Obtaining evidence that a connection exists between these two practices encourages me to continue to hone my craft as a design thinking coach and explore ways to deepen the practices of design thinking skills in my classroom. Knowing that we can measure a positive change on a student's MAT score after just four weeks of design thinking, it is exciting to consider the possible impacts that a long term design thinking focus could have on my students and their mindsets.

In addition to helping my students cultivate a growth mindset in science, I can also see the benefits of such a world-view on student's lives beyond the four walls of my classroom. Indeed, during the second round interviews, I asked students if they could make a connection

between design thinking and another one of their classes or real life experiences. Students had no trouble sharing about experiences with writing short stories in Language Arts, solving complex math problems, and the Metaphor Project in US History class. One eighth grader talked about the feedback process for their short story in Language Arts and said that getting the feedback from his peers was like, “when we tested the platforms that we built. The only way that you would know if the platform would float was to test it. The only way you know if someone gets your story is if they read it and tell you about it.”

They also talked about their experiences learning an instrument, creating visual art pieces, and participation in sports. One student shared a connection with the Imagine phase and her art class when she said that in her art process she has to “brainstorm like crazy if you want to have a good, original concept. That’s just like when we imagine in design thinking.” Another student pulled it all together when he shared that design thinking is like, “when you first start running, you don’t feel very good or when you’re working hard on a math problem it might be discouraging and you might doubt yourself. But then you keep practicing or do something a little bit different and it starts to click with math or you see your times go down in the races. It’s all about effort and trying.”

Drawing on this insight, I am eager to incorporate more personal reflections about the design thinking process. The interviews with students were so productive and the eighth graders demonstrated impressive insightfulness into their own experiences and capacity to connect the dots to design thinking. I am excited to foster an atmosphere of reflection and connection among design thinking activities, skills in science, and students’ experiences in their other classes or life outside of school. We know that students learn best when they feel connected to the curriculum

and developing a habit of reflection will bolster student learning of design thinking skills and their growth mindset abilities.

In addition to students' ability to connect science topics to their real life, it was also apparent that their lives outside of school impact their academic experiences. The students who I interviewed who experienced a decline in their scores shared that they had had negative experiences in their lives during the four-week treatment. One student found out that she was going to a new school at the conclusion of this academic year and she was feeling very anxious about this transition. Another student suffered a knee injury during pre-season that was threatening her ability to play softball in the spring. These insights about negative experiences, plus students' ability to connect design thinking with their outside lives, helped remind me of the interrelatedness of students' emotional health and their academic worlds. This reinforced my commitment to reflection and connection between design thinking and students' lives. If we can transfer some of the problem solving grit from design thinking and encourage students to develop their growth mindsets, this will help fortify them for challenges outside the science classroom.

I sincerely believe that meaningful educational experiences during adolescent years can change lives for the better; when students are given the tools to analyze and comprehend complex issues, they are empowered to grapple with important conversations in personal development as well as real world applications in local and global communities. This ability enables our students to grow into agents of positive change, work to unpack persistent societal challenges, and use their understanding to make a positive impact in their communities. I am aiming high with my plans for design thinking and the development of a growth mindset for my students. Now that evidence exists to suggest the positive link between these two frameworks, I

am eager to deepen my understanding of how they connect and how I can continue to foster the personal and academic development of my students.

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APPENDICES

APPENDIX A

INSTRUCTIONAL REVIEW BOARD EXEMPTION

MONTANA STATE UNIVERSITY  
Request for Designation of Research as Exempt  
MSSE Research Projects Only  
(6/16/14)

To qualify as exempt, this research **must**: 1) involve minimal risk and 2) be conducted in established or commonly accepted educational settings, involving normal educational practices. These include, for example, research on regular and special education instructional strategies or research on the effectiveness of or comparison between instructional techniques, curricula, or classroom management methods.

PLEASE TYPE YOUR RESPONSES. Applications can be emailed to irb@montana.edu. Submit application, along with any surveys, subject consent forms, and all other relevant materials. For information and/or assistance call 406-994-4706.  
**Please type responses in bold. Do not type in all capitals.**

Delete above two text boxes of instructions (and this sentence) prior to submission and/or printing.

\*\*\*\*\*  
THIS AREA IS FOR INSTITUTIONAL REVIEW BOARD USE ONLY. DO NOT WRITE IN THIS AREA.  
Confirmation Date: 11/30/21 *Mark J. Quinn*  
Application Number:  
\*\*\*\*\*

**DATE of SUBMISSION:** -Okay as exempt  
-MSSE Classroom assessment  
*Address each section - do not leave any section blank.* -Little/no risk  
-Dean approved  
I. INVESTIGATOR: **CJ Bell** -No concerns  
MQ 11/30/21

Name: **CJ Bell**  
Home or School Mailing Address: 307 November Drive Durham, NC 27712  
Telephone Number: 508-397-9143  
E-Mail Address: **cj.bell.rossi@gmail.com**  
DATE TRAINING COMPLETED: **2/15/2021** [Required training: CITI training; see website for link]  
Investigator Signature *CJ Bell*  
Name of Project Advisor: **Marcie Reuer**  
E-Mail Address of Project Advisor: **marcie.reuer@ecat1.montana.edu**

II. TITLE OF RESEARCH PROJECT: **Design Thinking and the Development of the Growth Mindset in the Middle School Classroom**

III. BRIEF DESCRIPTION OF RESEARCH METHODS (If using a survey/questionnaire, provide a copy).  
**Students will experience instruction in design thinking skills and then complete a design thinking project. Students' growth mindset levels will be assessed before and after the design thinking project in order to examine whether learning about and practicing design thinking skills impacts students' mindsets.**

APPENDIX B

INTRODUCTION TO DESIGN THINKING LESSON

## Design Thinking

1

**Design Thinking = empathetic approach to creative problem solving**

- **Empathy:** the ability to understand the feelings or perspective of another individual or situation
- **Approach:** strategy, game plan
- **Creativity:** the use of imagination or original ideas
- **Problem Solving:** the process of finding solutions to difficult or complex tasks

2

**Design Thinking = empathetic approach to creative problem solving**

- **Empathy:** the ability to understand the feelings or perspective of another individual or situation

3



4



5

**Design Thinking = empathetic approach to creative problem solving**

- **Approach:** strategy, game plan

6

Design Thinking Skills

- Interviewing / Surveys
- Observations
- Researching
- Visual Brainstorming – develop as many ideas as you possibly can, then refine
- Solo Flights and Collaboration
- Prototype and Test
- Feedback and Iteration

7

Variety of sophisticated data-tracking features:

- An app
- Music player
- Ways to sense how well the users were brushing every single tooth
- How sensitive their gums were



8

Design Thinking Skills

- Interviewing / Surveys
- Observations
- Researching
- Visual Brainstorming – develop as many ideas as you possibly can, then refine
- Solo Flights and Collaboration
- Prototype and Test
- Feedback and Iteration

9

Variety of sophisticated data-tracking features:

- Music player
- Ways to sense how well the users were brushing every single tooth
- How sensitive their gums were

Simple additions:

- On-the-go, USB charging
- Made it easier for users to order replacement brush heads





10



**Design Thinking = empathetic approach to creative problem solving**

•Creativity: the use of imagination or original ideas

11

**New England Aquarium**  
Dr. Rosalind Rolland

12



13



14

Dr. Rolland needs a cost-effective, reliable way to locate whale poop so that she can continue with her important research



15



16

**Design Thinking = empathetic approach to creative problem solving**

- **Empathy:** the ability to understand the feelings or perspective of another individual or situation
- **Approach:** strategy, game plan
- **Creativity:** the use of imagination or original ideas
- **Problem Solving:** the process of finding solutions to difficult or complex tasks

17



18

You have just been handed a design client.  
 You will be working to build a home for your client, based on their NEEDS.  
 Start thinking about how you will determine your client's NEEDS for a home

<ul style="list-style-type: none"> <li>• <b>Constraints:</b> things that CANNOT be done based on the problem situation</li> <li>• 2 minutes to plan</li> <li>• 12 minutes to build</li> <li>• Only the supplies available</li> </ul>	<ul style="list-style-type: none"> <li>• <b>Criteria:</b> things that MUST be done in order to be successful</li> <li>• Home must be 3 dimensional</li> <li>• Home must be named</li> <li>• Client must fit inside home</li> <li>• Be prepared to explain your thinking</li> </ul>
--	--

19

-How did you determine your client's needs?  
 -Was this an easy challenge or difficult challenge?

**Design Thinking = empathetic approach to creative problem solving**

20

1. How did you and your partner go about determining the needs of your client for their home?
2. Did you get any additional ideas for your client's home after viewing your classmates' home examples?
3. How did this activity go for you?
  - Was it easy to develop ideas for a home?
  - Was it hard to get started?
  - Did you have enough time?
  - Did you immediately have ideas for a home, or did it take a bit?
  - Would you have preferred to work independently, or do you prefer collaborating?
  - What worked / didn't work?

**6-minute written reflection**

21

**Design Thinking = empathetic approach to creative problem solving**

22

23

24

APPENDIX C

DENSITY CURIOSITY PROJECT SLIDESHOW TEMPLATE AND GRADING RUBRIC

## Density Curiosity Project

1

Title Page – include the following:

- Title of your project
- Your names
- The due date
- An image that represents your project

2

### Question!

“How does \_\_\_\_\_ connect to density?”

- What is the question that you are investigating?
- What prompted you to examine this topic?
- What is interesting about this topic to you?
- Define each key term in your question

3

### Investigation or Real-World Connection

- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>• INVESTIGATION</li> <li>• Write out the instructions for your investigation here</li> <li>• Treat it like a procedure and write out a numbered list of actions</li> </ul> | <ul style="list-style-type: none"> <li>• REAL-WORLD</li> <li>• Use photographs, diagrams, and text to explain your real-world phenomenon</li> </ul> |
|---|---|

4

### Claim!

- Well, what did you find out? What is the answer to your question?

5

### Evidence!

- What evidence do you have to support your claim?
- INVESTIGATION: Feel free to write in bullet points, or provide a data table, or a photograph of your experiment before/after
- REAL-WORLD CONNECTION: Add photos, quotes, diagrams, and text to show how your phenomenon connects to density

6

**Reasoning**

- Time to **EXPLAIN** what you learned
- Pretend that you are talking to a member of the class of 2025 and make sure that you explain how density and your investigation or research are related and how they impact each other.

7

**Things to Change in the Future**

**Things to Investigate in the Future**

8

**Sources:** Please place all URLs related to your research down below. Organize each URL by slide – include all URLs for images.

- **Question Slide**
- **Investigation or Real-World Connection Slide**
- **Claim Slide**
- **Evidence Slide**
- **Reasoning Slide**

9

**Sources IMAGES:** Put all URLs for images plus a label as to what image each URL belongs to

10

## Density Curiosity Project Checklist

Component	Criteria	Comments	Points
Title Page	Your names		1
	The due date (1/27 A&C) and (1/28 D&G)		
	An image that represents your project		
	The URL for the source of your image is pasted onto the “Sources IMAGES” slide		
Question: How does ____ connect with density?	Your question connects to density		2
	You define each key term in your question		
	If you have used a source to help you with your definition, you have added this source to the source slide under the “Question” Heading		
Question: Your interest was sparked by...	You explain what is interesting to your group about your question		1
	You explain how your group decided on this question		
	If you have included an image, the URL for the source of that image is pasted onto the “Sources IMAGES” slide		
Prediction	Prediction: You have written a clear, direct prediction. No ambiguity! You state exactly what you think is going to happen.		2
	Reasoning: There is a logical explanation for your prediction. You will want to talk about what you know about density or your investigation topic in this part.		
	If you have included an image, the URL for the source of that image is pasted onto the “Sources IMAGES” slide		
All Tests: Investigation - Process	Materials: you have a bulleted list of the items that you need		3
	Materials: there are amounts and units included in this list		
	Procedure: you have created a numbered list of the steps that you will take to carry out your investigation		
	Procedure: each step contains only <b>1 direction</b> – avoid compound sentences (no “ands”)		
	Procedure: you do not have any transition phrases (first, next, then...) in your procedure – the changing numbers are your transition		
	You have a picture or a sketch of your investigation set up		
	There are labels on this picture or sketch		
All Tests: Investigation - Results	Results: The results are reported clearly in text		3
	Results: There is a visual representation of your results – a photo or a sketch or a data table		
	Changes: You identify any changes that you need to make OR any errors that occurred, followed by changes that need to be made as a result of that error		

Component	Criteria	Comments	Points
Claim!	You write a clear statement that directly answers your question		2
	There is a modifier in your claim that tells us the direction of the relationship – increases/decreases, more dense/less dense – we need to know exactly what’s going on		
Evidence!	All of the evidence from all of your tests (data AND observations)		3
	There is a clear organizational scheme – we can tell which data AND observations are attached to each test or trial		
	There are units attached to numbers		
Reasoning	You begin by restating your claim		4
	You then summarize the data by including numbers AND units in your writing		
	When summarizing: <ul style="list-style-type: none"> <li>• Include context clues like “fastest” or “slowest” or “most dense, second most dense, third most dense...”</li> <li>• Report the data in an organized manner – for example, you could report it in order from most dense to least dense</li> </ul>		
	You include a summarizing sentence		
	You write this in bullet points		
Sources	The URLs for any research that you include in your Power Point are included on this slide and they are pasted under the correct heading		1
	You may delete any headings for which you do not have a URL		
Sources: Images	Any images have a URL posted on this page		1
	You have a label for which image each URL belongs to		
General	Your text shows evidence of proofreading (no spelling or grammar errors, text is nicely composed, slides are organized)		3
	You have a complete checklist		
Evidence of Design Thinking	<p><b>Understand:</b> fully comprehend density and your specific curiosity area</p> <p><b>Imagine:</b> brainstorm as many curiosity topics as possible</p> <p><b>Define:</b> pick 1 curiosity project and figure out how to test it</p> <p><b>Prototype:</b> develop an experiment plan – develop a second experiment plan or discuss changes for the future based on observations and results from first experiment</p> <p><b>Test:</b> run the experiment and make careful observations about the results AND the process of the experiment</p>		4

**Total**

APPENDIX D

PLATFORM PROJECT ASSIGNMENT SHEET AND GRADING RUBRIC

## Platform Project Assignment Sheet

### Problem Statement:

Using your understanding of Buoyancy, Density, and Forces, work to alleviate the storage issues at ports in the US by constructing a floating cargo container storage device.

Materials	Design Criteria
<ul style="list-style-type: none"> <li>• Foam trays</li> <li>• Tin foil</li> <li>• Popsicle sticks</li> <li>• Masking tape</li> <li>• Elmer's glue</li> <li>• String</li> <li>• Paper</li> <li>• Plastic cups</li> <li>• Bottle caps</li> <li>• Piper cleaners</li> <li>• Paper plates</li> </ul>	<ul style="list-style-type: none"> <li>• Your storage device must be able to hold the specified amount of cargo without sinking. You will determine the amount of cargo it can hold using math.</li> <li>• Your storage device must be made of at least two materials.</li> <li>• Your storage device must be able to stand up to wind and waves and not lose its cargo.</li> <li>• You DO NOT have to consider how you will get your cargo on and off your storage device. All that you have to thinking about is keeping cargo securely afloat.</li> </ul>

### Project Criteria:

- ***Design Log (10 points)***
  - As you build, test, and iterate on your device you must keep track of your changes.
  - You may create a handwritten design log (in your notebook) or a digital design log (PowerPoint, Word Document, OneNote, etc.)
    - Get approval from Ms. Bell for your Design Journal Format
  - Things to include in the design journal
    - Images with labels (either a photograph or sketch) of any storage device designs that you create
    - Results of any tests that you make on your storage device prototypes
    - A record of any changes that you make to your design and a brief explanation of why you made those changes
- ***Calculations and Explanations (12 points)***
  - Sinking Calculations: How deep will your storage device sink into the water based on the amount of cargo that it holds?
  - Buoyancy Explanation: A written explanation of how you will ensure that the Buoyant force exerted on your storage device by the water is enough to keep your storage device afloat with all of its cargo
    - A free body diagram will help with this!
- ***Stakeholder Bio (8 points)***

- Identify a stakeholder who is connected to the cargo ship problem
- Explain their connection to the problem
- Explain how your storage device will help fix their problem

<b>Timeline</b>	
Monday / Tuesday	<b>Class:</b> Introduce project and initial brainstorm of designs <b>Homework:</b> Set up design log, rough draft of Buoyancy Explanation, rough draft of Stakeholder Bio
Wednesday	<b>Class:</b> Work on building and testing – keep record for design log
Thursday / Friday	<b>Class:</b> Work on building and testing – keep record for design log <b>Homework:</b> Finalize design log, Buoyancy Explanation, Sinking Calculations, Stakeholder Bio
Project Due	<b>A &amp; C: Monday 2/14</b> <b>D &amp; G: Tuesday 2/15</b>
<b>Total Points</b>	<b>30 points</b>

## Platform Project Grading Rubric –

Component	Criteria	Comments	Points
Design Log	Problem statement (given by Ms. Bell) is present Description of your team's idea is present		10
	Each of your designs has: -Date of the design -The design number (1, 2, 3, etc.) -Materials List -Diagram (photo or sketch) with LABELS -Dimensions identified		
	The Results of your designs have: -Numeric data on how many containers (dice) the design can hold -Written observations about how it floats / sinks -Written list of changes to be made for the next design based on the results and observations		
	You have an explanation and image of your cargo container organization system -Written description -LABELED sketch -Total number of containers that your device can hold identified		
	You conduct a wind and waves test: -Observations during the test are recorded -Summary of how your device managed the wind and waves is written -List 1 – 2 changes that you would make to your design based on the observations / results of the wave test		
Sinking Depth Calculations	-Sketch of your final design in the water with dimensions (length, width, height, volume) labeled -All of your work is shown		6
	-Archimedes Principle is defined -The rule for whether an object will sink or float according to Archimedes is stated You explain how your storage device will follow this rule – include numbers here		
	There is a Free Body Diagram of your storage device in the water with cargo with the following information labeled: -Buoyancy Force and its numeric value -Gravity Force (weight) and its numeric value -The storage device with cargo -The tub -The water		6
Stakeholder Bio	Your stakeholder is identified clearly with text and a photo		8
	There is a brief explanation of the problem with the shipping industry		
	You explain how your stakeholder is specifically impacted by the problem in the shipping industry		
	You explain how your storage device will help to alleviate your stakeholder's problem		
	If you did any research (read an article, watched an interview, used information from the videos from HW) please include the URL's.		
Design Thinking	<ul style="list-style-type: none"> <li>• <b>Understand</b> the supply chain issue and concept of buoyancy</li> <li>• <b>Imagine</b> as many stakeholders or storage device designs as possible</li> <li>• <b>Define</b> 1 storage device design and 1 stakeholder's needs</li> <li>• <b>Prototype</b> your device and test materials along the way. Research the needs of your stakeholder. Work to ensure that your prototype fits their needs.</li> <li>• <b>Test</b> the prototype in the water and see how it functions. Write up your stakeholder's needs and explain how your device helps. Perform your calculations.</li> </ul>		3

**Total**

APPENDIX E

MINDSET ASSESSMENT TOOL AND SCORING RUBRIC

Name: \_\_\_\_\_

**Mindset Survey DIRECTIONS:** This is a voluntary survey that asks you to rate how strongly you agree or disagree with 20 statements. Please score your responses by selecting Strongly Agree, Agree, Mostly Agree, Mostly Disagree, Disagree, or Strongly Disagree in response to each statement. **Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.**

		Strongly Agree	Agree	Mostly Agree	Mostly Disagree	Disagree	Strongly Disagree
1	No matter how much intelligence you have, you can always change it a good deal.	5	4	3	2	1	0
2	You can learn new things, but you cannot really change your basic level of intelligence.	0	1	2	3	4	5
3	You are a certain kind of person and there is not much that can be done to really change that	0	1	2	3	4	5
4	I like my work best when it makes me think hard.	5	4	3	2	1	0
5	I like my work best when I can do it really well without too much trouble.	0	1	2	3	4	5
6	I like work that I'll learn from even if I make a lot of mistakes.	5	4	3	2	1	0
7	I like my work best when I can do it perfectly without any mistakes.	0	1	2	3	4	5
8	When something is hard, it just makes me want to work more on it, not less.	5	4	3	2	1	0
9	To tell the truth, when I work hard, it makes me feel as though I'm not very smart.	0	1	2	3	4	5
10	Trying new things is stressful for me and I avoid it	0	1	2	3	4	5
11	I often have negative emotions (frustrated, angry, sad, etc.) when I get feedback about my performance or work	0	1	2	3	4	5
12	I appreciate when people, parents, coaches, or teachers give me feedback about my performance	5	4	3	2	1	0
13	An important reason why I do my schoolwork is that I enjoy learning new things	5	4	3	2	1	0
14	Only a few people will be truly good at sports, you have to be born with the ability	0	1	2	3	4	5

15	The harder you work at something, the better you will be	5	4	3	2	1	0
16	Truly smart people do not need to try hard	0	1	2	3	4	5
17	Music talent can be learned by anyone.	5	4	3	2	1	0
18	You are either a science and math person or a LA and history person. You will not change much over the course of your schooling.	0	1	2	3	4	5
19	In general, grades tell you how hard someone works in class.	5	4	3	2	1	0
20	In general, grades tell you how smart someone is.	0	1	2	3	4	5

## Scoring Rubric

Score	Mindset Category	Description – people in this mindset group usually believe the following things:
90 – 68	Strong Growth Mindset	You really feel sure that you can increase your intelligence by learning and you like a challenge. You believe that the best way to learn is to work hard, and you don't mind making mistakes while you do it.
67 – 46	Growth Mindset with Fixed Ideas	You believe that intelligence is something you can increase. You care about learning and you're willing to work hard. You want to do well, but you think it's more important to learn than to always perform well.
45 – 23	Fixed Mindset with Growth Ideas	You lean toward thinking that your intelligence doesn't change much. You prefer not to make mistakes if you can help it and you also don't like to put in a lot of work, however you do want to learn. You may think that learning should be easy.
22 – 0	Strong Fixed Mindset	You strongly believe that your intelligence is fixed or that it doesn't change much. If you can't perform perfectly, you would rather not do something. You think smart people don't have to work hard.

Adapted from:

Dweck, C. (2006). *Mindset: The New Psychology of Success*. Random House, Inc.; New York, New York

APPENDIX F

STUDENT INTERVIEW QUESTIONS PRE- AND POST-TREATMENT

## Pre-treatment Questions:

1. **WARM UP:** How is it going for you today? Thank you so much for taking time to speak with me about the survey. The goal of this conversation is for me to learn a little bit more about your ratings from the Mindset Assessment Tool. Let's start with the big picture, how did you feel when taking the survey?
2. **ABILITY BASED:** Tell me about your response to Question #2 (You can learn new things, but you cannot really change your basic level of intelligence). Why do you think you rated this question as you did?
  - a. What is the difference between learning new things and intelligence to you?
3. **PERSONAL REFLECTION:** Tell me about your response to Question #10 (Trying new things is stressful for me and I avoid it). Why do you think you rated this question as you did?
  - a. Can you think of an experience where this was true for you?
4. **ABILITY BASED and PERSONAL REFLECTION:** Let's talk about feedback! You rated XX on Question 11 (I often have negative emotions (frustrated, angry, sad, etc.) when I get feedback about my performance or work) and XX on Question 12 (I appreciate when people, parents, coaches, or teachers give me feedback about my performance). Can you say a bit more about why you rated these questions as you did?
  - a. What is feedback to you? What type of feedback works best for you as a learner?
  - b. Is a grade on a final paper feedback? Why or why not?
5. **CHARACTERISTIC BASED and PERSONAL REFLECTION:** For #18 (You are either a science and math person or a LA and history person. You will not change much over the course of your schooling.) You wrote XX. Why do you think you ranked this as you did?
  - a. Which one are you? How do you think you became this way?
6. **ABILITY BASED and PERSONAL REFLECTION:** For #15 (The harder you work at something, the better you will be) you wrote XX. Can you say more about why you rated this as you did?
  - a. Can you think about an experience where this was true for you?

## Post-treatment Design Thinking Questions:

1. What do you think about “Design Thinking” and your experience with design thinking projects?
2. Was there a step in the DT process that made the most sense to you?
3. How did you see it used during the Platform Project?
4. Do you think that you use DT in your own life or in another class?
5. How do you think that DT connects to - the harder you work at something, the better you will be?

APPENDIX G

DESIGN THINKING BEHAVIORS RUBRIC

<b>Design Thinking Step</b>	<b>Design Thinking Skill</b>	<b>Observed / Notes</b>	<b>Not Observed</b>
<b>Understand</b>	Can the student successfully explain how their design for a platform supports the needs of their stakeholder?		
<b>Define</b>	Students restated the problem or the goal of the assignment during designing		
	Prioritize tasks during the class as to move the project forward		
<b>Imagine</b>	Students develop new ideas when encountering a novel problem		
	There is no judgement of new ideas		
	Students build on each other's ideas		
<b>Prototype / Test</b>	Work on 1 aspect of a design at a time (example test different materials to determine floating before building complete model)		
	Start with simple model of platform and increase complexity over time		
	Analyze and identify specific parts of the prototype that work and do not work		
	Effectively utilize feedback from tests of the model about what works and does not work to create a better model		
	Effectively use feedback from a teacher or peer to make changes to the model		
<b>Consider the User / Empathy</b>	Mention their user while designing their prototype		
	Able to clearly connect their user's needs to their prototype/solution when asked		

Developed based on the Design Thinking Rubric by Thomas Both (2016) at the Hasso Plattner Institute of Design at Stanford University