



# Increasing STEM Grit among Underrepresented Groups: Lessons from Our Fathers

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## Abstract

Research indicates that students with a high level of Grit and self-efficacy have higher levels of academic achievement. Grit is comprised of passion (consistency of interest) and perseverance of effort, for long-term goals. The purpose of this model is to increase Grit among underrepresented groups. It utilizes one aspect of self-efficacy, “vicarious experiences”, to increase STEM (Science, Technology, Engineering and Mathematics) Grit among underrepresented groups. Historical contributions from individuals from underrepresented groups in STEM fields are used vicariously to promote student Grit by showing examples of perseverance resulting in academic excellence. This model has implications for curriculum, instruction, assessment, professional development, and public policy articulation.

## Subject Areas

History, Mathematics

## Keywords

Science, Technology, Engineering and Mathematics, STEM, Grit, Underrepresented Groups, Self-Efficacy, Academic Achievement, Vicarious Experiences, Historical Contributions, Perseverance, African Americans, Curriculum, Instruction, Assessment, Professional Development, Public Policy Articulation

## 1. Introduction

The 13<sup>th</sup> Amendment (1865) formally abolished slavery in America by stating that “neither slavery nor involuntary servitude...shall exist within the United States, or any place subject to their jurisdiction” (U.S. Constitution—Thirteenth

Amendment|Resources|Constitution Annotated|Congress.gov|Library of Congress, n.d. [1]). After the revolt led by Nat Turner, many states passed laws forbidding teaching slaves to read and write (*Literacy as Freedom*, n.d. [2]). Once slavery ended, Jim Crow Laws and Separate but Equal policies, promoted a lower standard of education for African Americans (History.com Editors, 2018 [3]). In some instances, African Americans were not allowed to attend colleges or universities (see University of Mississippi History of Integration, 2021 [4]). Nearly 100 years after slavery was abolished in America, Title IV of the Civil Rights Act of 1964 was passed (Types of Educational Opportunities Discrimination, 2015 [5]). Title IV of the Civil Rights Act of 1964 prohibits discrimination in public schools because of race, color, religion, sex, or national origin. Public schools include elementary schools, secondary schools, and public colleges and universities. African Americans' education, attendance at public universities, and attainment of STEM degrees must be viewed considering the historical context of slavery and discrimination. Despite these challenges, tremendous strides have been made in STEM areas by those that have worked towards both scientific and discriminatory breakthroughs (*Learn More about These 19 Scientists for Black History Month|Science Buddies Blog*, n.d. [6]). This paper will present a model for increasing the vicarious self-efficacy of African American K-12 students by examining the professional achievements and Grit of African American STEM professionals.

According to CNBC, STEM-related occupations have been the best paying and fastest growing careers for decades (Smith, 2022 [7]). Data from the U.S. Bureau of Labor Statistics show that the average STEM worker earns \$100,000 per year. According to the Bureau of Labor Statistics, the average weekly earnings is \$1037. This represents a national annual salary of \$53,924. The average STEM worker earns nearly twice the national average (Employment in STEM Occupations, 2019 [8]). Hence, limited access to careers in STEM-related fields directly impact the earning potential of students. This lack of access undergirds a cycle of poverty.

The lack of participation of underrepresented groups in STEM career fields is well researched. Factors such as gender stereotypes (Bian, 2017 [9]), early STEM experiences (Dou, 2019 [10]), parental beliefs (Elliott, 2018 [11]), social belonging (Ito *et al.*, 2018 [12]; Lewis *et al.*, 2017 [13]; Rainey *et al.*, 2018 [14]) and limited role models (Olsson, 2018 [15]) affect students' attitudes towards STEM.

## 2. Research Background

According to leading research, the two dimensions of Grit are **passion (consistency of interest)** and **perseverance of effort**, for long-term goals (Duckworth *et al.*, 2007 [16]; Duckworth & Quinn, 2009 [17]). Duckworth *et al.* concluded that achievement of difficult goals involves both talent and grit. The research however did not address how grit related to self-efficacy. Passion or consistency

of interest refers to setting a goal and sticking with the plan. This implies that throughout difficult and demanding situations a “Gritty” individual will remain on task. Passion is an internal trait that drives a person towards a specific action. Passion or engagement implies involvement, commitment, enthusiasm, absorption, focused effort, zeal, dedication, and energy (Schaufeli, W.B., 2013 [18]). The antithesis of these actions include: disengagement, uncommitted, apathetic, distracted, unfocused, indifferent, uninterested, and inefficient behavior. A research study was designed to identify passion profiles toward one’s studies, and to compare students’ academic functioning (burnout, engagement, satisfaction, dropout intentions, and achievement) as a function of their passion profile. Four passion profiles were identified:

- 1) High (high harmonious and obsessive passions);
- 2) Moderate (moderate harmonious and obsessive passions);
- 3) Low (low harmonious and obsessive passions);
- 4) Optimal (high harmonious passion and low obsessive passion) in a sample.

Overall, highly passionate students (High and Optimal profiles) reported the most positive indices of academic functioning, while students in the Low Passion Profile domain evidenced the worst levels of academic functioning (Belanger & Ratelle, 2020 [19]). Belanger and Ratelle’s research involved 460 university students. Further research is needed on passion profiles for school-aged children.

Harmonious passion (HP) is a motivational force that leads to willful engagement. It is harmonious because the individual is in control and the choice aligns with the person’s life, goals, and desires (Belanger & Ratelle, 2020 [19]). HP is associated with life satisfaction, performance, and positive affect (Vallebrand, 2015 [20]). It negatively predicts burnout—directly and indirectly via positive associations (Birkeland and Buch, 2015 [21]).

The second component of Grit is Perseverance of Effort (Zamarro, 2020 [22]). The dimensions of Perseverance of Effort and Passion are interwoven. Passion represents an inner driving force. Due to this “drive” towards the individual’s own self-satisfying personal interests, the person will tend to persevere in the effort that they find enjoyable. Perseverance involves continuing to study after you’ve received a failing grade to ensure that you will perform better on the next exam. When an individual perseveres, they glean from every encounter, whether good or bad. They allow every experience to get them closer to their ultimate goal (Baruch-Feldman, Caren, 2017 [23]). Baruch’s “Grit Guide for Teens” focuses on building perseverance, resilience, self-control, and stamina. It does not address early elementary school students.

One example of a “Gritty” person is the African American chemist, Percy Julian. The grandson of slaves, Julian’s storied career saw the development of many drugs such as synthetic cortisone (for treating rheumatoid arthritis) and physostigmine (for treating glaucoma). Throughout his life, Julian’s home was torched, bombed and he was denied admission to graduate school all because of his race. Despite the difficulties faced, Julian persisted in making tremendous strides in the field of chemistry.

### 3. Academic/STEM Grit

In STEM areas, factors such as emotions, attitudes, values, beliefs, motivation, and anxiety affect student achievement (Al-Mutawah, M.A., & Fateel, M.J., 2018 [24]). Zimmerman and Brogan (2015) stated that “Grit predicts successful performance in a variety of contexts and found it to be positively correlated with undergraduate grade (point) average.” (Zimmerman, E., & Brogan, L., 2015 [25]). The results showed that Grit is positively and significantly correlated to academic achievement (**performance**) in math, while **attitudes** towards math and science were positively and significantly correlated to academic achievement in both subjects (Al-Mutawah, M. A., & Fateel, M. J., 2018 [24]). The non-cognitive factors of racism and vicarious experiences and their affect on Grit or Academic achievement, were not examined.

Research on the impact that Grit has upon academic achievement indicates conflicting viewpoints (Credé, M. *et al.*, 2017 [26]). The components of Grit include **passion (consistency of interest)** and **perseverance of effort**. Critics argue that passion does not play a significant role in determining academic success (Muenks, K., Yang, J.S., Wigfield, 2018 [27]). Muenks *et al.*, 2018, proposed that character traits such as self-efficacy, task values, and goal orientations were more strongly correlated with success than **passion (consistency of interest)**. Perseverance of effort however was a stronger predictor of grades.

The component of Grit that researchers tend to agree has a positive impact on student achievement is Perseverance. (Al-Mutawah, M.A., & Fateel, M.J., 2018 [23]; Muenks, K., Yang, J.S., Wigfield [26], 2018; Credé, M., *et al.*, 2017 [25]). Perseverance, however, that is not accompanied by a student’s belief in their academic success, will not lead to core academic success. This represents students who continue to work but do not believe that their effort/knowledge/skill is correct. Hence, perseverance must be accompanied by self-efficacy.

In 1977, Psychologist Albert Bandura developed the concept of Self Efficacy. It is defined as an individual’s belief in their capability to exercise control over their own functioning and over events that affect their lives. It is a person’s belief in their ability to succeed in a situation. Self-efficacy is developed from four sources:

- 1) Mastery experiences—How well you have “Mastered” a task in the past.
- 2) **Vicarious Experiences—Seeing others “like you” succeed at a task.**
- 3) Social Persuasion—Receiving positive verbal feedback that instills within an individual that they can accomplish a task.
- 4) Emotional states—“The emotional, physical, and psychological well-being of a person can influence how they feel about their personal abilities in a particular situation.” (Bandura, 1977 [28])

The unifying characteristic between Growth Mindset Traits and Grit Characteristics is Perseverance. Perseverance and choice are affected by student beliefs. Self-efficacy, the focus of control or Grit, predicts student perseverance and choice (Bandura, 1977 [28], Duckworth *et al.*, 2007 [16]).

*It's not that I'm so smart, it's just that I stay with problems longer.*

—Albert Einstein (1879-1955), physicist and developer of the theory of relativity

Researchers utilized a well-validated psychological intervention that is known to change beliefs about effort: a growth mindset intervention (Dweck, 2006 [29]; Yeager and Dweck, 2012 [30]). This theory is also referred to as an “incremental theory of intelligence” intervention (Dweck and Leggett, 1988 [31]). Growth mindset interventions shape students’ beliefs in their ability to learn and cause lasting improvements in school outcomes (Aronson *et al.*, 2002 [32]; Duckworth and Yeager, 2015 [33]). In the interventions, students learned about the brain’s potential to grow and change through:

- 1) dedication;
- 2) hard work on challenging tasks;
- 3) finding the right learning strategies;
- 4) seeking assistance from others.

The growth mindset intervention is designed to counteract the “fixed mindset,” which is the belief that intelligence or talents are fixed traits. By contrast, students with a “growth mindset” believe that their abilities can be developed (Bettinger *et al.*, 2018 [34]). This model utilizes one aspect of self-efficacy, “vicarious experiences”, to increase STEM (Science, Technology, Engineering and Mathematics) Grit among underrepresented groups. Historical contributions from individuals from underrepresented groups in STEM fields are used vicariously to promote student Grit by showing examples of perseverance resulting in academic excellence.

## 4. Methodology

“Increasing STEM Grit among Underrepresented Groups: Lessons from Our Fathers” is a model that uses **Vicarious Experiences**—seeing others “like you” succeed at a task. Within this model, K-12 lesson plans, and resources are suggested (Table 1). Students will view videos, read books, or perform research on individuals “like them” (vicarious experiences), that have succeeded in STEM-related fields.

**Table 1.** Suggested perseverance lesson plans and resources.

Grades 3 - 5	Katherine Johnson NASA Computer George Washington Carver: An Uncommon Life Understanding Character: The Life of Percy Julian Perseverance Perseverance and Personal Best
Grades 6 - 8	Understanding Character: The Life of Percy Julian The Secret Life of Scientists & Engineers Mae Jemison Katherine Johnson NASA Computer George Washington Carver: An Uncommon Life

**Continued**

Grades 9 - 12	The Secret Life of Scientists & Engineers Mae Jemison George Washington Carver: An Uncommon Life GARRETT MORGAN: Entrepreneur Extraordinaire
Other Resources	Keep Going! Building a Culture of Perseverance in Math Classrooms Perseverance: My Mindset Matters Overcoming Obstacles Neurosurgeon—Dr. Alexa Canady Many Rivers to Cross 11 Famous Hispanic Scientists Who Changed the Course of History

Learn More about These 19 Scientists for Black History Month|Science Buddies Blog, n.d., [5], Asset 1, 2021, Overcoming Obstacles [35], PBS Learning Media Teaching Resources for Students and Teachers, 2019 [36], Changing the Face of Medicine, (n.d.) [37].

**Participants**

Elementary, Middle and High School students from participating schools in grades Kindergarten through twelfth grade.

**Instruments**

The “About the Student Attitudes toward STEM Survey (S-STEM)” will be utilized. The S-STEM surveys were developed by the Friday Institute. The Friday Institute is a component within the College of Education at North Carolina State University, USA. The S-STEM survey proposes to measure changes in students’ confidence and efficacy in STEM (*About the Student Attitudes toward STEM Survey (S-STEM)—Friday Institute for Educational Innovation*, n.d. [38]).

The surveys should be administered as pre-posttest. Yearly interviews and questionnaires will also be utilized to collect information on race, grade level, school type, etc.

The following problems will be addressed:

- 1) What are the factors that contribute to underrepresented groups in STEM professions?
- 2) Does the lack of vicarious experiences contribute to underrepresented groups in STEM professions?
- 3) What is the impact of historical vicarious contributions on the STEM self-efficacy of underrepresented groups?

**5. Intellectual Merit**

The goal of this model is to allow students (particularly those from underrepresented and underserved populations) to experience the intellectual vicarious thrill of mastery of science, technology, engineering, and mathematics (STEM) subjects by reading about and engaging in the experiences of their ethnic progenitors. The model engages K-12 students and teachers in lesson plans that are aligned with the STEM-focused K-12 curriculums which incorporate the contributions of minorities. This represents the intersection of minority contributions to STEM fields and improving the self-efficacy of K-12 students via vica-

rious experiences.

## 6. Broader Impacts

The **Increasing STEM Grit among Underrepresented Groups: Lessons from Our Fathers**™ model will benefit society and advance societal diversity and inclusion goals by growing and preparing competent and skilled STEM minority candidates. The inestimable benefits for STEM recipients are unevenly distributed across potential stakeholders, with minority communities particularly left behind. Thus, this program will contribute toward the segments of society most underserved by STEM.

The program will also benefit society by helping to create a more intentionally minority STEM workforce. The curriculums will serve as training materials, create a culture of inclusion, and an awareness for interdisciplinary work as a standard to foster a STEM workforce that is culturally enabled to confront social challenges. Lastly, the vicarious experiences that are being examined will be scaffolded into a growth mindset model to ensure its lasting impact in the lives of our participants.

## 7. Conclusion

In the review of the literature, we were unable to find research that examined the effect of culturally relevant STEM mindset training with K-12 students from underrepresented groups. Since research has shown the importance of Growth Mindset, self-efficacy (vicarious experiences) and academic achievement, this indicated the need to present this model. This model has implications for curriculum development, professional development, instruction and policy articulation.

## Conflicts of Interest

The authors declare no conflicts of interest.

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