Spring 2021

Can I Be a Scientist?: Adolescent Exposure to STEM Literacy and Students' Conceptions of Identity

Cristopher C. Alvarado , '21

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Cristopher Castrellon Alvarado

Department of Educational Studies, Swarthmore College

EDUC 097: Thesis

Dr. Diane D. Anderson

May 18, 2021

Dedication

To all the brilliant Brown and Black scientists in the classroom who thought they were the only ones, trailblazers of the future...

To all my first-gen, low income peers who hid their status away, but now wear it like a badge of honor, the resistance that never yields to the institution…

To my father, an intellectual, who never let me take my education for granted…

To my mother, an angel, who taught me what love is...

I write for you.

Acknowledgements

I would like to acknowledge the contributions of all the students who took time out of their day to let me interview them and inquire about their educational backgrounds. Your responses led me to a unique gap in STEM literature and pedagogy that I otherwise would never have considered. Additionally, I would like to thank Casey Zakroff for letting me preview his STEM graphic novel ahead of release and informing me about a literary landscape of which I was previously unaware. I would also like to acknowledge the Educational Studies professors that have shaped my path at Swarthmore College, specifically Professor Jennifer Bradley, Professor Lisa Smulyan, Professor Roseann Liu, and especially Professor Diane Anderson, who has supported me endlessly throughout the creation of this thesis with delicious cups of tea. I would like to extend special thanks to Prof. Newmann Holmes for providing me feedback and advice about writing theory, and to Orah Cohen for checking over my messy first drafts as I checked her own thesis. I would also like to thank Professor Jeffrey Gauthier and my labmates for allowing my undergraduate research experience in the neurobiology lab to end positively despite my imposter syndrome. Finally, I would like to sincerely thank Professor Siwicki for being the first Science mentor I ever had here at Swarthmore and setting the bar so incredibly high. My pursuit of Neuroscience was a result of your care and thoughtful teaching.

Abstract

There is a crisis of disenfranchised students dropping out of STEM majors and careers. The national STEM major retention rates in undergraduate institutions hovers around 40%, and this number is disproportionately smaller among marginalized students, especially women and students of color (Dagley et. al, 2015). These students, who struggle to identify within academic STEM communities, are failed by the inadequacy of texts that are unable to stimulate interest and engagement in their STEM identities. Based on student interviews, research of the literary market, and my own experiences, there is a severe de-emphasis on STEM nonfiction literature in the classroom for adolescent-aged students. Using a theoretical framework informed by Gholdy Muhammad's Historically Responsive Literacy (HRL) framework, Pierre Bourdieu's five major concepts, and Jean Lave & Etienne Wenger's theory of situated learning informed by Claude Steele's research on stereotype threat, I will argue for a need for more STEM nonfiction texts aimed at engaging a "young adult demographic" to further engage students that may otherwise decide to stop pursuing STEM.

Keywords: STEM literacy, identity, text, possible self, Bourdieu, habitus, field, etc.

Can I Be a Scientist? Adolescent Exposure to STEM Literacy and Students' Conceptions of Identity

For as long as I could remember, I have had dreams of becoming a scientist. Although this path has changed various times over the years, the draws of science and technology have been quintessential in my academic development throughout college and beyond. During my time at Swarthmore College, I have explored my identities as a computer scientist, an engineer, and a neuroscientist, and I settled into this final role as a researcher. Formative experiences in classrooms and labs, either through caring professors, engaging curricula, or enriching assignments, contributed positively to these identities over time.

For many marginalized students however, including myself, this is a rose-colored perspective. The reality is that there is a crisis of disenfranchised students dropping out of science, technology, engineering, and math (STEM) majors and careers. The national STEM major retention rates in undergraduate institutions hovers around 40%, and this number is disproportionately smaller among marginalized students, especially women and students of color (Dagley et. al, 2015). These students, who struggle to identify within academic STEM communities, are failed by the inherent structures in place, especially at the most selective institutions where competition can be stifling and introductory "gatekeeper" courses challenge but ultimately discourage students from pursuing a major (Drew, 2011). Among these structures is the inadequacy of texts that are unable to stimulate interest and engagement in their STEM identities.

It came as a shock to me, then, to reflect on my own reading experiences and realize that despite spending so much time in high school and college *thinking* about science, I could not identify a single book or text that made a profound impact on my development as a STEM major or scientist. In fact, my experiences with these texts before I learned to read academic articles

were, for the most part, negative, instilling within me doubts of my capabilities as a scientist. As such, I began to reflect on my experiences and reading habits as an adolescent prior to college, only to realize that even then, *I could not recall reading a single science book that was not a textbook*.

It seems I am not alone in this sentiment. As is later discussed in depth, in a series of interviews with Swarthmore students, it became clear that there was a lack of focus on science nonfiction literature besides textbooks in classrooms nationwide during middle school and high school. This issue is strikingly reflected in the literary market as well. In fact, when looking up "science nonfiction books" through Amazon's Science and Math book department, there are over 60,000 results, but simply by adding "teen" or "young adult" to the key search, this number shrinks down to 20,000 and 8,000 respectively. A quick search on Barnes and Noble's website paints an even grimmer picture. While looking at the Biology & Life Sciences section of its website for books aimed at all audiences, a total of more than 26,000 results appear. How many of those are designated appropriate for young adults and teens? A mere 59.

Although there are various interventions needed in STEM education in order to improve the retention rate of marginalized students, whether it be piloting courses with more interactive curriculums or hiring more diverse faculty, *a widely overlooked issue is how STEM literacy must be adjusted in order to better represent and inspire students regardless of the rigor across higher education.* The intended focus of this essay, then, is to argue that there is currently a severe gap in non-fiction science books for adolescents. In other words, there is a need for more "YA STEM" non-fiction literature that not only caters to this demographic through age-appropriate text and visuals, but also emphasizes culturally relevant literacies and identities. Using frameworks such as Gholdy Muhammad's Historically Responsive Framework (HRL),

Bourdieu's five major concepts, and Jean Lave & Etienne Wenger's theory of situated learning informed by Claude Steele's research on stereotype threat, I will argue for a need for more STEM nonfiction texts aimed at engaging a young adult demographic to further *engage* students that may otherwise decide to stop pursuing STEM.

Theoretical Framework

For students underrepresented in STEM, the field presents obstacles and challenges in terms of learning that are initially quite daunting. Oftentimes, the skills that these students bring into these classrooms and spaces are not adequately supported by professors and institutional practices. Through the tradition of introductory "gateway" courses, dominated by White professors and rote instruction, among other factors, Black, Indigenous, and people of color (BIPOC) especially have to rely on external support systems in order to ensure their success within STEM. However, the best way to teach BIPOC students is to ensure that their learning environments have their needs in mind. Regardless of whether this environment is as broad as the community surrounding the student or as narrow as the pages of a book, establishing a framework in which these students are able to manifest their identities as a scientist, engineer, or other STEM professional is absolutely crucial to expanding their learning potential. Below, I attempt to build upon what STEM literacy is and should look like and expand upon it through the lens of Historically Relevant Literacies (HRL), Bourdieu's major sociological concepts, situated learning, and stereotype threat.

Literacy

Literacy, as was defined primarily by historic Black communities, is the ability to read and write one's life (Friere & Macedo, 1987). However, it encompasses much more than text or a rudimentary understanding of skills needed to communicate ideas. Rather, as described by Brian Street (1993), it is ultimately shaped by "context, power, and history", and it is ever evolving as new forms of representation are formed (Pahl and Roswell, 2010, 3). When we reflect on the plurality of these social contexts, we can then adapt our understanding of literacy into many other languages, cultures, and disciplines. As stated by Pahl and Roswell, "the word *literacies* signals that literacy is multiple, diverse, and multilingual and spans domains of practice…" (4). To narrow the focus of my research, my evaluation of STEM literacy and associated practice will focus primarily on *texts* as written manifestations of ideas. Nonetheless, it is important to acknowledge that beyond texts, literacies involve many modes through which ideas are represented, including but not limited to visual, aural, and textual (Pahl and Roswell, 2010, 4).

In regards to STEM literacy, according to the literature, there is not a set definition that is agreed upon by professionals in the field (Zollman, 2012). However, the *National Science Education Standards* (National Research Council, 1996) define *STEM literacy* as "the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (Zollman, 2012). This definition stands in stark contrast with the expectations of learning within a STEM classroom with what Pahl & Roswell have defined as "schooled literacy," which is what many curriculums in the classroom emphasize instead: literacy that is relevant to the types of activities needed for exams and assignments (Pahl and Roswell, 7). Nonetheless, even this definition, as mentioned by Zollman, has three fundamental problems:

1. The general definition of STEM, in addressing four separate disciplines (science, technology, engineering, and mathematics) then dilutes the essence of each.
2. The intersectionality of these disciplines is, then, not properly addressed with this definition.
3. **Personal needs of the individual, such as STEM identity building, are not met.**

The latter point is especially important, as it is the crux through which I will analyze the value of conception and retention of identity through exposure to *STEM texts*. In order to meet these personal needs, the individual must feel supported both by the teacher, institution, and communities in question and thus establish a connection of "belonging and becoming". Rather than focusing on the intellectual rigor associated with the content of these texts, I am primarily interested in focusing on both the power of rhetoric to weave connections from text to reader in a way that is both "culturally relevant" and increases the likelihood of students to adopt positive representations of possible selves. The former of these is specifically addressed by Gholdy Muhammad's Historically Responsive Literacy framework as a means of honing in on the excellence of BIPOC students, which is often dismissed by curriculums informed by these "schooled literacies".

Historically Relevant Literacy (HRL) and Possible Selves

Gholdy Muhammad discusses a need to design a framework for learning standards that are both written and designed by people of color and, unlike the standard definition of STEM literacy provided by the *National Science Education Standards*, emphasizes both academic and personal development (Muhammad, 2020, 11). In essence, the Historically Responsive Literacy

(HRL) framework is a model based upon the literacy practices of Black communities established in the 19th century. It establishes "teaching, learning, and leadership beliefs and practices [that] authentically respond to 1) students' cultural (and other) identities, 2) the cultural (and other) identities of others, and 3) the social times (historical and current)" (Muhammad, 2020, 48). Although Gholdy Muhammad frames these as a model to be utilized within the classroom, I will be using this framework to analyze the STEM literacy texts in question.

HRL conceptualizes literacy in four layers: identity development, skills development, intellect, and criticality (Muhammad, 2020, 57). Although all four of these are essential components for students to attain personal and academic success, as previously stated, we are primarily interested in the first of the layers as a means of cultivating interest for the other three layers to take shape. Identity, as it is defined within Muhammad's HRL framework is "composed of notions of who we are, who others say we are… and whom we desire to be…[and] it is dynamic and changing" (Muhammad, 2020, 67). It is formed by the social and cultural environments from which we stem, as well as the histories and practices we develop for ourselves (Muhammad, 2020, 67). Given the direct ties between learning and identity, it is crucial that BIPOC students are able to see their cultural, racial, and gender identities not only within the classroom, but also in the texts used to inform the classroom curricula (Muhammad, 2020, 69).

The purpose of introducing students to these texts is to form positive, enriching possible selves that then can cultivate their own excellence. The term "positive self" originates from self-concept research in the field of psychology and ultimately represents "individual ideas of what [one] might become, what [one] would like to become, and what [one is] afraid of becoming". This concept differentiates itself from identity in that it encompasses a link between

self-concept and motivation such that an individual can *imagine* a version of themselves that has not yet been manifested in reality (Markus & Nurius, 1986, 954).

According to Markus & Nurius, these possible selves are important because they provide incentives for future behavior and can provide context of one's current self (1986, 955). For instance, I, as a current neuroscience major, can envision one of my possible selves as a neurobiology professor at an academic institution because of the saliency of my experiences leading toward this desirable possible self. In that same vein, given my background as a low-income student, I can also envision a reality in which I both could have and, at a future point in time, may potentially work as a cashier at a grocery store. However, given the social connotations of said position, which lacks a need for technical skills and is therefore perceived as less "intellectually demanding", the context changes into a resulting undesirable possible self for a college graduate. In both examples, my possible self is informed not only by my immediate experiences, but also by the sociocultural and historical context of both myself and the considered roles as stigmatized by society (Markus & Nurius, 1986, 955). As such, I seek out the possible self that will not only satisfy my intellectual curiosity, but will allow me to expand upon my experiences within science.

In considering how BIPOC students are creating these possible selves as scientists and engineers, among other related professions, it is important to help motivate students to pursue these fields that have historically pushed us away. "Identities continually seek validation… the more important the identity, the more it is in need of validation" (Markus & Nurius, 1986, 956). Additionally, the activities and knowledge that we partake in to learn to be STEM professionals are a quintessential aspect of belonging to these social communities. In the case of STEM identity development, Carlone and Johnson state that individuals with a strong science identity

typically demonstrate *competence* within their respective discipline, possess the needed skills to *perform* in the field, and achieve both self and peer *recognition* for their contributions (2007). In other words, "learning thus implies becoming a different person with respect to the possibilities enabled by these systems of relations… thus identity, knowing, and social membership entail one another" (Lave & Wegner, 1991, 53). It is the responsibility of the teacher within the classroom and the administration of the institution to seek out resources that will provide this schema for marginalized individuals in the STEM field and allow them to persist. However, the discrepancy between how these students can pursue their own excellence and how academic institutions and other learning spaces force unwelcoming practices onto marginalized students is a tension that remains unresolved for many throughout their academic trajectories and careers. Bourdieu's theories, then, can lend a sociological perspective to how power functions in shaping people.

Bourdieu and his Five Major Concepts

Pierre Bourdieu was a French educational theorist who came from humble beginnings and carved a niche for himself in the academic space as a "reflexive sociologist" (Kramsch, 2008, 33). He used his own concepts to grapple with the structures of power that shaped his trajectory from the poorest rural region to bourgeois academic society. He recognized how the social hierarchies of his home country inevitably reward the dominant, "elite" ways of thinking, which was in conflict with his own ways of knowing and living. Amongst other work, he focused on five major concepts that served to inform his understanding of structures of power: *habitus*, *field*, *capital*, *distinction*, and *symbolic violence* (Kramsch, 2008, 33). Below, I will examine each of these within the lens of STEM literacy and its impact on marginalized students, providing example through my own college experiences:

Habitus refers to the habits and skills acquired from our life experiences, which is informed by our sociocultural and historical positioning (Kramsch, 2008, 38). We think and act unconsciously in ways that are shaped by our environment, whether that be through experiences or lessons from our family, friends, school, etc. For example, in my own case, being raised as an only child in a Latinx household, I was taught by my father to value my education, to be smart with my financial resources, and to keep to yourself while remaining cautious of others regardless of their perceived loyalty. Among many other habits and skills I could potentially cite, these are three that have remained constant as I've traversed through academic institutions. In the pursuit of my studies in neuroscience, these two former "natural" ways of being have continued to play a tremendous role in my persistence and motivation to understand concepts that are not intuitive to me and require hours of study. However, the latter habit, a product of my father's own *habitus* and upbringing in a rural coastal village to protect himself from potential criminals, was ultimately misplaced at a White institution where students are expected to approach their professors in office hours with zero reluctance instead of vice versa. These discrepancies are essential to highlight, as they inform the difficult experiences that underrepresented students in STEM seem to share.

Field refers primarily to the arenas or spaces with their own practices and roles. Participants in a respective *field* occupy these roles according to how their *habitus* aligns with the norms of the *field* (Kramsch, 2008, 39). For instance, among the fields I partake in, there is that of Mexican culture, music, and academia, to name a few. Each of these, of course, have larger organizations and institutions formed of "experts" with established credibility based on their economic, cultural, and social capital (Kramsch, 2008, 40). In the case of academia, these individuals are typically seen as researchers who have devoted countless years dedicated to their

specific field of study. However, when we pull apart the seams of these institutions, those that are typically given opportunities to pursue research, whether it be at an undergraduate, graduate, or doctoral level, are not BIPOC researchers. In my own experiences, I have typically been the only Latino researcher, if not the only student of color. At Swarthmore College currently, there is not a single Black professor in the Biology Department. Does this mean that I and these other marginalized researchers are simply lacking in capital, or are there greater historical & structural powers at play?

Capital is, in essence, the symbolic value of the sets of experiences you have had that you carry into a particular field. (Kramsch, 2008, 40). To put into the context of Bourdieu terminology, it is "the capacity to exercise control over one's own future and that of others" (Bourdieu et al., 1993, 4). For the budding STEM student coming from a household of two immigrant parents, one of whom had studied the equivalent of a bachelor's in Tourism and the other whom hadn't finished middle school, the capital that I had established from my "home field" that was relevant to the STEM research field entering college was almost nonexistent. However, from the experiences that I derived from high school, which included a number of biology and computer science courses, a unique opportunity as a senior to conduct undergraduate research, and above all, connections with legitimate researchers in the field, the institution I was a part of allowed me to *build capital for myself*. These "opportunities" to improve my symbolic position in the STEM research field are known as *distinctions* (Kramsch, 2008, 41). However, it is important to acknowledge that these distinctions have far-reaching implications about a student's motivations. Schools, in their meritocratic state, notoriously confer distinctions on students based on their grades, which, as Kramsch eloquently states "can give or refuse individuals the very social reality they need to survive in society" (Kramsch, 2008, 42).

Finally, it is crucial to mention Bourdieu's last major concept: *symbolic violence*. It refers to the power that those with greater capital exerted over those without it. This could be as simple as the power an older sibling has over a younger one, or it can be institutional, as a school exerts its power over a student (Kramsch, 2008, 42). However, what is ruthlessly "violent" about it is that it is subjected onto the individual in a way that makes it seem natural, inevitable, and impossible to change. In the case of a prospective STEM student like myself, at its best, this can manifest itself into "imposter syndrome," or a feeling of not belonging, that a student can learn to control. At its worst? It may establish what Carol Dweck refers to as a "fixed mindset" in which a student simply believes that they are unable to learn altogether (Dweck, 1999).

Both cases are undeniably rigid, but they are a product of the student's *habitus* directly interfering with their positioning within a *field*, thus resulting in less *capital* and opportunities for *distinction* due to the inherent *symbolic violence* of the institution, curriculum, professors, etc. Even more troubling is that students that do manage to successfully navigate through these spaces informed by a "culture of science" are then subjected to tokenized participation and social stigma from others that adversely affects their motivation to remain in the field (Hurtado et al., 2009). This issue is not particular to Private, White Institutions (PWI) such as Swarthmore; rather, it is a widespread issue across *all of academia* that has manifested itself in the racial issues of American society. In pitting BIPOC students in positions where they cannot see themselves within the classroom as successful students, all of sudden, whether it is ever verbalized or not, these students are threatened.

Situated Learning and Stereotype Threat

The fact that these students are threatened from pursuing STEM majors and careers as a whole is not only a danger to the BIPOC students that leave the academic pipeline, but it negatively impacts the entire STEM field as a whole. Within STEM, there has been a consistent inability to reach diversity goals in the STEM workforce through recruitment of underrepresented minority (URM) students (Estrada et. al., 2016). As of 2013, according to Daily and Eugene, only 28% of STEM employment is non-White. This is a tremendous issue, as URM students bring with them diverse talent and new perspectives to develop creative solutions and team synergy and well being (2013). With a limited population of BIPOC students in STEM fields who are able to serve as mentors for future generations, one has to beg the question: if everyone, regardless of the environment and context, is learning the same course material, why are URM students so scarcely entering the STEM field? One answer might lie in Lave & Wegner's theory of *situated learning* and how *stereotype threat* distorts an individual's ability to "learn".

When it comes to learning, it is often thought of as an acquisitional process. We seek to find out how we can best develop our cognitive processes over time and strategically optimize our consolidation of knowledge. This has been seen in work in which internalization is focal to learning such as Vygotsky's concept of proximal development, which is the difference in learning ability when working alone versus being assisted by a more knowledgeable, experienced individual (Lave & Wenger, 1991, 48). However, Lave & Wenger propose that learning is less about acquiring knowledge and is moreso a social process that needs to take place in the right context to properly develop (1991, 14). In other words, the theory of *situated learning* that Lave & Wenger propose hinges on coparticpants and a community rather than an individual mind (1991, 15). For the sake of simplifying these theories into one cohesive example,

we will imagine a common scenario in academia: an enthusiastic freshman looking to conduct summer research in a biology lab for the first time.

In order for any individual to develop into suitable mentors with the skills and knowledge necessary to succeed in a particular field, one must undertake learning as an activity that requires an individual's full participation within a community's sociocultural practices (Lave & Wegner, 1991, 30). This is known as *legitimate peripheral participation*, and it is "an analytical viewpoint on learning, a way of understanding learning" (Lave & Wegner, 1991, 40). A newcomer who invests time with a community and its practices, with time, will become an expert through a gradual and natural process, as "participation is always based on situated negotiation and renegotiation of meaning in the world" (Lave & Wegner, 1991, 51). This is often the case in most apprenticeships, as an apprentice is able to become involved in new activities and develop the skills needed to perform these activities through practice (Lave & Wegner, 1991, 52). However, as the community grows larger, with new individuals possessing unique tools and experiences, these "students" will participate within their respective community of practice and become masters themselves, and the skill being mastered will change in the process, ultimately transforming the learning taking place (Lave & Wegner, 1991, 16).

Let us place this within the context of our academic scenario: a first-gen, low-income student of Indigenous descent might be striving to be a researcher and is taking their first step by joining a professor's biology lab. The student is introduced to this professor's research in the introductory biology course they took during their previous semester, and after a couple of office hour conversations, the student and professor came to an agreement that they would work together in the lab over the summer. The student's responsibilities would entail animal husbandry, some data analysis using a coding language, and readings from academic papers from

the lab's respective field in biology. Although the Indigenous student will come into the lab not knowing any of these skills, through the nature of keeping a repetitive routine (i.e. feeding the animals in question, reading a new paper every couple days, etc) and practicing crucial soft skills, such as conducting the set up for an experimental procedure or pitching a research presentation, they will likely acquire the skills needed to be a successful lab biologist. Through this *legitimate peripheral participation*, the student may not yet be internalizing that the work being conducted is exactly what a professional biologist does in their day to day, but these skills the student has learned are undoubtedly being mastered with time. Through this kind of access the student will learn how to walk and talk as a biologist.

In a perfect partnership, the values and mutual respect between professor and student would align and form a fruitful relationship, but the reality is that far from that for most underrepresented STEM students. URM students will perceive that they are one of a few, if not the only student of a particular identity present within an academic space. These are *identity contingencies*, or circumstances that an individual has to deal with in spite of their identities (Steele, 2011, 3). Social stigma in these spaces can lead to *stereotype threat*, a fear that one will either be perceived or perform according to negative stereotypes about a certain identity (Steele, 1997). In the case of the Indigeneous student, if they immediately perceive themselves as the only BIPOC student within the lab, this *identity contingency* will lead to pressure and anxiety to perform as well, if not better, than their White peers. The amplified self-awareness to these stereotypes that an Indigenous student does not fit the representation of a scientist according to Western ideology would further escalate these pressures (Steele, 2011, 33).

Stereotype threat, then, informs how successful the process of situated learning is for a student. If the relationship with this professor is poor or if the student is thrown into situations

where all they are allowed to do is routine, mundane work instead of helping develop new experimental designs, then impartial learning will arise from it. Similarly, the same can happen outside of the STEM field or academia in general; Lave & Wenger state that "conditions that place newcomers in deeply adversarial relations with masters, bosses, or managers; in exhausting overinvolvement in work; or in involuntary servitude rather than participation distort, partially, or completely, the prospects for learning in practice" (1991, 64). The same would occur if a student's abilities to perform are questioned due to their identities. As such, it is crucial that teachers mitigate these biases by creating situations in which limited progress or development is not perceived by the individual as being a result of these performance stereotypes (Steele, 1997). In the case of the professor in our example, they must be aware of the doubts that might arise in the Indigeneous student and not only periodically remind them of the unique traits they bring to the lab, but also emphasize the qualities that made them an excellent candidate to become a researcher in the first place.

This example of the aspiring researcher, while salient, ignores the possibility that students might not have the opportunity to do research in the first place due to the nature of introductory "gatekeeper" courses. URM students are immediately placed at a disadvantage due to lacking the *cultural capital* needed to either make an impression to be recruited or reach out to a professor in the first place. To prevent this diverse talent from being lost from the academic STEM pipeline, either major institutional changes must take place in PWIs nationally, or BIPOC students must manifest a strong scientific identity earlier in their adolescent development. I posit that one feasible way of achieving this is by focusing on developing literary tools that will strengthen these identities through a student's own agency. As has been shown through the HRL framework,

using science nonfiction books that directly help manifest positive possible selves, specifically as it relates to BIPOC STEM excellence, can help achieve this goal. As such, I chose to focus on learning more about adolescent experiences with STEM literacy development through nonfiction texts.

Interviews & Data Analysis

In order to draw upon students' exposure to STEM literacy, or more specifically written STEM texts, during their adolescent years in school, I needed to inform myself of students' diverse contexts to account for their reading experiences during this time. To do this, I had a brief glimpse into the childhood and adolescence of these students and the opportunities or lack thereof in STEM through several informal interviews with informants of convenience. Using the information gathered from these interviews, I was able to parse through the recordings and identify potential gaps in regards to mismatches in STEM identity and a general lack of access to engaging scientific texts in and out of the classroom that appeared to be imminent for both URM students and socioeconomically privileged students.

Participants

I informally interviewed ten informants, all college students who had declared a STEM major, and asked them a series of questions. Eight of the 10 students were students at Swarthmore College, while the remaining two were from the University of North Carolina - Chapel Hill and North Carolina State University respectively. In regards to participants' genders, 50% of participants identified as female (n = 5) and 50% identified as male (n = 5). Interviews

were then conducted through either phone call or Zoom. In regards to participants' socioeconomic levels, 40% of participants identified as low-income (n = 4).

Materials

All students were required to have a device (i.e. phone, laptop, etc.) with stable internet connection. They were contacted for recruitment through online means such as text message or social media communication, such as Facebook Messenger. See Appendix A for an example of a recruitment sent to prospective participants. Interviews were then either conducted through audio or video communication, either through phone call, Zoom Call, or FaceTime. These questions consisted of one general background question and discussed items regarding students' self-perceived STEM identity, experiences reading during childhood and adolescence, and exposure to other STEM-related content. See Appendix B for the full list of questions asked during the interview.

Procedures

After calling each participant and greeting them, participants were read an oral consent script. They were told about the overall objective of the interview, as well as the types of questions that they would be asked (as detailed above), and finally asked for permission to record the interview. See Appendix C for the full consent form. Students then responded to each of the questions in conversation format; most interviews lasted about an average of half an hour, with two lasting a little more than an hour. At the end of the interview, students were read a debrief and then asked if they had any additional questions. See Appendix D for the full debrief form.

Once all concerns had been clarified, participants were thanked for their participation in the study and dismissed.

The theoretical framework above served to inform the questions that were asked during the interviews. These questions, ranging from Likert-scale type questions about their self-perceived STEM identities to specifics regarding the participant's reading experiences in their childhood and adolescence, helped provide context into how the participants exposure to STEM literacies during adolescence were informed or may have otherwise benefitted from culturally relevant texts. Within these interviews, I was able to pinpoint three key themes that directly related to areas where academic institutions had failed to make a positive impact on student's conception of STEM identity: "Mismatches in STEM Identity and Belonging", "Lack of Science Texts in Mandatory Readings", and "General Lack of Science Nonfiction Texts". Below, I detail my analysis with examples of students who had disclosed their status as underrepresented students in STEM.

Mismatches in STEM Identity and Sense of Belonging

Throughout each of these conversations, there were answers to two questions that struck me as particularly salient in informing how students, particularly those from more disadvantaged or marginalized backgrounds, perceived their sense of identity as a STEM student and how they felt they belonged within the STEM community: "From a scale of 1 to 10, how strong would you say your STEM identity is (how much do you like science)?", and "From a scale of 1 to 10, how strongly would you identify as a scientist/engineer?" (The profession was changed depending on the student's declared major.) In the case of most students, the score indicated in both questions

would be similar, with the latter sometimes receiving a reduced score due to students believing that they had not reached a professional level where they could completely call themselves a scientist. These scores would be relatively high, averaging around a score of 8.

However, there was one of the low-income identifying students whose response was particularly intriguing. Naomi, despite indicating a relatively high score for the first question, mentioned very passionately that she did not at all identify as an engineer within the Swat community and beyond. These sentiments were similarly reflected, albeit not as intensely, by all but one of the other low-income identifying students. These students were all students of color.

When I asked Naomi why she scored her identity as an engineer so poorly, she directly cited the Engineering Department's lack of support for underrepresented students. Naomi, with a deep appreciation of her Latinx culture rooted in Indigenous tradition and *habitus*, was being forced to conduct engineering in a way that was informed dominantly by a notion of Western science and is an example of *symbolic violence*. This disconnect between the *fields* of Indigenous and Western science is particularly reminiscent of the stories told in Kimmerrer's *Braiding Sweetgrass*, with the most similar example being the story of a graduate student with Indigenous roots conducting an experiment comparing Sweetgrass harvesting methods through Western science methodology to appease otherwise unsupportive faculty (2013). Although another student, Francisco, did not exhibit this same interest in Indigenous culture and science as Naomi, he did also emphasize similar critiques about the Engineering Department's lack of support. This shows that while the role of the institution is clearly vital to retaining students within the trajectory of a STEM degree and/or career, the student's conception of their "possible self" is rather formed through more personal, socioculturally relevant means. The next set of questions

helped inform whether this could be done through texts that were read through students' own agency.

General Lack of Science Nonfiction Texts

After inquiring about participants' established STEM identities, the questions consequently focused on how prior reading experiences informed their interests in school and STEM in particular. When asked "Are there any books off the top of your head that informed your decision to want to pursue science?" there was a wide range of responses. While some of the students had a particularly hard time naming a single book, there were a couple of students from both low and high socioeconomic backgrounds that called attention to either one formative text or generalized a certain subcategory (i.e. science picture books). There were a few that mentioned spending a lot of time with kid-encyclopedia type of books as well.

Despite this optimistic slew of responses, the next series of questions ("Did you read for leisure in high school? If you did, out of those books that you would read for leisure during high school, were any of those science non-fiction? What about non-book formats?") provided much needed context for the issue at hand: most of this exposure to scientific written texts was happening at an early age but not being pursued as an adolescent. Seldom was this perceived drop in engagement due to a student's own conscious decision. More often than not, students who read a lot as a child would cite not having as much time available due to school work and other responsibilities and shifting attention towards denser fictional works. Ironically, though, there were also a number of students who, despite not reading as much during their high school years, seemed to regain this interest later into their college years. This points towards an important issue: tt seemed as though among the potential factors affecting the focus on science

non-fiction books, one of the most salient was simply a lack of availability. This would indicate that while these students at their adolescent age may have lost an interest in reading, they didn't have the means (at least through written text) to engage even if they wanted. This lack of availability was conflated with the agendas of institutions in developing literate, career-ready students in the next series of questions.

Lack of Science Texts in Mandatory Readings

Finally, I focused specifically on inquiring about STEM or STEM-related literacy (i.e. sci-fi content). Responses for these questions seem to vary among individuals, with the exception of two questions: 1) "Were any of the books that were assigned to you for mandatory reading (in classes, summer reading, etc.) nonfiction? How about science nonfiction?" and 2) "Would reading "easy-to-digest" science nonfiction books during your adolescence have been helpful in further forming your scientific identity?" For these two questions, there were seldom any exceptions to the responses given by the students. However, these exceptions are noteworthy.

In regards to this question of mandatory reading, there were a couple of students who recalled being assigned a nonfiction book at some point during middle or high school years. However, these books normally entailed a memoir or biography of some kind. There was only one student who was able to recall being assigned a book specifically focusing on scientific content. (To be clear, this did not include any books in which a scientist or other STEM professional was the focal point of the book). Kimberly recalled that at the beginning of high school, she was given a summer reading book related to climate change; although she could not remember the exact name of this book, she then pointed out that this assignment was an anomaly that was not to be repeated at her school afterwards.

Towards the end of the conversation, these students were then asked if having these "easy-to-digest" books, or rather books with accessible scientific language, would have been useful in their STEM identity formation. Although those that had identified as less reading-inclined seemed to show more casual interest than the other students, there was not a single person I interviewed who said no. At this point, several students noted that if they had been pointed towards more of these books in the first place, they likely would have taken advantage of them in much the same way they did with other books. This prompts a number of questions: 1) Are the institutions and strict adhesion to standard curricula (such as Common Core Standards) preventing students from branching out and exploring these texts? And, 2) are there, then, enough of these adolescent-level science books currently available in the market? These questions reveal a severe gap in attention towards an age-demographic that is crucial for retaining many potential students, especially those that are underrepresented, within STEM.

Discussion

It should be noted that not every single question and their implications of how STEM literacy is addressed outside the context of the classroom was thoroughly analyzed. However, it remains abundantly clear through these three themes picked from these conversations that there is fundamentally a lack of consideration on an institutional level for scientific texts that immediately appeal to a young adult demographic. At most, these texts are relegated to *textbooks prime for rote memorization or tools for educators to set-up their lesson plans.* Although the latter use might be all that is needed under the care of a master teacher, the agency of the student to study what they want and develop these interests organically might be stripped away through forced learning and a mismatch of *habitus* and *field*. As discussed through our framework, a

space and text that is not conducive to a BIPOC student's learning will simply alienate and discourage them from continuing to pursue STEM. Below, I address what these texts may look like, how they can be implemented in the classroom, and limitations and recommendations for further research, pedagogical use, and publications.

Multimodal Texts & Classroom Applications

One of the recurring themes that came up in the informal interviews with the informants of convenience was the lack of scientific texts, but textbooks were explicitly excluded from our criteria. This is because within the STEM classroom, the textbook is often used as a resource that is heavily integrated into the curriculum of the course, but "teachers who rely exclusively on a textbook have already fallen short in their curriculum and instruction" (Muhammad, 2020, 145). The textbook serves as an entirely neutral presentation of course material that, in the worst case, can help propagate the "culture of science" that alienates URM students in the classroom. Within the realm of childrens' books, animals and White characters were represented in 27 percent and 50 percent of these books while characters with ethnic/racial identities typically underrepresented in STEM were represented in 10 percent or less of these books (Huyck, Dahlen & Dahlen, 2019). The amount of diverse representation, as well as authorship, is likely similarly underwhelming for scientific texts despite opportunities to include these in word problems, images, and chapter introductions. Nonetheless, given its value in the classroom, it made sense to deconstruct the textbook to see what elements serve a useful purpose and what could be scrapped to improve interest among BIPOC populations according to an HRL framework.

When analyzing a common scientific textbook, it is important to note that there are several components beyond the written prose. Primarily, there is a plethora of images serving as

visual aids for information discussed in the text and, depending on the subject matter, example problems or discussion questions that allow students to grapple with the material in more depth. Additionally, there are reference pages in the back that serve to guide the reader to specific concepts and their locations within the book and a glossary to keep track of definitions of key words in the text. While these literary tools are standard for educational texts, they can also prove to be useful in formats not as commonly associated with learning. One format that is heavily consumed by the adolescent demographic and could be incorporated within the classroom is the comic book or graphic novel. Their multimodal nature serves to amplify the meaning of the words and images more powerfully than it would otherwise (Kress, 2000).

As previously mentioned, information can be written, spoken, and visualized in various representations called *modes*, and the possibilities of meaning making that can be derived from these modes are then described as *affordances* (Pahl & Roswell, 2010, 4). These affordances, then, become more powerful as they are spread out through more modes because "the shaping of meanings into modes is always culturally influenced, and it is materially and socially situated" (Pahl & Roswell, 2010, 5). When analyzed from the perspective of situated learning, multimodal texts can provide more opportunities for knowledge building and reading development that is crucial for a scientist, and this in turn will help manifest a stronger STEM identity.

One of the major possibilities that are much more accessible in a graphic novel, for instance, is the inclusion of a narrative. In a conversation with Dr. Casey Zakroff, a STEM non-fiction graphic novel writer, he made the point that the writing in graphic novels and similar literature should dictate both text and art. The knowledge-driven text is storyboarded within the narrative in such a way that the scientific concepts are introduced organically. According to Gholdy Muhammad, this is known in the literature as "layering texts" and can improve the

academic and personal success of the reader (2020, 147). By striking a balance of text and images, the book can turn from a strictly educational text to more literary experience. This helps make the science much more accessible, which is the purpose of scientific communication. In other words, by making the learning less obvious, as is needed within the scope of effective situated learning, an educator can shape the literacy practices of an individual and the meaningful experiences that come with it.

Through this narrative building, these scientific texts can suddenly take advantage of its affordances to create culturally responsive texts. Texts like the textbook that are solely informed for the purposes of school are doomed to disengage students, so creating opportunities for the student to engage with a curriculum with powerful ties outside of the classroom is crucial (Pahl & Rowsell, 2010, 7). As stated so eloquently by Gholdy Muhammad, "...we need more diversity in texts in and out of the classrooms and also access to other literature when the school-sanctioned literature isn't enough" (Muhammad, 2020, 139). A science-based graphic novel aligning with the HRL would be a perfect example of a text that would appeal to the adolescent demographic while forming or strengthening STEM identity. Incorporating a culturally and historically responsive text such as this one into a STEM lesson plan would tremendously benefit all parties involved in the classroom.

Limitations

Certainly, a graphic novel can only account for so many affordances. A proper investigation of STEM literacy that moves closer to BIPOC excellence would involve many more multimodal texts, including but not limited to movies/film, TED Talks and other video, memes, podcasts, and social media posts. These formats can introduce new affordances that can

be as equally stimulating for STEM identity development. In addition, it is important to note that although we are generalizing STEM literacy into one cohesive whole, each of the four main disciplines within STEM (science, technology, engineering, mathematics) and their respective sub-disciplines can be characterized differently. These threads would need to be further analyzed under the established theoretical framework in future research both within an academic context and the literary market.

Within my own research, there are a number of limitations for which I need to account. As a Brown first-gen low-income Latino student, my experiences directly serve as a lens through which to begin to grapple with my understanding of these systemic powers in place. However, there is inherent bias in how I may interpret these misgivings in comparison to other underrepresented groups, especially women and Black students in American institutions. For example, a major gap I did not have an opportunity during the time conducting interviews was to learn about the experiences and perspective of a Black STEM student. Though this would of course be remedied in a future study, it will be important to be conscious of the fact that although there may be shared experiences among BIPOC individuals, their racial histories and traumas are not, even within the scope of the STEM field.

Finally, all of the students interviewed are people with whom I have previously established a connection. Although this establishes a familiarity that likely made it easier to learn a background that otherwise may have been difficult to parse out, it inherently limits the scope of my subjects. Future research would involve adolescents of various ages, academic backgrounds (i.e. HBCU/HSI students, technical apprentices, drop outs, etc.) and interest in STEM (i.e. humanities and social studies majors) in order to provide a more thorough understanding of this work.

Recommendations

With all this in mind, I propose that there be a focus on expanding the potential of YA non-fiction STEM literature with regard to future research, high school reading experiences, and publishing. By focusing on creating exciting, motivating literary experiences for adolescent BIPOC students, they will be able to sustain an interest in STEM through a means that, with access to a public library and/or the Internet, is much more accessible than summer research or experiential programs.

Given the increasingly technology-reliant ecosystem in which students are consuming and learning new knowledge, it is absolutely crucial that as researchers, we adapt our understanding of "reading" to fit the engagement of Gen Z readers. In using graphic novels and other forms of multimodal texts, we are inviting students to learn through popularized media, and although more interactive formats such as video games may be better in involving the student in a process of situated learning with a professor, written literature will be better suited for placing dense, concept-focused information in a cohesive package.

More specific research can also be conducted to ensure that YA non-fiction STEM literature align with the standards of BIPOC excellence proposed by Gholdy Muhammad's HRL framework. By focusing on producing text with vocabulary and rhetoric that is not alienating to students like an academic article or a textbook might be, educators can avoid situations that may amplify internalized imposter syndrome in students and further demotivate them from pursuing a STEM track. On the other hand, it is important to continue to clarify the distinction between "children" nonfiction versus "teen" or "young adult" nonfiction so as to not underwhelm or patronize adolescent readers.

One of the most significant gaps identified through informal interviews with informants of convenience was the lack of STEM non-fiction texts being used in the classroom and included in summer reading lists. This points both towards a narrow minded perception of multimodal texts as literacy development tools and a lack of readings available in the literary market that fit this broad scope of "YA non-fiction STEM literature" As such, it is important that educators adapt existing curricula in middle school and high school STEM courses and research how to best pedagogically pair these texts together. Additionally, major publishing companies, especially those in the graphic novel industry, should invest in the potential of creating educational, narrative driven texts and create more explicit selection of science books oriented towards adolescents.

With these recommendations in place to increase the amount of STEM YA nonfiction literature available in the classroom and the marketplace, my goal and hope is that this will create yet another avenue for brilliant BIPOC students to manifest an identity that may otherwise never come to fruition. These adolescent texts will serve as a fundamental intersection between this valuable identity work so often incorporated in children's picture book and the dense, conceptual knowledge included in textbooks and academic literature, thus eliminating the neutrality that is often associated with the STEM field. My expectation is that this work, which has identified a tremendous gap within the literature regarding STEM literacy, can be expanded by others so that educators, writers, and students alike may also continue to enrich the STEM field and its limitless possibilities for mending the world through practical solutions.

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Appendix

A. Recruitment Script

Hi _____,

I hope you've been doing well. I'm currently working on a thesis project regarding how exposure to STEM literacy and/or literature affects STEM identity development in adolescence. I was wondering if you would be willing to be interviewed for 20-30 minutes so that I might ask you some questions regarding your educational background with STEM and reading experiences. If you could text me back or send me an email at calvara1@swarthmore.edu to set up a time to Zoom, that would be greatly appreciated. Have a great rest of your day!

Best,

Cris Alvarado

B. List of Questions for Thesis Interviews

Original question: How does exposure to STEM literacy/and or literature (literacy — any form, literature — just books) at an early age affects STEM identity development in adolescence?

Objective: Trying to narrow down what my focus should be — currently, I've decided to focus mainly on the adolescent part of STEM identity development and understand why we do not have books that meet the "YA nonfiction criteria"

Questions:

- Could you describe what your educational background was like? (Social economic background and some of the demographics)
- **From a scale of 1 to 10, how strong would you say your STEM identity is (how much do you like science)? Why?**
- **From a scale of 1 to 10, how strongly would you identify as a scientist?**
- Why do you like science?
- Were there any key figures, whether close in your life or not, that were formative in your STEM identity formation?
- From a scale of 1 to 10, how much has money (future global gains) been formative in your STEM identity formation? Why?
- Have there been any formative experiences that have kept you engaged in science?
- Has there been an experience that has been detrimental to your STEM identity?
- Are there any books off the top of your head (not textbooks, but "easy to digest") that informed your decision to want to pursue science?
- Did you read for leisure in high school? If you did, out of those books that you would read for leisure during high school, were any of those science non-fiction? What about non-book formats?
- **Were any of the books that were assigned to you for mandatory reading (in classes, summer reading, etc.) nonfiction? How about science nonfiction?**
- Did you do much reading at all in general (as a kid) from elementary to middle school age? Did that change at all during high school?
- How has sci-fi in any way influenced your interest in science, whether it be through books or any media?
- In terms of multimedia literacy, was there anything during your high schools that you would consume, and did any of that carry on into college or your future formation of STEM identity?
- **Would reading "easy-to-digest" science nonfiction books during your adolescence have been helpful in further forming your scientific identity?**

C. Consent Script

Permission to Take Part in a Human Research Study Investigators: Cristopher Alvarado (calvara1@swarthmore.edu)

Before starting this interview, I wanted to inform you of some of the details regarding the study and ask for your consent to be recorded if you agree to participate. The question of this study was how exposure to STEM literacy and/or literature affects STEM identity development in adolescence. The purpose of this interview will be to ask you a series of questions that would help me narrow down the focus of the study.

What would you need to do?

If you choose to participate, you will be asked a series of questions regarding your educational background with STEM and reading experiences in general. I expect this to take 20-30 minutes, but please make sure you have blocked out a full hour just in case we go over time.

What are the benefits of participating?

If you choose to, your participation will help contribute to the growing literature on STEM literacy and pedagogy.

Do you have to participate?

Participation is completely voluntary. There will be no consequences if you do not wish to participate. If you decide to participate now, but later decide that you do not wish to continue, you can let me know in the middle of the interview and we will not use your responses. You may choose to stop at any time. You do not have to answer any questions that you do not want to.

Are there any potential risks?

There are no potential risks other than potentially recounting an educational experience that may have been traumatic to you. You may choose to stop your participation at any time during the course of this study.

Will this be confidential?

Your participation will be confidential, no identifiable information will be shared, and you will be referred to by a pseudonym in any research outputs.

Who is conducting this research?

I, Cris Alvarado, am conducting this research under the supervision of Professor Diane Anderson in the Educational Studies department. If you have any questions or concerns, you may contact her at dander1@swarthmore.edu.

If you are unsure about any of the details provided, please let me know now so I can answer your questions. If you'd like some more time to think about it, we can also postpone for a later time. If not, then I would appreciate it if you could verbally consent to your participation in the study and recording of this interview. Thanks so much!

D. Debrief Script

Thank you for taking the time to complete this interview with me!

At the beginning of the interview, you were informed that the framing question of this study was how exposure to STEM literacy and/or literature affects STEM identity development in adolescence. From there, you were informed that the purpose of the interview was to ask a series of questions that may help identify whether there is a gap in the literary market for "YA non-fiction STEM literature", or in other words, science books that specifically target adolescents. The experiences that you have described will both help in identifying whether this gap is indeed present and not being addressed in high schools, thus affecting students' development as well as whether this is an issue that is supplemented by multimedia and other forms of literacy.

Why is this important to study?

The national STEM major retention rates hover around 40% and are disproportionately greater for marginalized students, especially women and students of color. Despite there being strategies to help mitigate conditions that lead to these dropouts, such as mentorship programs and learning communities, there is little literature written regarding the texts being utilized in the classroom and students' engagement with them in the classroom. I hope that my research can add to the existing literature on STEM literacy and pedagogy.

What if I want to know more?

If you are interested in knowing more about this study or have questions, please do not hesitate to contact me here: (Types email into chat box or orally spells it out.) Cristopher Alvarado (calvara1@swarthmore.edu)

Please refrain from sharing information about this study with others, and thanks again for participating!