The Impact of Growth Mindset Perceptions in a 9th-Grade Science Class

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To all those in the teaching profession and to all our students

With Gratitude, Jon Edwards

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Chapter 1. Introduction

My perspectives on teaching are informed by three periods of my engagement with public schooling: my K-12 education, my postsecondary education, and my daughter's journey through school. My K-12 schooling was influenced by the teachings of the Children of God, a cult that had a disastrous effect on the many children raised within it (Edwards, 2018; Hough, 2021). While my parents officially left the cult, moving from Spain to my grandparents' in Canada when I was three years old, they kept many of the beliefs about society and education. What I take from my childhood is that teachers often have limited knowledge of what goes on beyond the school doors. This experience has made me more compassionate toward our most vulnerable humans, whom we are asked to nurture and help grow in a system that is not always kind to them. As educators, we need to do everything we can to nurture students' confidence, help them grow, and let them know that they matter.

Throughout my childhood, there was a constant dissonance between my family's values and formal education. Influenced by cult indoctrination, my close family, along with much of my extended family, believed that the education system was a part of a broader evil societal structure rooted in the need to control students. As a result, we were repeatedly told that teachers were just there to babysit kids, or worse, to create followers and capitalists. We were also told teachers were just there for a paycheck and were "in and out at the bell." When we were not in school, we learned through life experience, with a few other children around besides my siblings. By 10th grade, this lack of structure exhausted me. I insisted on going to a regular school, and my parents finally agreed. In retrospect, the high school diploma afforded me many opportunities that my siblings have not had. When I compare our career paths, one thing I clearly see is that public schools can provide many students with the opportunity to learn, to see potential across a spectrum of interests, and to avoid getting stuck in insecurities.

Besides holding an anti-establishment belief system, my family struggled financially. For most of my life, my parents relied on Canadian social assistance, proud to be outside of "the system." It continues to amaze me how my mom found ways to keep food on the table and kids clothed, but it also meant that my parents were distracted by those economic struggles and had little energy to support my education. For example, I cannot remember a moment when my parents asked about my grades or which classes I was taking from 10th to 12th grades. Soon after graduating from high school, I moved from British Columbia to California, where I formed my current educational identity. I met my spouse, who persuaded me to enroll in a local community college. Unlike me, she grew up in a family that deeply valued education. She offered to go to classes with me, though she had already graduated from UC Santa Cruz with honors.

I fell in love with learning at the community college. I had peers to talk to about class content and assignments. I learned that I was a capable learner and started to challenge myself. I went from contemplating an associate degree to attending a four-year university: UC Berkeley. There, I worked toward my undergraduate degree in Atmospheric Science and did two years of research on methane clathrate stability in our oceans. I then continued on this path by enrolling in a PhD program at Oregon State University, where I studied ice cores from Greenland and Antarctica. I enjoyed the discoveries made during the lab and fieldwork. I won a graduate teacher of the year award and research awards, and was ready to complete my doctoral studies.

Then, my spouse and I welcomed our daughter into the world, which brought me both sweet memories and numerous challenges. As our daughter got older, we started to see her struggle in certain areas. When she entered elementary school, teachers suggested that we speak with our pediatrician. We scheduled a series of tests for autism, and without really understanding what a diagnosis meant, we were faced with reevaluating what was important to us. Shortly after learning of my daughter's diagnosis, I had an interview as one of two finalists for a postdoctoral research position at Cambridge University. However, this would have meant uprooting our family and living on a postdoctoral employee salary. It was not feasible for us, and so I looked for full-time employment closer to home.

Looking back, it is hard to imagine my life going any differently than it has. Rather than continuing my pursuit of academia, I have found out how much I love teaching. I have since worked as a science writer and editor for a middle school science textbook, taught Upward Bound summer classes, and led teaching workshops. Through my life experiences and my daughter's eyes, I see the importance of inclusion in a classroom with students of different abilities. I also see how vulnerable some students can be when taught by those who hold preconceived notions about (dis)ability. Most importantly, these experiences showed me how critical it is to believe in all students' potential for sustaining growth, especially those who are most marginalized and excluded in school and society.

Guiding Pedagogical Theory

My teaching is informed by growth mindset theory, which posits that a student's intrinsic belief in their ability to develop their intelligence profoundly affects their success in learning at school (Dweck & Leggett, 1988). In a growth mindset, intelligence is not seen as "fixed" and immutable but as something that can grow. Dweck and Leggett (1988) considered students who avoid challenging tasks to exhibit a "helpless pattern," while those who seek out challenging tasks exhibit a "mastery-oriented pattern." In other words, students with a "fixed mindset" about intelligence tend to blame themselves for not being able to do something. In contrast, those with a growth mindset see setbacks as temporary challenges and part of the learning process. Consequently, students with a growth mindset often perform better on difficult tasks than those with a fixed mindset, even when their initial abilities are equal. Growth mindset is composed of three key tenets: 1. intelligence can be developed, 2. failure can be reframed as a learning opportunity, and 3. goals are defined as a process rather than an endpoint in learning.

The first tenet contends that how a person perceives the cause of their success or failure affects their response to a challenging event (Gningue et al., 2024). The perspective that ability is a fixed attribute is pervasive in education related to Science, Technology, Engineering, and Mathematics (STEM). Van Aalderen-Smeets and Walma van der Molen (2018) observed that a fixed mindset often leads to choice aversion among students regarding STEM pathways. A focus on growth mindset that aims to develop students' intelligence would be beneficial for increasing all students' engagement in STEM and for more diverse representation of students of Color and female students in these fields (Yeager et al., 2019).

The second tenet posits that failure can be reframed as a key part of the learning process (Dweck, 2017). A growth mindset entails embracing rather than avoiding failure and, in doing so, finding motivation to grow as a learner. In a STEM classroom, teachers can leverage their pedagogy and assessment to encourage students to fail forward. For example, employing student-centered teaching can promote student efficacy in learning (Gningue et al., 2024). This includes STEM lab discovery rather than textbook solutions, and class discussions rather than lecturing. Feldman (2023) also noted that if students are allowed to retake assessments to achieve concept mastery, failure can be treated as part of the learning process rather than as an endpoint.

The third tenet emphasizes process-oriented rather than goal-oriented learning. While goal-oriented learning often emphasizes achievement, process-oriented learning focuses on expanding one's ability to master challenging situations (VandeWalle et al., 2001). For example, the Next Generation Science Standard (NGSS, 2013) states that experiential learning through labs and activities should not be geared toward predictable textbook outcomes. Teachers need to encourage students to practice science as an iterative process in which failure is a pathway to discovery. In facilitating process-oriented learning in STEM, more students, especially those underrepresented in these fields, can develop a positive academic identity (Tan & Maeda, 2021).

Growing up in a family where traditional education was not valued, I saw how a lack of support created a gulf of confidence in schooling. Time and again, I saw my siblings struggle to make it through school. They would quickly convince themselves that they could not succeed after hitting a few stumbling blocks. They saw those stumbling blocks as a series of unattainable goals rather than a process toward gaining expansive knowledge. My observations of their experiences and those of some of my students over the last few years have made me realize that they would benefit from sustained support in developing a growth mindset to overcome learning obstacles.

Connection to InTASC Standards

The goal of this action research is to create a learning environment that fosters a growth mindset in students. In my first three years of teaching, I have noticed that when students are allowed to understand and process failure in class, they are more likely to thrive in learning activities. For students who often struggle with school work, I have observed a decrease in academic anxiety when presented with a learning structure where failure is treated as a process rather than an endpoint. For high-achieving students, the focus on failure as a process encourages them to take on greater challenges. When students ask why no one ever gets 100% on tests, I respond that we are always learning. These observations helped me identify three key InTASC standards that align with the growth mindset theory: 1. learner development, 6. assessment, and 10. leadership and collaboration (Council of Chief State School Officers, 2011).

The first tenet of growth mindset theory aligns with InTASC standard #1, which emphasizes that a learner's development stage varies and that the teacher must design materials appropriate for each learner. For example, teachers can have an open discussion with students about how growth and fixed mindsets can affect our learning and guide students to move toward a growth mindset. In a STEM class, this can look like creating two posters: one containing student comments indicating fixed mindsets and the other containing growth mindsets. Teachers can help students track their mindset changes over time, showing how these shifts have empowered them to become future scientists who believe intelligence can be developed.

The second tenet of growth mindset theory fits well with InTASC standard #6 in several ways. Standard #6 focuses on the use of assessment to engage learners in their own growth. An important aspect of developing a growth mindset is allowing students to fail and to demonstrate mastery. For example, when a student gets the transitions between rock types correct, the teacher can ask her to demonstrate how she envisions the process. When the student has misconceptions about the process, the teacher can help her adjust her thinking until she discovers the correct answer. At that point, she will be ready for the test retake. In so doing, teachers can encourage students not to rush through assignments or assessments, but focus on learning (Feldman, 2023).

InTASC standard #10, leadership and collaboration, complements the third tenet of growth mindset theory, as collaborative learning can encourage students to focus more on the collaborative process of knowledge development and academic leadership. This is especially relevant to STEM education, where the very nature of scientific discovery often requires scientists to collaborate to produce new knowledge that can benefit humanity. Many scientists recognize that knowledge is gained through everyone’s leadership in trial and error rather than discrete endpoints. Thus, STEM educators need to foster a collaborative learning environment that empowers students to focus on the joy and rigor of doing science, not simply achieving it.

Summary

Samuel Beckett famously wrote, “Ever tried. Ever failed. No matter. Try again. Fail again. Fail better.” It is through failure that we learn how to improve and refine our knowledge. Students who have a growth mindset are not afraid to fail. They see it as a challenge rather than an ending. During my formative years, I have seen firsthand how a lack of support can affect one’s growth mindset. To cultivate a growth mindset, students need the right support to fail forward. This is especially important in STEM, where failure is integral to scientific success. By connecting the tenets of growth mindset theory with InTASC standards, I hope to cultivate a learning environment where students recognize their capacity to grow, embrace failure as a stepping stone to success, and prioritize the learning process over the end goal.

Chapter 2. Review of Relevant Research and Scholarship

Dweck and Leggett (1988) presented the foundational model for growth mindset theory in their work on motivation and personality. The key question that motivated this study is why two individuals with equal ability would demonstrate very different abilities in response to a challenge. The authors used two goal-orientation descriptors: some individuals will be oriented toward performance goals, while others will be focused on learning goals. They hypothesized that the difference was due to the individual's goal orientation. From this conceptualization of goal orientation, a model is presented in which an individual's goal orientation determines a pattern of responses when faced with a challenge. The model generally finds that individuals oriented towards performance goals tend to struggle more than those oriented towards learning goals when faced with challenging tasks. In other words, if starting at the same cognitive level, an individual with a strong intrinsic belief characteristic will do better at working through challenges without becoming frustrated or losing confidence.

This classic scholarship helps characterize how implicit ideas about intelligence can play powerful roles in determining student mastery and growth. The goal of my action research is to help students take on challenges and learn to fail forward. To do this, I need to present students with consistent, challenging tasks and guide them to focus more on the learning process rather than the goals. A limitation of this study is that it presents a generalized theory. More empirical research is needed to identify secondary factors that contribute to individuals' growth mindsets and responses to challenges.

Tan and Maeda (2021) investigated the link between 9th-grade students' perceptions of teachers' growth mindsets and their science identity, which extends into the post-secondary years. Drawing on growth mindset theory, the authors asked two main questions: 1. Does a student's perception of a teacher's growth mindset affect their science identity over two periods, first over the student's 9th-grade year and then over the span of high school? 2. Does this perception have a disproportionate impact on students of Color and female students? The authors examined a dataset from the U.S. National Center for Education Statistics containing pertinent information on approximately 16,000 9th-grade students across 944 schools. They concluded that a student's perception of a teacher's growth mindset positively affects the student's science identity, and this positive impact occurred across nearly all groups.

This article reaffirms the importance of a growth mindset in science teaching. A strength of this article was that it defined the key concepts of a growth mindset in the science classroom and explained the importance of a student's perception of a teacher's growth mindset. The methodologies and analyses were clearly described. However, after establishing a positive correlation between growth mindset and academic identity, the authors do not further explain why the correlation exists. Addressing this limitation would make this study more methodologically robust.

Feldman (2023) drew on the growth mindset theory to argue for a grading transformation from the traditional 0-100 scale to a 0-4 scale to improve accuracy and promote a more equitable assessment of students. In the proposed grading framework, numerical grades should assess whether students have reached proficiency in a given outcome, rather than whether they have performed a series of tasks. For example, including a citizenship grade in a STEM class does not reflect whether a student has met the academic goals for the material. Having filler assignments that do not evaluate subject mastery prevents both students and teachers from developing a clear idea of what students need to master. By targeting grading methods towards proficiency, teachers are better able to serve students' academic needs and foster their growth mindset.

This book clearly defines a grading structure that can reduce students' anxiety about assessment uncertainty and outlines a data-driven approach to improving students' mastery of academic content through classroom practices. One criticism of the text is that, at times, it leans heavily on analogies that can be interpreted in alternative and inconsistent ways. Regardless, this book provides sound guidance on designing, implementing, and evaluating assessments to foster a growth mindset among students.

Gningue et al. (2024) investigated the impact of teachers' mindsets on how science and math are taught and student engagement with course materials. The research was based on the theory that a growth mindset corresponds with a self-belief of malleable abilities, while a fixed mindset corresponds to fixed ability. The authors explored the following research questions: " 1. What kinds of mindsets do Noyce teachers demonstrate in their teaching? 2. To what extent do Noyce teachers' mindsets relate to their ways of teaching?" (Gningue et al., 2024, p. 3). Using a qualitative case study approach, the researchers analyzed classroom observations, open-ended interviews, and teaching belief questionnaires of seven STEM teachers. The researchers found that teachers who espouse a growth-mindset pedagogy are better able to support students' academic growth and promote a positive classroom environment.

Gningue et al. (2024) was important to my research because it reinforced the significance of teachers' mindsets in shaping student learning. It helps me reflect on which aspects of my teaching reflect a growth mindset. For example, if I am maintaining a growth mindset in my teaching, I should employ student-centered STEM pedagogy and labs that promote students' efficacy in learning. The primary limitation of the study was its scope: seven participants. Other factors, such as administrative oversight of teachers, could also limit their pedagogical practices. Addressing these limitations can enhance the study's internal validity.

Kaplan et al. (2005) explored the hypothesis that school-related stress in early adolescence can negatively impact future academic performance. Drawing on growth mindset theory, the authors conducted a quantitative longitudinal study of 1,078 school-aged adolescents, extending back to the late 1970s. Interviews and questionnaires were administered to measure self-attitudes. Using a 10-point scale, students' academic performance was measured as the dependent variable, and school stress, the independent variable, was assessed via an index based on a series of yes/no responses. The authors found that academic stress stemming from high expectations can negatively affect students' future learning outcomes. High expectations on their own do not lead to high academic performance and may actually be counterproductive. The authors suggested that additional student support, such as participation in a social community, can reduce their academic stress and improve their growth mindset.

This article is important because it highlights the need to reduce students' stress to help them succeed. High expectations without proper support can negatively impact students. It is important that, in addition to measuring students' academic success, teachers also measure their emotional well-being. The article is important because it provides a quantitative measure of how stress predicts student achievement over a discrete time frame. Not only does this yield more robust conclusions, but its clear methodology also provides a guideline for further research. Furthermore, this study does not aim to explain the dependent variables, such as student achievement three years later, but rather that stress can serve as a predictor and that additional variables need to be measured to gain a full understanding of the causes of variability in student performance. This provides a path forward for future research on the topic.

Claro et al. (2016) described how a growth mindset mitigates the effects of poverty on student achievement. The study built on growth mindset theory and, for the first time, identified a relationship between socioeconomic status and growth mindset. The study examined a large dataset of 10th-grade students (n=168553) from Chile. It focused on two survey questions that were asked of each student: 1) “Intelligence is something that cannot be changed very much,” and “You can learn new things, but you can’t change a person’s intelligence” (Claro et al., 2016, p.1). Students answered each question on a scale of 1-6 from strongly agree to strongly disagree. The survey data were then compared using statistical linear regression to standardized test scores and socioeconomic data. The authors identified a clear relationship between mindset and academic achievement. When applied to students in the bottom 10th percentile, the approach is more likely to foster a fixed mindset; however, when they do have a growth mindset, they do much better academically.

The importance of the study lies in highlighting the powerful impact of poverty on student self-assessment and its foundational role in students’ academic success. In particular, a growth mindset can buffer students against the impact of poverty on academic achievement. The study provides a powerful impetus for implementing interventions that help underserved students develop a growth mindset. While the study was conducted in Chile, its implications are important for all educators to consider. A follow-up study of students from other parts of the world may yield more valuable insights.

van Aalderen-Smeets and van Aalderen-Smeets (2018) developed a theoretical model of how implicit beliefs about one’s abilities in STEM influence future choices to pursue a STEM career. In the first model, a student’s implicit belief impacts self-efficacy and confidence. If a student’s implicit belief is fixed, a setback will reinforce low self-efficacy and confidence, leaving the student with no choice but to pursue STEM. In the second model, a fixed implicit belief reinforces stereotypes about gender and race when the student is faced with a setback. In the third model, a student's implicit belief can either reinforce or undermine negative motivation if fixed. The three models provided distinct testable hypotheses that would show how a fixed versus a growth mindset might affect a student's choice of or avoidance of STEM pathways.

This article provides a systematic approach to considering secondary steps resulting from mindset endmembers. It describes how a student's mindset is a precursor to their career, shaped by confounding factors such as stereotypes, motivation, and self-efficacy, and exacerbated by a fixed mindset. In addition to providing insight into how fixed and growth mindsets can impact students' STEM pathways, it also deepens my understanding of how certain groups may be more susceptible to fixed-mindset thinking. As a theoretical model, the research lacks empirical testing. With respect to the separation of influences on STEM choice, the authors recognize that the variables are not independent, nor do they expect them to be treated as such. Thus, future research should continue to examine the empirical implications of this theoretical model.

Bostwick et al. (2019) examined students' growth orientation and its impact on their mathematics outcomes. The authors looked into 2949 middle and high school students in Australia over a period of one academic year. They identified these variables on student learning: growth mindset, self-based growth goals, and task-based growth goals. Then, they investigated how the variables co-vary and how they predict student performance in class. They found that the growth-orientation variables, in coordination, were strong predictors of how a child might do in math. Their findings point to the importance of treating shared motivational variables as a growth mindset in a holistic manner.

This paper examines how shared variables can affect a student's math performance. These factors are likely to carry over across all STEM subjects, especially given students' assumption that math is a necessary prerequisite for being good at science. A key shortcoming of this paper is that it was not always clear how the shared variables were distinguished from growth mindset or growth-focused goals. There seems to be some circularity in the argument that the same predictions could be made by looking at the growth mindset alone, since the components addressed make up the growth mindset. Future research on this topic should address this methodological limitation to make its arguments more theoretically robust.

Sisk et al. (2018) added a somewhat counter-argument to the literature on growth mindset theory. Using a meta-analytic approach, the authors focus on two questions regarding the growth mindset and its interventions on academic improvement. The first question was, "[w]hat is the magnitude of the relationship between mind-sets and academic achievement, and under which circumstances does the relationship strengthen or weaken (Sisk et al., 2018, p. 550)?" The authors narrowed an initial search of 15858 articles to 273. The second question was, "[d]o mind-set interventions positively impact academic achievement, and under which circumstances does the impact increase or decrease (Sisk et al., 2018, p. 550)?" The authors narrowed the search to 43 studies. For both questions, the authors used regression analysis to determine whether there are significant correlations between mindset interventions and academic outcomes. They found that the correlation was very weak ($r=.10$) with respect to academics. The authors concluded that the benefits of growth mindset interventions were minimal and resources might be better used elsewhere.

In applying growth mindset theory to my project, I found it important to incorporate not only studies that support this theory but also those that may be at odds with it. One key aspect of the paper that is important to my own work is recognizing the importance of statistical verification. From my perspective, this study had two limitations: 1. The authors did not clarify when the meta-analysis was conducted, and 2. Were the results truly independent? Future studies could conduct a large-scale primary research study to achieve greater control over the sample population and assess variable independence.

Yeager et al. (2019) examined the effects of a brief online growth-mindset intervention on 9th-grade students. This study extends growth mindset theory to examine the effects of growth mindset interventions on underachieving students. Students in the study were given two brief online interventions, each lasting about 25 minutes, and given 20 days apart. The first intervention session focused on student understanding of what it means to have a growth mindset. The second intervention session focused on how students could apply growth mindset concepts in their lives. The participants' test scores were then analyzed for improvement in response to the intervention, with a focus on demographic differences. At the end of the study period, students who took the online intervention improved their GPA. The study also examined how school norms and social groups influenced the intervention's lasting impact. The authors noted that, in addition to intervention, schools with support for student environments and peer groups had longer-lasting effects than those without such support.

While the study fell short of providing a catch-all intervention for all school settings, it did show that even brief growth mindset interventions can have a lasting impact. The methods of this study were very robust. An outside research group selected schools and student populations to minimize selection bias. The population size was large enough to exclude spurious results from undersampling, and student selection was randomized within each school. In my research, this supports efforts to regularly reinforce a growth mindset in the classroom to improve students' academic performance. It also emphasizes the importance of creating a culture that values academic excellence to amplify the impact of growth mindset interventions.

Summary

In recent years, increased attention has been given to the growth mindset in schools. This literature review reinforces the idea that fostering a growth mindset and reducing impediments to student success can go a long way toward creating an environment where students can thrive (Dweck & Leggett, 1988; Bostwick et al., 2019). This is particularly important in STEM, where academic performance anxiety and other related factors often result in underrepresentation of students of Color and female students in STEM. The equitable grading design by Feldman (2023) provides an assessment framework that minimizes the influence of non-academic variables on student performance. Gningue et al. (2024) showed that teachers' reflections on growth or fixed mindsets in the classroom influence student engagement: growth mindset teaching is more student-centered and engaging. Tan and Maeda (2021) and Kaplan et al. (2005) highlight that when measuring the impact of a growth mindset on students, it is imperative to examine whether they perceive a growth mindset in their teachers. Claro et al. (2016) also demonstrate the importance and impact of a growth mindset on those students who are most vulnerable. However, not all studies on this topic indicate that growth mindset interventions are successful for students. The impact of a growth mindset on students can extend to secondary factors as well (van Aalderen-Smeets & van Aalderen-Smeets, 2018). For example, a student with a fixed mindset is also more likely to be affected by stereotype threat. It is important in my own research to consider the potential feedback regarding students' mindsets. Sisk et al. (2018) observe a weak correlation between growth mindset interventions and academic success. Thus, we must create an environment that demonstrates a belief in every student's ability to grow and minimizes impediments to their success, such as undue academic stress and inequitable grading practices.

Chapter 3. Methods

As educators who continue to learn and develop our craft of teaching, we must take reflective steps to understand how we are currently serving our student populations and where we may be failing them. Whether we are novice or experienced teachers, we can always find better ways to deliver the best education for students. One way we can engage in reflective practice in our teaching is through action research. Action research is the disciplined inquiry into our pedagogical practice. The process of action research is by and for the person taking action, or in this case, the teacher (Sagor, 2000). Situated within the traditions of qualitative research methods, action research is anchored in teachers' investigation of research questions closely related to their practices, guided by a relevant pedagogical theory. Sagor (2000) outlined seven steps to conduct action research: 1. Finding a Focus, 2. Clarifying Theories, 3. Identifying Research Questions, 4. Data Collection, 5. Data Analysis, 6. Reporting, and 7. Action Planning. Each step should be centered around a desired outcome in one's teaching practice.

Sagor (2000) stated that teachers could keep a reflective journal over a defined period, recording notes guided by a leading question or concern about teaching. Once they have a focus, they can select a relevant theory, which entails understanding their beliefs and insights about the defined focus. Next, teachers can research what has been done and what questions have gone unanswered in the academic literature, and then articulate their own research questions. The next steps are to collect and analyze data. It is important to collect data from a variety of sources so that teachers can triangulate for a robust analysis that paints a clear picture. Finally, teachers can report their findings and develop an action plan based on them. This action research project examines the following research questions: *1. How did I foster a growth mindset in my 9th-grade science classroom? 2. How did students respond to my pedagogical efforts?*

Action research is an appropriate means of studying these questions. First, the nature of the research questions requires self-reflection on how students respond to my pedagogy. This includes an interactive analysis of how I presented material, assessed student work, and how students worked in my class. Second, the time commitment is exceedingly taxing for other types of research, especially for a new teacher. Action research is an efficient means of understanding a problem and determining a plan of action in response to that understanding. Additionally, action research allows us to share our results with teaching colleagues and create a culture of reflection and inquiry on our teaching practices.

Contexts of the Study

Located in rural Oregon, Cascade High School (pseudonym) is defined by a tight-knit community in which teachers are often alumni of the school, and students have known one another for many years. The school touts a 94% graduation rate for its students. To reach this milestone, emphasis is placed on ensuring regular student attendance, with late arrivals or missed classes resulting in consequences such as detentions and referrals. 74% and 16% of the students are White and Latinx, respectively. American Indian/Alaskan Native, Asian American, African American, Multiracial, and Native Hawaiian/Pacific Islander students make up the rest of the student population. Multilingual students make up 13% of the population, and students with disabilities make up 15%. The gender makeup of the students is 51% male and 49% female, with information on non-binary students unavailable. The area has a very mixed socioeconomic demographic. For students with limited means, completing assignments, especially with online components, can be difficult. This is exacerbated by the school's rural location and lack of public transportation, which limits some students' access to after-school support.

I conducted this study in a 9th-grade science class. The students took two science courses during the school year: Integrated Science A, which focused on Physics, and Integrated Science B, which delved into Earth and Space Science. My class consisted of 14 students. One student is a multilingual speaker who receives special education services. Another student is on a 504 plan. One student self-identifies as Indigenous, one as Asian, two as Latinos, nine as Whites, and two as unknown ethnicity. There were 8 male students and 6 female students in the class. No students in this class openly identify as LGBTQIA. This may be a response to the conservative values generally held at the school. Most students in this class grew up in Oregon. For the school as a whole, 60% of students are eligible for free or reduced lunch.

Students bring a lot of strength to the classroom. Many have known each other for a long time, and they have learned to work well together. For new students, I have generally seen them being welcomed. Many also have prior knowledge from their parents or grandparents. They can recall stories of climatic events such as the floods, the Aumsville tornado, or the great snowfalls of the 1950s. This knowledge is ingrained in the way of life of families who have lived in the area for generations. There is also a strong hunting-and-sustenance culture at the school. I am not a hunter, but it is a valuable way to engage with my students. When they leave for week-long hunting trips, I ask them to keep a hunting journal, explaining how there is a lot we have learned about our climate and environment from sportsman groups. This allows me to build more culturally relevant materials into the official district curriculum.

Data Collection & Analysis

The focus of this action research was on the freshman Integrated Science A and B, with data collected over an entire year. The data included informal classroom observations, reflective journals about my teaching, lesson plans, informal surveys, and student assessments. Data analysis began with open coding, following the methods described by Sagor (2000) to identify patterns. The second round of data analysis used focused coding, guided by the three tenets of growth mindset theory. Data triangulation was also used to ensure that the major themes of the findings are congruent with the conceptual framework. In other words, each theme had a wide range of data from which I could exclude spurious findings. Then, my thesis supervisor provided feedback that clarified my analysis. These procedures enhanced the study's internal validity.

Researcher Positionality

Taking a position at Cascade High School as a teacher, I found it uncomfortable hearing daily announcements for the Christian Athletes and Young Life Christian groups, but nothing about a pride club or support groups for students of Color at the school. Over time, I realized this was a needed strength for the school. While I am a White, cisgender male and do not share the lived experiences of marginalized students, I can stand as someone who is there to support them at the school. Additionally, I can work with conservative students by connecting to their culture. For example, when teaching about climate change, I was able to draw on their cultural practice of hunting in the fall. This helped students recognize that when I challenge or encourage them to fail forward, I do so because I believe in their ability to grow. From my own childhood, I recognize how important it is to make these connections and to foster a sense that it is ok to fail because that is when we learn the most. Growing up with oppositional views towards school, I missed out on early connections with teachers who may have given me the opportunities I needed to fail and foster a growth mindset. Thus, I want to make every effort to ensure that my students always feel welcome, recognize their ability to learn and grow, and feel safe learning from failure and enjoying the learning process rather than merely achieving an academic goal.

Chapter 4: Findings

Three themes emerged from data analysis. They are: shaping students' beliefs about intelligence, reframing failure as a learning opportunity, and emphasizing the learning process rather than the end goal. Each theme is discussed with supportive data.

Theme I: Shaping Students' Beliefs about Intelligence

Some of the students I taught already developed a growth mindset, while others held fixed perceptions of intelligence. Thus, a crucial part of my instruction was to create and scaffold learning opportunities that challenged those fixed mindsets. First, I analyzed factors contributing to their low self-efficacy: peer influence, familial pressure, and societal projection. For example, if students of Color and female students do not see themselves reflected proportionally and accurately in STEM curricula, it is more difficult for them to believe they would succeed in the field. When these students encountered academic challenges, they were more likely to fall into a routine of retreat and avoidance of challenging academic tasks. This was corroborated with one of my journal reflections: "With each group of students who enter my classroom, there were those, regardless of their abilities, who did not believe they could thrive in STEM."

These observations propelled me to devise a plan to help students practice changing their beliefs about their capability in STEM. Prior to the first module test in the trimester, I presented a lesson on fixed and growth mindsets, followed by a discussion of how they can affect learning. I then asked students to think about activities where failure is an expected part of learning. One student, who played the cello, commented, "When I practice a piece for a recital, I make a lot of mistakes at first." A few other students shared that making mistakes is a normal part of becoming better at sports, "We don't start making 3-point shots in basketball without failing first." I then demonstrated poor shooting form and asked the students how I might fix it. This discussion was to help students see ways outside the STEM class in which they demonstrate a growth mindset.

Next, I instructed students to write down phrases they might say about schoolwork that resemble fixed mindsets on a colored sticky note and place the note on a whiteboard. We then discussed the phrases and how we could change them into growth-mindset statements. Students returned to the whiteboard, picked up a peer's sticky note, and wrote a growth-mindset statement in response on a different-colored sticky note. At the end of the activity, we discussed how we can impact our own mindsets and others' by showing subtle ways that we do not believe in them. I shared with the students, "When I let you struggle through a task, I trust your ability to solve the problem on your own." The board was left up throughout the trimester. Whenever students made a fixed-mindset comment, I would give them a sticky note to write down, and another to write a counter-statement to reinforce a growth mindset in class (Figure 1 & Table 1).

Figure 1. White Board Containing Students' Sticky Notes

Fixed-Mindset Statements	Growth-Mindset Statements
I will never be able to do this.	I am in DECA. I got this. I am positive!
It’s too hard. I can’t do this.	I will try my best and learn from my mistakes.
I’m done, it’s not working.	You are doing amazing!
This is impossible.	This is hard, but it’s how I learn.
I am not good at this. Why do I even try?	Maybe I need a new strategy to make this work.
I am bombing this test.	I can retake it and learn from my mistakes.
I hate tests!	Don’t give up! You are trying.
It’s too hard. I can’t do this!	What can I do to improve?
I can’t sing!	You can’t sing yet. Sing and enjoy!

Table 1. Student Statements about their Beliefs

I also reinforced a growth mindset by building on the cultural assets students bring to the classroom and connecting their experiential knowledge to the STEM curriculum. For example, I encouraged students who are recent immigrants to write in their home language at first, if needed. When creating rockets in freshmen science, I had students decorate their rockets and design posters in ways that are meaningful to them. Some students chose to put the Mexican flag or their favorite sports slogans on their rockets. Moreover, I helped students make connections to their culture through concrete phenomena they could see and understand. One of the unit’s final projects asked students to discuss the climate system in the Willamette Valley. I created a list of weather events that some of their families lived through, and then they researched and presented on it. For example, a tornado hit their town the year many of them were born. I played a news clip about the tornado that featured a student’s uncle. Students’ research also noted that the Tornado Fitness Gym is now where the plumbing store once stood. These curricular approaches conveyed to students that their lived experiences function as a valid path to their academic knowledge in earth science and complement their growth in STEM.

To continue understanding students' self-perception and how it shapes their beliefs about their capability in STEM, I distributed an informal, anonymous survey prior to the summative assessments at the end of the first trimester. The survey contained five questions: 1) Do you feel confident in your knowledge of the topic you are being tested on? 2) Do you feel confident that you can succeed on the assessment for this unit? 3) Do you feel that Mr. Edwards believes in your ability to grow and learn the material for the assessment? 4) If you stumble on the test, do you feel that you can recover and succeed if given another chance? and 5) If you do well on the test, how confident are you that you will do well on the next assessment? I asked students to rate these questions on a scale of 1-5, with 1 being negative and 5 positive.

When comparing students' answers to their assessment grades, I found a clear correlation between students' self-confidence and their test performance. For example, I noticed that student engagement in more difficult activities was lower for those who also scored low in confidence when evaluating their answers to question one. Similarly, students' answers to question two suggested that their belief in their knowledge going into the first test correlated strongly with their test scores (Figure 2). These results informed me that I needed to adjust my teaching to support students with low self-efficacy and challenge those who are academically confident.

Figure 2. Informal Survey Results

For the final assessment of the trimester, I had students create posters describing different components of the climate system. The assignment was broken down into smaller components that students completed over a couple of weeks. While this was still a rigorous project, breaking it down into smaller tasks helped those with lower confidence get early help, make revisions in smaller chunks, and build confidence to try various approaches toward an end product they can be proud of. Consequently, students who scored lower on tests and more challenging activities performed better in these guided, well-paced activities. For those more confident learners, I pushed them to reach for higher-level scientific reasoning. I reminded them that our goal was the learning process rather than an end product. As long as time allows, we can continue learning. Some students resisted this notion. They wanted to be done and know their grade. Others gladly kept moving forward and adding more to their poster. In the end, many students turned in posters that were scientifically informative and aesthetically pleasing. Another teacher who taught the same class asked to use my students' posters as examples for his classes the following trimester.

In sum, I noticed that students with a fixed mindset tend to avoid challenging academic tasks and underperform on assessments in my class. The learning activities I facilitated and the assessment approaches I used helped shape students' fixed perceptions of intelligence. In doing so, I created a learning environment that encouraged students to rethink the idea that their capability in STEM is not a fixed status but an evolving process.

Theme II: Reframing Failure as a Learning Opportunity

My pedagogical efforts also shaped how students viewed failure in my class. I wanted students who were struggling in STEM not to be treated as deficient, but rather to be seen as having not yet mastered the topic. The power of "YET" is that the road to mastering a concept is always in front of you, despite the hurdles you may have to overcome. What I wanted to know was whether students saw themselves in this light. That is, when faced with adversity, would they recognize that they could work through it or feel defeated by it? Additionally, in what ways did my teaching contribute to their beliefs? Results from the informal survey provided me with some insights into my inquiries.

I noticed that students with IEPs or 504 plans were more likely to respond with a 1 on the survey because they did not believe they could recover after the test, even after I explained the test retake policy. About a quarter of the class responded with a 3 on the 1-5 scale, meaning they were unsure if they would be able to recover. This trend indicated that I needed to focus on addressing these students' fears and perceptions of failure. One decision I made was to encourage these students to retake tests and see if this would help them recognize their ability to overcome failure. I took two key actions to accomplish this goal. First, about a week after the test, we had a make-up day when students could retake it. I mentioned that it would be great to go into the winter break feeling good about their learning and improving on their understanding of academic concepts. This framing avoided the stigma that "If you have to retake a test, you must be a poor student." Consequently, 45% of the students retook the test, and the average test score increased by 6%.

The second action I took was to focus on encouraging students with IEPs or 504 plans. During my prep period, I went to the special education study hall and administered the retest there to convey to students my commitment to their ability to succeed. When preparing students for a test retake, I often addressed minor misconceptions that had a greater impact on the test, because a single misconception could be tied to multiple pieces of knowledge necessary for mastery. I worked with students through a process of inquiry to help them arrive at the correct understanding. For example, when a student got the transitions between rock types wrong, I asked her to demonstrate how she envisioned the process and helped her adjust her thinking until she arrived at the correct answer. At that point, she was ready for the test retake. By allowing students to retake tests in this way, I am encouraging them to see failure as a stepping stone to success in my class.

For larger apparent misconceptions, I arranged time with students after school to review the test and identify where they were struggling. For example, I would work in the library with them, where they could also see others getting help on class work. This helped me normalize recovery from academic struggles. The extended time and support were especially valuable for multilingual students. Often, I would discover that these students understood more than was indicated on the test due to a language barrier, test anxiety, or both. By working with them during and after school, I was able to build their confidence to help them overcome their anxiety about making mistakes on tests. As a result of my efforts, two things occurred on my second informal survey. The responses of 1s decreased, and those of 3s and 4s increased (Figure 3). This suggests that when test retakes are not just available to students but encouraged and properly scaffolded, they are more likely to recognize their ability to overcome failure.

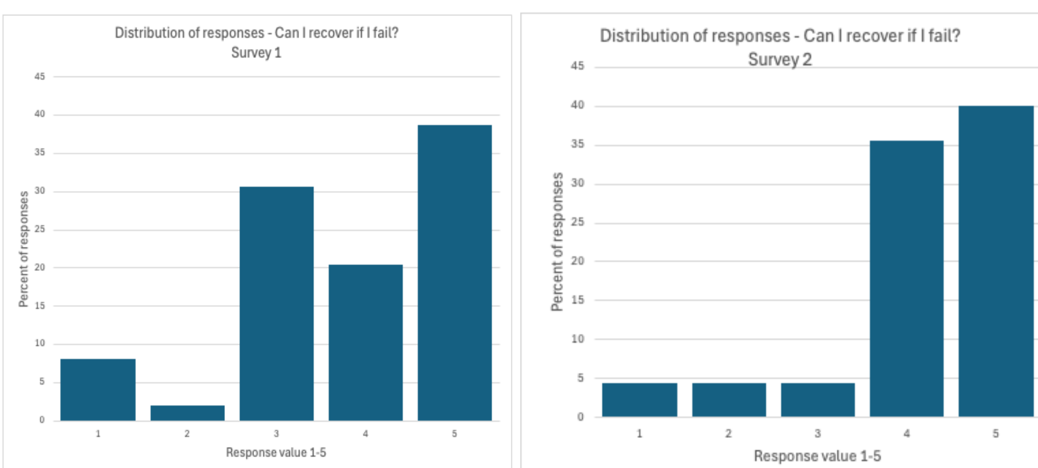

Figure 3. Comparison of Survey 1 & 2

Another way I reframed failure as a critical part of learning was by using inquiry-based labs and projects in which students collaborate to understand a phenomenon rather than to find an expected answer. For example, I introduced a rocket project as a capstone for the first trimester, which asked students to design a water rocket to fly the length of a football field in a straight line. I then described how students would use trial and error, along with the knowledge they had gained throughout the class, to complete their rockets. Students were provided with a variety of resources, including playdough, string, duct tape, sand, water bottles, and cardboard. They were also welcome to bring materials from home.

Before students started the project, they were required to research the evolution of rocketry, beginning with the Chinese use of gunpowder-filled bamboo, thrown into fires to create a celebratory bang during religious festivals. Students then learned about the application of Newton's laws to steam-propelled motion, and eventually to modern rockets, and the years of trial and error before the United States and the Soviet Union were able to launch a rocket into space, and eventually to the moon. I showed a video of rocket launch failures that illustrated the importance of enhancing scientific accuracy through human mistakes (Travis, Mathew, 2007).

Each day, students were assigned incremental aspects of the rocket design to consider. Some of the incremental tests included a bottle toss at the center of mass, testing paper darts to determine the center of pressure, and a pressure-and-temperature test to determine the conversion of work into potential energy via pressure. Each test required students to draw on their prior knowledge and develop their own ideas about the best design through iterative trial and error. As students worked on the project, I provided them with regular feedback and leading questions to encourage them to move forward. In the end, each team produced a design they were proud of, and I displayed their posters for their families to see during the academic showcase.

In sum, my pedagogical efforts encouraged students to engage with the idea that failure is a necessary path to success. By encouraging them to retake tests and providing hands-on projects that require them to learn through trial and error, my approaches to failure as a learning process helped students frame their thinking around learning as a methodical iteration of errors rather than learning through dictated answers to questions.

Theme III: Emphasizing the Learning Process Rather than the End Goal

Another way I cultivated students' growth mindset was by sequencing the curriculum to reinforce the importance of learning as a process rather than a set of discrete end goals. For example, we studied velocity and displacement in the first unit of freshman science. In the last module, the focus is on work and energy. Work directly related to displacement and an object's energy can be related to velocity. As students worked on their capstone projects, I asked them to incorporate concepts from every unit we had studied in class. While the trimester had distinct sections marked by summative assessments, we never left a topic behind. This was reflected in a class brainstorming session and pre-assessment for the rocketry project, in which students were asked to recall information they had learned throughout the trimester. I recorded the following notes on student participation: 1) Some prior knowledge was taught earlier, but some students had not retained it and needed additional reinforcement, especially around the concepts of energy conservation, and 2) Student writing demonstrated their ability to use scientific vocabulary in structured sentences and paragraphs and indicated how well they had synthesized the concepts.

These observations helped me adjust my teaching so that students could reprocess concepts in the curriculum introduced earlier in the trimester. For example, I set up a series of demonstrations and activities to help students visualize relationships among concepts. One activity had students pump air into a two-liter bottle with a pressure gauge attached. I instructed students to use the hand pump in turns so that everyone could feel the pressure increase and the pumping become more difficult. I also asked students to describe the procedure each time they pumped air into the bottle and where it was being transformed. Doing and describing this activity helped them recognize that the air they put in was transferred into potential energy. I also had a student measuring the temperature of the bottle as air was added, demonstrating how heat and pressure are related. When air was let out, they saw the bottle cool down, which is a result of air doing work as it expands. When assessing the students' posters, I noticed a better understanding of the conservation and transfer of energy than what was observed on the pre-assessments. In other words, emphasizing the learning process helped students better achieve academic goals.

Another way I emphasized the learning process was by removing grades from formative assessments. When I first started assigning formative assessments during the trimester, I noticed that students repeatedly asked whether they had to be turned in for a grade. It seemed the students had become accustomed to having small formative assignments graded for completion, and I often had to reiterate that I would not grade these assessments. Instead, I provided regular feedback and stamped their assessments. Many students wanted to ensure they received a stamp on their work, indicating that they gravitate toward this form of instructional acknowledgment over a traditional grade. To further convey to students that grades do not capture their full potential as learners, I shared a personal story of my understanding of a meaningful learning experience vs. a perfect grade:

> I had just entered my dream school, UC Berkeley, and I was super excited about the classes I was going to take. One of them was called Atmospheric Chemistry and Physics. It was a super hard class. In fact, this class was way over my head, and I really struggled. I worked incredibly hard to get through the class, harder than in any class I have ever

taken. In the end, I got a B for the class. When I think back on that class, I can say with confidence that B was the best grade I ever received.

I then asked students, “Why do you think it is the best grade I’ve ever gotten?” Students chimed in with various answers, including “You never got As,” “Because you worked hard,” and “Because you learned the most.” I acknowledged their answers and added, “It was the best grade, not because I failed a lot in this class, but because each time I figured out where I needed to improve. The class taught me to focus more on the process of learning.” Sharing this personal story with the class communicated my teaching orientation: Students need to put more effort into learning academic concepts rather than getting a perfect grade in my class.

My pedagogical efforts helped students gradually learn to focus on the struggle and joy of learning rather than on a good grade. By the middle of the trimester, students had stopped asking about grading on formative assessments, and there did not appear to be a large dip in completion rates. In labs, I saw students become more relaxed in their learning. Instead of rushing through the assignment to ensure they got the points, students slowed down and began asking their own questions. For example, a student was experimenting with a couple of pencils and a ruler after completing a worksheet on momentum. He placed the pencils end to end, then struck the first with his pencil and watched the second fly due to the transfer of momentum. After seeing this, I quickly designed a lab around what he did and asked all students to try it a few days later. I also added a few adjustments so students had additional steps in their inquiry. When the school administrator observed the students performing the lab, he said it was the best class he had observed from me and was impressed by the level of student engagement. Thus, eliminating the stress of grades for students allowed them to become more fully engaged in learning content.

In sum, through sequencing the curriculum, reteaching academic concepts, and removing grades from formative assessments, I redirected students' desire for a perfect grade to motivation for deeper learning. Shifting their goal-oriented learning to process-oriented learning played a critical role in fostering students' growth mindset, which further developed their capacity as future scholars and practitioners in STEM.

Chapter 5. Discussion, Limitations, and Conclusion

When developing my class around growth mindset theory, I began with the foundational framework of Dweck and Leggett (1988), who posited that two key characteristics of how one thinks about their ability to develop intelligence can explain a person's tendency to take on or avoid challenges: fixed mindset and growth mindset. Throughout this action research project, I drew on this theory to understand how my students, especially those underrepresented in STEM, processed academic challenges, whether they exhibited a fixed or growth mindset, and how they responded to my growth-mindset-oriented teaching. My pedagogical approach was similar to those illustrated by Gningue et al. (2024), who demonstrated the impact of growth-mindset teaching practices on student engagement, and Bostwick et al. (2019), who showed the impact of growth mindset on student decisions to choose STEM classes.

The primary goal of my pedagogy was to help students develop a growth mindset and self-belief that they can develop their abilities and intelligence in STEM. My first step was to recognize that to shape students' growth mindsets, it was equally critical that they recognized mine. As Tan and Maeda (2021) noted, the way a student interprets a teacher's growth mindset significantly impacts their academic identity. Thus, I distributed an informal growth-mindset survey to understand students' insights. I also identified key traits of fixed and growth mindsets and consistently worked to steer my teaching toward a growth mindset. For example, when I caught myself overusing lectures to teach students rather than using inquiry-based learning, I quickly adjusted my teaching to align with the characteristics of student-centered teaching described in Gningue et al. (2024).

To further develop students' growth mindsets, I used an approach similar to what Yeager et al. (2014) described. For example, near the start of the academic year and before the first test, I developed an intervention plan that focused on developing students' growth mindsets towards STEM. The goal of this intervention was to help students gradually reframe failure as a critical learning process. In the intervention, students wrote down fixed-mindset phrases they might say about themselves and then came up with a growth-mindset alternative response that mediated their negative perceptions of failure (Claro et al., 2016). When students underperformed on a summative assessment, I discussed the outcome as part of the learning process and encouraged them to retake the test after addressing any misconceptions.

van Aalderen-Smeets and van Aalderen-Smeets (2018) proposed that growth and fixed mindsets can amplify other key factors that affect students' educational pathways. For example, a student with a fixed mindset will be more susceptible to stereotypes. Thus, I integrated student insights and assets into the curriculum while attending to secondary factors that affect their learning. For example, as the school is centered in an agricultural area, student projects included concepts related to the region. I also guided students in developing new questions from their learning and found ways to incorporate them into future lab activities. These pedagogical efforts increased students' orientation toward a growth mindset, consistent with Sisk et al. (2018).

In my assessment of students, I leaned on Feldman (2023) to develop grading practices that reinforced a growth mindset. I set a 50% minimum score for students so they would not be demoralized by a 0, which can disproportionately affect grades. I encouraged them to retake tests, empowering them to learn from failure. I gave verbal or written feedback on formative assessments, rather than assigning points. In doing so, I emphasized the learning process rather than the end goal. This approach helped many students redirect their goals away from grades to engaging with academic concepts. It also decreased anxiety about performance on formative assignments, helping students focus on learning outcomes rather than grade outcomes. In sum, my grading techniques enhanced students' growth mindsets, corroborated by Kaplan et al. (2005).

Limitations

My action research project, as with any empirical study, has several limitations. When developing students' growth mindsets, I had no control over potentially opposing variables outside my classroom. It is possible that while I was teaching students to embrace failure as a continuum of learning, their learning was confined to discrete targets in other spaces, where failure and success became endpoints. To some extent, this limitation could be overcome by extending growth-mindset interventions across the entire school. Since school culture plays a significant role in reinforcing a growth mindset among students, future research can address this theoretical limitation.

A key methodological limitation is that the study period was too short to capture the full impact of my pedagogical methods. However, through this action research, I have created a framework for a future reflective study of my teaching practices. I will continue to examine my pedagogy to ensure I reinforce a growth mindset in my students. A second methodological limitation is that, as a developing teacher, I am undergoing rapid change in my teaching abilities, particularly in behavior management and curriculum development. Because of this, there are confounding variables that are difficult to disentangle from my study's objectives. As I continue to improve my teaching practices, the impact of my pedagogy will also become clearer.

A practical limitation of my research is that not all schools are flexible in their grading and curriculum that teachers use in their classrooms. A key element in my pedagogy is using test retakes to encourage students to fail forward and minimize formative grades for points, thereby decentralizing students' focus on grades as an endpoint of learning. However, teachers can still teach through the growth mindset to shape student learning. They can also learn more about students' perceptions of their growth mindset to adjust their teaching. In so doing, teachers can maximize the impact of growth mindsets.

Conclusion

Growing up in a family that did not value education made it difficult to develop a strong growth mindset early in my life. However, as I became older, I surrounded myself with people who had a deep respect for school and education. Gradually, I formed my academic identity and began to develop a growth mindset toward learning (and life). This experience inspired me to use the growth mindset theory for my action research project. Throughout the study, I have taught students to pursue knowledge for conceptual mastery rather than to get a good grade. I have created learning opportunities that helped them reframe failure as a necessary step to success. Together, we learned that our intelligence can be continuously developed and nurtured. As I conclude this project, I am still reflecting on my teaching by asking myself: How can I help students become more engaged in learning and trust their capacity to grow? I hope my project will encourage more teachers to realize that we will go much further when we all grow together.

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