

NEUROMATHEMATICAL TRICHOTOMOUS MIXED METHODS ANALYSIS: USING THE NEUROSCIENTIFIC TRI-SQUARED TEST STATISTICAL METRIC AS A POST HOC ANALYTIC TO DETERMINE NORTH CAROLINA SCHOOL OF SCIENCE AND MATHEMATICS LEADERSHIP EFFICACY

By

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ABSTRACT

This study examines the leadership efficacy amongst graduates of The North Carolina School of Science and Mathematics (NCSSM) for the classes of 2000 through 2007 from a neuroscientific and neuromathematic perspective. NCSSM alumni (as the primary unit of analysis) were examined using a novel neuromathematic post hoc method of analysis. This study is grounded in the theoretical construct that non-cognitive psychological (also called motivational) factors are core components of leadership efficacy (self-efficacy), indicative of NCSSM graduates (who had high academic performance and attained STEM [Science, Engineering, Technology, and Mathematics] degrees). In this neuroscientific mixed-methods analysis, a quantitative phase was conducted to collect the data captured by the Mind Garden Leadership Efficacy Questionnaire. A Post Hoc qualitative analysis was conducted in the second phase of the data analysis, using the applied neuromathematic Trichotomous-Squared Test methodology (that has an associated qualitative researcher-designed Inventive Investigative Instrument (Osler, 2012a) embedded within the statistical methodology). An additional outcome of the research investigation was the development of a new assessment methodology called the "Mason Leadership Efficacy Model".

Keywords: Analysis, Education Science, Inventive Investigative Instrument, Investigation, LEQ [Leadership Efficacy Questionnaire], Leadership Efficacy, Mathematical Model, Mind Garden, Neuromathematics, Neuroscience, North Carolina School of Science and Mathematics, Outcomes, Post Hoc, Research, STEM, Self-Efficacy, Static Test, Statistics, Trichotomy, Tri-Squared Test, Variables, Variance.

INTRODUCTION

The objective of this study was twofold. The first objective was to examine the leadership efficacy of graduates of the North Carolina School of Science and Mathematics (NCSSM) as the main unit of analysis. The second objective of the study is to determine the efficacy of the Mind Garden Leadership Efficacy Questionnaire (LEQ) to determine if it is an effective method of determining leadership efficacy through an innovative, precise, and content-specific post hoc statistical analysis methodology: The Tri-Squared Test (Osler, 2012a). The unit of analysis is The North Carolina School of Science

(NCSSM) which has particular focus on the completion rates of its graduates in Science, Technology, Engineering, and Mathematics (STEM) degrees, as an assessable learning outcome. The research is lensed from the theoretical construct that the NCSSM moderate leadership cultivation fosters non-cognitive skills, particularly those acquired through leadership development that instills resilience within its graduates. It is this resilience that allows NCSSM students to persist in attaining STEM degrees and follows them long after they graduate. Investigations into youth leadership development point to the significance of leadership skills

learned during adolescence in the areas of critical thinking, problem solving, and reflection. These are the same skills deemed crucial in fitting youth for fruitful employment, particularly in science, technology, engineering, and mathematics (Wagner, 2008). A critical component of leader efficacy is the notion of self-efficacy. Bandura (2010), for example, noted that self-efficacy was the belief that, an individual has special aptitudes and assets to chance the demands of a precise chore. Hannah et al. (2008) also stated efficacy beliefs affected whether a person thought in self-enhancing or self-debilitating ways, including the way they motivated and preserved themselves in times when encountering hitches.

McCormick's (2002) research on self-efficacy theory additionally stated that personal efficacy influenced the objectives people selected, their aspirations, how much effort they exerted on a given task, and how long they persisted in the face of difficulties, obstacles, and disappointments. Hannah et al. (2008) also supported this notion when they surmised leadership efficacy was a detailed type of confidence associated with the knowledge and abilities associated with leading others. Furthermore, McCormick (2002) added that self-efficacy was a personal belief, a self-judgment about one's task-specific capabilities, to perform the leadership task that was the essential causal factor. NCSSM promotes self-efficacy through its leadership development. This is a critical part of Science & Mathematics enlightening its students to recognize their academic talents and full capabilities under stringent STEM academic rigor.

Against this backdrop, the unit of analysis (NCSSM) presents a topical case for the study of leadership efficacy because it has a learning environment, which supports youth leadership development by immersion in a state-supported residential program focused on accelerated preparation in science, mathematics, and humanities. Education administration researcher, Sedlacek (2004) outlines the significance of considering non-cognitive skills that are strengthened through leadership, in the admissions criteria and the instructional design of an institution in the following areas:

- Leadership: demonstrates strong leadership in any area of his/her background (e.g. church, sports, non-educational groups).
- Long-range goals: able to respond to deferred gratification, plan ahead, and sets goals.
- Strong support person: seeks and takes advantage of a strong support network or has someone to turn to in a crises or for encouragement.
- Community: participates and is involved in his/her community.
- Nontraditional learning: acquires knowledge in sustained or culturally related ways in any field outside of school.

As the research unit of analysis, within its operational framework, NCSSM understands the value of including non-cognitive variables as a component of the admissions selection criteria that is assessed for student enrollment. This is clearly evident in the mission statement of the school, which appears in the following sub-section, and offers support to the rationale for this study.

1. Objective of the Study

The objective of this study was to examine the leadership efficacy amongst graduates of the North Carolina School of Science and Mathematics (NCSSM) for the classes of 2000 through 2007 from a neuroscientific and neuromathematic perspective. NCSSM alumni (as the primary unit of analysis) were examined using a novel neuromathematic post hoc method of analysis. This study is grounded in the theoretical construct that non-cognitive psychological (also called motivational) factors are core components of leadership efficacy (self-efficacy), indicative of NCSSM graduates (who had high academic performance and attained STEM (Science, Technology, Engineering, and Mathematics) degrees). It holds promise for increasing both student interest and diversity from an ethnic perspective to strengthen the STEM pipeline. In this study, the Hannah and Avolio (2013) Mind Garden Leadership Efficacy Questionnaire (LEQ); a battery of three instruments designed to assess individual perceptions of personal leadership efficacy across three constructs (through the implementation of a qualitative

survey tool). In this neuroscientific mixed-methods analysis, a quantitative phase was conducted to collect the data captured by the Mind Garden Leadership Efficacy Questionnaire. A Post Hoc qualitative analysis was conducted in the second phase of the data analysis, using the applied neuromathematic Trichotomous-Squared Test methodology (that has an associated qualitative researcher-designed Inventive Investigative Instrument [Osler, 2012a] embedded within the statistical methodology). Based on the results of the study, the alternative hypothesis [H₁] that stated that there are significant differences in the perception of the Leadership Efficacy by the NCSSM Alumni from the classes of 2000-07 in terms of their overall "Leadership Efficacy" in regards to: Execution or "Leadership Action Efficacy"; Capacity or "Leader Means Efficacy"; and Environment or "Leader Self-Regulation Efficacy" was accepted. The research led to the development of a new assessment methodology called the "Mason Leadership Efficacy Model".

2. Key Terms Related to Neuroscience and Neuromathematics

2.1 Brain-Based Learning

Brain-based learning refers to teaching methods, lesson designs, and school programs that are based on the latest scientific research about how the brain learns, including such factors as cognitive development—how students learn differently as they age, grow, and mature socially, emotionally, and cognitively (Hidden Curriculum, 2014).

2.2 Cognition

Cognition is a term referring to the mental processes involved in gaining knowledge and comprehension. These processes include thinking, knowing, remembering, judging, and problem-solving. These are higher-level functions of the brain and encompass language, imagination, perception, and planning (Cherry, 2014).

2.3 Neuroscience

Neuroscience is a branch of science that deals with the anatomy, physiology, biochemistry, or molecular biology of nerves and nervous tissue and especially their relation to behavior and learning (Neuroscience, 1963).

2.4 Neuromathematics

A new terminology first introduced in this research that pertains to the use of brain-based neuroscience in terms of mathematics grounded in the mathematical law of trichotomy (Osler, 2012a) exemplified in the advanced post hoc use of the Tri-Squared Test (Table 1) to analyze and determine the trichotomous: (a) Viability; (b) Validity; and (c) Verifiability of the research hypothesis [H₁] and its associated outcomes (Figures 1, 2, and 3. respectively).

3. Key Terms Related to NCSSM Leadership Efficacy and Associated STEM Inquiry

3.1 Educational Science

Educational science is the study and application of solutions to improve and enhance the learning environment and learning in general (Osler, 2013a).

3.2 Eduscience

The term "Eduscience" which is a portmanteau of the two terms "Education" and "Science". Eduscience is solution-driven and is actively concerned with the transfer and dissemination of knowledge (Osler and waden, 2012b).

3.3 Tri-Squared Test

Transformative Trichotomous-Squared Test provides a methodology for the transformation of the outcomes from qualitative research into measurable quantitative values that are used to test the validity of hypotheses. The advantage of this research procedure is that it is a comprehensive holistic testing methodology that is designed to be a static way of measuring categorical variables directly applicable to educational and social behavioral environments, where the established methods of pure experimental designs are easily violated. The unchanging base of the Tri-Squared Test is the 3 × 3 Table based on Trichotomous Categorical Variables and Trichotomous Outcome Variables. The emphasis on three distinctive variables provides a thorough and rigorous robustness to the test that yields enough outcomes to determine if differences truly exist in the environment in which the research investigation takes place. (Osler, 2012a).

3.4 Inventive Investigative Instrument

To effectively use Tri-Squared in a research investigation, one must first develop a series of “trichotomous categorical variables” based on associated “trichotomous outcome variables”. This is the first initial and crucial step for using Tri-Squared as a valid, reliable, and objective means of analyzing data. Second, a specific “trichotomy-engineered” or “Inventive” (i.e., original) Investigative Instrument must be created and implemented based on the initial trichotomous categorical variables and outcomes. This insures that the research investigation is consistent throughout the study and that the later Tri-Squared computations are validly reporting what actually took place in the research environment. The “Inventive Investigative Instrument” can be psychometrically delivered as a test, qualitatively delivered in the form of a research questionnaire, provided anonymously as a survey, given as in-depth questions during an interview, or evaluated as a comprehensive metric via an assessment rubric. As long as the trichotomous categorical variables are measured according to the established associated trichotomous outcome variables then the research has merit within the strict confines and rigorous requirements of the Tri-Squared Test (Osler, 2012a).

4. The Neuroscientific Neuromathematical Brain-Based Learning Model

The Osler Holistic Neuroscientific–Neuromathematic

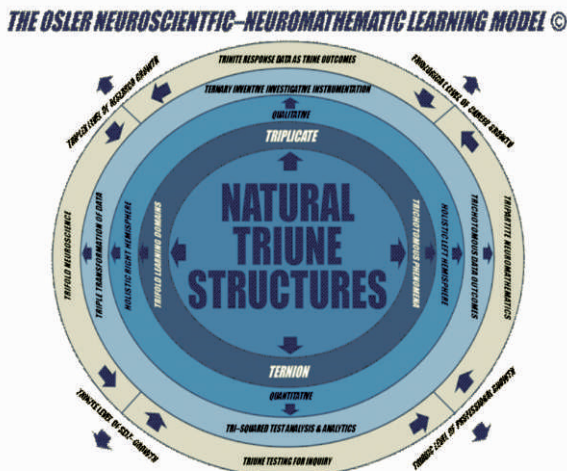


Figure 1. The Osler Holistic Neuroscientific–Neuromathematic Learning Model©

Learning Model© (Figure 1) presents the triune aspects of neuroscientific trichotomous research [as an outcome of this research inquiry in terms of the neuroscientific use of the “Mathematical Law of Trichotomy” (Osler, 2012a)] that can be readily applied research investigations that are grounded in the commonly found threefold aspects of nature. This model is grounded in Cognitive Science, Brain-Based Learning, and the Instructional Systems Design. In the center of the model are the naturally occurring triune aspects that can be found (many times both holistically and trichotomously such as in the three elementary components of an atom: Proton, Neutron, and Electron) in nature. Neuromathematics is the trichotomous expression of the neuroscientifically advanced triune aspects of the brain (further detailed in Figure 2) in terms of applied law of trichotomy mathematics (Osler, 2012a). The repetitive nature of three exists throughout the model as the triplex, triadic, and tripartite nature of triune structure extends and radiates out while remaining holistic, cyclical, and ultimately empowering for researcher, in their field and their profession in terms of the extended trifold nature of: research growth, self-growth, professional growth, and career growth.

5. The Multiple Neuromathematic Triune Structures of the Human Brain

In Figure 2, Multiple Trifold/Tripartite/Triplex Structure of the Human Brain model illustrates the neuromathematic trichotomous neuroscientific organizations of the human brain (in reference to Figure 1. In terms of “Trilimbic” systemic structure: Hypothalamus/Amygdala

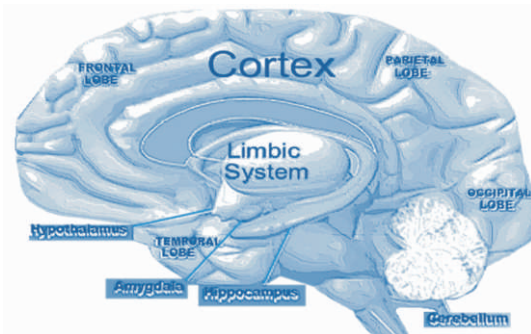


Figure 2. A Detailed Illustration of the Multiple Neuromathematic Triune Structures of the Human Brain that are the Building Blocks of Leadership Efficacy

/Hippocampus, "Trilobitic" structural groupings: Frontal/Parietal/Occipital; Frontal/Temporal/Parietal; Frontal/Temporal/Occipital; Parietal/Temporal/Occipital; etc., and "Tricerebral" systemic structure: Cortex/Limbic /Cerebellum) that lend to leadership include: The "neocortex" portion of the human brain that has the cluster of myelinated sheaths of neuronal axons as dynamically active brain structures involved in higher cognitive functions that trichotomously and holistically include: (1) advanced cognitive thought processes; (2) systemic and sequential functions that are involved in detailed planning; and (3) active procedures involved in the process of dynamic mental modeling and detailed sensory simulation(s). The internal "limbic brain" refers to the portion of the brain comprised of the basal ganglia (also more commonly referred to as the "basal nuclei") that comprise the multiple subcortical internal human brain nuclei and its internal structures that are neuromathematically and trichotomously in charge of advanced emotional intelligence represented by: (a) advanced engaging teamwork through social interactions that can be expressed as parental nurturing and group-think mechanisms that are expressed as compassionate behavior; (b) advanced interactive and empowering neurocordial metacognition typically expressed as external and mutual reciprocity; and (c)

advanced perceptive and perspective insight that creates internal interpretation of rapport expressed as external empathy and connectivity with others. The "cerebral cortex" portion of the human brain that has the cluster of cortical columnar microcircuits as the active and interspersed brain structures involved in cognitive holistic neuromathematic trichotomous functions that are not limited to but primarily include: delta) the active sensory perception of place [location]; nabla) the active sensory perception of the passage of time [happening(s)]; and the active sensory perception of matter [existence].

6. The Neuroscientific Leadership Efficacy Research Model

In the Mason Leadership Efficacy Model (Figure 3) [as a holistic research outcome of Figure 1], the first perimeter or the center of the model defines the research population targeted for analysis. For the present study, graduate represents 2000–2007 graduates of NCSSM. The second perimeter represents the qualitative stage of the model, where participants completed the Mind Garden Leadership Efficacy Questionnaire. In the third perimeter, the initial analysis of data is conducted providing descriptive outcomes using an inferential statistical method. Perimeter four is the post hoc stage of the process where qualitative data is transformed into quantitative data using the Tri-Squared test. The fifth or final perimeter captures level of leadership efficacy of participants. A detailed discussion of the MLEM in relation to the findings of the current research and framing an outline for future direction is explained in the following sections (Mason, 2015).

7. The NCSSM Mission Statement

The North Carolina School of Science and Mathematics was established in 1979 and the mission includes the following: (1) To educate academically talented students to become state, national, and global leaders in science, technology, engineering, and mathematics; (2) To advance public education in North Carolina; and (3) To inspire innovation for the betterment of humankind, through challenging residential and virtual programs driven by instructional excellence and the excitement of

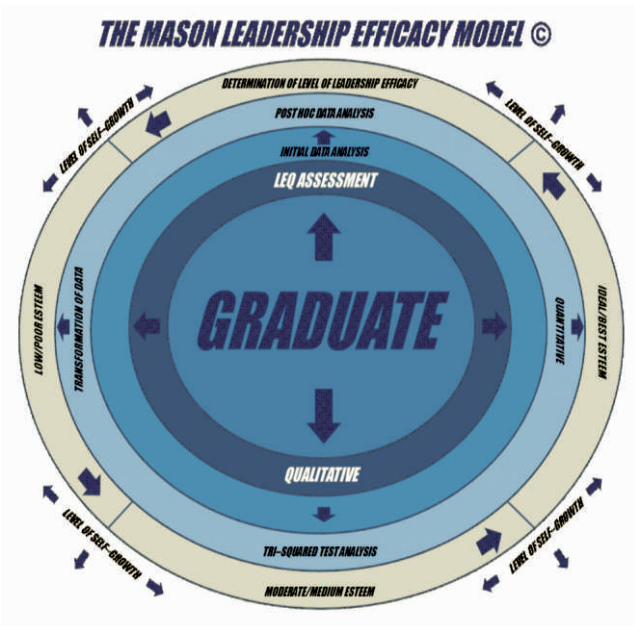


Figure 3. The Mason Leadership Model ©

discovery (NCSSM, 2013).

Embedded in the unit of analysis' [NCSSM] admissions portfolio is the rating instrument for cognitive and non-cognitive responses from its applicants. The current rating criteria for all applicants cover areas on STEM interest (as a non-cognitive variable), awards (that includes certificates, honors, recognitions and another non-cognitive variable), leadership (the variable under analysis in this study - yet another example of a non-cognitive variable), grades, rigor of course of work/program, the NCSSM math test, guidance counselor reference (a 4th non-cognitive variable), English, Math, and Science Teacher Evaluations (final non-cognitive variable) (NCSSM, 2013). In academic year 2013, the unit of analysis stated that its applicants provided additional background information going back to their seventh grade year in an open-ended format. This is an important part of the application process because of the minor age and experience range of candidates that are applying for enrollment.

The application process to gain academic admissions into NCSSM is extraordinarily stringent. It is an accomplishment in and of itself. Admissions seeking candidates are also required to provide information on their involvement in the community, schooled-based extra-curricular activities, leadership activities, and service learning activities. As such, a much greater insight is gained by NCSSM admissions into the specifics of entering candidate leadership capabilities. Thus, the leadership cultivation process at the unit of analysis starts before the candidate enrolls and thereby aids in the future leadership development process. The pre-leadership enrollment process assesses both cognitive and non-cognitive variables of academic performance for future leadership success. NCSSM as the unit of analysis defines leadership efficacy from the perspective of a moderate leader (one who is humble, non-superior, and engaging). The moderate leadership criterion can be defined from the Mind Garden Leadership Efficacy Questionnaire (LEQ) in the areas of: "Leader Action Self-Efficacy"; "Leader Self-Regulation Efficacy"; and "Leader Means Efficacy". Sedlacek (2004) points out "it is important to pursue

cultural and gender-relevant activities of the individual applicants rather than treat them as if they all come from the similar environments"(p. 46). In addition, NCSSM also emphasizes the significance of community service as a leadership requisite in its curricula as applied to all students prior to graduation. In sum, leadership efficacy is therefore an important norm in the instructional design of NCSSM, and its effectiveness and influence in shaping its graduates attitudes in terms of demonstrated leadership (as they successfully matriculate through NCSSM and in many cases go on to complete of a four-year STEM degree). Such a model of success both deserves and requires an in-depth auxiliary analysis of its leadership efficacy through noted and vetted leadership analysis tools (the Mind Garden LEQ) using advanced novel neuroscientific [neuromathematic] statistical analysis methodologies (the post hoc Tri-Squared Test).

8. The Rationale for Studying Youth Leadership Development

This section builds upon the previous sections, which briefly highlighted the rationale for studying youth leadership efficacy at NCSSM in part because it has a learning setting, which supports youth leadership development by engaging in a state-supported residential program concentrated on augmented planning in science, mathematics, and humanities. NCSSM intends to enhance skills in leadership and self-efficacy in its students, to help prepare them for the rigors of college programs in STEM degrees. The connection between leadership skills, and college achievement has been theoretically explored (Dweck, Walton, & Cohan, 2004; Ingold, 2014). Ingold (2014), for example, noted the development of leadership skills, including self-awareness, the development of self-management skills, and the ability to inspire others to achieve group goals, among others, were essential in the expenditure of energy and the perseverance required when completing a STEM degree.

Meanwhile, Dweck et al. (2004) stressed the significance of the non-cognitive factors of academic tenacity and perseverance, which helps promote long-term learning achievements. The authors added that there were

characteristics and behaviors of academically tenacious students, including working academically hard, seeking out challenges, and seeing the school as futuristically relevant, among others, which were significant in their successes. The academic tenacity appears to develop through leadership efficacy. NCSSM graduates practice similar academic tenacity and perseverance through the mixture of leadership development and academic excellence in STEM curricula, which is a part of its nontraditional educational model.

According to the study funded by CISCO, “nearly 28% of high school freshmen declare interest in a STEM-related field—around 1,000,000 students each year. Out of these students, over 57% will lose interest in STEM by the time they graduate from high school”. Over the years, Colleges and Universities in the U.S. have experienced substantial volatility in the proportions of students initially reporting aspirations to major in an undergraduate STEM-related discipline (Pryor, Hurtado, DeAngelo, Palucki Blake, & Tran, 2010). In this report, nearly 31% of all students who entered the University of California, Los Angeles, as freshmen in 1971 reported plans to major in a STEM discipline, on its Cooperative Institutional Research Program (CIRP) freshmen survey. Figure 1 indicates a 4% reduction in the percentage of students interested in STEM degrees in 2009 (about 35%). In spite of this, the percentage of college readiness of students willing to pursue degrees in STEM disciplines is increasing. Figure 1 is a graphical representation of the more current STEM degree college readiness in Math and Science disciplines.

The development of leadership skills to correlate with academic excellence sits at the core of NCSSM educational pedagogy. Indeed, as previously indicated, NCSSM's academic and residential learning paradigm supports the concept that, critical thinking, problem-solving, and reflection skills are essential to leadership development. It appears this approach has practically helped NCSSM graduates in achieving college degrees. NCSSM (2013) also supported this view, when it noted its graduates persisted in the attainment of STEM degrees at levels that exceeded the national averages. In addition, of the 2,141 graduates of the cohort classes of

2000–2007, 82.8% (1,685) completed a Bachelor's degree in a STEM-related field. However, in spite of the postulation that, the development of leadership efficacy helps NCSSM graduates in college degree achievements, no study on institutional leadership as an Educational model that promotes leadership in STEM pipeline preparation has ever been explored in the school. Therefore, the rationale for this dissertation is to investigate the impact of NCSSM learning outcomes on non-cognitive skill, including leadership and self-efficacy, particularly in relation to college achievement of its alumni. In addition, the supplementary objective is the development of a novel model, to study and assess the effects of NCSSM program learning outcomes concerning non-cognitive factors, including leadership and self-efficacy.

9. Theoretical Foundation of the Research Investigation

'Leader Self and Means Efficacy Theory' is unique in that it captures both leaders' self-efficacy, the confidence individuals have in their own capabilities to lead, as well as leaders' beliefs in the extent that their peers, senior leaders, resources, and other means in their environment will support their leadership: means efficacy.

Empirical research on the Mind Garden Leadership Efficacy Questionnaire shows that leader efficacy is comprised of three components—two in domain of self-efficacy and one in the domain of means-efficacy (Hannah and Avolio, 2013). The respective definitions of the three components are as follows:

9.1 Leader Action Self-Efficacy (for the Purposes of this Research Investigation)

It was neuromathematically [trichotomously] defined as: Leaders' perceived capability to effectively execute various critical leader actions, such as (a) Motivating, (b) Coaching, and (c) Inspiring followers, and getting followers to identify with the organization goals and vision.

9.2 Leader Self-Regulation Efficacy (for the Purposes of this Research Investigation)

It was neuromathematically [trichotomously] defined as: Leaders' perception capability is to (a) Think through complex leadership situations, (b) Interpret their followers

and the context, and (c) Generate novel solutions using effective leadership with followers.

9.3 Leader Means Efficacy (For the Purposes of this Research Investigation)

It was neuromathematically [trichotomously] defined as: Leaders' perception that they can draw upon others in their work environment [as (a) Peers, (b) Senior Leaders, (c) Followers] to enhance their leadership and that the organization's policies and resources can be leveraged to impact their leadership.

The conceptual framework of this study supports the theoretical construct that non-cognitive skills acquired through youth leadership development is critical to meeting the increased demand for students prepared to successfully matriculate to STEM post-secondary programs of study. In contrast to the historical preference for using cognitive variables such as standardized test scores and grade point average, to predict performance, non-cognitive variables have proven significant in the prediction of academic performance for nontraditional populations. Non-traditional students include women, first-generation college attending and under-represented minorities in STEM fields.

10. Rationale for Conducting the Neuroscientific Leadership Efficacy Research Inquiry

An evaluation of NCSSM's educational model in post-secondary STEM pipeline preparation has never been undertaken. NCSSM's academic and residential learning paradigm supports student social cognitive development in the areas of critical thinking, problem-solving, and reflection. These same skills are considered essential to the development of leadership efficacy. The problem investigated was two-fold. The first part of the study examined the perceptions of leadership efficacy of the NCSSM graduates based on their scored responses on the Mind Garden Leadership Efficacy Questionnaire. The second part of the study involved the use of tri-squared to additionally validate study results.

The theoretical framework introduced in Bandura's 1977 research article established that the concept of self-efficacy as being central to the discussion of predictive

behaviors. In a learning environment, efficacy expectations held by students are governed by beliefs that they have the ability to execute particular behaviors necessary to produce a particular outcome. According to Bandura (1997), outcome and efficacy expectations are differentiated. Although an individual believes that certain behaviors will produce a certain outcome, if they harbor major doubts about their ability to perform the requirements such information does not influence their behavior. "The strength of peoples' convictions in their own effectiveness is likely to affect whether they will even try to cope with given situations (Bandura, 1977, p. 3)". This conceptual framework supports that construct that personal mastery affect both initiation and persistence of coping behavior. This concept is illustrated in modular form in Bandura's Triadic Reciprocal Determinism [TRD] Model in Figure 4.

Triadic Reciprocal Determinism [TRD] was a component of Bandura's original theoretical paradigm, was a foundational part of the conceptual framework that guided the research investigation. Triadic Reciprocal Determinism is the central concept of Bandura's Social Cognitive Theory. TRD refers to the dynamic, reciprocal interaction of the person (individual with a set of learned experiences), environment (external social context), and behavior (responses to stimuli to achieve goals) as shown in Figure 4. Triadic Reciprocal Determinism suggests that people produce their environments, and are not just

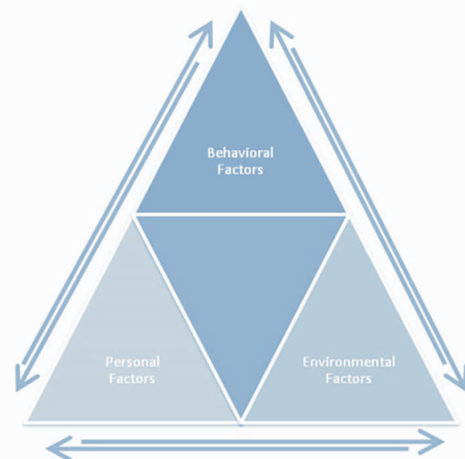


Figure 4. Bandura's Triadic Reciprocal Determinism [TRD] Model as the Foundation of the Trichotomous Neuroscientific Neuromathematic Research Conceptual Framework

products of it (Davidson, 2005) and (Bandura, Davidson, and Davidson, 2003). A person's on-going functioning is a product of a continuous interaction between cognitive, behavioral, and contextual factors (Bandura, 2001). For example, when a student enters the school building and the bell rings, presumably, the student makes sense of what the bell means and will head to his/her designated class to begin the classroom session. Cognitive, behavioral and contextual elements have been employed in the aforementioned example (Nash, 2014). Nash also states that, "Classroom learning is shaped by factors within the academic environment, especially the reinforcements experienced by oneself and by others. At the same time, learning is affected by students' own thoughts and self-beliefs and their interpretation of the classroom context" (Nash, 2014). This conceptualization is examined in the research investigation in the examination of self-efficacy as a fundamental component of leadership efficacy as espoused and embedded in the NCSSM curriculum and academic climate.

Perceived self-efficacy in the paradigm of leadership efficacy influences one's choice of behavioral settings, as through avoidance mechanisms one is not likely to attempt activities which exceed their coping skills. Efficacy expectations also determine the amount of effort one will exert as well their rate of persistence when encountering obstacles and aversive circumstances. Bandura points out that those who persist in the subjectively threatening activities that are in fact relatively safe will gain corrective experiences that reinforce their sense of efficacy, thereby eventually eliminating their defensive behavior (Bandura, 1997). This is not meant to imply that expectations be used as the sole determinant of behavior. Considerations of incentives for performing particular tasks must be taken into consideration as well. Interest in the self-processes by which human agency is exercised holds significant predictive value for academic institutions seeking to expand the population of STEM degree seekers (from a leadership perspective), thereby strengthening the pipeline of diverse workers into STEM careers (as leaders in STEM and STEM associated fields). Therefore, self-influences serve as important proximal

determinants at the core of leadership causal processes. In 1993, Bandura theorized that how people feel, think, motivate themselves, and behave are all influenced by efficacy beliefs. He suggests that self-efficacy beliefs are developed through four major constructs, including cognitive, motivational, affective, and selection processes (critical areas and arenas vital to both leadership and leadership efficacy).

Bandura (1993) further expanded his initial research and demonstrated that people's primary responses to new challenges is to rely on past performance in assessing their efficacy and setting goals. Yet, as they developed a self-schema regarding their efficacy through additional experience, their performance outcomes became driven more by closely held beliefs about self-efficacy. It has been documented that perceptions of self-efficacy influences performance not only directly, but also through its powerful effects on goal setting and analytic thinking (critical leadership components). It is important to note that within the strategy of strengthening the pipeline of students prepared to pursue STEM careers, educators are additionally advantaged when considering cognitive and social cognitive indicators of academic performance (as the unit of analysis does at the outset of its candidate selection and admission processes). This is and should be an all-inclusive and implicit process that is actively and regularly pursued. By doing so expands the diversity of populations prepared for leadership in STEM careers and directly impacts the global competitiveness and innovation in the United States and society as a whole.

1.1. Neuromathematic Research Questions

The research investigation sought to capture data on the leadership efficacy amongst NCSSM graduates from the Classes of 2000–2007. The research is guided by the following trichotomous research questions:

- (1) What is the leadership efficacy of 2000–2007 graduates of the North Carolina School of Science and Mathematics as captured by the Mind Garden Leadership Efficacy Questionnaire?
- (2) How do their perceptions of leadership efficacy as captured by the Mind Garden Leadership Efficacy

Questionnaire, align with research on non-cognitive indicators of academic performance?

(3) Do the outcomes of the post hoc qualitative to quantitative mixed methods analysis support the initial Mind Garden Leadership Efficacy Questionnaire NCSSM 2000–2007 outcomes?

12. Post Hoc Neuroscientific Research Hypotheses

Tri²H₀: There are no significant differences in the perception of the Leadership Efficacy by the North Carolina School of Science and Mathematics Alumni for the classes 2000–07 in terms of their overall “Leadership Efficacy” in terms of Execution or “Leader Action Efficacy”; Capacity or “Leader Means Efficacy”; and Environment or “Leader Self-Regulation Efficacy.”

Tri²H₁: There are significant differences in the perception of the Leadership Efficacy by the North Carolina School of Science and Mathematics Alumni for the classes 2000–07 in terms of their overall “Leadership Efficacy” in terms of Execution or “Leader Action Efficacy”; Capacity or “Leader Means Efficacy”; and Environment or “Leader Self-Regulation Efficacy.”

The aforementioned Post Hoc Research Hypotheses yield the following mathematical hypotheses using the Tri-Squared Test as the Post Hoc data analysis procedure.

Associated Post Hoc Two-Tailed Tri-Squared Test Neuromathematical Hypotheses are,

$$H_0: \text{Tri}^2 = 0$$

$$H_1: \text{Tri}^2 \neq 0$$

13. Terms Relevant to the Research Investigation

The following list of terms applies to the specific scientific terminology used throughout the research investigation. The research terms that apply to the study are defined in detail as follows:

13.1 Leadership Action Efficacy/LAE- (Equal to “Execution”: as Mind Garden Leadership Efficacy Questionnaire Items—Energize; Develop; and Coach)

Leaders' perceived capability to effectively execute various critical leader actions, such as motivating, coaching and inspiring followers, and getting followers to identify with the organization and its goals and vision

(Hannah & Avolio, 2013).

13.2 Leadership Efficacy

The confidence the individuals have in their own capabilities to lead as well as leaders' belief in the extent that their peers, senior leaders, resources and other means in their environment will support their leadership (Hannah & Avolio, 2013).

13.3. Leadership Efficacy Questionnaire

The LEQ is based on Leader Self and Means Efficacy Theory and is unique because it captures both leader's self-efficacy, the confidence individuals have in their own capabilities to lead, as well as the leaders' beliefs in the extent that their peers, senior leaders, resources, and other means in the environment will support their leadership: means efficacy. Personal efficacy is only half of the leader efficacy story—leaders must also generate confidence that their context will support their performance as a leader. Research has shown that means efficacy operates along with self-efficacy to separately and distinctly influence performance—the LEQ captures both (Hannah & Avolio, 2013).

13.4 Leadership Means Efficacy/LME- Equal to “Capacity”: as Mind Garden Leadership Efficacy Questionnaire Items—Inspire; “Get My”; and Utilize)

Leaders' perceptions that they can draw upon others in their work environment (peers, senior leaders, followers) to enhance their leadership and that the organization's policies and resources can be leveraged to impact their leadership (Hannah & Avolio, 2013).

13.5 Leadership Self-Regulation Efficacy/LSRE- (Equal to “Environment”: as Mind Garden Leadership Efficacy Questionnaire Items—Determine; Motivate; and Remain)

Leader's perceived capability to (a) think through complex leadership situations, interpret their followers and the context, and generate novel and effective solutions to leadership problems; coupled with (b) the ability to motivate oneself to enact those solutions using effective leadership followers (Hannah & Avolio, 2013).

13.6 Mind Garden

An independent publisher of psychological assessments and instruments. Their organizational goal is to “preserve and grow” important psychological assessments . . . [in] the quest to grow the health of the human psyche, [Mind Garden] facilitates feedback and self-understanding. Mind Garden serves members of the academic, research, and consulting communities by offering high quality, proven instruments from prominent professionals. [Mind Garden] features two major types of instruments: Assessments Measures, such as the State Trait Anxiety Inventory (STAI), the Ways of Coping Questionnaire (WAYS), and the Adjective Check List (ACL); and Developmental Measures such as the Multifactor Leadership Questionnaire (MLQ), the Wellness Evaluation of Lifestyles (WEL), and the Social Skills Inventory (ISS; Mindgarden, 2013).

13.7. National Consortium of Specialized STEM Schools (NCSSS)

The initial thrust to establish a national consortium came from four schools: North Carolina School of Science and Mathematics; Thomas Jefferson High School for Science and Technology; Louisiana School for Mathematics, Science, and the Arts; and the Illinois Mathematics Science Academy. These schools hosted an organizational meeting in the spring of 1988 at Thomas Jefferson High in Alexandria, VA, and 11 additional schools responded to their invitation to join the efforts. These 15 founding member institutions established the National Consortium for Specialized Secondary Schools of Mathematics, Science, and Technology, as a non-profit 501(c)(3) organization. In early 2014, to continue to move forward as the leader in STEM at the secondary level, Consortium Board of directors voted to shorten the name to better identify the membership and constituency of the Consortium. The new name, the National Consortium of Secondary STEM Schools (NCSSS) reflects the core membership, while preserving the rich heritage and history of the Consortium (National Consortium of Specialized STEM Schools [NCSSS] at www.ncsss.org, 2015).

13.8. National Student Clearinghouse

The Clearinghouse serves as a trusted agent to the participating institutions, providing support for their compliance, administrative, student access, accountability, and analytical needs. Services are designed to facilitate compliance with FERPA, the Higher Education Act, and other applicable laws. Clearinghouse services comprise four service areas: Data Exchange, Financial Aid, Research Services, and Verification Services. Research Services, which was used for this study, offers services and reports that draw on the Clearinghouse's unmatched information resources on student-level educational outcomes nationwide (National Student Clearinghouse, 2015).

13.9 Non-cognitive Factors

Psychological or motivational factors and may include students' beliefs about themselves, their feelings about school, or their habits of self-control. “Educators, psychologists, and even economists recognize the importance of non-cognitive factors in achievement both in school and in the labor market” (Dweck et.al., 2014, p. 2).

13.10 North Carolina School of Science & Mathematics (NCSSM)

The U.S.'s first public residential high school opened its doors in 1980 to 150 juniors. The program has since grown to 680 juniors and seniors representing each of North Carolina's 13 US Congressional Districts. Over the course of its institutional history, NCSSM has enrolled students from each of North Carolina's one hundred counties. NCSSM is the 17th constituent member of the University of North Carolina system and does not fall under the auspices of the NC Department of Public Instruction; a disruption of traditional state education system practices. Doing so, however, allows a flexibility of instructional methodology, curriculum development, creativity and innovation in a campus community that is not bound to administering End of Grade/EOG or End of Course/EOC tests. This also allows for an increased degree of immersion in STEM curricula, providing graduates with opportunities to cover subject matter in greater depth and detail (NCSSM 2012 &

2013 at www.ncssm.edu).

13.11 Self-efficacy

A person's estimate or personal judgment of his or her own ability to succeed in reaching a specific goal (e.g., quitting smoking or losing weight), or a more general goal (e.g., continuing to remain at a prescribed weight level); (Hughes & Demo, 1989).

13.12 STEM

Science, Technology, Engineering and Mathematics is abbreviated as STEM (HERI, 2010).

13.13 Tri-Squared Test

Trichotomy-Squared Test is a comprehensive statistical test of specifically developed for the field of Education Science, or Eduscience. Eduscience is a broad field and its professionals are directly involved in the field. The primary positions in the learning environment that the Eduscientist assume are in the following areas: Administration (which includes Leaders, Organizational Heads, and Organizational Management Professionals), Instruction (which includes Teachers, Professors, and Facilitators), Practice (which includes Practitioners in a variety of Specified Areas and Arenas), and Technology (which includes Educational Technologists, Instructional Technologists, and Information Technologists; Osler, 2012a and 2013a).

14. Research Limitations

This study is delimited to the sample size of the number of identified NCSSM graduates from the classes of 2000–2007. Contact information for graduates is gained through, NCSSM Alumni Affairs periodic contact update requests. NCSSM obtained data on graduation demographics through the National Student Clearinghouse, a trusted source for education outcomes and student educational outcomes research (National Student Clearinghouse, 2015). The sample size represents only one third of the total alumni population.

15. Research Investigation Significance

This study holds significance for the assessment of leadership efficacy of students seeking enrollment in the secondary accelerated STEM educational programs and

its associated grounding in neuroscientific brain-based learning. Dweck states, "Use of non-cognitive factors offer promising considerations for "raising the achievement of underprivileged children and, ultimately, closing the achievement gaps based on race and income" (Dweck, 2014, p. 2). Additional importance was placed on the implications for assessing measurable leadership development outcomes of the NCSSM educational model, which have never been analyzed or studied in intimate detail. An assessment methodology designed to measure the impact of STEM leadership development on the rate of attainment of degrees and work in STEM careers currently does not exist. Such a model could help address the crises in students prepared to successfully meet both the social and rigorous academic demands that serve as deterrents to the pursuit of STEM studies.

16. Data Analysis

Post Hoc data analyzed using the Trichotomous-Squared Test Three by Three Table (Table 1) designed to analyze the research questions from the Mind Garden Leadership Efficacy Questionnaire with the following Trichotomous Categorical Variables: a_1 = Execution: Leader Action Efficacy; a_2 = Capacity: Leader Means Efficacy; and a_3 = Environment: Leader Self-Regulation Efficacy. The 3×3 Table has the following Trichotomous Outcome Variables: b_1 = Maximum (Scores: 68–100 = A High Level of Confidence); b_2 = Moderate (Scores = 34–67 = A Medium Level of Confidence); and b_3 = Minimum (Scores = 0–33 = A Low Level of Confidence). The Inputted Qualitative Outcomes are reported in the followings.

The LEQ post hoc Tri-Squared Test determined that the alternative hypothesis: the null hypothesis (H_0) is rejected at $p > 0.05$ is 9.488. There are significant differences in the perception of the Leadership Efficacy by the North

$n_{ij} = 68$	TRICHOTOMOUS CATEGORICAL VARIABLES			
$\alpha = 0.05$		a_1	a_2	a_3
TRICHOTOMOUS OUTCOME VARIABLES	b_1	55	69	253
	b_2	372	324	339
	b_3	49	33	35

$$Tri^2 df. = [C - 1][R - 1] = [3 - 1][3 - 1] = 4 = Tri^2_{[C]} = Tri^2_{[R]}$$

Table 1. Post Hoc Qualitative Outcomes of the Tri-Squared Test for the Mind Garden Leadership Efficacy Questionnaire

Carolina School of Science and Mathematics Alumni for the classes 2000–2007 based upon the experience of NCSSM's integrated leadership curriculum in terms of their overall "Leadership Efficacy" in terms of: Execution or "Leader Action Efficacy"; Capacity or "Leader Means Efficacy"; and Environment or "Leader Self-Regulation Efficacy," was accepted. Trichotomous Outcome Variables overwhelmingly selected "Moderate" in the domains of execution [means] = $a_1b_2=372$, capacity [action] = $a_2b_2 = 324$, and environment [self-regulation] = $a_3b_3 = 339$. Thus, the Hypothesis H_1 is accepted.

The study population included a total of 68 participants comprised of NCSSM graduates 2000-2007. Of the 68 Mind Garden LEQ responders, 57% were female and 43% were male. All participants fell between the ages of 24-23 years of age. At 16%, the largest group of responders indicated that they were 31 years of age, while 2% indicated they were 24 years of age placing 28 years as the mean age of the sample. Racial composition of participants was 82.4% Caucasian, 8.8% African American, 4.4% Asian or Pacific Islander, and 1.5% other.

17. Results

The results of the data for Research Question 1 reveal that, NCSSM graduates 2000-2007 demonstrate a moderate level of leadership efficacy at a rate of 76.1% in the domain of leader action efficacy, 73.6% in the domain of leader action efficacy, and 83.4% in leader self-regulation efficacy.

Research Question 2 revealed that, levels of leadership efficacy of the sample and their attainment of STEM degrees align with research on non-cognitive variables as indicators of future academic performance. The LEQ post hoc Tri-Squared test determined that, the the null hypothesis H_0 is rejected at $p > 0.05$ is 9.488 and H_1 was accepted. Trichotomous Outcome Variables overwhelmingly selected "Moderate" in the domains of execution [means] = $a_1b_2=372$, capacity [action] = $a_2b_2 = 324$, and environment [self-regulation] = $a_3b_3 = 339$. The research results are supported by the following statement, "Many researchers point to the development of leadership skill sets such as self-awareness, the ability to

work and use self-management strategies, awareness of the importance of working from personal and professional values, and the ability to deal with and inspire others to achieve group goals as also being necessary to the development of drive and persistence to complete STEM degrees" (Ingold, 2014).

This research investigation was designed to address a gap in literature regarding the relationship between the non-cognitive variables acquired through youth leadership development and attainment of STEM degrees. The results of this study are intended to advise, inform, and strengthen the K–12 pipeline of students prepared for STEM careers. Fredrickson (2001) theorizes that psychological resources such as self-efficacy have been shown to promote a flourishing and broadened perspective on possible thought and behavior choices during times of change and stress. Having the opportunity to navigate many of those challenges through enrollment in an academically demanding residential program, two years prior to college facilitates student leadership self-efficacy. Life skills associated with the three constructs of leader self-efficacy include critical thinking, problem solving, intrinsic motivation, risk-taking and self-awareness. According to Bloom's Taxonomy, there are six different levels of cognitive domain of factual and conceptual knowledge progressing from elementary to complex (Apple & Krumsieg, 2001). Apple and Krumsieg (2001), Anderson and Krathwohl (2001) expanded the single dimension of the original taxonomy into a two-dimensional framework consisting of both factual/conceptual knowledge and cognitive process. High quality educational objectives employ both. NCSSM educational methodology fosters the development of skills that encourage thinking skills at level three through level five. Graduates are able to apply, construct, analyze, dissect, model relationships, connect functions, theorize, hypothesize and create an original work. The report Post-secondary Outcomes for NCSSM Graduates 2000–2007 (NCSSM, 2013) places the rate of completion of STEM bachelor's degrees at 54% overall. NCSSM under represented minority graduates demonstrate a 45% completion rate of undergraduate STEM degrees. The

Bayer Facts examine the dual issues of diversity and under representation in STEM. In this study, more than three-quarters (77%) of those polled say significant numbers of women and under represented minorities are missing from the U.S. STEM workforce today because they were not identified, encouraged or nurtured to pursue STEM studies early on (Bayer, 2010).

18. Research Implications

From a policy perspective, the NCSSM residential program is meeting its mission helping to strengthen the pipeline of students prepared for study in STEM programs in universities across the world. On a global basis, students in China earned about 23%, those in the European Union earned about 19%, and those in the U.S. earned about 10% of science and engineering degrees (www.nsf.gov/statistics/seind12/pdf/c02.pdf). Research into the high rate of graduates obtaining STEM degrees across all state funded residential programs in the US holds implications for the expansion of this successful educational model.

From a practical perspective, the future of state funded residential programs requires broadening and expanding funding resources for growth and sustainability. Thirty-five years ago when NCSSM opened its doors, it was the only program focused on STEM preparation of high school students. As a disruptive model, NCSSM predates the comprehensive school reform movement of the early 1990s and has inspired development of STEM magnet, charter, independent, private, and early-college programs. As a practice, NCSSM admits students that demonstrate leadership skills and are engaged in service to the community. Such criteria are purposeful in assessing students for enrollment as if provides insight into an applicant sense of entitlement or service. Response outcomes show that NCSSM alumni perceptions of leadership self and means efficacy demonstrate a high level of humility based on survey data.

From the perspective of youth leadership development, this research holds implications for informing best practices for nurturing leadership efficacy amongst students in public secondary education in preparation for

STEM degrees. Investigations into youth leadership development demonstrate the importance of leadership skills learned during adolescence in the areas of critical thinking, problem solving, and reflection, as critical to fitting youth for successful employment; particularly in STEM. (Cano, 1993; Celuch & Slama, 1999; Densten & Gray, 2001; Gréhaigine, Godbout, & Bouthier, 2001; Myers & Dyer, 2006). Initiatives for future STEM education in public schools should be focused on environments that foster decreased external competitiveness among students by fostering a growth mindset that embraces a sense of internal competitiveness or drive to become one's best self. NCSSM's approach eliminates class rank as a measure that creates academic isolation, arrogance and avidity. Humility, generosity and philanthropy characterize NCSSM graduates.

How the perceptions of leadership efficacy were captured by the Mind Garden LEQ (in terms of NCSSM Alumni), aligns with current research outcomes regarding non-cognitive indicators of academic performance. Results from the current research have yielded rich insights into the perceptions of leadership efficacy of NCSSM graduates. NCSSM alumni from 2000-2007 demonstrate moderate levels of leadership efficacy at a rate of with a mean score of 76% in the domain of leader means efficacy; 74% in the domain of the leader action efficacy; and 83% self-regulation efficacy. The results of the research investigation culminated in the creation of the MLEM as an outcome and detailed product of in-depth investigative inquiry. In regards to the MLEM, the research outcomes determined that NCSSM graduates from the 2000–2007 time period possess a refreshing degree of humility in light of their academic and career attainments. Anecdotally, alums speak of the sense of responsibility to honor the investment by their local and statewide community to fund a state supported residential high school education. They noted that a cultivation of a spirit of servant leadership through work service and community service requirements or meeting the demands of learning to live independently like having to manage time, cleaning, and maintaining their residence halls aided in the development and eventual growth of

their individual sense of leadership efficacy.

19. Research Recommendations

This study presented several statistically significant findings. The additional benefit would be gained from exploring many of these findings in greater detail using both qualitative and quantitative research methods. Doing so would allow the researcher to investigate unique findings. For example, LEQ administered to alumni from earlier graduating classes, with additional years of work experience. "As leaders develop Leadership Means and Self Efficacy over time through such activities as role modeling, mastery experiences and vicarious learning, we expect more efficacious leaders will build increased motivation to take on leadership roles and challenges" (Hannah et al., 2012). Subsequent studies should address some limitations of the study. Surveying incoming juniors, rising and graduating seniors would provide valuable data. Follow-up surveys should be conducted every year in order to inform youth leadership development initiatives that foster leadership self-efficacy. It is critical that, qualitative data be collected as well. Allowing student voices to be heard and to inform learning modalities both academically and residentially focused on Leadership Self and Means Efficacy development.

Although residential programs can optimize access to students for more hours of the day, youth leadership development initiatives can be successfully implemented within traditional day programs. Community, religious, social, fraternal, and civic organizations alike have a responsibility to sponsor programs designed to foster academic preparation nurture leadership self and means efficacy. Parents should also consider the importance of children participating in residential summer and leadership programs, provides children with the opportunity resilience and confidence that characterize STEM degree obtainers. Mentoring techniques can be a means of building agency with students as a function of youth leadership development. In order to remain globally competitive, the United States must broaden the pipeline of students pursuing STEM degrees. Youth leadership development programs should be designed to inspire

elementary and middle school aged students to embrace STEM studies. Programs targeting underserved and underrepresented students in STEM degree and career fields should ensure they have role models with which the students identify. Gainen (1995) noted that, students majoring in STEM had the greatest rate of attrition. Professional development should also ensure faculty and staff are equipped with tool kits designed to create dynamic and engaging youth leadership development opportunities with their students. According to Bandura, cognitively generated motivation is a product of the exercise of forethought that allows envisioned successful future outcomes to become a source of motivation to regulate current behaviors. As an actionable outcome, students with fixed mindsets believe their intellectual ability is limited. Dweck et al. (2014) concluded that, these students are often full of concern about their ability, and this can lead, in the face of challenges and setbacks, to destructive thoughts (e.g., "I failed because I am dumb"), feelings (humiliation), and behavior (giving up). In contrast, students with a growth mindset will embrace the exact same challenge as an opportunity to learn and grow. It is a mindset that fosters transcendence of setbacks while remaining focused on long-term learning.

Critical to the understanding of how to motivate and inspire youth toward STEM Education is the recognition of learning processes that hinder growth mindset development. It holds promising implications for greater diversity and inclusion of nontraditional populations such as under-represented minority, first generation college attending and women, in STEM careers. A recent research study showed that although students with more of a fixed mindset and students with more of a growth mindset entered junior high school with identical past achievement test scores (these same students' math grades differed by the end of the first academic term and diverged increasingly over the next two years). Students with a growth mindset showed continuous improvement; those with the fixed mindset did not (Dweck et al., 2014).

Conclusion

In terms of a professional standpoint, neuroscientific

neuromathematical research has the ability to assess leader action, leader means, and leader self-regulation efficacy offers a disruptive approach to assessing future student motivation and success. This research holds lots of promise for assessing characteristics for enrollment that open the gates to greater numbers of underserved and underrepresented minority students gaining STEM access to careers. There is something about the sense of ability and self-worth that shines on the face of an NCSSM third trimester junior or graduating senior. They are critical thinkers, problem solvers and community leaders. Research has shown that when people believe that they have the attributes required to meet challenges that they will, as reinforced over time, develop a standardized response pattern. With high levels of practice and familiarity, even complex events can become less demanding or even automatic processes for experienced individuals.

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