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EXPLORATION OF PREVIOUS SCIENCE EXPERIENCES AND SOCIOCULTURAL FACTORS THAT INFLUENCE SCIENCE LITERACY OF FIRST-YEAR COLLEGE STUDENTS

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EXPLORATION OF PREVIOUS SCIENCE EXPERIENCES AND SOCIOCULTURAL FACTORS THAT INFLUENCE SCIENCE LITERACY OF FIRST-YEAR COLLEGE STUDENTS

A DISSERTATION APPROVED FOR THE DEPARTMENT OF
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Science literacy is an important element for individuals in any society. How a person engages with scientific information can help or hinder the progress of society. Science literacy can advance society through evolution of technology, advancements in healthcare, and comprehensive ways to protect the planet. While a scient literate society itself should be a global goal, modern science is rooted in Eurocentric ways of knowing. It is important to understand that the differences in social and cultural experiences play a part in how people see and interact with the world around them. The purpose of this study was to examine relationships between previous science experiences, sociocultural experiences, and science literacy of first-year college students.

To gain a better understanding of factors that contribute to science literacy, an anonymous survey was distributed to first year college students at a single university. The survey was designed using the embedded method which included both quantitative and qualitative questions which pertained to participants' demographics, previous science experiences, sociocultural experiences, as well as a science literacy assessment. Correlation analysis was utilized to assess quantitative responses. Reflexive thematic and sentiment analysis was used to analyze qualitative responses. Lastly, critical discourse analysis was employed to investigate instances of identity, agency, and power, identified within open-ended responses.

Results indicated that there were a greater number of relationships between sociocultural experiences and science literacy than between previous science experiences and science literacy. Furthermore, critical analysis identified several instances of identity, agency, and power in participant responses.

Chapter 1 Introduction

Introduction to the Problem

Science is a practice which allows us to learn about the natural world. Science gives us the tools to investigate, understand, and describe natural processes, structures, and mechanisms of the universe. *Science literacy* refers to the extent to which an individual can comprehend, understand, discern, and communicate scientific information as well as engage in scientific practices and identify reliable scientific information. Science literacy is an essential element to any society. It allows for citizens, including those in positions of power, to respond to problems surrounding the health of the people, the preservation of our planet, and the advancement of technology and society in a reasonable, evidence-based, and well-informed way. Science literacy has become an umbrella term to include various ways of understanding and engaging with science and scientific information. Science, as is commonly understood, stems from a Eurocentric way of knowing which has shaped how most people in this day and age understand the natural world. Limiting science to being defined in a Eurocentric manner has also shaped how science practitioners and science educators approach their respective practices. The exclusion of various ways of understanding the natural world leads to further restriction in what is deemed science, complicating how members of some communities may interpret and ultimately understand science. This may also obscure outcomes of science literacy assessment as it is traditionally evaluated. Who has decided what science *is* and how that influences science literacy should be taken into consideration when addressing these topics. While this study relies on a science literacy assessment that is grounded in the Eurocentric understanding of science, probing social and cultural aspects alongside of assessing science literacy could garner greater insight into factors that may influence a person's science literacy as it is understood in the United States.

External factors that influence a person's science literacy may lead to potentially positive or negative consequences in everyday life. How scientific information is received and understood could be influenced by social, political, or even cultural beliefs. Sociopolitical or sociocultural influences could look very different depending on the community. Variations in how scientific information is received and what is done with that information could also depend on what views a community may have on societal issues, such as climate change, or how that community may politicize scientific information based on belief systems. The hegemonic nature of Eurocentric science has served in an advantageous manner to those who hold such identities as white, cis, heteronormative, often times Christian, males. Therefore, the world is designed to serve people who hold similar identities, so external factors may not have as much weight or influence on their science literacy. However, this does not leave much room for interpretation for those who hold different identities. This sends a message that the only way to succeed in science is to learn the discipline as it aligns with the Eurocentric way of knowing, without exception. Transfer of knowledge in this manner can perpetuate harm and cause erasure of knowledge. It may also contribute to feelings of inadequacy or inability due to external factors that may have shaped how people who hold different identities or who come from different backgrounds have come to understand the world around them. By rigidly aligning to Eurocentric science, we do a disservice to the entire science community by having a less robust understanding of the world around us which leads to lack of progress in science. Adhering to a singular way of practicing science, we also forfeit the opportunity to create a more encompassing understanding of the scope of science literacy. Furthermore, exclusionary practices upheld by Eurocentric science may contribute to the continued distrust of science by historically excluded communities to the detriment of the advancement of science, hindering improvement in science literacy, and perpetuating the legacy of distrust in science.

Background

Science Literacy in the Modern Age

Science is integral to every aspect of the world in which we live. The ability to understand and respond to scientific information is important to all communities worldwide. The sharing of information has shifted from being mostly local and community-based to information being wide-spread nationally and globally. The expansion in the availability of information is a result of the age of technology. The increase in global accessibility of information has given an even greater platform to those who want to share reliable, evidence-based information, as well as those who want to share opinion-driven and belief-based information. While there is room for all types of information in the world, it becomes problematic when citizens can no longer distinguish reliable information or sources from unreliable, non-evidence-based sources. Even evidence-based information is open to attack and rebuttal.

The age of technology has lent itself to the rapid dissemination of scientific information across multiple types of media platforms. This allows for real-time responses, rebuttals, and refutes to evidence-based scientific information garnering greater confusion among the general public. While news media outlets try to remain neutral in how they discuss scientific information, not all media outlets or platforms abide by such standards. This has been shown to play a role in how the general public understands scientific topics such as global warming (Kortenkamp & Basten, 2015). For instance, there are people who hold public office who openly denounce global warming (see Armitage, 2005; Layzer, 2007; Sanchez, 2003). Depending on a person's political affiliation, they may be more inclined to accept what a member of their own political party states about topics such as global warming, even if the person holding public office is not, themselves, an expert on the topic.

There are entire communities that do not believe information concerning global pandemics nor participate in factors to protect public health (MacDonald, 2018, 2020; Schmid & Betsch, 2019). In public forums there have been many contentious debates surrounding SARS-CoV-2, the current vaccines, as well as the trustworthiness and reliability of our science experts who are delivering information to the public. This is not a new concern within the science community and was eerily foreshadowed over 30 years ago:

> Personal decisions, for example about diet, smoking, vaccination, screening programmers or safety in the home and at work, should all be helped by some understanding of the underlying science. Greater familiarity with the nature and the findings of science will also help the individual to resist pseudo-scientific information. An uninformed public is very vulnerable to misleading ideas on, for example, diet or alternative medicine (Royal Society, 1985, p. 10).

Howell and Brossard (2021) discussed the potential usefulness of science literacy to combat misinformation and stated, "The common but as yet untested assumption is that greater science literacy could help stem the believability and spread of science-related misinformation and ultimately help improve informed decision-making at the individual and collective levels" (p. 1). With the rapid evolution of technology, a growing number of media sources, and increased distribution of misinformation, a lack of science literacy among our students and citizens could have deleterious impacts on society. Thus, critical thinking and evaluation of information becomes ever more imperative.

While the availability of vast amounts of information can be a wonderful thing, the reality is that there is a lot of misinformation that circulates on social media platforms (Allcott et al., 2019; Chou et al., 2018). Misinformation is often biased by political, social, and/or cultural opinions lacking any reliable evidence. Dissemination of such misinformation can be due to malicious intent, or it may be passed along by unsuspecting individuals with good intentions. The greater distribution of misinformation leads to a more complicated issue for the general public to discern what is and what is not reliable information. To further complicate the matter, it has been observed that even reliable and evidence-based scientific information is experiencing what seems like a growing amount of pushback.

Cobern et al. (2022) addressed the tentative nature of science and science dissenters, "Recalling what they learned at school regarding the tentative nature of science, dissenters may interpret repeated assertions of uncertainty as reinforcement that science is 'highly tentative'" (p. 2). While science, by nature, is an ever-evolving field of knowledge, it is not tentative in totality. It seems that there is a need for deeper exploration into how beliefs counter to the nature of science are influenced and upheld, especially in the face of evidence-based scientific information.

It is not enough to only consider how people think about scientific information. It is also important to consider what people do with that information. Actions stemming from scientific communication could have impacts on individuals, communities, and the future of this planet. Direct actions could be as simple as recycling or reducing waste generation, or more complex, such as taking appropriate precautions to support public health during times of global pandemics.

For instance, human behavior, such as increased generation of waste and use of fossil fuels, directly contributes to global warming (Otto et al., 2014). Global warming is of major concern to this planet and its deleterious effects are believed to be happening at a faster rate than first estimated (Carey, 2012; Chen et al., 2017; Xu et al., 2018). There are efforts to try to cap the global temperature increase. However, it is now estimated that if human activity remains the same, we could be beyond that cap by 2045, if not sooner (see Chen et al., 2017; Gergan et al., 2020; Mesarović, 2019; Zandalinas et al., 2021).

Indirect actions, such as perpetuating misinformation or voting, can impact policy and funding that in turn impact science research and science education (Kyza, et al., 2020; Reyna, 2021). We should be concerned that impacts on politics and policy directly affect what we teach and how we teach. Real world consequences, if misinformation continues to be perpetuated, could lead to evidence-based scientific information no longer being the guiding parameters of science education policy, leaving our society even more vulnerable. This becomes a critical issue when considering the future of science and society in the era of global access to information (Dimock, 2019). This further highlights the importance of societies to not only be able to understand and evaluate the reliability of scientific information being conveyed, but to also know how to respond to it with reasonable action.

Importance of Science Literacy Assessment

The disconnect between how people interact with evidence-based scientific information once they are exposed to it should be of concern. Science literacy has been a national topic of interest for decades. The term science literacy has been defined and re-defined several times throughout the years (Allum et al., 2018; Liu, 2009). While the term itself has held a place of contention among educators and scholars alike, there is something to be said of the value of science literacy, how people understand and engage with evidence-based scientific information, and how those understandings inform their actions within daily life. This becomes even more relevant in the light of how exclusionary practices have isolated various ways of knowing, having a greater impact on historically excluded and minoritized communities. The negative impact of upholding only a Eurocentric way of understanding and practicing science hampers our ability to have a broader approach to science. In a time where the world is becoming amplified with greater cultural diversity, a reimagination of what science with a more nuanced approach has the potential to move science literacy forward. Liu (2009) advocated for an expansive re-envisioning of science literacy stating that, "Improving science literacy requires reconceptualizing science literacy to be both a state and life-long process, as both a personal choice and an economic necessity, and as both a personal enhancement and civic participation" (p. 309).

The Next Generation Science Standards (NGSS) are the current standards in place to facilitate science literacy among K-12 students in the United States. Though the K-12 national science standards have changed over the years, the current NGSS is rigorous and should promote a strong foundation for student engagement with scientific information (NGSS Lead States, 2013). While still exclusionary in nature, meaning that the current standards are not regionally or culturally specific, the NGSS has evolved in attempts to be more inclusive and culturally sensitive. The current NGSS supports science proficiency similar to what Liu (2009) was promoting. The current NGSS was implemented in 2013 and includes science and engineering practices, disciplinary core ideas, and crosscutting concepts (NGSS Lead States, 2013).

The NGSS provide the foundation for critical engagement with evidence-based scientific information through scientific practices such as "analyzing and interpreting data…engaging scientific evidence from argument…and obtaining, evaluating, and communicating information" (NGSS, 2013, p. 94). However, it has become evident that there is a disconnect between the anticipated outcome of science literacy through employment of the NGSS in K-12 and how people engage with scientific information in real world settings. Based on the rigorous standards set forth by the NGSS, science literacy should be relatively uniform across this nation, however, that is not the case. The NSB (2022) reported a large disparity across states in science proficiency. The report points out "Disparities in K-12 STEM education and student performance across demographic and socioeconomic categories and geographic regions are challenges to the U.S. STEM education system, as is affordability of higher education" (NSB, 2022, p. 2). Demographic and socioeconomic challenges are just some of the factors that may play into differences in science proficiency within the classroom.

It stands to reason that there must be additional factors or other influences that play into the proficiency of science literacy in society. Such factors may reside within educational discourse or educational institutions and areas of inequities within. There may be aspects beyond the classroom that contribute to the observed disconnect. It is also important to understand that the evaluation of science literacy should not halt at the completion of Grade 12. There have been efforts to assess science literacy in post-secondary academic institutions, however, these assessments have been limited in number. Additionally, neither K-12, nor post-secondary assessments have evaluated sociocultural influences and their potential impacts on science literacy.

Sociocultural Experience and Science Education

Educational institutions are obvious realms of education; however, students are not blank canvases when they step into the classroom, nor do they create knowledge in a vacuum. Lev

Vygotsky developed sociocultural theory and described the importance of social learning and its impact on informing a child's cognitive abilities (Daneshfar & Moharami, 2018). Sociocultural theory differed from previous theories in that it impressed the importance of social relationship and dialogue as the primary step of integrating information on an individual level. The norms and practices of specific cultures are important for how an individual in a community develops knowledge (Scott & Palinscar, 2013). Sociocultural experiences can vary from community to community and from household to household. Location, environment, and personally- or community-held beliefs can all be contributors to a person's sociocultural experience. Political and religious affiliations, cultural traditions, values, customs, and social norms are also associated with one's sociocultural experience (Tolbert & Bazzul, 2017). Some of these factors may be long-standing, but as societies become more global and technologically advanced, the number of influences that could factor into a person's sociocultural experience also increases. Widening gaps in socioeconomic status, growing recognition of sociocultural issues, and continued reports of inequitable treatment among historically excluded groups has led to greater interest in advocating for equity, inclusion, and accessibility (EIA) efforts in education and within science.

Sociocultural theory and research can be used as tools to combat exclusionary practices through increased understanding of the social identities our students hold, the social environments from which our students come, and the cultural practices in which they participate. It may also help to shed light on the very real sense of distrust that many communities have toward science. When entire communities' ways of knowing and understanding the world have been left out of the analects that guide science learning, it is more difficult to garner trust in the subject matter and in authority on that subject matter. Deep rooted suspicion is also understandable give that communities that have been historically excluded from the text have been experimented on unknowingly or against their will, in addition to forced erasure of knowledge and culture (e.g., the Tuskegee experiment, residential boarding schools). Being more sensitive and understanding to past experiences must come at the forefront of any endeavor to increase inclusion in subject matter and in practice. The varied experiences of our students are nuanced, valid, and should be acknowledged and valued.

Sociocultural experiences can contribute to how information is received by our students, and how they engage with that information. It is important to take the time to understand these things about our students as well as to infuse information regarding identity and various sociocultural experiences into the teaching process (Gay, 2018). Having a greater appreciation of the various identities and backgrounds represented by students can begin to shift our ways of thinking about how we, as individuals, come to know what we do. Understanding sociocultural differences could also inform our teaching practices in order to pave the way for deeper connections with the content we deliver. Incorporating sociocultural theory in science practice may help to overcome distrust due to the historical aspects of how harmful and exclusionary practices have limited the integration of socially and culturally nuanced knowledge within science. It may also help to combat a growing distrust in science, and to a greater extent education, due to advancements in modern day technology, expansive communication platforms, and the deepening divide in the current political climate by leveraging life experiences.

Purpose Statement

Theme One: Goals and Purpose of Science Literacy

A science-literate population is important for the progress of any society. Engagement with science is a vital process for the success of ourselves and our planet. Science, while not one of the highest priority subjects in school, is still considered part of the core curriculum in K-12 education in the United States. Science standards are the foundation of science education in US public schools. Most science education in the US public school system is guided by the NGSS (NGSS Lead States, 2013). Some states have generated specific science frameworks that have been modeled off the NGSS (e.g., https://www.cde.ca.gov ; https://sde.ok.gov/science-implementation/science-framework; https://www.doe.mass.edu/frameworks/scitech/2016-04.pdf). However, there are a few states that have not adopted nor have science frameworks modeled off the NGSS.

Iterations of science standards have been implemented within schools and routinely revised and updated to keep up with the ever-expanding world of science, to include engineering. The most recent iteration of national standards, the NGSS, was carefully created to provide a thorough science foundation and scaffolded system of science learning beginning in kindergarten and spanning through Grade 12. The learning objectives outlined in the NGSS span many areas of science and include important skill building that are not only crucial to science, but also to everyday life (NGSS Lead States, 2013). Skills such as understanding scientific processes, developing questions based on evidence, data interpretation and analysis, and being able to identify reputable and trusted sources of information aid contribute to support critical thinking as well as effective scientific communication (NGSS Lead States, 2013). The depths to which the NGSS lay the foundation to engage with science and scientific topics should ensure students who successfully complete secondary school have a rich understanding of various science topics. Additionally, students should be thoroughly capable of demonstrating an understanding of scientific information, critically examining evidence that is presented to them, and applying science literacy as they interact with the world around them.

Theme Two: Importance of Assessment of Science Literacy

In order to gauge the level of science literacy among citizens, some form of assessment is necessary. In K-12 education systems in the US, assessment is accomplished through required standardized testing. There is no universal assessment for science literacy in post-secondary education. Various forms of assessment could be categorized under content testing at the undergraduate level or entrance exams for graduate or medical school, such as content-specific GREs or the MCAT. However, these forms of assessment are usually testing content and comprehension, and not critical examination or application. Expanding assessment to non-science-related majors and to those who did not attend post-secondary school could expand our understanding of the influence of K-12 science education in the age of NGSS. Asking how citizens understand, interpret, and engage with scientific information in real-world situations could inform us to a greater degree of science literacy within a population.

Theme Three: Sociocultural Impacts on Learning in Science Education

Sociocultural perspectives lend context to how information is received and processed. Current events, such as the global pandemic and concerns about global warming, have been everywhere in the news and on social media. Students are exposed to information and misinformation at ever-increasing rates. Topics such as these have become extremely polarized and are divisive issues for citizens in the US and worldwide. Given the rigorous standards and expectations set forth by the NGSS, it would be reasonable to believe that issues such as global warming or public health initiatives would not be divisive, but instead, topics in which a vast majority of the population would be able to engage with on a critical and thoughtful level.

As there is not a national requirement for adoption of the NGSS, the differences in standards of learning in science education may be one factor that has contributed to variances in science literacy across the country (NSB, 2022). However, it is not just the content that is being delivered which accounts for differences in science education. It is also extrinsic factors such as sociocultural influences. This has been demonstrated in science education research that has explored social and cultural impacts on student learning (see Ceci et al., 2009; Gilbert & Yerrick, 2001; Maulucci, 2010). A deeper understanding of our students' social and cultural experiences can positively contribute to learning outcomes. The incorporation of more inclusive and contextualized science material could pave the way for greater reception of the material and a strengthened science literacy among students. This can also create a safer environment which can support greater learning outcomes (Soares & Lobez, 2020). Expanding our current techniques and material with expanded sociocultural perspectives in science education can lead to more inclusive science communities as well as increase engagement with science.

Purpose of Study

Assessing science literacy allows us to understand how students and citizens understand and engage with scientific information. Sociocultural experiences can vary depending on the environments in which one was raised, cultural experiences, traditions, and beliefs within the community, at home, and at school. The purpose of this study is to investigate how sociocultural experiences influence science literacy. A limited amount of research has been done on influences of sociocultural experience in science education and to date, there have been no published studies that have utilized critical sociocultural research in science literacy. By further understanding nuanced factors that may influence science literacy, we can more responsibly create an environment in which science is more inclusive, more trustworthy, and less refuted.

Research Questions

A. *How do previous science experiences relate to students' science literacy?*

B. *What sociocultural factors correlate to students' science literacy scores?*

Significance

This study aimed to understand how previous science experiences and sociocultural experience affect science literacy among first-year college students. Identifying previous experiences with science, social, and cultural factors that either help or hinder science learning could contribute to ways in which we as science educators can expand best practices to ensure strong science literacy that is more equitable, inclusive, and accessible. The use of embedded design contributed to more comprehensive understanding of the findings. By applying a critical lens through critical discourse analysis to evaluate previous science experiences, sociocultural experiences, as well as science literacy assessment outcomes I was able to further assess how element of power, identity, and agency relate to students' experiences. Findings from this study can lend themselves to more focused research in areas where relationships between previous science experiences, sociocultural experiences, and science literacy were identified.

Definition of Terms

Student- I refer to student as any person that is in a formal education attending school in an early childhood education (ECE), primary, secondary, or post-secondary education setting.

Sociocultural- The social and cultural aspects that I discuss in this research are vast. As I speak to sociocultural experience, or perspective, it encompasses any and all influences in a person's life that shapes their way of knowing and being in the world through social and cultural interactions, understandings, environments, norms, traditions, and expectations.

Science literacy- For the intents and purposes of this study, I refer to science literacy as the ability to understand science content as it relates to the context, the ability to identify basic scientific concepts, interpret, analyze, and critically evaluate scientific information and the reliability of that information, and the ability to apply science inquiry as a way to problems solve and make informed decisions in their lives.

Power- In the context of this research, I define power as a relational factor among people, institutions, and establishments. Power conveys a hierarchical nature of relationships and in that hierarchical structure there is understood to be elements of influence. The influence acted out within relationships among people or imposed by institutions and establishments can be helpful or harmful dependent on the relationship of the individuals involved.

Assumptions/Limitations

This study assumes that students who choose to participate have various sociocultural experiences. For the intent of this study there will not be efforts made for purposeful sampling. Due to the nature of the delivery method of this study (anonymous survey) there was no way to anticipate a demographically diverse pool of participants. Additionally, there was no way to guarantee the number of students that would choose to participate in this study. This study was limited in scope in that it investigated a single university in one region of the country. Because of this, there could be commonality among respondents based on where they, as students, have decided, were influenced, or were able to attend university.

Positionality Statement

I am a queer, non-binary, neurodivergent researcher who has spent many years in science spaces. I have been both a scientist and science educator. I have personally experienced harm within these spaces and witnessed how science spaces and classrooms alike can be exclusionary and perpetuate hurtful systems, be them intentional or unintentional. My identity has contributed to how I have had to navigate within these spaces, to include hiding parts of myself to protect myself from further undue instances of harm. My interest in critical evaluation of science resources and science spaces is part of my endeavor to contribute to the facilitation of more equitable, inclusive, and accessible science communities within education and beyond where science learning can take place without harm, oppression, or exclusionary practices. I situated myself in this study perform this research as objectively as possible through the use of anonymous data, systematic quantitative analysis, reflexive thematic qualitative analysis. Understanding that my identity contributes to how I view the world around me and may contribute to bias within my analysis, I relied on iterative rounds of self-reflection in tandem with reflecting on the data. I also relied on input from my colleagues to assess for biases within my analysis.

Conclusion

How students engage with scientific information outside the classroom is of great importance. Our planet faces multiple crises in the face of real-world issues, particularly as the ongoing SARS-CoV-2 pandemic continues to ravage through countries and global warming imposes imminent threat to future generations. Critically evaluating the sociocultural backgrounds of our students can aid in a deeper understanding of factors that could affect science literacy. The areas probed for this study include the following: 1) Students' previous experiences with science and science education, 2) Sociocultural experiences of traditional first-year college students at a large public university in the central U.S., and 3) How students engage with scientific information. It is up to us, as science educators, to find new ways and best practices to ensure the science literacy of our students.

Chapter 2 Literature Review

Introduction

To date, there has yet to be any published empirical studies conducted on critical sociocultural research within science literacy. This work is grounded in sociocultural theory with a critical lens. This literature review serves two purposes. First, it describes the conceptual and theoretical framework for this study. Second, it describes the state of the research related to science literacy and sociocultural as well as critical research in science education. The literature reviewed within compares and contrasts understandings and measures of science literacy. Literature reviewed also lays the foundation for an understanding of where the current research stands in critical research and sociocultural influences on science education. It is through exploring the vast amount of literature, historical and current, that I define what I mean when I refer to science literacy, power, identity, and agency as well as how I evaluated science literacy among students.

Conceptual and Theoretical Framework

The primary guiding framework for this study is critical sociocultural theory. However, due to the finite areas of research in which critical sociocultural theory has been applied, I relied heavily on the foundational theories that lend themselves to critical sociocultural theory. Critical sociocultural theory draws from both sociocultural theory and critical theory (Moje & Lewis, 2020). Sociocultural theory draws from constructionism in that it ascribes to the ideal that there is not one individual truth or one single way of knowing. Sociocultural theory relies on the belief that meaning is constructed through experience and interaction with the world around us. "We do not create meaning. We construct meaning. We have something to work with. What we have to work with is the world and objects in the world" (Crotty, 1998, pp. 43-44). That is, while there is no meaning ascribed to an object before a human has interacted with and assigned meaning to it, the object still existed and remained in existence with the potential of meaning (Crotty, 1998). Within education, there are multiple epistemic ideologies; however, even these are limited to those who created them. The ways in which a person or groups of people understand the world is not limited to one specific way of knowing. Examples of various ways of knowing are shown in expanding bodies of work which incorporate indigenous ways of knowing back into curricula (see Ahenakew, 2016; Brown, 2010; Kincheloe, 2011; Kitson & Bowes, 2010; Metallic, 2009). These are just a few examples that highlight the need to have a greater appreciation for how students from various backgrounds interact with science being taught and how knowledge is constructed in consideration of their own backgrounds and experiences.

Humans carry with them their own individual histories, perspectives, and ways of being in the world which are reflected in their individual identities, backgrounds, and unique experiences. All of these things can contribute to how a person constructs unique meaning to the interactions with the world around them (Shiro, 2013; Walker & Soltis, 2009; Noddings, 2013). However, the individualistic understanding laid forth does not consider how factors such as context and social environments contribute to knowledge construction.

Social Constructivist Theory

Social constructivist theory incorporates the understanding that while there are many different ways of knowing, that the construction of knowledge is moderated by social environments before becoming individualized understandings (Kim, 2001). This study relied on the understanding that students construct meaning of the world around them through interactions with their peers and their surroundings (Crotty, 1998). Therefore, knowledge construction does not take place on an individual level; it is through interactions with those around us that informs how we make meaning of the world (Crotty, 1998; Hodson & Hodson, 1998). While humans carry with them their own individual histories, perspectives, and ways of being in the world, there is also valuable influence that comes from the communities and environments in which people live and learn.

Sociocultural Theory

Sociocultural theory adds the elements of community and environmental influence that expand beyond social constructivist theory. Sociocultural theory was influenced by Lev Vygotsky as he proposed social learning theory, or social constructivism. Vygotsky's stance was that learning was mediated through the social environment and preceded individualistic knowledge. Amineh and Asl (2015) wrote, "Vygotsky holds an anti-realist position and states that the process of knowing is affected by other people and is mediated by community and culture" (p. 10). Sociocultural theory is supported by social constructivism in that sociocultural theory surmises that both social and cultural experiences influence learning.

Sociocultural theory and research have expanded to take into consideration many different factors of an individual's life and the role those factors play in learning. Context is an important factor in the areas of social and cultural understanding, as context can change given the environment. Alfred (2002) addressed the importance of context in how it relates to the social construction of meaning, to include the environment in which the construction of meaning occurs in that "learning cannot be considered to be content-free or context free, for it is always filtered through one's culture and cultural identity" (Alfred, 2022, p. 5).

There has been pushback on sociocultural theory (see Lupton, 1999; Sawyer, 2002; Sundin & Johannisson, 2005). Critics have questioned its relevance within education research, especially in STEM-related subjects, as these are often thought of as objective learning topics (Lemke, 2001). Science disciplines have historically relied on objectivity, meaning every endeavor is merit-based, fueling the thought that subjectivity or human experience should have no influence on science learning outcomes (Mijs, 2016; Rogriguez, 1998; Young, 2017). We, as humans, are subjective by nature. We are influenced by those around us, the society in which we live and with which we interact, and the culture by which we are surrounded. Despite the divisiveness of the relevance of sociocultural theory in learning spaces, it is important that areas that address social and cultural aspects be implemented in research to combat such pushback. The incorporation of sociocultural perspectives in research directly challenges problematic, long-lived systems within education such as hegemonic ruling, heterogeneity, powerholding groups impressing their ways of knowing and being, upholding the status quo, and perpetuating oppressive systems.

Transformational Theory

This study also incorporated Nohl's framework of transformational theory. Transformative learning theory differentiates itself from other learning theories as it focuses on conditions under which learning occurs as an adult which is separate from other learning processes in that it is not typically influenced by indoctrination and is often accompanied with critical reflection (Mezirow, 1996). Transformative learning theory as proposed by Mezirow, however, focused on ideal conditions of learning. The assumption that there are ideal conditions for learning fails to take into consideration the reality of inequity, unequal access to resources, social and culture influences, or other factors that may contribute to learning. More recently, Nohl (2015) proposed a new model of transformative learning that is based on the analysis of a number of different social groups previous models had used as the foundation of his study. Nohl proposed a model that consisted of a five-phase approach to transformative learning theory. The five phases propose that the “transformation process begins with a (1) non-determining start and continues with (2) a phase of experimental and undirected inquiry and a (3) phase of social testing and mirroring. The process is boosted during a (4) shifting of relevance and, finally, leads to (5) social consolidation and the reinterpretation of biography” (Nohl, 2015, p. 39). Shifts in understanding of information and worldview as supported by Nohl’s transformational theory model are often observed during post-secondary education. College is one place where students are often exposed to multiple cultures and perspectives that differ from what they have known in their lives up to that point.

Critical Theory

Critical theory has been used to investigate the roles of power on systems and institutions in hopes to shine a light on areas that have been unduly impacted in inequitable ways due to some social, historical, or political aspect. Critical theory has focused on systems and power and how those relate to and shape society (Crenshaw, 1990). It is a theory whose goal is to critique and challenge the system and make change within society.

Inequities within education have been long-fought battles and are often a symptom of systems of power that aim to maintain the status quo. The system designed in the United States has been put in place to uphold the status quo historically related to the agenda and power of the cis, white, Christian, heteronormative male. This centers whiteness and specific social standings within society, politics, and education. Centering whiteness and other values related to whiteness, Christianity, and heteronormativity are problematic as it devalues the lived experience of anyone outside of or on the margins. (Butler, 2002; Foucault, 1970; Rubin, 2002).

It is through the application of critical theory that harmful systems can be investigated and exposed. Critical theory allows us greater understandings of the influence of power in the system and how these power relations can create harm. It is only through understanding these systems that we can reduce harm and increase equity in education. Harm has been perpetuated by means of covert racism that fuels government policies and laws which in turn affect school policies (Rothstein, 2017). It is problematic as the power holding group continues to create educational policy that upholds agendas that only align with their specific ideology (Apple, 2012; Moutsios, 2010).

Critical Sociocultural Theory

Furthermore, this study was guided by critical sociocultural theory, which pulled from both critical theory and sociocultural theory. Critical theory aims to critique society in order to make change (Horkheimer, 1972). Critical theory has also been applied to learning processes to look beyond how meaning has been made through sociocultural context. Critical inquiry questions power structures within societies and among groups. Although, critical inquiry is not solely an investigative pursuit for understanding's purpose alone. Critical theory requires the use of theory and reflection on systems in place and questions asked in a way that when answers are uncovered or brought to light facilitates change in a practical manner. "Critical inquiry remains a form of praxis—a search for knowledge, to be sure, but always emancipatory knowledge, knowledge in the context of action and the search for freedom" (Crotty, 1998, p.159).

While critical theory is concerned with the critique of society where the ultimate goal is emancipation or liberation of all people from marginalization or oppression, Vygotsky's sociocultural theory is used to examine the nuanced relationships between individuals and learning processes based on various unique experiences. Sociocultural theory identifies social and cultural influences within one's life and the relationship those influences have on the individual as well as the influence the individual has on their culture, social norms, or community and how those may impact learning (Lantolf, 2000; Scott & Palinscar, 2013).

Critical sociocultural theory and research identifies ways in which power, identity, and agency each contribute to our roles in society and within the system (Moje & Lewis, 2020). When referring to identity, I refer to not only race, gender, ability, and the myriad of other identities that people hold, but to how the intersectionality of such identities further influence learning and meaning making (Crenshaw, 1990). Agency is an expansion of identity as it refers to a person's ability to express or suppress their identity or parts of their identity depending on the situation or environment (Huang & Benson, 2013; Lier, 2007). It is only through critically understanding and acknowledging our unique perspectives and experiences that we may continue to find new ways in which to support our students in their growth and development through fostering intentional and meaningful education.

Review of the Literature Organized by Themes

In this section, I discuss the search description as well as the review of the literature. The review of the literature has been organized into three themes. The first theme is science literacy. Science literacy has been a topic of debate since the concept's inception. This section presents historical and working definitions of science literacy, to include both of the terms *scientific literacy* and *science literacy* and how those two terms have been used interchangeably. I present how science literacy has influenced the generation and maintenance of national science standards and how this contributes to a continued need to investigate and understand the nuances of science literacy, especially in the modern age. I discuss the impacts of advancements of technology and the digital age on science literacy and the changes in how scientific information can be consumed, and potentially misunderstood by the general public. Furthermore, I also show how extrinsic and intrinsic factors cannot be ignored in our understanding of science literacy.

The second theme addressed in this literature review is assessment tools used in science literacy. This section begins by addressing the importance of science literacy in the age of misinformation. I discuss various tools that have been created to assess science literacy for various education levels. I also provide examples of how science literacy assessments have been administered in different parts of the world and that findings show differences of strengths in areas of science literacy skills dependent on which part of the world the study was conducted. I also present findings from studies that have incorporated science literacy assessment tools in their research highlighting strengths of each assessment and pointing to areas where the assessments could be expanded to be more representative. Additionally, I present global research that describes differences in science literacy outcomes from different countries who have implemented science literacy assessments.

The third and final theme discusses sociocultural influences on science education. In this section I explore research executed in relation to race, gender, and socioeconomic status as it relates to science education. I will discuss how inequities have been perpetuated in science education based on areas such as race and socioeconomic status. I also highlight studies that have utilized critical theory to explore issues of power, identity, and agency within systems and the roles they have played in science education. This literature review aims to give insight into the dynamic nature of science literacy, the ways in which science literacy has been assessed and how those assessments are limited in their scope as well as to show evidence of the complexities of social and cultural aspects that have influenced science education.

Search Description

Literature reviewed for this study was obtained through literature searches using both a robotically curated database (https://scholar.google.com/) as well as a database curated by hand (https://libraries.ou.edu). The selection process and criteria for the collection of articles remained the same for both databases. Any review articles that were returned during literature searches were initially probed for relevance and content. Empirical research cited in review articles was then further examined. Empirical research articles used came from a variety of peer-reviewed academic journals and were able to be obtained electronically through either database or using inter-library loans (ILL) through libraries.ou.edu. Search parameters were limited to a variety of keyword searches and were consistent among each database used. Various searches were conducted using the following either individually or assorted combinations of the keywords: “multicultural”, “diversity”, “equity”, “inclusion”, “accessibility”, “representation”, “education”, “science”, “science education”, “STEM”, “STEM education”, “critical theory”, “critical discourse analysis”, “transformative learning theory”, “critical sociocultural theory” “sociocultural”, “socioeconomic”, “social reproduction”, “science literacy”, and “scientific literacy”.

Literature was also sourced from academic books based on empirical research and the accompanying articles published for the associated studies. Additionally, statistics surrounding diversity, equity, inclusion, accessibility, and any other demographic data associated with science education were initially identified from national and/or global entities that are accredited and well established. The articles associated with studies from which the statistical analysis results were sourced were then examined for further review.

Literature (books, journal articles, or other) were first reviewed to ensure that they were appropriate for addressing any or a variety of the areas of sociocultural research, critical theory, critical sociocultural theory as well as within science, science education, science, technology, engineering, and mathematics (STEM), STEM education and science literacy. Any literature deemed to provide insight into the current state of these areas, within six years where possible, specifically within science, science education, and critical sociocultural research were reviewed further. In areas where there was limited current literature available, articles were assessed from the most recent publications that could be found. Additionally, some older publications were included in order to lay foundational groundwork and to be used as comparison for historical context. Literature that did not adhere to these criteria was not included as part of this literature review.

For information on statistics, the most recently published statistics that were analyzed and reviewed from credible sources were used to provide evidence. Older statistics using the same criteria were used to compare and contrast trends in areas of changing demographics in science and science education in certain related areas over time. It is important to expand our gaze beyond recent demographics and to include historical context to gain deeper insight of the bigger picture of what is happening from a demographic standpoint in science and science education. Coupling demographic data with student self-report sociocultural experience can lend itself to understanding nuances that have been overlooked in the past by the exclusion of student experience.

Science Literacy

Science literacy is a critical component for successful societies, as science affects the life of every citizen. Science is not simply what goes on in laboratories or in the health industry. It is foundational to the advancement of technology, necessary for the health and wellness of the people, and critical for the survival of this planet. Science plays a part in every life process and activity, and it is imperative that the citizens of a society know how to understand, interpret, make sense of, and use scientific information. As the relationship between society and science continues to change, so increases the need for science literate societies.

Science literacy is not a new concept and therefore has undergone several iterations over time of what precisely science literacy is, what defines science literacy, and how to apply our understanding of science literacy to assess the science literacy of students and citizens. The variety of definitions and arguments that surround science literacy have caused confusion for not only the general public, but for those who study and evaluate it. Science literacy scholars have aimed to not only define and re-define science literacy, but some have also attempted to categorize types of science literacy. For instance, Shen (1975) discussed three types of science literacy (practical, civic, and cultural). Shamos (1995) also tried to further categorize science literacy into cultural, functional, and true science literacy. Other scholars and entities have tried to amalgamate the types of science literacy that Shen and Shamos categorized into overarching definitions that include some or all of the categories they defined (see AAAS, 1990; Feinstein, 2010; NRC, 1989; OECD, 2007). DeBoer (2000) spoke to the challenges of a strict definition of science literacy due to the relationship of scientific understanding and stated "We have seen from this historical analysis that scientific literacy is about the public's understanding of science. That understanding is open-ended and ever-changing. It is organic, not static" (p. 597).

While a thorough review of the literature in the vast area of science literacy is beyond the scope of this literature review, this section aims to give a broad overview of science literacy. In this section I present the historical context of science literacy as well as provide examples of shifts in the body of science literacy work over the years that have contributed to the difficulty in a universally agreed upon definition of science literacy. I will discuss the role that science literacy has had in shaping the national science standards. This section includes scholarly arguments for the importance of a scientifically literate society and how technological advancements as well as life in the digital age have impacted and further complicated what we have understood about science literacy. Finally, I discuss factors such as extrinsic influences and identity that have been shown to be important components that can highlight differences in reported science literacy.

Historical Overview of Science Literacy

Science literacy has been explored in depth throughout the years. Presently, there is not a unified definition or clear and agreed upon understanding of the term science literacy. The evolution of the construct of science literacy has been a complicated one since its genesis. The term first began to appear in the literature in the late 1950's. Hurd (1959) recognized "Science instruction can no longer be regarded as an intellectual luxury for the select few" (p.13) and expressed concern over whether the general population as well as education in the United States would be able to keep up with the evolving science and technology, as it shifted so quickly from the nuclear age to the electronic age and into the space age. Hurd (1959) further discussed the need for science education to happen at the forefront of possibility and stated, "Understanding science means knowing something about the procedures of theoretical inquiry and recognizing these procedures as the means by which the imagination of man and the laws of nature are focused upon unsolved problems" (p. 19). Sir Charles Snow expressed concern over the growing divide between scientists and nonscientists in an address he gave in 1959 (Snow & Smoluchowski, 1961). Hurd and Snow both exhibited concern for the growing need for society to be science literate as they laid the groundwork for the ever-expanding body of work science literacy.

Since the late 1970's and early 1980's, contested and wavering definitions of science literacy have created a sense of distrust among the public as well as among scholars. Several attempts have been made to consolidate the term of science literacy as it is relevant to the objective outcome of science education (see Table 1). Larger governing bodies within the scientific community, such as the AAAS and the NRC have also tried to step in and intervene to bring a clearer definition of science literacy (AAAS, 1990; NRC, 1996).

Science literacy, like all other subject matter specific literacies, evolved from literacy, which defines a person's ability to read, write, and communicate effectively. Science literacy is also concerned with how a person understands natural phenomena beyond the context of traditional literacy. In the early 1980s, the state of science education in the United States became a national concern. After the National Commission on Excellence in Education (NCEE) published the article commonly referred to as "A Nation at Risk" in 1983, the concern for education status in the United States was brought into public view. While this was not the first or only publication that raised concern over the state of the education system in this country, it did help pave the way for the creation of national education standards with the 1989 publication of national standards for mathematics (NRC, 1989; Romberg, 1989).

Table 1

Expectations of a Scientifically Literate Person

Agency	Expectations
AAAS	Emphasize connections in the natural and social sciences, mathematics, and technology. Understand interdependence of science math and tech and human enterprise Understand key concepts and principles Be familiar with natural world Use for individual and social purposes
NRC	Understand unifying science concepts Engage with science as inquiry Understand various science content (life science, earth science, technology, etc.) Ask and answer questions derived from curiosity about everyday experiences Be familiar with nature of science Understand social perspectives of science
OEDC	Engage with science-related issues Engage with the ideas of science, as a reflective citizen Explain phenomena scientifically Evaluate and designing scientific inquiry Scientifically interpret data and evidence
NSTA	Understand what science is Use scientific information in daily decision making

The development of national science standards took several years following the release of the national standards for mathematics. The push for national science standards re-energized the area of science literacy as it was foundational in the standards' development. However, the controversy surrounding a single, unified definition of science literacy continued.

Difficulty of Defining Science Literacy

Throughout the published literature there have been the uses of both *science literacy* and *scientific literacy*. Often, these terms are used interchangeably, or have conveyed the same underlying context. A narrow definition has yet to be agreed upon due to the broad scope of scientific information and what scholars deem as necessary to be science literate. However, there is clear agreement that science literacy should include the expectations of understanding and engagement with scientific information that would be normally fostered through the Next Generations Science Standards (NGSS) in K-12 school settings (NRC, 1996; NGSS, 2013).

The controversies that surround the definitions of science literacy and the confusion between *science literacy* and *scientific literacy* have destabilized the strong foundation that was laid in the endeavors to increase science literacy. These attempts to re-legitimize what science literacy means in order to assess the science literacy of the general population have remained an evolving body of work. Regardless of which term is deemed most appropriate, it is important to understand the overall goal of assessing and understanding science literacy, the role that plays within our society, and why it is important. For the intents of this study, I use a definition of science literacy that incorporates the science education received in the classroom with the usefulness of science education into everyday life, similar to the views expressed by Feinstein (2010) "referring to the very specific notion that science education can help people solve personally meaningful problems in their lives, directly affect their material and social circumstances, shape their behavior, and inform their most significant practical and political decisions" (p. 169).

Science Literacy and National Science Standards

The generation of science assessments began shortly after the national mathematics standards were created in the late 1980s. The first set of national science standards took several years to be finalized, as the National Science Education Standards (NSES) were not released by the NRC until 1996. One of the major issues that arose in the attempts to develop assessments for science literacy is similar to the major contention around the term science literacy itself. Just as there is not an agreed upon definition for science literacy, there is neither a measurable set of skills that have been agreed upon to be the standard for assessment of science literacy (Bauer et al., 2007). As national science standards continued to change, Bauer et al. (2007) suggested that it was necessary to evaluate the extent to which science concepts are understood in addition to how students view science and society.

Shortly after the first iteration of national science standards was created, an international initiative to assess student learning was created. In 1997 The Program for International Student Assessment (PISA) was formed by the Organization for Economic Co-operation and Development (OECD). OECD currently has 38 countries that hold membership with the organization, to include the United States (OECD, 2007). Since 2000, the intention of PISA was to evaluate students annually on content knowledge in reading, math, and science but only evaluated one content area each year. Therefore, every three years student science literacy is evaluated through PISA. The student assessment consists of a student test and questionnaire.

The national science standards have been utilized to guide science curriculum as well as in the development of assessment tools. In turn, the outcome of assessments on science literacy have been used in an attempt to reform science education. When discussing the overlapping goals and parallel development of national standards by the NRC and Project 2061of the AAAS, Timothy Goldsmith cautioned,

> One danger is that the word "standards" particularly "national standards" suggests a straightjacket [sic] of conformity in which the creativity of teachers is certain to be undermined…A second objection comes from the opposite direction when the standards are viewed and judged by people outside the profession whose views of education have been molded by their personal experiences of yesteryear. For them, if the physics lesson

appears to lack some familiar feature, such as electrical circuits and bulbs and batteries, "Where's the content?" becomes the "Where's the beef?" of public dialogue. So, it is essential for everyone to understand the richness of what the standards and benchmarks are trying to accomplish (Goldsmith, 1995, p. 116).

What Goldsmith addressed was a continued growing distrust of and lack of usefulness of standardized education. However, there is still a need to be able to assess our students' understanding of content, their ability to problem-solve, and their skills to effectively communicate science.

The development of national science standards was further guided by publications from the American Association for the Advancement of Science (AAAS), specifically *Science for All Americans* (1980) and *Benchmarks for Science Literacy* (1994) (Bybee & McInerney, 1995). These standards set out to clearly define what a student should know about science and what they should be able to do relevant to science content. In 1996, the NSES by the NRC broadly defined science 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" (p. 22).

Currently, the NGSS is the standard for what should be implemented in science education in schools today (NGSS, 2013). One of the main arguments during the early 2000's was that the goals set forth by the AAAS and the NRC were extrinsic in nature (Liu, 2009). That is, that the goal of science literacy was something to be achieved or obtained by a certain time. It has been estimated that the amount of time students in their K-12 journey spend engaging with science in school is less than 4% (Liu, 2009). Liu (2009) argued that science literacy is not only an intrinsic process, but one that should be approached as a lifelong learning process. While the estimated time spent on science in the classroom is a meager amount, teachers may mediate this through their influence and instructional practices, which may impact how students respond to science learning (Feinstein, 2010; Hwang et al., 2018).

Science Literacy and the Advancement of Technology

A reasonable and working understanding of scientific information should not be reserved for those with specialized secondary education or post-secondary degrees. In the development of a self-assessment tool for science literacy among undergraduate students, Vandegrift et al. (2020) argued that science education should lay the foundation for non-science geared students, or non-science majors, to enact science literacy, as science in everyday life impacts them just the same. This should hold true for students who do not pursue higher education, as a strong foundation of science literacy is good for society. Bucchi and Saracino (2016) found that visual science literacy provides a greater way of communicating science to a larger audience. Their findings showed that more people could recognize images as opposed to answering questions about science content and history in text form (Bucchi & Sarcino, 2016).

Just as science is a dynamic subject, so must our approach be to science literacy. Elshahed and Tyson (2020) discussed the challenges and advancements of science literacy due to the changing landscape of media communications, specifically social media. They addressed the increased amount of scientific information that is able to be shared globally due to social media platforms as well as discussed concerns for gatekeeping of information and quality of content (Elshahed & Tyson, 2020). Additionally, there is a large amount of incorrect and unvalidated information available on social media platforms. Misinformation can be convincing for those who are not educated in the critical evaluation of information and its sources. While the vast availability of misinformation may not come from nefarious sources, it is still capable of causing an outcome of misunderstanding (Howell & Brossard, 2021).

Science Literacy in the Digital Age

Science literacy has played a crucial role within societies and on individuals. Conversely, societies and individuals have played a crucial role in science literacy. Howell and Brossard (2021) argued the need for stronger science literacy in the digital age and the importance of "being able to navigate scientific processes, science issues as they interact with broader society, how we all receive mediated information, and how we form opinions on that information are all crucial for that literacy" (p. 7). As technology and platforms of communication evolve and our understanding of how younger generations engage with information expands, it will be important to continue to reassess science literacy in ever-changing cultural climates. "Today's world needs informed and competent citizens who are capable of comprehending and utilizing knowledge at hand and employing such knowledge in a sociocultural context" (Elshahed & Tyson, 2020, p. 15).

Howell and Brossard (2021) wrote on the complexities and importance of science literacy in the digital age and in the age of misinformation:

> We need to expand our conceptions of what it means to be science literate in today's environments of complex science, social issues, and information networks. The stakes for decision-making are high, and the potential benefits of science literacy to help us do so are as well. It is crucial to think of science-literate citizens (and perhaps of science-literate communities) in ways that account for the realities of our modern, digital world, across the lifespan of scientific information as people access and act on it. This will only

be possible if we address civic science literacy, digital media science literacy, and cognitive science literacy. (p. 7)

This is an important point to consider not only for teaching and science communication, but also for evaluation of science literacy in the digital age.

Extrinsic Influences on Science Literacy

Just as the world has changed and methods of information delivery have evolved, so has our understanding of factors that influence learning. This holds true as science literacy assessment results differ across the US regardless of the NGSS being foundational to science learning in the public school system (NSB, 2022). It is important to understand how external factors could influence a person's understanding of science or how they engage with scientific information outside of the classroom. Few studies have been done on extrinsic factors that specifically play a role in science literacy.

McPhetres and Zuckerman (2018) described how negative attitudes toward science have been associated with a person's religious beliefs. Their study examined how religiosity, that is religious beliefs and practices beyond simple religious affiliation, impacted belief and trust in science. The findings presented showed that there was an association between religiosity and negative attitudes toward science and untrustworthiness in science sources (McPhetres & Zuckerman, 2018). This is an example of how extrinsic influences could moderate ways in which a person learns science or thinks about scientific information. Political polarization is another area that was examined in relation to the effects on science literacy.

Drummond and Fischhoff (2017) found that the amount of science literacy and education that a person holds can influence the polarization of their views on science topics. They examined the level of education, religious and political beliefs, and beliefs about six science topics (genetically modified food, stem cell research, human evolution, the Big Bang, climate change, and nanotechnology). Drummond and Fischhoff (2017) found that there was greater polarization of beliefs among those with more general and science education and greater science literacy. They showed a significant association of religious beliefs on nanotechnology, the Big Bang, human evolution, and stem cell research, while there was a significant association of political beliefs on climate change, human evolution, the Big Bang, and stem cell research.

However, when Fischer et al. (2022) examined the relationship between polarized climate change beliefs and motivated reasoning, they discovered that there was contradictory evidence of political beliefs against climate change or motivated reasoning. Their study supported the findings of Drummond and Fischhoff that showed greater polarization of climate change beliefs among those with greater science literacy. However, they were unable to conclude that political beliefs drove motivated reasoning toward climate change beliefs, although they did find that prior held beliefs influenced a person's ability to discern trustworthy from untrustworthy information (Fischer et al., 2022). Fischer et al. (2022) wondered "What factors could explain the present replication of polarization as a function of science literacy without lending support to science literacy driving motivated reasoning? One plausible interpretation is that science literacy is correlated with other traits or mechanisms that do drive polarization" (p. 11). However, extrinsic factors are not the only aspects that have been investigated in regard to ways in which science literacy has been impacted.

Identity and Science Literacy

There is only a limited amount of research conducted that evaluates the implications of intrinsic factors, such as identity on science literacy. To date, Allum et al. (2018) is the only group who investigated the impact of race on science literacy. Their study was conducted in a limited capacity. They were concerned that, "the distribution of science literacy is unequally stratified, particularly if this stratification reflects broader patterns of disadvantage and cultural dominance as experienced by minorities and educationally underserved populations" (p.861). Allum et al. were concerned that data gathered through means such as the Science and Engineering Indicators (SEI) survey module of the General Social Survey (GSS) analyzed results against limited demographic information and therefore was missing crucial evidence of disparities among respondents who hold different racial identities.

Allum et al. (2015) investigated the differences among Black and Hispanic individuals responses to GSS from 2006-2016 (https://gss.norc.org/) relative to white persons in the United States. They found that science literacy did seem to be impacted negatively when compared to race demographics and reported higher means on the science literacy quiz for white respondents, followed by lower means for Hispanic and Black respondents, respectively (Allum et al., 2018). Even after they adjusted for factors such as sex, socioeconomic status, education level, which they believed could reduce the science literacy disparities, they did not see significant reduction in mean differences. Allum et al. (2015) suggested that there should be further investigation into confounding factors of disparities they found science literacy in underserved populations and that quality of teaching, and the learning environment might play an important role as well.

Kristyasari et al. (2018) performed a study that examined differences in mastery of low, medium, and high category science literacy of junior high students from low-, moderate-, and high-categorical schools. This study assessed five indicators of mastery of science literacy. The five indicators investigated were recognizing the scientific question, identifying the evidence, drawing conclusion, communicating the conclusion, and demonstrating the understanding of the scientific concepts. Results showed that there were differences across categories of science literacy based on both the categorical-level school and the reported gender of the students (Kristyasari et al., 2018). Kristyasari et al. (2018) reported that female respondents performed at a much higher rate than the male respondents, and that the female participants were able to perform mastery of four of the five indicators assessed (recognizing the scientific question, identifying the evidence, communicating the conclusion, and demonstrating the understanding of the scientific concepts), while the male respondents were only able to demonstrate mastery of one of the five indicators (drawing conclusion). Furthermore, they reported that in the low- and moderate-category schools, mastery by female students was better than that of females in high-category schools (Kristyasari et al., 2018). Identities and aspects of our identities play a large role in every aspect of our lives. The complexities of identity and the implications of intersectionality should be taken into consideration when looking how any and all identities that a person holds could potentially influence the way a person engages with science literacy.

The minimal body of work investigating the impact that both intrinsic and extrinsic factors have on science literacy leaves us with a large gap in our understanding of the complexities that surround students being or becoming scientifically literate. In order to understand the differences in science literacy among students, it will be valuable to evaluate influences beyond micro-level analysis limited to classroom and curriculum. By taking a macro-level approach and looking beyond the classroom and into community as well as other social factors against formally assessed science literacy outcomes, we may be able to greater understand nuanced and complex influences that may help or hinder science literacy.

Assessing Science Literacy

Science literacy is critical for successful societies. As a way to improve science education, AAAS developed Project 2061 in 1989 to push for a reform to standardize science curriculum and improve science literacy among students (AAAS, 1990). In order to determine how well our students are learning the concepts laid forth in the national standards the assessment tools were developed. There has not been just one standard assessment tool required to be used to evaluate science literacy. Contrarily, there have been a number of assessment tools created and implemented within the body of science literacy research. In this section I will begin by discussing the importance of science literacy to combat misinformation. I will present the historical timeline of the creation of science literacy assessment tools and their utilization. As I discuss the different assessment tools, I shall touch on differences and similarities among the assessment tools as well as on problematic areas within the assessment tools themselves.

Science Literacy Assessment

We have seen an increase in concern over misinformation worldwide. With the increasing accessibility of information and the ability for anybody to make claims to the general public, it has become more crucial than ever that people are skilled with the ability to critically evaluate scientific information. Science literacy assessment has been employed in recent years as a way to try and understand if science literacy can protect people from misinformation. Howell and Brossard (2021) discussed the need for science literacy to encompass what they called the "science lifecycle". This included how science information is generated, how communication of that information takes place and is re-packaged by media outlets, and how opinions are formed based on that information (Howell & Brossard, 2021). Their model highlighted the types of science literacy (civic, digital media, and cognitive) they deemed necessary to support an informed society with individuals that were able to combat misinformation. They discussed how the science lifecycle could be utilized to resist misleading information found on digital media platforms. For example, they discussed an issue that they call the "digital divide" (p. 4). The digital divide described the differences in society of the population "representing who has access to online tools" (Howell, & Brossard, p. 4). The digital divide describes not only access to information on digital platforms, but how information was sought out, such as through entertainment or news. They encouraged the integration of the science lifecycle model as a useful tool to help increase science literacy and as a way to combat misinformation (Howell & Brossard, 2021).

Sharon and Baram-Tsabari, (2020) also discussed the concern of society's ability to discern misinformation and evaluated the science literacy literature to identify ways in which current science literacy assessments supported or deviated from the goal of helping combat misinformation. By evaluating the National Academies' report, they classified four components of science literacy that were most valuable to combating misinformation that had not yet been addressed in the science literacy literature. The four components of science literacy that they determined were critical for identifying misinformation were "(a) Understanding of scientific practices, (b) Identifying and judging appropriate scientific expertise, (c) epistemic knowledge, and (d) dispositions and habits of mind, such as inquisitiveness and open-mindedness". (Sharon and Baram-Tsabari, 2020, p. 873). Sharon and Baram-Tsabari as well as Howell and Brossard point to the growing need for us as educators and academics to re-evaluate and reimagine how we teach and assess science literacy that reflect the face of a changing society and an ever-increasing amount of available information alongside misinformation.

Development of Assessment Tools for Science Literacy

In an effort to address the specificity and rigid nature of prescribed outcomes of science literacy, DeBoer (2000) argued that science literacy should be a flexible literacy that supports local needs that are appropriate for a given community. DeBoer spoke to the lack of an agreed upon definition of science literacy and the selective nature to which the national science standards are used. He argued that "we should accept the fact that scientific literacy is simply synonymous with the public's understanding of science and that this is necessarily a broad concept" (DeBoer, 2000, p. 594). However, assessing science literacy is necessary to facilitate a general understanding of the impact of the NGSS on our students and how that translates beyond the K-12 classroom.

There have been few validated and usable science literacy assessment tools to date. Gormally et al. (2012) developed the test of scientific literacy skills (TOSLS) as a way to assess scientific information and arguments among undergraduate students. This tool was developed, validated, and used specifically for undergraduate biology students. Gormally et al. identified a set of nine skills they deemed necessary for science literacy:

> to (I.) understand methods of inquiry through: the ability to identify valid scientific argument; to evaluate the validity of sources; to evaluate the use and misuse of scientific information; to understand elements of research design and how they impact scientific findings/conclusions and (II.) to organize analyze and interpret quantitative data and scientific information through graphical representation of data, and scientific information; read and interpret graphical representations of data; solve problems using quantitative skills, including

probability and statistics; to understand and interpret basic statistics; and to justify inferences, predictions, and conclusions based on quantitative data" (p. 367)

They stated the goals of science literacy should be concept recognition and analysis as a way to be able to critique scientific outcomes in order to make informed decisions as well as to assess quality and reliability of sources (Gormally et al., 2012).

The TOSLS utilizes a mixture of multiple choice and short answer questions. It was pilot tested and validated through expert faculty evaluations and student interviews. Descriptive statistical characterizations of each response were analyzed. Their analysis suggested that "the tested skills are related and that it is meaningful to view a student's score on the TOSLS as a measure of his or her scientific literacy skills" (p. 373). A second round of multiple choice only testing occurred over three semesters in a pre- and post-test manner to evaluate learning growth and validity of the measure (Gormally, 2012). Results were quantified using estimated marginal means and analyzed using an analysis of covariance (ANCOVA). Their findings indicated that the TOSLS was sensitive enough to detect single semester learning gains and repeated administration of the tool confirmed its validity (Gormally, 2012). The free and available assessment has been used in several studies to evaluate science literacy in various environments (see Prabowo & Fidiatuti, 2017; Segarra et al., 2018; Utami, 2021; Waldo, 2014), while Gormally (2012) also suggested that the tool could be used to guide and modify science curriculum to aid in an increase of citizens' science literacy.

Fives et al. (2014) relied on DeBoer's broad definition of science literacy when they developed an assessment for science literacy for middle school students. They also spoke to scarcity of science literacy assessment tools and stated that "existing measures have three key limitations in that they (1) tend to be field/discipline specific, (2) are intended for students at the secondary or university levels, and (3) ignore the assessment of students' motivation for and beliefs about science." (p. 557) The third sentiment was echoed by Benjamin et al. (2015) when they critiqued previous assessments developed to gage science literacy concerned that they failed to be useful in the determination of success in STEM fields.

Prior to the work of Benjamin et al., Fives et al. (2014) created an assessment that could be accomplished with pencil and paper and was reliant on two parts. The Science Literacy Assessment (SLA) includes a multiple-choice section that assesses demonstratable science literacy with every day, not discipline specific, content (SLA-D) and a section with Likert-scale questions that addresses motivation and beliefs (SLA-MB). They used a multistage approach for the development stage of SLA-D assessment items, while items of the SLA-MB were either modified from Wigfield and Eccles (2000), repeated from Kettlehut's (2010), or generated by the authors to greater align with their conception of science literacy (Fives et al., 2015).

The SLA-D assessment development consisted of two pilot studies and a third prototype study that used variations of the assessment tools and were administered in different orders, and descriptive and correlation statistics were run on the results (Fives et al., 2014). Both pilot studies asked "1. How do middle school students respond to items on this? 2. Are indicators of test difficulty (discrimination index, correlations) reasonable for all items? 3. How should the test be revised to better measure scientific literacy?" (Fives et al., 2015, p.563). They utilized findings from the pilot studies to revise and omit items on the assessment prior to the administration of the pilot study. They found no significant difference between the SLA-D versions (1 and 2) for either pilot study. This SLA tool is not suitable for use at a post-secondary level as it was designed for use in middle schools. Additionally, limitations remain in the validity and reliability of this assessment tool. The authors admit to four limitations of the assessment's validity including its unknown generalizability. First, they pointed to the fact that they did "not provide evidence based on relations to other variables. This first omission is a serious limitation of our current work" (Fives et al., p. 574). They also discussed the limited nature of the study within a single school district and few teachers were tasked to review the tool, and lastly, they did not "provide any evidence based on test consequences" (p. 574) (Fives et al., 2015).

In an attempt to understand the link between science literacy and success in STEM disciplines, Benjamin et al. (2015) developed and validated the Scientific Literacy Survey for College Preparedness in STEM (SLSCP-STEM). The SLSCP-STEM was designed to assess attitudes, content knowledge and scientific reasoning skills of incoming first year college students and to determine their preparedness as STEM majors (Benjamin et al., 2015). Benjamin et al. (2015) argued that there was a need for an assessment tool to be specifically applied to STEM majors, whereas previously developed assessment tools were geared toward all students. They further argued that the Test of Scientific Literacy Skills (TOSLS) only assessed two abilities that involved inquiry methods quantitative data. They claimed, "SLSCP-STEM is unique in that it focuses on utilitarian scientific literacy of incoming undergraduate freshman STEM majors, and it assesses scientific literacy through the lenses of scientific attitudes and behaviors, content knowledge, and scientific reasoning" (p. 608). However, Benjamin et al. (2015) acknowledged the lack of knowledge about the impact of race, gender, ethnicity on science literacy, although stated there was ongoing analysis of their findings in those regards.

The SLSCP-STEM was designed as a tool to predict the success of STEM majors as well as to develop interventions, not categorize students (Benjamin et al., 2015). However, to date, there have been no peer-reviewed empirical studies that have applied the SLSCP-STEM. In 2021 it was shown to be used in two different research studies, one unpublished that assessed student resilience in HBCUs, and one dissertation that looked at first-year nursing students.

Global Assessment of Science Literacy

Assessing science literacy has not only occurred within the United States. Science literacy is a global concern. Grammatikopoulous et al. (2019) utilized the Greek version of an SLA adapted from an assessment implemented by Samarapungavan et al. in 2009 for kindergarten students in the United States. While no information was provided which described the creation of the Greek version of the SLA, the authors often cited work performed by Samarapungavan et al. (2009) and Mantzicopoulos & Samarapungavan (2013). The SLA evaluated science inquiry processes and life science concepts. The outcome of their study showed that even in kindergarten there is evidence to support the ability to develop science inquiry skills (Samarapungayan et al., 2009). The Greek version of the SLA was administered to Greek students in early childhood education (ECE) settings. Results showed relatively similar means of science literacy performance between children assessed in the Grammatikopoulous et al. (2019) and the Samarapungavan et al. (2009) study. While the overall knowledge level was reported to be comparable, Grammatikopoulous et al. (2019) findings presented interesting evidence that Greek children performed better in areas of science inquiry, while US children performed better in areas of life science concepts, attributing these results to the differences in curriculum.

Ardiyanti et al. (2019) looked at research on science literacy done in Indonesia. The study narrowed down and evaluated literature specific to Indonesia in order to gain a macro view of how science literacy was being evaluated. Their findings showed five research methodologies and a variety of data collection methods used among the 18 studies evaluated (Ardiyanti et al., 2019). The five methodologies were experiment, development, action research, descriptive, and quasi experiment, and the data collection methods included: questionnaire, interview, document analysis, observation, rubric, worksheet, essay, multiple choice, and video recording. Beyond the methodologies and data collection, this study determined that there was a need for the development of learning media within context to improve science literacy (Ardiyanti et al., 2019). This demonstrated how science literacy assessments can inform our need as a science community to continually re-evaluate the *what* and the *how* in terms of ways in which science literacy assessments are being delivered. It further showed what we can learn from the data collected, and how we must re-imagine ways in which we create and deliver science curriculum that holds relevancy and meaning for the students in an ever-changing world. In the 21st century, we, as science educators, need to continue to re-evaluate and generate assessment tools that reflect our goal to make science literacy a priority for our students and our society.

Sociocultural Influences on Science Education

Limited research has been done on sociocultural experience within the biological or the life sciences and science education. Ceci et al. (2009) explored sociocultural and biological factors in regard to underrepresentation of females in science, specifically math-intensive science, and concluded that both sociocultural factors and biological factors were responsible for said underrepresentation. They stated, “Reasons for preferring non-mathematics fields may include both free and coerced choices, which can be influenced by biological and sociocultural factors that either enable or limit women” (Ceci et al., 2009, p. 251). Findings that highlight both influence from biological and sociocultural factors in learning contend the belief that biological factors are not a reliable source of one’s ability to do science and may support continued marginalization within science disciplines.

Drawing from multicultural education methods, Rivera Maulucci (2010) argued for the incorporation of social and cultural materials within middle school science in order to combat continued marginalization of students from historically excluded backgrounds and described the necessary support that teachers require to provide more representative learning environments. Gilbert and Yerrick (2001) investigated how students from a rural community and in low track science courses identified their place in the school environment and how their placement in low-track science contributed to social reproduction. They found a subverted effort for quality science in the classroom based on cultural negotiations and low student expectations:

> Two entirely different cultures of school coexist in the same physical environment, cultures that mutually carve out their entities around rules of power and discourse. They are literally two separate worlds residing in one school. Unfortunately, the interactions within and across boundaries drastically impair some students' standards of science instruction and level of engagement (Gilbert & Yerrick, p.594).

While sociocultural theory and research does offer greater insights into the moderating effect of social and cultural influences and has allowed us to understand our students and their learning, sociocultural theory has been critiqued due to it not addressing power, identity, and agency and how power relations affect the learning environment.

The genesis of critical theory was a reaction to fascism and a critique on the social movement as well as means for liberation. Critical theory has been applied to politics, policy, the legal system, power in society, as well as education (e.g., Castells, 1996; Forst, 2001; Giroux, 1986; Ozanne & Murray, 1995; Peca, 2000; Tollefson, 2006). While individuals in positions of power are not the target of critical theory, the systems that those individuals uphold are often exclusionary and hold prejudice for anyone that does not hold an identity that reflects that held by the people in the positions of power. Science education and therefore science literacy is not immune to influences of systems of power. Lather (2004) critically evaluated science education and policy in the United States and warned "that the movement towards 'evidence-based policy and practice' oversimplifies complex problems and is being used to warrant governmental incursion into legislating scientific method" (p. 759). He nodded to the complex nature of society:

> Values and politics, human volition and program variability, cultural diversity, multiple disciplinary perspectives, the import of partnerships with practitioners, even the ethical considerations of random designs: all are swept away in a unified theory of scientific advancement with its mantra of 'science is science is science' across the physical, life and social sciences (Luther, 2004, p. 762).

This oversimplification of *science is science is science* has hindered science education on the basis of an objective nature of science. The nuances and complexities of societies and cultures are just relevant to our understanding of what influences science education and science literacy. In this section I will discuss exclusionary practices within STEM disciplines based on race and gender. I will present findings of social, community, and economic influences that have influenced the education of our science students. Lastly, I will discuss the impacts of race and gender on science education.

Race, Gender, & STEM

Within education exclusionary practices create greater inequity in learning spaces through the curriculum and resources used, as well as the centering of the white and often male identity. This is also true within science spaces. We know that there have been problematic trends of exclusionary practices within STEM disciplines. Racism and sexism are two of the most researched topics in this area. Leonard (2009) described the detriment of the post-Civil Rights era of colorblindness and how the attempt to diminish the relevance of race further contributed to the division of equal opportunities within education. He addressed the compounding factors of race, social status, and the education system. While overt racism is not as common, there are still frequent reports of instances of sexual harassment within science spaces. Covert and systemic examples of racism and sexism within science spaces continue to be published, showing that this is still a problem within the science discipline (e.g.,Harrison & Tanner, 2018, Martin, 2019; Torres, 2012; Yang & Carroll, 2018).

STEM disciplines have often been thought of as neutral domains. That is, due to the claimed objective nature of the subject matter, it has been long assumed that people who have been successful in STEM are those who were able to be successful in understanding the content and performing in that STEM area. This is what has been long referred to as merit-based success, or meritocracy. This way of thinking about success within STEM, though still common, is highly problematic. It ignores real-world factors at play, such as racism or sexism and it ignores the experiences that students in STEM classrooms bring into and take away from those spaces. One of the ways this is reproduced is through the white centering nature of science curriculum (Bratman & DeLince, 2022).

White centering is problematic due to the implications of people from other racial or ethnic backgrounds being at a deficit when white knowledge is the standard (Battey & Leyva, 2016). Battey & Leyva (2016) exposed how whiteness was reproduced “symbolically and materially” (p. 59) in mathematics education, which further marginalizes other ways of knowing that are not historically Eurocentric. This is reflected in the science education as well (Gough, 2014).

Aikenhead (2006) discussed the ways in which many, especially people from Indigenous communities, often feel unwelcomed within science classrooms. They speak to the harm done by the very nature of Western science and how Eurocentric ways of knowing have historically disregarded other ways of knowing and invalidated ideals that do not align with Western knowledge (Aikenhead, 2006). Battey & Leyva (2016) echoed those sentiments and further expressed how racial hierarchies common in mathematic are reinforced by identity within mathematic spaces through the elements of academic (de)legitimization, co-construction of meaning, as well as agency, and resistance.

Battey and Leyva (2016) showed how marginalization of non-white students is perpetuated in multiple elements: ideological discourses, physical space, history, and organizational logic; all nested within an institution. They spoke to the racial hierarchies within mathematics and stated that they are upheld due to the "social construction of whiteness as a privileged identity in everyday society is maintained in classrooms and other mathematics spaces through inequitable learning opportunities as well as feelings and experiences of academic de-legitimization experienced by historically underserved students of color" (Batty & Leyva, 2016, pp. 70-71).

It is through the use of critical theory that these types of marginalization and the systems that perpetuate them are able to be exposed. The call for diversification within science disciplines has been in response to the inequities within science education. Unfortunately, many of those efforts have lacked long-term sustainability. While demographic data has shown the ebbs and flows of increasing and decreasing diversity among science students, we must look beyond the numbers and ask ourselves why these fluxes have continued to occur (Eagly, 2021; Funk &

Parker, 2018; Rivers, 2017). Long-term sustainable change must come from an overhaul of the system, which is why critical theory is so crucial to this type of research.

McGee (2020) found that much of the work that has been done to expand diversity in STEM spaces, specifically among underrepresented and racially minoritized people in the United States, has been inadequate for sustainable change. They argued that in order to make lasting change to diversify, not assimilate, students in STEM, it is necessary to take a critical look at the structural racism that persists within STEM itself. McGee contended that, "What we really do not need in STEM is more of the same type of students from the same institutions, taught by the same professors, learning the same curriculum, working at STEM institutions where everybody looks (and quite possibly thinks) similarly" (p. 640).

Inequities within these spaces have been highlighted to an even greater degree when individuals hold more than one identity from any given historically excluded group, such as race, gender, sexual orientation, and disability (Cho et al., 2017; Crenshaw, 1990). The intersectionality of these identities further stratifies societal disadvantage. The more historically excluded identities an individual holds, or the degree of their intersectionality, increases the amount of exclusion or disadvantage to which they are subject within power relations and within the system (Crenshaw, 1990; Saatcioglu & Corus, 2014).

Master and Meltzoff (2020) discussed awareness that students have around identity and social stereotypes and how stereotypes have negatively impacted success in STEM courses. Inequities in knowledge or education based on gender have been identified in various disciplines, such as mathematics, physics, and engineering, to name a few (see Bowden, 2017; Evans et al., 2020; Anaya, 2021; Posselt, 2020). Social stereotypes, especially those based on social class, lend themselves to maintaining social reproduction and social inequity (Durante & Fiske, 2019).

While no social identity is singular and a determinant of social class, social status has historically been closely associated with race and cultural difference, which has led to inequities in education (Durante & Fiske, 2019; Master, 2020; Rekker et al., 2015; Santiago et al., 2011).

Communities, which are often separated based on socioeconomic status, tend to have additional factors that compound the disadvantages associated with their sociocultural standing, such as greater poverty, increased mental illness and higher crime rates (Rekker et al., 2015; Santiago et al., 2011; Torres et al., 2018). Increased instability and lack of access to resources can negatively impact a person's physical and mental well-being. Added challenges can further complicate educational success (Masters, 2020). Boehme et al. (2020) discussed how neighborhoods in low socioeconomic areas are often subject to underfunding and lack of community support.

There are further consequences that can be associated with social reproduction. Not only does social reproduction influence *how* we learn and *what* we learn, but also *who* is deemed important to learn about. Representation within the classroom and curriculum can play an unintended role in inequity in education and the perpetuation of the status quo. A lack of representation in our curriculum does not allow for our students to learn about different cultures, social structures, ways of knowing or ways of being. Limited exposure to other cultures or social identities in these spaces contribute to hostile environments. Hostile environments have also been created through more covert mechanisms that are often times very difficult to recognize at first glance and are often driven by unconscious forms of social reproduction that aim to maintain and uphold the status quo (Berk, 2017).

Factors that contribute to hostile environments may seem innocuous to those who have always seen themselves reflected in the curriculum, in the textbooks, in the educators, but a lack of representation in such spaces are just a few examples of factors that have been cited as having contributed to these hostile environments (Posselt, 2020). Microaggression has also shown to be a contributing factor to the creation of hostile classrooms or science communities (Berk, 2017; Lee et al., 2020). Berk (2017) argued that interactions with students or other people that undermine their identity can lead harm for those individuals on the receiving end of microaggressions. Evidence showed that hostility in learning spaces, whether overt or covert, can play a role in how students engage or disengage with their educators or the curriculum (Freeman, 2020; Lee et al., 2020). Hostile environments can lead to students' unwillingness to participate in class activities or class discussions, and negatively impact mental health (Christensen et al., 2021).

There is evidence that within STEM fields and higher education there have been and still are roadblocks in place that deter people of historically excluded groups from pursuing careers or education in STEM disciplines (Davidson, 2011; Laurence & Bentley, 2016; Moise, 2021). As science educators, regardless of whether these instances are happening within the classroom or in industry, we should be alarmed and motivated to advocate for change in all ways possible within science. Hostile and harmful environments can change the way students engage with the material, each other, and even society (see Freeman, 2020; Lee, 2020). The influence of representation in science and science education or the lack thereof, could play a role in the ways in which people participate in science in and out of the classroom. So, what does this mean for science literacy? It suggests that science literacy may not be approached in an inclusive and equitable manner, especially to students who come from historically minoritized communities.

Critical Research in Science Education

Barton (2001) utilized critical ethnography to determine a path toward liberation and increased science literacy in urban schools. Her study aimed to understand the continued challenges in science education based on race, gender, and class in urban science education from a collaborative story written by the author and two, fourth-grade, Mexican American, females that experienced homelessness. Barton found that the science education in the urban school was inequitable to the students that were a part of her research. Her work exposed the need for science education to be responsive to the lives of students, especially those that hold minoritized identities (Barton, 2001). Urban schools tend to have greater diversity in their student populations than rural or suburban schools, however, that does not mean that rural and suburban area schools are immune from the important need to be critically examined.

Torres (2012) investigated the disparity of women of color in STEM. She analyzed documents from ADVANCE from the National Science Foundation and ISU to identify factors at play that upheld the status quo. Torres found three themes that she stated were "connected through three interlocking systems of oppression (as described by Collins, 1994, 2004) - capitalism, patriarchy, and racism" (p. 36). The three themes she identified were "1.) political economy of equity and diversity in STEM, 2.) maintenance of male dominance and the status quo; and (3) "universal women" and the normalization of Whiteness" (p. 36). Her findings challenged the notion that the call for diversification in science was fully supported by the systems in place as "the rhetoric of "full participation" comes with the caveat of conformity and subjugation for both White women and women of color…this should tell us that current programs and practices are not working" (Torres, 2012, p.41). The call for a deeper look at reform in STEM education is not isolated only to science. Martin (2019) also challenged the notion of reform within mathematics. He described how mathematics was rooted in antiblackness through evaluating analyses at inter- and intrapersonal levels as well as at the structural level. He concluded that any reform in mathematics that did not center Black liberation would ultimately continue to perpetuate antiblackness in mathematics as well as drive Black people away from the discipline (Martin, 2019). The structural inequities are pervasive in STEM education. Additionally, due to the nature of how studies are categorized, subsets of people holding multiple underrepresented identities can be lost in the data, for instance Black women or non-binary individuals of any race.

Espinosa (2011) investigated what factors contributed to the persistence of women of color in STEM majors in college. She analyzed longitudinal survey data from the Higher Education Research Institute (HERI) Cooperative Institutional Research Program (CIRP) at UCLA that included background information and a senior reflection survey focused on the students four-year college experience. She found that both the collegiate environment and experience played a larger role in the persistence in STEM disciplines than prior education or family factors (Espinosa, 2011). This study did not take into consideration factors such as conformity within systems that Torres addressed.

Blair et al. (2017) examined the relationship between teacher identity and the promotion of gender equity in STEM classrooms. They interviewed 18 undergraduate instructors in engineering programs and found that there were three dominant discourses: gender blindness, gender acknowledgment, and gender intervention. Blair et al. (2017) stated that gender blindness ignores the important component of gender as identity, that gender acknowledgement allowed for instructors to relinquish their own responsibility to further create gender equity in their classroom, and that gender interventions actually promoted increased gender equity efforts but was the least used among the instructors. It was noted that none of the three discoursed identified were satisfactory for contributing to less gender bias, and that there was a need for expanded discourse (Blair et al., 2017).

The continued findings of systems that uphold hegemony in education and systems of power that perpetuate inequity and exclusion. The continued exclusion of historically minoritized and underrepresented voices has limited the depth and breadth of science knowledge. It has also limited our ways of teaching students science in a way that is meaningful and culturally relevant to them. Further investigations that question systems that aim to maintain the status quo could give us deeper insight into factors that must be addressed and pushed back against in order to create sustainable and equitable change in science education. Greater understanding of how harm is perpetuated through exclusion caused by systemic exclusion has the potential to generate environments where more students feel safe and motivated to engage in science learning and a sense of belonging in science communities, therefore increasing science literacy within society.

Conclusion

Problems moving toward equity in science and science education remain. These issues persist through the maintenance and support of programs in place meant to maintain the status quo and perpetuate social reproduction. It is through these mechanisms that the problematic nature, such as hostile learning environments persists. Without critical inquiry into the many outcomes that maintaining these systems play, it is unlikely that there can ever be meaningful progress towards a more equitable, inclusive, and accessible science community.

Continued exclusion and underrepresentation may also contribute to how students engage with science outside the classroom. This is echoed in the fact that the global majority is left out of meaningful education as well as the conversation, while the power holding minority controls the outcomes and fate of education and policies that affect that education. These same power-holding few control the outcome of how disasters, such as the ongoing pandemic and global warming, are handled. If our students are not supported in ways which encourage and facilitate science literacy and the enactment of science literacy within society, then the potential to perpetuate catastrophic harm to society and the planet may be imminent.

As has been presented, science has not progressed in a way that is wholly and equitably representative. We can and should find ways in which we, as educators, can do our part to help build a science community that is more inclusive and less hostile. By critically considering the role that sociocultural experiences play in our students lives and investigating potential impacts of previous experiences with science education, we may begin to see the extent to which these external factors impact the foundation of science learning in our students.

Depending on the social influences within a community, science literacy can be enhanced or hindered. Through social reproduction, there can be increased access and resources available to enrich science learning. Social reproduction can also create greater inequities in science learning due to issues such as less funding, decreased access, limited resources, and lower expectations of the students. It is through a reimagination of the approaches we take to understanding our students, our teaching and learning environments, as well as being aware of how we can strive for educational democracy that there is hope for an equitable future.

Furthermore, exploring student perspectives into issues such as global warming or the ongoing pandemic, and how their feelings are associated with their science education could lend to deeper insights into the true impact of the NGSS in our school systems. Through exploring the relationship between sociocultural experience, experiences in science and science education and how students engage with the enactment of science literacy, perhaps we can begin to understand the complexities and nuances that contribute to such confusion and lack of meaningful action that has been especially highlighted in society over the course of the SARS-CoV-2 pandemic.

Chapter 3 Methodology

Introduction

This study utilized a mixed methods approach in order to investigate the relationship between previous science experiences, science literacy, and sociocultural experiences among traditional first-year university students. Informed by critical sociocultural theory, this research aimed to probe a deeper understanding of how students' science literacy may be influenced by social and cultural factors. Additionally, this study pulled from transformative learning theory to guide our understanding of learning in university students. Insights from this study will help science educators, curriculum developers, and the science community as a whole gain valuable understandings into what roles extrinsic factors, such as previous science experiences along with social and cultural aspects play in the development of students' relationship with science and how those components correspond to science literacy.

For the qualitative aspect of this study, basic qualitative research was chosen to answer research questions as it allows for an investigation into individual experiences without being constricted to other methodological approaches, such as case study, where the research would be restricted to a bound system (Creswell & Creswell, 2017). Basic qualitative research supported this investigation in that it allowed for greater flexibility in the study design and facilitated the opportunity to gain insights into the perspectives of individuals who participated in the study by having a less rigid structure than other defined qualitative methods (Merriam, & Tisdell, 2016). In order to gain a clearer understanding of how science learning and engagement with scientific information is mediated by social and cultural influences, it was important to investigate the unique experiences and perspectives of the individuals.

The quantitative portion of this study assessed demographic information, sociocultural aspects, previous science experiences, and responses to science literacy questions. Descriptive statistics were used for initial evaluation of responses. Descriptive statistics were employed to analyze demographic data, sociocultural responses, and previous science experience data alongside science literacy responses. Correlation analysis was utilized in order to assess correlations and emerging patterns.

Both qualitative and quantitative factors were taken into consideration when exploring how sociocultural experiences impacted science learning and engagement with scientific information. Furthermore, critical evaluation of responses to open-ended questions associated with previous science experiences, sociocultural experiences and science literacy assessment allowed for a deeper understanding of potential power dynamics that can influence how student's experience the world around them. Information from critical analysis may also shed light onto issues of power within society that may impact students' engagement with science and their understanding of what is reliable scientific information. This study aimed to consider if previous science experiences along with social and cultural matters influenced students' science literacy, taking particular interest in how social and cultural influences impacted their relationship with scientific information and education.

Methodological Justification

Research that has evaluated sociocultural issues as well as social reproduction has historically been qualitative. Qualitative methods have been important in evaluating what is going on within systems that continue to maintain the status quo. Anyon (1980, 1981), Federici (2019), and Reichelt (2019) examined power structures that contribute to inequality within communities and schools. Work that has addressed social reproduction within schools has provided long-standing insights into how schools contribute to the perpetuation of division of people based on socioeconomic standing (Bakker & Gill, 2019). Results of studies that investigated inequities in classrooms have also contributed to the understanding of how our schools themselves play a crucial role in the sociocultural experiences that formatively shape our students. Studies which incorporated sociocultural aspects laid the groundwork to understanding how social inequities play a large part in our schools (Bourdieu, 2018; Reichelt, 2019). Unequal foundations in society can contribute to ways in which students absorb, understand, and incorporate what they learn in school.

The majority of research that has assessed science literacy, or scientific literacy, has been quantitative in nature. For instance, work that has surrounded areas such as diversity, equity, inclusion, and accessibility (EIA) within science, often interlaced with science, technology, engineering, and mathematics (STEM) studies, has often assessed demographics of within STEM communities in order to understand the ever-changing landscape of who makes up the populations within science, STEM, science education, or STEM education (Eagly, 2021; Funk & Parker, 2018; Rivers, 2017). The evaluation of demographics in this area is utilized to assess the impact of efforts employed to advance EIA efforts within science or STEM.

Other studies have laid theoretical foundations for the definitions of science literacy, both variable and evolving (e.g., Champagne et al., 1989; Feinstein, 2010; Laugksch, 2000). They have paved the way for assessments and evaluation of science literacy among students both in terms of prescriptive and descriptive applications (Feinstein, 2010). While the majority of this work has been quantitative, there is valuable need to evaluate science literacy through the lens of one's personal experience, especially when evaluated against sensitive subject matter, such as identity, agency, and social and cultural experiences.

While the quantitative information analyzed within studies that evaluate the community make-up of science or STEM is extremely useful for monitoring shifts to the demographics within these spaces, it only tells a partial story of demographic changes. Quantitative studies that evaluate demographic data leave out critical information, such as perspective and experience that could detail why certain changes in demographics are taking place or why there has not been more progress in areas of EIA. Quantitative studies have revealed the who and how many, but not the why. Additionally, demographic studies alone ignore social and community factors that play a role in moderating learning of scientific information. While a lot of this work has been guided by quantitative studies, there has also work that has been done within the realm of EIA, be it within the science or STEM community, that has been of a qualitative nature (Bianchini, 1997; Mansour & Wegerif, 2013; Master & Meltzoff, 2016; Posselt & Grodsky, 2017).

The qualitative aspect of exploring social and cultural influences in science spaces is critical to helping obtain a more holistic understanding of changes that could be made within science classrooms and communities. Very little research to date has explored the impact of identities on scientific literacy, and what has been published was quantitative and descriptive in nature. The limited literature has investigated disparities in race and gender, individually without considering the impact of intersectionality (Allum et al., 2018; Kristyasari, 2018). The key nature of basic qualitative research is to explore and uncover how people make sense of their lives and experiences (Creswell & Poth, 2016). Merriam and Tisdell (2016) list the three key characteristics of basic qualitative research as, "(1) how people interpret their experiences, (2) how they construct their worlds, and (3) what meaning they attribute to their experiences" (p. 24). By including qualitative methods in this study, I was able to probe deeper into student's experiences and perceptions about their previous science and lived experiences as well as exploring their reasoning behind how they answered certain science literacy assessment questions.

Design of Study

Setting

Data were collected at an R1 public university in the Southwest region of the United States, herein referred to as Central University. Data was collected during the Spring Semester 2023 and the Fall Semester 2023. Central University is a large school that has both graduate and undergraduate programs with a total number of 26,695 students enrolled where 19,774 were classified as undergraduate students. The majority of undergraduate students were enrolled as degree-seeking students, while 2% of undergraduates enrolled were identified as non-degree seeking. There were slightly more females enrolled than males. The majority of students were identified as white, while 36% identified as a race or ethnicity other than white.

Participants

Participants for this study were sourced from a pool of students who were enrolled as first-year students during Spring Semester 2023, Fall Semester 2022, or Fall Semester 2023 at Central University. The total number of potential participants was approximately 5000 students. Participants were a minimum of 18 years old with a maximum age of 22. The purpose of limiting the age to 22 years old was to ensure an appropriate range of students that fit the traditional description of a first-year college student. This age constraint was accommodated for individuals who may have taken a gap year or taken longer to complete secondary school. Additionally, narrowing the age range attempted to limit the participation of non-traditional students, such as those that served four years in the military directly after high-school, or who chose to begin college later in life for any given reason. It was assumed that situations like having been in the military, or having waited until later in adulthood to begin schooling at the university level would therefore have further confounding factors such as a greater wealth of life experiences that would contribute to their experience and understanding of the world around them. The inclusion criteria for participation were 1) be at least 18 years of age but not older than 22 years of age, 2) enrolled as a student at Central University, 3) be a first-year traditional college student. Of the total number of potential participants, I received 200 responses, of which six did not consent, and 16 did not qualify for this study. Of the 178 respondents who did consent and were within qualifying criteria, 137 did not complete the entire survey, leaving 41 respondents who participated in this study

Data Collection

Data collection was accomplished utilizing an online survey created and deployed using Qualtrics (November, 2023). The survey consisted of four sections, the demographics block, the previous science experience block, the sociocultural experience block, and the science literacy assessment block and can be found in its entirety in Appendix A. The first section contained consent, qualifying questions, as well as questions related to participant demographics, herein referred to as the demographics block. The second section contained questions related to participants' previous science experiences that included qualitative questions, herein referred to as science experience block. The third section contained questions surrounding the sociocultural experiences of the participants which included qualitative questions, herein referred to as the sociocultural block. The final section contained the science literacy assessment. The entire survey was designed to take no longer than 30 minutes for participants to complete. In order to avoid participant fatigue, the demographics, science experience, and sociocultural blocks contained 12 questions or less each.

There was no compensation for participants associated with this study. The survey link generated using Qualtrics was distributed via Central University mass email to all first-year undergraduate students enrolled at Central University. Students were given a brief synopsis of the purpose of the study included with the recruitment email that contained the electronic survey link. The recruitment email and survey link were sent three times over the course of the Spring Semester 2023 and twice over the course of the Fall Semester 2023. Direct in-person contact or through personal email with any students was not conducted. While the survey was designed to be anonymous, all data collected were assessed for any identifiers that may have been included and were de-identified by a third-party before I began data analysis. I garnered guidance and adapted this survey from various sources appropriate for each respective section of the survey, utilizing validated assessment tools where possible.

Survey Design

Consent was requested as the first question of the demographics section. If consent was declined, the participants were directed to the end of the survey. During the first round of data collection in Spring Semester 2023, all participants who agreed to consent continued to three qualifying questions that pertained to their eligibility. The first qualifying question asked the participants if they are within their first year of university. Any responses other than yes were directed to the end of the survey. The second qualifying question pertained to age range. Participants who chose an age range other than 18-22 were directed to the end of the survey. All qualifying participants were allowed to continue participating in the survey. The third qualifying question asked if they had been enrolled in an introductory science course during the Fall 2022 or Spring 2023 semester at Central University. After initial evaluation of responses from the first round of data collection, it was identified that the third question eliminated a vast number of students willing to participant in the study and was also deemed an unnecessary qualifier for the nature of this study. For the second round of data collection during Fall Semester 2023, the question regarding was science course enrollment was retained, but modified from being a qualifying question, therefore, a response of "no" allowed students to continue participating in the survey. The remaining questions in the demographics section included major field of study, race, ethnicity, gender identity, sexual orientation, political affiliation, and ability. The available response choices were expanded beyond traditional binary or limited responses to make it as representative as possible for students who hold various and intersecting identities (Fernandez et al., 2016). The suggested language for more inclusive demographic data collection was modeled from the office of regulatory affairs and research compliance (ORARC, 2020).

In order to elicit participants' perceptions of their previous science experience, survey items were developed containing multiple choice, Likert-scale questions related to participants' experiences from kindergarten to Grade 12, as well as open-ended questions which probed household and community views toward science. Due to a lack of a single validated tool that assessed the specific science experience questions of interest in this study, the multiple choice and Likert-scale questions were modeled from the National Center for Education Statistics (NAEP) Science Report Card Science Assessment (NAEP, 2019). Additional questions and response choice design were modeled from the ASPECT survey tool which is a validated survey tool developed to gain a more holistic understanding of student experience (Wiggins et al., 2017). Questions used clear and concise language as well as standardized responses choices. The first question in this block asked if the participant considered themself a science person.

Questions asked logistical questions of participants' previous science experiences, such as how many science classes were taken in high school and whether they considered themselves an active participant in science classes. Questions related to how they perceived their science experiences included questions related to overall science experiences, how engaging they found previous science courses, and whether they felt previous science courses fostered creativity and valued critical thinking. Additionally, participants were asked how they perceived their own attitude toward science to be influenced by their household and/or community. Reliability of survey items were established using expert review and a pilot study. Results from the pilot study indicated that there was no redundancy in question, nor were there any prompts that garnered unclear responses. No changes were made in the previous science experiences block for the final survey design. This section also contained open-ended questions which probed participants' perception of attitudes toward science within their households and communities.

The sociocultural experience section contained questions related to participants' cultural and social identities as well as their experiences. For questions in this section response options were also expanded beyond the traditional limited choices following the guidance of Fernandez et al. (2016) and ORARC (2020) that was utilized in the demographics section. There is a lack of validated tools in which to assess sociocultural experiences among students and those that have been validated are study area specific (see Pishghadam et al., 2011). As this is a very nuanced and sensitive area of study, care was taken to formulate relatively general questions regarding sociocultural experience. The formulation of this section of the survey was guided by Chapter 10 of Gipps' *Review of Research* (1999) which explains how power and control can be present in assessments of various kinds and that care should be taken to not to impose undue harm within assessment development. Gipps (1999) highlighted the importance of equity within assessment guided the development of questions that elicit responses which highlight interrelation aspects familial, social, and cultural experiences in regard to knowledge development. Additional questions of this section were designed based on elements described by Daneshfar and Moharami (2018) who pointed out the importance of interactions among social and cultural aspects of one's experience in science education and Lemke (2001) who wrote on the importance of factors such as religion, language, and aspects of encounters of culture in everyday life. Caution was taken to ensure neither harm nor trauma were perpetuated in these questions. Multiple choice questions in this section probed the participants' previous school experiences, household experiences, and community experiences. Questions that pertained to participants' sociocultural experiences included in what type of community they attended school, what type of school they attended, and whether they were involved in extra-curricular activities before attending college. Questions that probed household experiences included the number of languages spoken within the home in which they were raised, whether they grew up in a multi-generational household, highest level of education obtained in the household in which they were raised, and whether they had any household responsibilities, such as chores or caretaking before attending college. Community geared questions included with what religion they affiliate, the type of community in which they lived before attending college, and whether they and/or their family was involved in community activities. The open-ended questions in this section probed how education was viewed in their household or community, and what their personal views on education were. The open-ended questions in this survey, found in the science experience, the sociocultural, and the science literacy sections were formulated with careful consideration to avoid leading questions (Merriam & Tisdell, 2016). The open-ended questions were developed in order to gain a greater understanding of student perceptions, experiences, and attitudes in each respective survey section, as well as garner insight into why participants selected certain science literacy responses.

Finally, the science literacy block was developed using a condensed version of the TOSLS due to the limited number of validated and tested assessment tools (Gormally et al., 2012). The TOSLS is a validated and reliable tool, is freely available, and has been widely used. The science literacy assessment was condensed from the original TOSLS version, which contains 28 questions, to half of the number of questions for this study to further avoid participant fatigue. Further modification included the addition of open-ended questions for a richer assessment of students' background and perception within science education. Question numbers as they were assigned on the TOSLS assessment were grouped by the categories listed in Table 2 and a random number generator was used to select a subset of question that was representative of those skill descriptions. Gormally et al. (2012) reported pre-test and post-test internal validity scores of 0.73 and 0.75, respectively. Selected questions were then entered into Qualtrics and assessed for accessibility issues. Questions with accessibility issues were then replaced with another question from the same skill assessment category. Prior to analyzing all data, Cronbach's alpha was performed on the science literacy responses in order to assess reliability of the modified TOSLS science literacy assessment. First, all responses were transformed based on correctness, where incorrect responses were coded to 0 and correct responses were coded to 1. Reliability analysis was run which resulted in a Cronbach's alpha score of 0.766, therefore, the assessment was deemed reliable. Following verification of reliability of the science literacy assessment, data were analyzed for descriptive statistics as well as for relationships among variables. Additionally, the science literacy survey was embedded with an open-ended question that asked the participant why they selected the answer that they did for questions 1, 2, 3, 4, 8, 11, 12, 13 to probe for justification of their responses to those questions.

Table 2

TOSLS Question Adjustment for Assessment

Skill Description from TOSLS (Gormally et al., 2016)	Number of Questions in TOSLS	Number of Questions in this Study
Identification of a valid scientific argument	3	2
Evaluation of the validity of sources	5	2
Evaluation of use and misuse of scientific information	3	2
Understanding elements of research design	4	1
Making a graph	1	0
Interpretation of graphical representations of data	4	2
Problem solving using quantitative skills	3	1
Understanding and interpreting basic statistics	3	1
Justification of inferences, predictions, and conclusions based on quantitative data	3	3

Data Analysis

Data Preparation

Once the data were de-identified, participants' responses were assessed for completeness. Responses from participants who did not consent, or who did not fully complete the survey were removed from the data set used for analysis. Participants' responses were labeled Participant 1 through Participant 41. Data from the fully completed surveys were then separated by respective survey block for initial evaluation. Consent responses, qualifying question responses, and survey duration data were removed. All multiple-choice questions resulted in nominal or ordinal data.

Nominal and ordinal data for each block were grouped together. Data from the demographics block, previous science experience block, and sociocultural experience block were first assessed manually to determine if any of the responses had not been selected. All response options per question were assigned a number (coded) and responses for each question were tallied.

Following initial evaluation of this coded data, responses that had not been selected by any participants were removed. All responses that had been selected by at least one participant were then re-coded for ease of statistical analysis. For example, when asked to identify their ability, the original survey options were able-bodied, disabled, and prefer not to say. These responses were initially coded 1, 2, and 3, respectively. However, only able-bodied and prefer not to say were selected by participants, while the choice of disabled was not selected by anyone. Therefore, the response option for disabled was removed whereas able-bodied and prefer not to respond were recoded as 1 and 2, respectively. Where participants selected more than one response on questions, an additional "more than one selected" category was created, and responses for those given questions were also re-coded.

Likert-scale and continuous data responses were also grouped together per respective blocks. Individual science literacy questions in the science literacy block were scored by hand in accordance with the original survey, with the identifier of 1 for a correct response, and 2 for an incorrect response. Science literacy assessment scores per participant were determined. The sum of correct responses across each science literacy assessment question was tallied and percentages of correctness were calculated across all responses for each question. The percentage of correctness for each question was then grouped under their respective overarching science literacy category: I) understand methods of inquiry that lead to science knowledge or II) organize, analyze, and interpret quantitative data and scientific information (Gormally et al., 2012).

Quantitative Analysis

All quantitative data analysis was accomplished using SPSS (version 29). First, all multiple-choice responses were subjected to categorical coding, that is, all multiple-choice response options were enumerated. For instance, in the demographics block, a question that asked participants what their intended major of study was had four response options: science; technology, engineering, or mathematics (TEM); non-science or non-TEM; have not yet chosen a major. These responses were then categorically coded 1, 2, 3, and 4, respectively. Once all multiple-choice responses were transformed into categorical codes they were imported into SPSS where variable labels, data type (nominal, ordinal, or scale), and coded responses were assigned. Descriptive statistics were performed on all quantitative data to obtain the frequencies of responses. Means and standard deviations were generated for Likert-scale and continuous response data. Histograms were generated in order to visualize Likert-scale responses in addition to descriptive statistics. T-tests were performed where necessary in order to assess statistical significance between groups.

Once initial quantitative analysis was completed on all data from each survey block, cross analysis was performed in order to assess relationships across categories. For cross analysis purposes, demographic data including race, ethnicity, nationality, gender, sexual orientation, political affiliation, and ability status were grouped with sociocultural experiences, as it can be argued that there are social and cultural implications associated with those identity characteristics (Grimson, 2010; Scheepers & Ellemers, 2019). Further categorization was accomplished by grouping participant demographic data into those who held identifying characteristics that aligned with what is commonly seen as the dominant cultural group in the United States (white, cis, heteronormative, an American citizen, not of Hispanic, Latino/a/x, or of Spanish origin) and those identifying as holding one or more identities that do not align with the dominant cultural group (non-dominant culture group). Categorical coding as previously described was accomplished on grouped identity characteristics where the dominant and non-dominant culture groups were coded 1 and 2, respectively . Further categorization for cross analysis included expanding the dominant culture group category to include those who identified as Christian, and those who did not identify as Christian into the category of participants who held non-dominant culture identities. Modified identity characteristic groups were also categorically coded as 1 and 2, respectively, for analysis in SPSS.

As no previous work has been published to date that focuses on previous science experiences and sociocultural experiences and how they relate to science literacy, it was important to assess all components for relationships between variables. In order to demonstrate relationships between previous science experiences and science literacy, previous science literacy experiences and sociocultural experiences, as well as sociocultural experiences and science literacy, bivariate correlation analysis was performed. Bivariate correlation analysis was selected because the results indicate the strength of a relationship between factors as well as indicate the confidence in the resulting strength of the given relationship. By assessing Pearson's correlation r as well as p-values generated through this analysis, I was poised to answer what previous science experiences relate to students' science literacy, which previous science experiences correspond to sociocultural experiences, and what sociocultural factors correlate to science literacy scores. The resulting relationships identified between previous science experience, sociocultural factors, and science literacy assessment scores, could give scholars insight into where to probe deeper for an even richer understanding of how certain factors may influence science literacy.

Bivariate correlation analysis across categories was performed in SPSS in order to evaluate aforementioned relationships. A prespecified $\alpha=0.05$ was utilized in order to assess results with 95% confidence. Pearson's r as well as p-values were recorded for each correlation run. Pearson's r values were assessed using Cohen's (1988) standards. P-values were used to assess confidence in Pearson's r values. Where the p-values were greater than 0.05, the confidence of Pearson's r value was carefully considered (Hahs-Vaughn & Lomax, 2020). First, previous science experience data were analyzed against individual science literacy scores. Next, previous science experience data were analyzed against sociocultural data, which included demographic data that were identified as having characteristics that could be associated with social and/or cultural factors. Then sociocultural experience data which included identity demographic data were analyzed against science literacy scores. Finally, previous science experience data and science literacy assessment scores were analyzed against dominant identity and non-dominant identity group data with and without religious affiliation included. To further support correlation analysis findings general linear regression analyses were performed. ANOVA significance values, R-square values, coefficient statistics along with Durbin-Watson statistics were recorded for linear regression analysis.

In order to evaluate how individual science literacy questions were associated with science literacy skills and overarching science literacy categories, bivariate correlation analysis was performed on each individual science literacy assessment question against responses to previous science experience and sociocultural experience data. Pearson's correlation and p-values were recorded. P-values were used to identify statistical significance. All instances where statistical significance was identified and tallied per science literacy question. Questions with the most statistically significant results per category (either previous science experience or sociocultural experience) were grouped respectively and reported. Individual science literacy assessment questions were then grouped by the overarching theme of what skills they were associated with per TOSLS: either I) Understand methods of inquiry that lead to scientific knowledge or II) Organize, analyze, and interpret quantitative data and scientific information. Patterns in relationships were then identified.

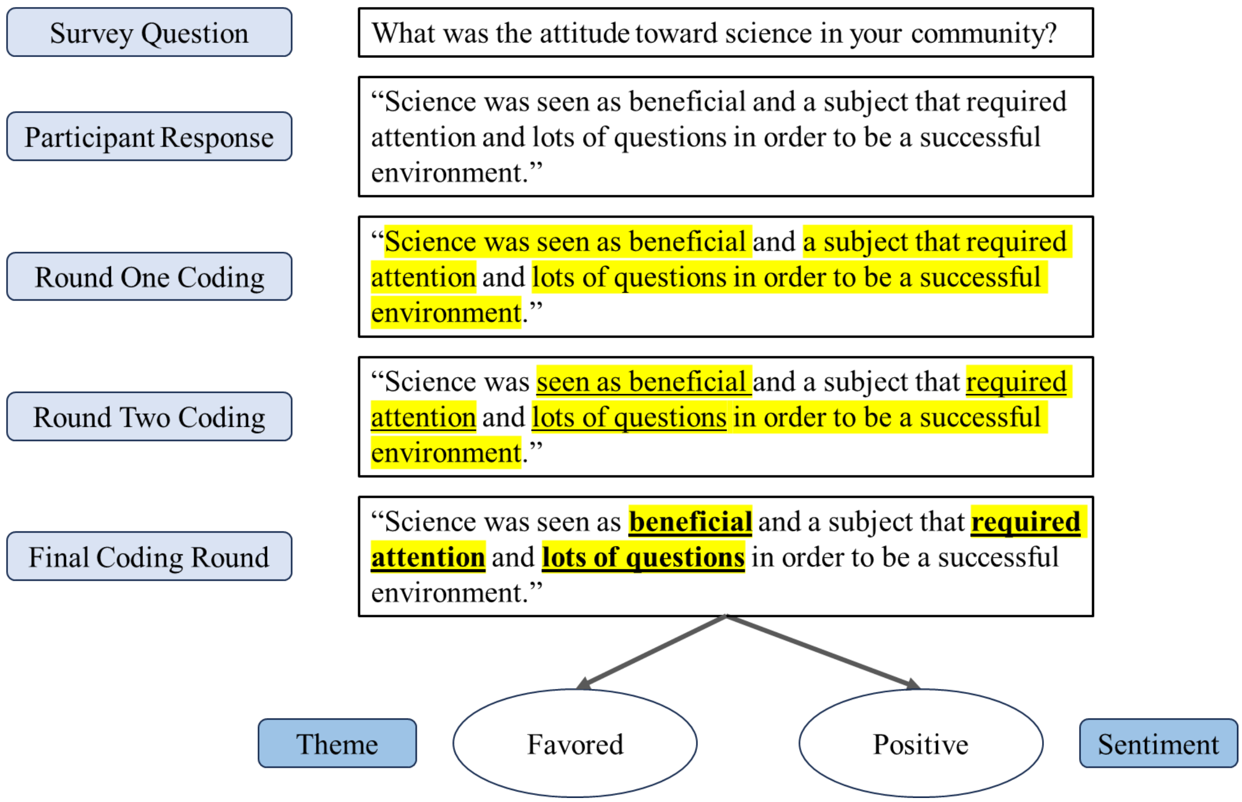
Qualitative Analysis

Studies that involve participants' perception, feelings, attitudes, and understanding of a given topic are not well-defined. In order to gain a richer understanding of the lived experiences of the participants and how those experiences may have influenced their perceptions or understandings, qualitative aspects were necessary to include in this study. By including open-ended questions, participants were free to respond in their own words without the need to choose from a preselected list of responses. Data from these questions provided a deeper understanding of the attitudes and perceptions of the participants. Furthermore, information gleaned from the qualitative portion of this study was able to be used employed in an embedded analysis method, as described below, to provide greater depth and breadth the findings from this study.

All responses to open-ended questions in the previous science experience, sociocultural experience, and science literacy blocks were separated from multiple choice or Likert-scale style data. Responses to each question were organized by participant number and response and saved as comma-separated value (CSV) worksheets. All open-ended response data were processed for codes, themes, and sentiments using qualitative data analysis software NVivo (version 14). Reflexive thematic analysis was applied for careful data exploration and to cautiously identify repeated themes within the data (Braun & Clark, 2006; Byrne, 2022; Terry & Hayfield, 2020). Iterative rounds of coding were performed which allowed for lengthy responses to be reduced to more manageable units for analysis. This also allowed for a way to clearly interpret participants' responses and summarize findings as they relate to the research questions of this study. Furthermore, this allowed for sentiments to be extracted from more simplified coded responses (see Figure 1). During the first round of coding, in-vivo codes were identified to preserve the authenticity of participants' responses by preserving exact words and phrases used by participants. The second round of coding truncated initial codes and key words and phrases from round one coding to further make analysis more manageable. Codes that emerged from round two were subjected to a final round of coding and were grouped into themes that had been identified through coding iterations. Sentiment analysis was also performed on all response codes to group responses by carefully analyzing the feelings and/or attitudes espoused in participant responses. Sentiment categorization ranged from very negative to very positive. Consistent sentiment analysis was performed across all question responses. A final assessment of codes, themes, and sentiments were performed for verification where final themes and sentiments were analyzed against the original response to ensure integrity of the findings.

Figure 1

Example of Thematic and Sentiment Development



Following thematic and sentiment analysis of open-ended question responses, results were quantified to support embedded design (Lieberman, 2005). Embedded analysis allowed for a nested approach that included both qualitative and quantitative data to provide a deeper understanding of participants' experiences and perceptions in relation to previous science experiences, sociocultural experiences, and science literacy assessment results. Embedded design was employed by embedding open-ended questions within the survey itself. Embedded analysis was accomplished by quantifying qualitative response data which provided greater breadth and depth to the data that emerged from this study. Initial evaluation of open-ended question responses in the science literacy assessment section was completed by careful cross-analysis to the science literacy question with which it was associated. Care was taken in the re-alignment of the science literacy qualitative response data with the quantitative response data to ensure the integrity of the embedded analysis for this portion. This method also allowed for a clearer picture of question-answering strategies utilized for the science literacy assessment questions.

Furthermore, critical discourse analysis (CDA) was also performed on responses to open-ended questions in the previous science experience, sociocultural, and science literacy blocks to identify instances of identity, agency, and/or power (IAP) within participants' response. CDA includes critiquing discourse as it relates to social context as well identifying systems of power within cultural narratives that contribute to social inequalities (Mullet, 2018; Rogers, 2004). Guidance for critical analysis on participant responses to open-ended questions was taken from *Reframing Sociocultural Research on Literacy* (Lewis et al., 2020) which expands beyond the assessment of power structures as seen in CDA to include identification of instances of identity and agency that may be effected by such power and reminds researchers to "recognize that power is produced in people's everyday lives and instantiated in institutions, systems, and socioeconomic structures that shape, and, at time, control people's everyday lives" (p. 21). The existing codes of identity, agency, and/or power were utilized for this analysis. For the critical analysis portion, hand-coding was performed in order to closely evaluate participants' responses for words or phrases that were associated with systems, institutions, ways of understandings, or influence commonly that contribute to aspects of IAP. Critical analysis findings of IAP were carefully compared to the questions where the instance was identified. This allowed for identification of areas within participants' precious science experiences, sociocultural experiences, or areas of science literacy which may have been unknowingly influenced or hold relationship to identity, agency, and/or systems of power.

Conclusion

Mixed methods were utilized in this study to evaluate survey data from anonymous participants. Survey design was assessed for accessibility issues before distribution. The science literacy assessment was modified from the original TOSLS version and Cronbach's alpha was performed in order to ensure reliability of the modified assessment. Descriptive statistics were generated for responses where appropriate. Bivariate correlation analysis was run across all quantitative responses and dominant versus non-dominant group identity data. Pearson's coefficients were assessed using Cohen's (1988) guidelines for strength in relationships. Furthermore, p-values were used to determine statistical significance and/or confidence in relationships among cross-analyzed items. Additionally, general regression analysis was performed on all quantitative data as well as grouped identity characteristics.

Iterative rounds of coding were performed on responses to open-ended questions to identify themes and sentiments within open-ended question responses. First, open coding was performed followed by subsequent rounds of coding, theme identification, and sentiment grouping. Embedded design was employed in the survey design and embedded analysis was performed on qualitative data from previous science experience, sociocultural experience, and science literacy assessment responses. Finally, critical discourse analysis was performed on responses to open-ended questions to identify any responses that indicated elements of identity, agency, and/or power.

Chapter 4 Results

Introduction

This study aimed to identify relationships between first-year college students' previous science experiences, sociocultural backgrounds, and science literacy. An anonymous survey that collected demographic data, information about previous science experiences, sociocultural experiences, and that included a science literacy assessment was disseminated through Central University mass email system. Mixed methods were utilized to evaluate both quantitative as well as qualitative aspects of participants' lived experience as reported in survey responses. Descriptive statistics and correlation analysis were performed on all multiple choice and Likert-scale responses. Themes and sentiments were identified that emerged from iterative rounds of coding open-ended question responses. Critical discourse analysis was employed to identify instances of identity, agency, and power within open-ended responses. Embedded analysis was performed across quantitative and qualitative findings. Some demographic data, such as gender, sexual orientations, and political affiliation were evaluated as a part of sociocultural factors, as they can both describe the demographics of participant, as well as be considered social and/or cultural factors. Furthermore, the science literacy assessment was embedded with qualitative questions to garner understanding as to why a participant selected the answers that they did. The data analyzed were used to gain a deeper understanding of these relationships and to answer the following research questions:

A. How do previous science experiences relate to students' science literacy?

B. What sociocultural factors correlate to students' science literacy scores?

Descriptive Analysis

Descriptive Statistics of Demographics Data

Between Spring Semester 2023 and Fall Semester 2023 rounds of data collection, 200 students enrolled at Central University responded to the electronic survey. Of the 200 respondents, six did not consent, and 16 did not qualify due to not identifying as having been within their first year of college. Among the 178 respondents who did consent and were within qualifying criteria, 137 did not complete the entire survey, leaving 41 respondents who did complete the survey, to include the science literacy assessment, herein identified as participants (N=41). Mean and standard deviations for all demographic data were calculated (see Table 3).

During the Spring Semester 2023 data collection, it was identified that the including the qualification that a participant be enrolled in a 1000- or 2000-level introductory science course disqualified more than half of the respondents which led to a very low participation rate where only four participants completed the survey in totality. As being enrolled in an introductory science course was not critical to answering the research questions of this study, the question was not utilized as a qualifying question in the subsequent Fall Semester 2023 round of data collection. Within the pool of participants, 36 participants indicated they were enrolled in a 1000-level or 2000-level introductory science course at Central University during Fall Semester 2022, Spring Semester 2023, or Fall Semester 2023. Participants self-reported the introductory science course or courses in which they were enrolled with the majority reporting to have been enrolled in a biology course (63.4%) (see Table 4).

Table 3

Means and Standard Deviations for All Demographic Data

Demographic	Coded Variable	M	SD
Enrolled in Science Course			
Yes	1		
No	2	1.1	0.33
Intended Major			
Science	1		
TEM	2		
Non-Science/non-TEM	3		
Undecided	4	1.8	0.94
Race			
Native American/Alaskan Native	1		
Asian	2		
Black	3		
White	4		
More than one	5	3.8	0.93
Ethnicity			
No, not of Hispanic, Latino/a/x, or of Spanish origin	1		
Yes, Mexican American, Chicano/a/x	2		
Yes, Another Hispanic, Latino/a/x, or Spanish origin	3		
Some other race, ethnicity, or origin	4	1.5	1.02
Nationality			
American/US Citizen	1		
European	2		
Serbian	3		
Asian	4		
Canadian	5		
Unknown	6		
More than one	7	2.0	1.94

Demographic	Coded Variable	M	SD
Gender			
Male	1		
Female	2		
Nonbinary/Third gender	3		
Transgender	4		
Prefer to self-describe	5		
Prefer not to say	6	1.9	1.05
Sexual Orientation			
Straight/Heterosexual	1		
Bisexual	2		
Asexual	3		
Gay/Lesbian	4		
Pansexual	5	1.5	1.03
Political Affiliation			
Not political	1		
Democrat	2		
Republican	3		
Independent	4		
Prefer to self-describe	5		
Prefer not to say	6	2.9	1.63
Ability			
Able-bodied	1		
Prefer not to say	2	1.1	0.31

Note. N = 41.

Table 4

Participant Introductory Science Course Enrollment by Subject

Introductory Science Course	Number of Participants Enrolled	
	Frequency	%
Biology	26	63.4
Chemistry	5	12.2
Physics	1	2.4
Astronomy	1	2.4
Geology	1	2.4
Physical Geography	1	2.4
Psychology[a]	9	22.0
Sociology[a]	1	2.4
None	5	12.2

Note. N = 41. Some participants self-reported enrollments in more than one introductory science course.

[a]Social science courses.

In addition to enrollment in science courses, participants reported their intended majors, with more than half of participants reporting an intended major in science (53.7%) or technology, engineering, or math (17.1%) (TEM) (see Table 5).

Table 5

Intended Majors of Participants

Intended Major	Number of Participants	
	Frequency	%
Science	22	53.7
TEM	7	17.1
Non-Science/non-TEM	11	26.8
Undecided	1	2.4

Note. N = 41.

Demographic data were collected related to identity to include race, ethnicity, nationality, gender, sexual orientation, and political affiliation. As demographic data of this nature can be considered associated with social and/or cultural aspects of a person's life, this data was also used in correlation analysis and assessed as sociocultural factors (Grimson, 2010; Scheepers & Ellemers, 2019). The majority of participants identified as white (73.2%), not being of Hispanic, Latino/a/x, or of Spanish origin (85.4%), and identified as having American nationality (75.6%). Several participants identified as holding more than one race (12.2%), and one participant identified as holding more than one nationality (2.4%). More than half of participants identified as female (53.7%) as well as straight or heterosexual (75.6%). There were more participants that reported to be apolitical (26.8%) than any other political category, however, there was a similar distribution of those who reported to be Democrat (19.5%), Republican (17.1%), or Independent (17.1%). All participants except for one identified as able-bodied (97.6%), where one participant who did not identify as able-bodied preferred not to state their ability status (see Table 6).

Table 6

Identity Demographics of Participants

Identity Demographics	Number of Participants	
	Frequency	%
Race		
Native American/Alaskan Native	2	4.9
Asian	3	7.3
Black	1	2.4
White	30	73.2
More than one	5	12.2
Ethnicity		
No, not of Hispanic, Latino/a/x, or of Spanish origin	35	85.4
Yes, Mexican American, Chicano/a/x	1	2.4
Yes, Another Hispanic, Latino/a/x, or Spanish origin	2	4.9
Some other race, ethnicity, or origin	3	7.3
Nationality		
American/US Citizen	31	75.6
European	1	2.4
Serbian	1	2.4
Asian	1	2.4
Canadian	1	2.4
Unknown	5	12.2
More than one	1	2.4
Gender		
Male	15	36.6
Female	22	53.7
Nonbinary/Third gender	1	2.4
Transgender	1	2.4
Prefer to self-describe	1	2.4
Prefer not to say	1	2.4

Identity Demographics	Number of Participants	
	Frequency	%
Straight/Heterosexual	31	75.6
Bisexual	6	14.6
Asexual	1	2.4
Gay/Lesbian	1	2.4
Pansexual	2	4.9
Political Affiliation		
Not political	11	26.8
Democrat	8	19.5
Republican	7	17.1
Independent	7	17.1
Prefer to self-describe	5	12.2
Prefer not to say	3	7.3
Ability		
Able-bodied	40	97.6
Prefer not to say	1	2.4

Note. N = 41.

Descriptive Statistics of Previous Science Experiences

Previous science experience data showed varied histories and differences among the attitudes, perceptions, and experiences of participants. Mean and standard deviations for all previous science experience multiple choice data were calculated (see Table 7).

Table 7

Means and Standard Deviations for Previous Science Experience Multiple Choice Data

Previous Science Experience	Coded Variable	M	SD
A science person			
Yes	1		
No	2		
Do not know	3	1.4	0.67
Number of high school science courses			
1-2	1		
3-4	2		
5-6	3		
7 or more	4	2.5	0.67
An active participant			
Yes, rarely	1		
Yes, occasionally	2		
Yes, frequently	3	2.3	0.55
Fostered creativity			
Yes	1		
No	2		
Do not know	3	1.6	0.74
Valued critical thinking			
Yes	1		
No	2		
Do not know	3	1.4	0.63
Had a negative experience			
Yes	1		
No	2		
Do not know	3	1.7	0.56

Note. N = 41.

When asked if they considered themselves a science person, more than half of participants responded yes (68.3%). Participants who responded as considering themselves a science person more often had taken a greater amount of science courses during their high school years, while the more than half of respondents reported that they took three to four science courses during high school (56.1%). The amount in which they reported that they actively participated in previous science courses varied with the highest amount stating that they were occasionally an active participant in science courses (63.4%) followed by those who reported that they were frequently active in science courses (31.7%). Most respondents who identified as not knowing whether they were science people or tended to not have taken three to four science courses during high school. Interestingly, those who responded as being active participants in previous science courses did not exclusively identify as being a science person (see Table 8).

Table 8

Science Identity, Number of High School Science Courses, and Science Course Participation

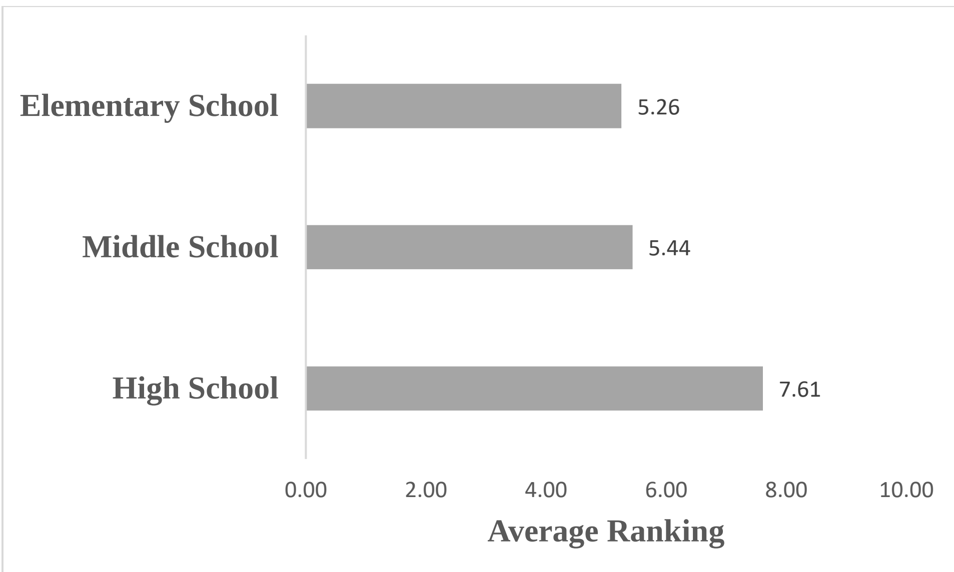
Science History	Number of Participants	
	Frequency	%
A science person		
Yes	28	68.3
No	9	22.0
Do not know	4	9.8
Number of high school science courses		
1-2	1	2.4
3-4	23	56.1
5-6	14	34.1
7 or more	3	7.3
An active participant		
Yes, rarely	2	4.9
Yes, occasionally	26	63.4
Yes, frequently	13	31.7

Note. N = 41.

I asked participants to rank their overall previous science experiences as well as to rank how engaging they found their previous science experiences in elementary, middle, and high school using a scale from 0-10, 0 corresponding to a poor experience or not at all engaging and 10 being excellent experience or very engaging, respectively. High school experiences resulted in the highest means for both science experience (M = 7.61) and engagement (M = 7.63) (see Figures 2 and 3).

Figure 2

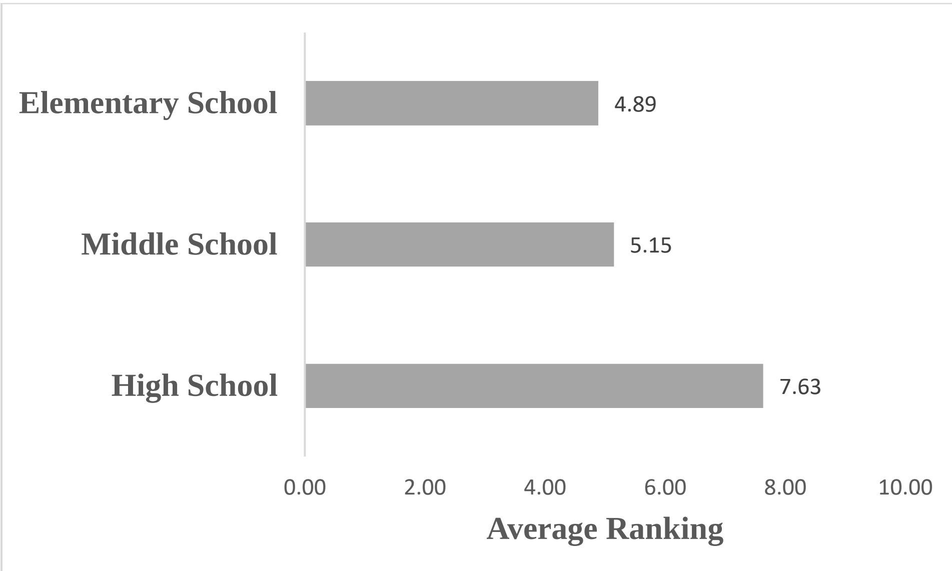
Average Overall Ranking of Participants' Previous Science Experiences



Note. Mean scores of overall science experience in elementary, middle, and high school. Six participants did not respond to elementary school science experience.

Figure 3

Average Ranking of How Engaging Participants' Found Previous Science Experiences



Note. Mean scores of how engaging previous science courses were in high school, middle school, and elementary school. Five participants did not respond to elementary school science experience.

Creativity and critical thinking were both identified in participants' previous science experiences. When asked if creativity was fostered in previous science courses, more than half of participants responded yes (53.7%). Similarly, over half of participants answered that they felt that critical thinking was valued in their previous science experiences (65.9%), which resulted in more participants that associated critical thinking rather than creativity with previous science courses (see Table 9). Additionally, when asked if they had ever had a negative experience while discussing scientific topics either in school or outside of school, 14 participants responded that they had a negative experience (34.1%), 25 participants responded that they had not had a negative experience (61.0%), while two did not know whether they had ever had a negative experience discussing scientific topics (4.9%).

Table 9

Creativity and Critical Thinking in Previous Science Experiences

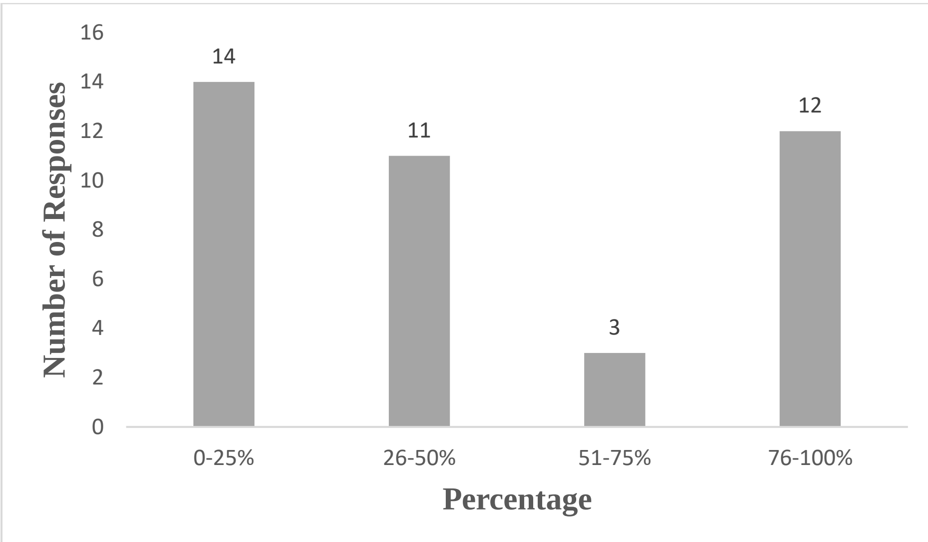
Science Environments	Number of Participants	
	Frequency	%
Fostered Creativity		
Yes	22	53.7
No	13	31.7
Do not know	6	14.6
Valued Critical Thinking		
Yes	27	65.9
No	11	26.8
Do not know	3	7.3

Note. N = 41.

Finally, when participants were asked on a scale of 0 to 100, 0 being no influence at all and 100 being very influential, to what extent did they perceive that their household's or community's attitudes toward science influence their own attitude toward science, fewer participants perceived that their attitude toward science had been influenced by their household or community (M = 47.78 +/- 35.5). When little to no influence (0% - 25%) and marginal to little influence (25% - 50%) were combined, over half of participants reported that their family and/or community had little to marginal influence on their attitude toward science (34.1%; 26.8%), respectively (see Figure 4).

Figure 4

Influence of Household and/or Community's Attitude Toward Science



Note. The extent to which participants' perceived their own attitudes toward science was influenced by their household's or community's attitude toward science. One participant did not respond to the extent to which they felt their attitude toward science had been influenced.

Descriptive Statistics of Sociocultural Experiences

Participants were asked to report on a wide variety of social and cultural experiences including religious affiliation, aspects of household and community environments in which they were raised, as well as in regard to their school experiences. Mean and standard deviations for all sociocultural experience multiple choice data were calculated (see Table 10). The majority of respondents identified as Christian (51.2%), with the second highest response to religious affiliation being Atheist (22.0%) (see Table 11).

Table 10

Means and Standard Deviations for Sociocultural Experience Multiple Choice Data

Sociocultural Experience	Coded Variable	M	SD
Religious Affiliation			
Christian	1		
Hindu	2		
Buddhist	3		
Atheist	4		
A Religion Not Listed	5		
Prefer to Self-Describe	6		
Prefer Not to Say	7		
More than one	8	3.0	2.47
Number of Languages Spoken			
One	1		
Two	2		
Three or more	3	1.3	0.60
Multigenerational household			
Yes	1		
No	2		
Don't know	3	2.0	0.44
Type of community raised in			
Rural	1		
Suburban	2		
City	3		
More than one	4	2.0	0.99
Highest level of education			
Middle school	1		
High school	2		
Some college	3		
Bachelor's degree	4		
Graduate/Professional degree	5		
Don't know	6	4.0	1.18

Sociocultural Experience	Coded Variable	M	SD
Community involvement			
No	1		
Yes, just the participant	2		
Yes, just the family	3		
Yes, participant and family	4	3.2	1.19
Type of school community			
Rural	1		
Suburban	2		
City	3		
More than one	4	1.8	0.58
Type of school			
Traditional public	1		
Private	2		
More than one	3	1.2	0.58
Extra-curricular activities			
No	1		
Yes, a few	2		
Yes, a lot	3		
Prefer not to say	4	2.5	0.64
Household responsibilities			
Yes, household chores	1		
Yes, caretaking	2		
Yes, other responsibilities	3		
None	5		
More than one	6	2.4	1.86

Note. N = 41.

Table 11

Religious Affiliation of Participants

Religious Affiliation	Number of Participants	
	Frequency	%
Christian	21	51.2
Hindu	1	2.4
Buddhist	1	2.4
Atheist	9	22.0
A Religion Not Listed	2	4.9
Prefer to Self-Describe	1	2.4
Prefer Not to Say	2	4.9
More than One Listed	4	9.8

Note. N = 41.

I asked participants to identify aspects of the household environments in which they grew up or were raised. These aspects included the number of languages that were spoken within the household, whether the participants were raised in a multigenerational household, the highest level of education within the household, and what kind of household responsibilities they had while growing up. The majority of participants lived in households where only one language was spoken (78.0%), followed by households where two language was spoken (14.6%). Only a few participants were raised in a multigenerational household (12.2%) whereas most participants were not (80.5%). The highest education level reported within a household ranged from middle school to graduate or professional degrees, in which an equal number of participants reported that the highest level of education was either a bachelor’s degree (34.1%) or a graduate/professional degree (34.1%). When asked if they had household responsibilities growing up, which included household chores, caretaking, or responsibilities other than chores or caretaking, most participants reported that they had household chores (58.5%) followed by those that reported that they had more than one household responsibility (31.7%) (see Table 12).

Table 12

Aspects of Households in Which Participants Were Raised

Household Environment	Number of Participants	
	Frequency	%
Number of Languages Spoken		
One	32	78.0
Two	6	14.6
Three or more	3	7.3
Multigenerational Household		
Yes	5	12.2
No	33	80.5
Don't know	3	7.3
Highest Level of Education		
Middle school	1	2.4
High school	5	12.2
Some college	5	12.2
Bachelor's degree	14	34.1
Graduate/Professional degree	14	34.1
Don't know	2	4.9
Household Responsibilities		
Yes, household chores	24	58.5
Yes, caretaking	2	4.9
Yes, other responsibilities	1	2.4
None	1	2.4
More than one	13	31.7

Note. N = 41.

Questions that regarded aspects of the community environments in which participants lived were limited to the types of communities in which participants lived and whether they and/or their families were involved in community activities. The highest percentage of participants were raised in suburban communities (53.7%) followed by rural communities (29.3%). The majority of participants responded that both they and their families were actively involved in their community (65.9%) (see Table 13).

Table 13

Aspects of Communities Where Participants Grew Up

Community Aspects	Number of Participants	
	Frequency	%
Type of Community		
Rural	12	29.3
Suburban	22	53.7
City	2	4.9
More than one	5	12.2
Community Involvement		
No	6	14.6
Yes, just the participant	7	17.1
Yes, just the family	1	2.4
Yes, participant and family	27	65.9

Note. N = 41.

Finally, participants were asked about aspects of their school experiences. This included what type of community in which the school(s) they attended were located, what type of school(s) they attended, and whether or not they were involved in extra-curricular activities. More than half of participants reported that the school that they attended was located in suburban areas (56.1%) followed by rural areas (24.4%). The majority of students attended traditional public schools (82.9%). Most students reported being involved in a lot of extra-curricular activities (53.7%), followed by a few extra-curricular activities (39.0%) (see Table 14).

Table 14

Aspects of Participants' School Experiences

School Aspects	Number of Participants	
	Frequency	%
Type of Community		
Rural	10	24.4
Suburban	23	56.1
City	3	7.3
More than one	5	12.2
Type of School		
Traditional public	34	82.9
Private	4	9.8
More than one	3	7.3
Extra-curricular activities		
No	2	4.9
Yes, a few	16	39.0
Yes, a lot	22	53.7
Prefer not to say	1	2.4

Note. N = 41.

Descriptive Statistics of Science Literacy Assessment Results

Science literacy assessments were individually scored and then averaged which resulted in a mean science literacy score of 9.5 out of 14 with a standard deviation of +/- 3.22 points. Individual questions were also scored to identify strengths and weaknesses in overarching science literacy skills of science literacy assessment by frequency (see Table 15).

Table 15

Percentages of Correct Responses of Science Literacy Assessment Questions

Overarching Science Literacy Category from TOSLS (Gormally et al., 2012)	Question	% Score	Science Literacy Skill Description from TOSLS (Gormally et al., 2012)
Understand methods of inquiry that lead to scientific knowledge	1	82.93	Identification of a valid scientific argument
	2	58.54	Evaluation of the validity of sources
	3	92.68	Evaluation of the use and misuse of scientific information
	4	48.78	Understanding the elements of research design
	8	70.73	Identification of a valid scientific argument
	11	56.10	Evaluation of the validity of sources
	12	68.29	Evaluation of the use and misuse of scientific information
Organize, analyze, and interpret quantitative data and scientific information	5	73.17	Interpretation of graphical representations of data
	6	85.37	Problem solving using quantitative skills
	7	51.22	Understanding and interpretation of basic statistics
	9	43.90	Justification of inferences, predictions, and conclusions based on quantitative data
	10	58.54	Interpretation of graphical representations of data
	13	80.49	Justification of inferences, predictions, and conclusions based on quantitative data
	14	51.22	Justification of inferences, predictions, and conclusions based on quantitative data

The science literacy category that had the highest percentage of correct responses was participants' ability to understand methods of inquiry that lead to scientific knowledge, however, a t-test resulted in a p-value of 0.58 which is greater than prespecified $\alpha = 0.05$.

Correlation Analysis

Data collection with expanded response options presented limitations to statistical analysis in that by providing a larger number of options, it decreased potential grouping of data to ensure appropriate variance for certain statistical analyses, such as ANOVA. Additionally, the limited number of participants contributed to a few instances where only a single participant selected a given response option. Correlation analyses were utilized to lay the foundation for relationships that may impact science literacy. As the first study of its kind, care was taken not to group variables together for the sake of generating a mean, and therefore compromising the nuance of data acquired. The statistical output of correlation analysis between variables where only one participant selected a given response (e.g., race) should be interpreted with caution as specific outputs may not reveal the complete impact of the relationship between variables.

Relationships Between Science Literacy and Previous Science Experiences

Bivariate correlation analysis identified relationships between science literacy assessment scores and previous science experiences as well as confidence in the resulting strengths of relationships (see Table 16). Confidence Intervals for 95% confidence were calculated where applicable. Only one area was identified to have a Pearson's r of 0.3 or greater with a p-value less than 0.05. Analysis between aspects science literacy assessment scores and previous science experiences that fostered creativity resulted in a Pearson's r score of 0.4 with a p-value of 0.02.

Correlation analysis was run on each science literacy question along with previous science literacy experience responses identified relationships between categories. Analysis of relationships among respective categories showed relationships with previous science experience and science literacy assessment questions one, three, eight, and 12 with a Pearson's r above 0.2. Regression analysis was also performed on previous science experience versus science literacy assessment scores. Only one aspect resulted in an ANOVA significance of <0.05 (Table 17).

Table 16

Relationships Between Science Literacy Assessment Scores and Previous Science Experiences

Previous Science Experiences	Pearson's Correlation (r)	95% CI		p-value
		LL	UL	
A science person	0.1	-0.210	0.399	0.51
Number of science courses	0.1	-0.236	0.376	0.63
An active participant	0.2	-0.103	0.489	0.18
Previous high school experience	-0.1	-0.388	0.227	0.58
Previous middle school experience	0.0	-0.294	0.322	0.92
Previous elementary school experience	0.0	-0.360	0.306	0.86
Engaging high school experience	0.0	-0.302	0.313	0.97
Engaging middle school experience	0.0	-0.330	0.285	0.88
Engaging elementary school experience	0.1	-0.280	0.375	0.76
Fostered creativity	0.4	0.061	0.603	0.02*
Valued critical thinking	0.1	-0.262	0.352	0.75
Previous negative experience	0.0	-0.282	0.333	0.86
Attitude toward science influenced	-0.2	-0.327	0.296	0.92

Note. Pearson's correlation (r) values are reported as absolute values.

*Indicates statistical significance.

Table 17

Regression Analysis of Science Literacy Assessment Scores and Previous Science Experiences

Previous Science Experience	ANOVA (sig.)	R-square	Standardized β	Durbin-Watson
A science person	0.51	0.01	0.106	1.8
Number of high school science courses	0.63	0.01	0.078	1.8
An active participant	0.18	0.05	0.214	1.8
Overall high school experience	0.58	0.01	-0.088	1.9
Overall middle school experience	0.92	0.00	0.016	1.8
Overall elementary school experience	0.86	0.00	-0.030	1.5
Engaging high school science	0.97	0.00	0.006	1.8
Engaging middle school science	0.88	0.00	-0.025	1.8
Engaging elementary school science	0.76	0.00	0.054	1.5
Fostered creativity	0.02	0.13	0.366	2.1
Valued critical thinking	0.75	0.00	0.050	1.8
Had a negative experience	0.86	0.00	0.029	1.8
Influence	0.92	0.00	-0.017	1.9

Note. All collinearity and VIF values = 1.0.

Relationships Between Science Literacy and Sociocultural Experiences

Bivariate correlation analysis identified relationships between science literacy assessment scores and sociocultural experiences as well as confidence in the resulting strengths of relationships (see Table 18). There were six areas identified to have a Pearson's r of 0.3 or greater. These areas were gender, sexual orientation, ability, religious affiliation, the type of schools the participants attended, and participants' involvement in extra-curricular activities.

Table 18

Relationships Between Science Literacy Assessment Scores and Sociocultural Experiences

Sociocultural Aspects	Pearson's Correlation (r)	95% CI		p-value
		LL	UL	
Identity				
Race	0.1	-0.204	0.404	0.49
Ethnicity	-0.2	-0.443	0.159	0.32
Nationality	-0.2	-0.490	0.100	0.17
Gender	0.3	-0.066	0.515	0.12
Sexual orientation	0.3	-0.003	0.560	0.05*
Ability	-0.4	-0.632	-0.108	0.01*
Political identification	0.1	-0.239	0.373	0.64
Religious affiliation	0.3	0.021	0.577	0.04*
Household				
Number of languages spoken	0.0	-0.308	0.307	1.00
Multigenerational household	0.0	-0.349	0.265	0.77
Highest household education	-0.2	-0.490	0.100	0.17
Household responsibilities	0.0	-0.319	0.296	0.94
Community				
Type of community raised in	0.1	-0.174	0.430	0.37
Community involvement	0.2	-0.496	0.092	0.16
School				
Type of community attended school	0.1	-0.250	0.363	0.70
Type of school(s)	0.3	-0.015	0.552	0.06
Extra-curricular activity involvement	-0.3	-0.518	0.062	0.11

Note. Pearson's correlation (r) values are reported as absolute values.

*Indicates statistical significance.

Regression analysis was also performed on sociocultural experiences versus science literacy assessment scores. Results indicated two aspects resulted in an ANOVA significance of < 0.05 (Table 19).

Table 19

Regression Analysis of Science Literacy Assessment Scores and Sociocultural Experiences

Sociocultural Experience	ANOVA (sig.)	R-square	Standardized β	Durbin-Watson
Race	0.49	0.13	0.112	1.8
Ethnicity	0.32	0.03	-0.158	1.9
Nationality	0.17	0.05	-0.217	1.9
Gender	0.12	0.06	0.250	1.9
Sexual Orientation	0.05	0.10	0.308	1.8
Political identification	0.64	0.01	0.075	1.8
Ability	0.08	0.17	-0.407	1.8
Religious affiliation	0.04	0.11	0.331	1.8
Number of languages spoken	1.00	0.00	-0.001	1.8
Multigenerational household	0.77	0.00	-0.046	1.8
Type of community raised in	0.37	0.02	0.143	1.9
Highest level of education	0.17	0.05	-0.217	1.8
Community involvement	0.16	0.05	-0.225	1.7
Type of school community	0.70	0.00	0.063	1.8
Type school	0.06	0.09	0.298	1.8
Extra-curricular activities	0.11	0.06	-0.254	2.0
Household responsibilities	0.94	0.00	-0.013	1.8

Note. All collinearity and VIF values = 1.0.

Correlation analysis was run on each science literacy question along with sociocultural experience responses and identified relationships between categories. Analysis of relationships among respective categories identified that there were relationships with sociocultural experiences and science literacy assessment questions two, four, five, seven, nine, 10, 11 and 14 with a Pearson's r above 0.2.

Bivariate analysis performed when identity characteristics were grouped together as either dominant identity characteristics, which were white, cis, heterosexual, or having characteristics other than white, cis, heterosexual, or non-dominant identity characteristics as it related to previous science experience as well as science literacy scores. A modification to dominant identity characteristic was made to include Christian as an identifier within the dominant identity characteristics group. There were slight differences identified in resulting Pearson's r values for grouped identity versus previous science experience analysis with or without Christian as an identifier (see Table 20). Identity grouping that excluded Christian as a parameter versus science literacy score analysis resulted in a Pearson's r of .01 with a p-value of 0.44 and 95% CI lower limit of -0.193 and an upper limit of 0.414. When the identity characteristic grouping was modified to include Christian as a status quo characteristic identifier, bivariate correlation analysis resulted in a Pearson's r of 0.4 with a p-value of 0.02 and 95% CI lower limit of -0.056 and an upper limit of 0.599. Regression analysis was also performed on dominant identity characteristics with and without religious affiliation versus science literacy assessment scores (Table 21).

Table 20

Relationships Between Grouped Identity Characteristics and Previous Science Experience

Previous Science Experiences	Identity Group without Religion				Identity Group with Religion			
	Pearson's Correlation (r)	95% CI		p-value	Pearson's Correlation (r)	95% CI		p-value
		LL	UL			LL	UL	
A science person	0.1	-0.370	0.243	0.66	0.0	-0.265	0.349	0.77
Number of science courses	0.0	-0.316	0.300	0.96	0.2	-0.144	0.455	0.28
An active participant	0.1	-0.174	0.430	0.37	0.1	-0.219	0.392	0.55
Previous high school experience	0.2	-0.082	0.504	0.14	0.1	-0.170	0.433	0.36
Previous middle school experience	0.1	-0.204	0.404	0.49	0.1	-0.184	0.422	0.41
Previous elementary school experience	0.1	-0.390	0.274	0.71	0.0	-0.301	0.364	0.84
Engaging high school experience	0.2	-0.132	0.464	0.25	0.0	-0.284	0.331	0.87
Engaging middle school experience	0.0	-0.331	0.284	0.87	0.0	-0.314	0.301	0.96
Engaging elementary school experience	0.1	-0.407	0.245	0.59	0.0	-0.311	0.345	0.91
Fostered creativity	0.0	-0.346	0.269	0.79	0.1	-0.259	0.355	0.74
Valued critical thinking	0.0	-0.304	0.311	0.98	0.1	-0.179	0.426	0.39
Previous negative experience	0.1	-0.384	0.227	0.59	0.0	-0.327	0.288	0.89
Attitude toward science influenced	0.0	-0.336	0.287	0.87	0.1	-0.224	0.394	0.56

Note. Pearson's correlation (r) values are reported as absolute values.

Table 21

Regression Analysis of Science Literacy Assessment Scores and Grouped Identity Characteristics

Grouped Identity Characteristics	ANOVA (sig.)	R-square	Standardized β	Durbin-Watson
Dominant	0.44	0.02	0.123	1.9
Dominant with Religion	0.02*	0.13	0.362	1.9

Note. All collinearity and VIF values = 1.0.

*Indicates statistical significance.

Qualitative Analysis

Within the administered survey, there were embedded open-ended questions in the previous science experience, sociocultural, and science literacy blocks. For all open-ended questions, responses were analyzed in NVivo. Reflexive thematic analysis was performed to identify emerging themes. Sentiment analysis was performed on identified themes. Emerging themes and sentiments that resulted from this analysis are reported below.

Emergent Themes and Sentiments from Previous Science Experiences

In the previous science experiences block of the survey, two open-ended questions were included. The questions asked participants, based on their experience, what the attitudes toward science were in their household and community. Only one participant did not respond to the open-ended questions in this block (N = 40).

Question 1: In your experience, what was the attitude toward science in your household?

There were three themes that emerged from question one. These themes were identified as 1) supportive, 2) unsupportive, and 3) neither supportive nor unsupportive. Examples of coded responses that were identified to fit under the theme supportive for household attitudes toward science were “very supported”, “encouraging”, and “positive, talked about frequently”. Examples of responses categorized under the theme of unsupportive for household attitudes toward science were “slightly negative” and “lots of pseudoscience and incorrect science”. Neutral or indifferent responses, for instance, were reported as “indifferent” or “there was no attitude towards science. It was just a topic”. The majority of participants responses were associated with the supportive theme (n = 24), with the fewest responses associated with unsupportive (n = 3) (see Table 22).

Table 22

Emergent Themes from Household Attitudes Toward Science

Emergent Theme	Number of Participants	
	Frequency	%
Supportive	24	60.0
Neither supportive nor unsupportive	13	32.5
Unsupportive	3	7.5

Note. N = 40.

Sentiment analysis resulted in five sentiments related to question one. Those sentiments were negative, slightly negative, neutral, slightly positive, and positive. Responses which included degree adverbs in context to a positive or negative sentiment were categorized with the extreme ends of the sentiment scale as appropriate. One participant responded with “lots of pseudoscience and incorrect science” and another reported that “my family was full of religious nuts who believe science is a hoax made up by liberals”. Both of those responses were categorized as very negative sentiments. Responses that included words such as “indifferent”, or phrases such as “no attitude towards science” were included under the neutral sentiment group. The majority of responses fit within neutral to very positive sentiment groups, where positive sentiment group resulted in the highest number of responses (n = 18) (see Table 23).

Table 23

Sentiments of Household Attitudes Toward Science

Sentiments	Number of Participants	
	Frequency	%
Very negative	2	5.0
Negative	1	2.5
Neutral	11	27.5
Positive	18	45.0
Very positive	8	20.0

Note. N = 40.

Question 2: In your experience, what was the attitude toward science in your community?

There were five themes that emerged from question two. These themes were identified as 1) untrusted, 2) favored, 3) unfavored, 4) mixed, and 5) indifferent. Examples of coded responses that were identified to fit under the theme untrusted were “limited and untrusted” as well as “somewhat skeptical”. Favored responses included “science is big in my community, especially agricultural science” and “it is generally accepted in my community although not often discussed”, while unfavored responses included such as “a little unnecessary but it was just part of school”. Responses that were categorized under the theme of mixed for community attitudes toward science were “a mixture of pro scientific and pseudoscientific people” and “pretty decent except for during the 2 years I spent in Christian school, there they actively denied it. Everywhere else it was pretty good.”. While indifferent responses, for instance, were reported as “not necessarily prominent but not rebuked either” or “there is no attitude towards science in my community. It was just a topic/course”. The majority of participants’ responses were associated with the favored theme (n = 19), with the fewest responses associated with the themes mixed (n = 4) and untrusted (n = 2) (see Table 24).

Table 24

Emergent Themes from Community Attitudes Toward Science

Emergent Themes	Number of Participants	
	Frequency	%
Untrusted	2	5.0
Favored	19	47.5
Unfavored	6	15.0
Indifferent	9	22.5
Mixed	4	10.0

Note. N = 40.

Similar to responses to the question of household attitudes toward science, community attitudes toward science resulted in five sentiments. Those sentiments were negative, slightly negative, neutral, slightly positive, and positive. As above, any response which included degree adverbs in context to a positive or negative were categorized with the extreme ends of the sentiment scale as appropriate. One participant responded with “Limited and untrusted” which was categorized as a very negative sentiment. Responses that included words such as “neutral”, or phrases such as “not very talked about” were included under the neutral sentiment group. The majority of responses were identified to fit within the positive sentiment groups (n = 15), followed by neutral (n = 10), then negative (n = 7), (see Table 25).

Table 25

Sentiments of Community Attitudes Toward Science

Sentiments	Number of Participants	
	Frequency	%
Very negative	2	5.0
Negative	7	17.5
Neutral	10	25.0
Positive	15	37.5
Very positive	6	15.0

Note. N = 40.

Emergent Themes and Sentiments from Sociocultural Experiences

Within the sociocultural experiences block of the survey, two open-ended questions were included. The questions asked participants how education was viewed in their household and/or community as well as what their views were on education. All 41 participants responded to both open-ended questions in this block (N = 41).

Question 1: How was education viewed in your household and/or community?

There were five themes that emerged from question one. These themes were identified as 1) important, 2) respected or valued, 3) competitive, 4) indoctrination, and 5) mixed. The theme important was further sub-categorized into two sub-themes 1a) generally important and 1b) important for opportunity or success. Responses that were identified to fit under the theme important included words such as “positive” or “important”. Responses that specifically identified importance for success or opportunity, such as “it’s a gateway to a better career”, or “very important to pursue in order to gain better opportunities for oneself” were grouped in sub-theme 1b. All other responses identified to fit under the theme important were grouped in sub-theme 1a. Responses that specifically mentioned “respected” or “valued” were grouped under that respective theme. One participant responded that their household and/or community viewed education as “competitive” which warranted its own theme. Indoctrination was mentioned in two participants’ responses. The response that was identified under the theme indoctrination indicated, “my family believes schools indoctrinate kids into being gay/liberal/etc.”, however, the other response that mentioned indoctrination read “an opportunity or indoctrination, depending on the topic” so that particular response was grouped with the theme mixed, along with the response “self led [sic] education was favored in my household. My community preferred Bible study”. The majority of participants reported that their household and/or community viewed education as important (n = 33) (see Table 26).

Table 26

Emergent Themes from Household and/or Community Views on Education

Emergent Themes	Number of Participants	
	Frequency	%
Important	33	80.5
Generally important	29	70.7
Important for opportunity or success	4	9.8
Respected or valued	2	4.9
Competitive	1	2.4
Indoctrination	1	2.4
Mixed	4	9.8

Note. N = 41. Frequencies of the two subcategories of the theme important sum to the overall theme important frequency.

Sentiment analysis resulted in five sentiments related to question one. Those sentiments were very positive, positive, neutral, slightly negative, and negative. Responses which included degree adverbs in context to a positive sentiment were categorized with the extreme end of the sentiment scale as appropriate. Responses that included the word “important” or “respect” as well as participants’ responses such as “it’s a gateway to a better career” and very pro education” were grouped under positive sentiment. Responses such as “Education was seem [sic] as advancement, but not required” and “self led [sic] education was favored in my household. My community preferred Bible study” were classified as neutral sentiments. One participant responded with “An opportunity or indoctrination, depending on the topic” and another reported that “my family believes schools indoctrinate kids into being gay/liberal/etc.”. Both of those responses were categorized as very negative sentiments whereas the former was classified as slightly negative and the latter as very negative. Most responses fit within positive to very positive sentiment groups, where the positive sentiment group resulted in the highest number of responses (n = 21) (see Table 27).

Table 27

Sentiments of Household and/or Community Views of Education

Sentiments	Number of Participants	
	Frequency	%
Very positive	14	34.1
Positive	21	51.2
Neutral	4	9.8
Slightly negative	1	2.4
Very negative	1	2.4

Note. N = 41.

Question 2: What are your views on education?

There were two main themes that emerged from question two. These themes were identified as 1) important, and 2) mixed. The theme important was further separated into four sub-themes. These were defined as 1a) generally important, 1b) general education is important, 1c) important for the future or success, and 1d) important for society or the world. Examples of coded responses that were identified to fit under the theme important were any responses that included words such as “important” or “positive”. For sub-theme 1b, responses “everyone should at least finish high school and heavily consider college” and “I think education is important. Base subjects like English, math, science, and history” were placed under this category. For sub-theme 1c, any response that directly identified education as important for success or for the future was added to this group. Phrases included in sub-theme 1c also included “I want to become educated so I can become a doctor and prove my family wrong, as well as help people” and “investment in the future”. For sub-theme 1d, phrases such as “it is very important, for both the individual, the community, and the world”, “A nessecity [sic] for a sufficient worldview”, and “without education, the world doesn’t continue to survive and evolve” were placed in this group. All other responses that were identified under the theme important, but did not fit into sub-themes 1b, 1c, or 1d, were grouped in sub-theme 1a as generally important. Mixed responses included “it’s beneficial but not necessary”, “if you want it go for it if not that's fine too”, and “it's a good thing to pursue, but it may not be for everyone. Most participants’ responses were associated with the important theme (n = 35) (see Table 28).

Table 28

Emergent Themes from Participants’ Views on Education

Emergent Themes	Number of Participants	
	Frequency	%
Important	35	87.5
Generally important	22	55.0
General education is important	2	5.0
Important for the future or success	5	12.5
Important for society or the world	6	15.0
Mixed	6	15.0

Note. N = 41. Frequencies of the four subcategories of the theme important sum to the overall theme important frequency.

Only three sentiments were identified in the participants’ views on education. Those sentiments were very positive, positive, and neutral. Any responses which included degree adverbs in context to a positive sentiment were categorized with the extreme end of the sentiment scale as appropriate. Examples of responses that were grouped as positive sentiments were "necessary and important", "important to learn new things to better understand people and situations", and "important and integral to society". Responses such as "good thing to pursue, not for everyone" and "beneficial but not necessary" were included under the neutral sentiment group. The majority of responses were identified as positive sentiment groups (n = 18) (see Table 29).

Table 29

Sentiments of Participants' Views on Education

Sentiments	Number of Participants	
	Frequency	%
Very positive	15	37.5
Positive	18	45.0
Neutral	8	20.0

Note. N = 41.

Emergent Themes and Sentiments from Science Literacy Assessments

Within the science literacy block of the survey, open-ended questions were included after multiple choice questions 1, 2, 3, 4, 11, 12, and 13 of the science literacy. The prompt was identical following each question identified and asked participants to briefly explain why they selected the answer that they chose. Across all responses, six themes emerged that related to question-answering strategies. Themes that emerged were 1) effective knowledge organization, 2) guesswork, 3) keyword thinking, 4) process of elimination/deductive reasoning, 5) recognition of elements of scientific method/experimental design, and 6) word knowledge. All participants responded to all open-ended questions (n = 41) except for Question 11 (N = 39) and Question 13 (N = 40).

Examples of responses that related to effective knowledge organization were "using scientists that all support the same idea will have to back-and-forth action with an opposing idea which may lead to biased results in a conducted study", "people who are basing their thoughts not off of data and actual research are just stating opinions with nothing backing their claims, while physical data cannot be disputed", and "the paragraph we read was an overall summary of findings from research conducted by several scientists, which matches the secondary review". These response types showed how participants organized their thinking in order to respond to the question. Responses that aligned with guesswork stated things like "looked good", "idk it just seemed the most right", and "no idea". Keyword thinking, which associated words in the answer choices with words in the question posed were "it says that it came from a MSNBC news report, and the option I selected had the words "media reports" in it", "correlates between mercury and children with autism", as well as "only conclusion that matched previous statements". Process of elimination/deductive reasoning responses were identified as such when participants stated why they did not choose other options. Examples of process of elimination/deductive reasoning responses were "I chose my answer because it made the most sense out of all the other options. Option 2 talks about genes and how it can affect reproduction. I do not have the greatest understanding of science, but from my point of view, genes can affect how your body developed and how your body produces products. Without this gene, it can quite possibly affect reproduction" and "a yearly screening data with immunized and non immunized [sic] autistic children would show a better set of results rather than testing for only blood mercury levels or the rate of autistic children born because those numbers could be accurate but also not be related so it would be better for the yearly screening data". Responses that exhibited recognition of elements of scientific method/experimental design were "if the article was peered reviewed, it would mean that someone has checked the information is true and the results can be replicated if it was done correctly", "it's the only one that uses proper deduction and empiricism to come to a conclusion/hypothesis", and "there is a control and treatment group that was randomly assigned and limits any confounding variables by limiting exercise and weight". Finally, word knowledge responses were related to when participants expressed understanding of words associated with the question and answered seemingly due to prior knowledge of words or concepts associated with the question or answer itself. Examples of word knowledge were "most private schools are based around one religion, so the study should've taken place on a large, diverse campus", "they are biased because of their political beliefs", and "it is good to not assume that drugs will not have bad long term [sic] consequences. If assumed, there is a risk of the drug being recalled and people getting sick".

Analysis of each theme in relation to each question with which it was associated showed differences in frequency of how often the different answering strategies were used by participants. Science literacy assessment Question 1 asked "Which of the following is a valid scientific argument?". The highest frequency of responses was associated with the theme exhibit recognition of elements of scientific method/experimental design (n = 14) followed by process of elimination/deductive reasoning (n = 11) (see Table 30).

Table 30

Emergent Themes from Science Literacy Assessment Question 1

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	8	19.51	4	9.76	4	9.76
Guesswork	3	7.32	3	7.32	0	0.00
Keyword thinking	3	7.32	3	7.32	0	0.00
Process of elimination/deductive reasoning	11	26.83	10	24.39	1	2.44
Recognition of elements of scientific method/experimental design	14	34.15	12	29.27	2	4.88
Word knowledge	2	4.88	2	4.88	0	0.00

Note. N = 41.

Science literacy assessment Question 2 provided an excerpt modified from modified news report from MSNBC .com and asked, "The excerpt above comes from what type of source of information?". The highest frequency of answering technique employed was identified to be keyword thinking (n = 13) followed by effective knowledge organization (n = 12) (see Table 31).

Table 31

Emergent Themes from Science Literacy Assessment Question 2

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	12	29.27	6	14.63	6	14.63
Guesswork	2	4.88	0	0.00	2	4.88
Keyword thinking	13	31.71	10	24.39	3	7.32
Process of elimination/deductive reasoning	2	4.88	0	0.00	2	4.88
Recognition of elements of scientific method/experimental design	4	9.76	0	0.00	4	9.76
Word knowledge	8	19.51	8	19.51	0	0.00

Note. N = 41.

Science literacy assessment Question 3 asked "Which of the following actions is a valid scientific course of action?". The highest frequency of responses was associated with recognition of elements of scientific method/experimental design (n = 16) followed by effective knowledge organization (n = 9) (see Table 32).

Table 32

Emergent Themes from Science Literacy Assessment Question 3

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	9	21.95	7	17.07	2	4.88
Guesswork	5	12.20	4	9.76	1	2.44
Keyword thinking	1	2.44	1	2.44	0	0.00
Process of elimination/deductive reasoning	7	17.07	7	17.07	0	0.00
Recognition of elements of scientific method/experimental design	16	39.02	16	39.02	0	0.00
Word knowledge	3	7.32	3	7.32	0	0.00

Note. N = 41.

Science literacy assessment Question 4 provide four research study examples and asked, “Which of the following research studies is least likely to contain a confounding factor (variable that provides an alternative explanation for results) in its design?”. The majority of responses were identified to be associated with effective knowledge organization (n = 17) followed by process of elimination/deductive reasoning (n = 8) (see Table 33).

Table 33

Emergent Themes from Science Literacy Assessment Question 4

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	17	41.46	5	12.20	12	29.27
Guesswork	3	7.32	1	2.44	2	4.88
Keyword thinking	2	4.88	0	0.00	2	4.88
Process of elimination/deductive reasoning	8	19.51	6	14.63	2	4.88
Recognition of elements of scientific method/experimental design	7	17.07	7	17.07	0	0.00
Word knowledge	4	9.76	1	2.44	3	7.32

Note. N = 41.

Science literacy assessment Question 8 stated "Creators of the Shake Weight, a moving dumbbell, claim that their product can produce "incredible strength!"" and asked, "Which of the additional information below would provide the strongest evidence supporting the effectiveness of the Shake Weight for increasing muscle strength?". Most responses were grouped under process of elimination/deductive reasoning (n = 12) followed by effective knowledge organization (n = 8) as well as word knowledge (n = 8) (see Table 34).

Table 34

Emergent Themes from Science Literacy Assessment Question 8

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	8	19.51	6	14.63	2	4.88
Guesswork	5	12.20	2	4.88	3	7.32
Keyword thinking	6	14.63	5	12.20	1	2.44
Process of elimination/deductive reasoning	12	29.27	11	26.83	1	2.44
Recognition of elements of scientific method/experimental design	2	4.88	2	4.88	0	0.00
Word knowledge	8	19.51	3	7.32	5	12.20

Note. N = 41.

Science literacy assessment Question 11 asked participants to select "The most important factor influencing you to categorize a research article as trustworthy science is:". The highest frequency of responses was associated with effective knowledge organization (n = 15) followed by word knowledge (n = 12) (see Table 35).

Table 35

Emergent Themes from Science Literacy Assessment Question 11

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	15	36.59	9	21.95	6	14.63
Guesswork	3	7.32	2	4.88	1	2.44
Keyword thinking	1	2.44	0	0.00	1	2.44
Process of elimination/deductive reasoning	5	12.20	4	9.76	1	2.44
Recognition of elements of scientific method/experimental design	3	7.32	3	7.32	0	0.00
Word knowledge	12	29.27	4	9.76	8	19.51

Note. N = 39.

Science literacy assessment Question 12 asked participants to select "Which of the following is not an example of an appropriate use of science?". Similar to Question 11 grouping, for Question 12 responses most of responses were associated with effective knowledge organization (n = 15) followed by word knowledge (n = 11) (see Table 36).

Table 36

Emergent Themes from Science Literacy Assessment Question 12

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	15	36.59	13	31.71	2	4.88
Guesswork	6	14.63	1	2.44	5	12.20
Keyword thinking	2	4.88	2	4.88	0	0.00
Process of elimination/deductive reasoning	4	9.76	2	4.88	2	4.88
Recognition of elements of scientific method/experimental design	3	7.32	2	4.88	1	2.44
Word knowledge	11	26.83	8	19.51	3	7.32

Note. N = 41.

Science literacy assessment Question 13 stated "A researcher hypothesizes that immunizations containing traces of mercury do not cause autism in children" and asked, "Which of the following data provides the strongest test of this hypothesis?" The majority of responses were identified to be associated with effective knowledge organization (n = 13) followed by recognition of elements of scientific method/experimental design (n = 11) (see Table 37).

Table 37

Emergent Themes from Science Literacy Assessment Question 13

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	13	31.71	10	24.39	3	7.32
Guesswork	5	12.20	4	9.76	1	2.44
Keyword thinking	3	7.32	1	2.44	2	4.88
Process of elimination/deductive reasoning	2	4.88	2	4.88	0	0.00
Recognition of elements of scientific method/experimental design	11	26.83	11	26.83	0	0.00
Word knowledge	6	14.63	4	9.76	2	4.88

Note. N = 40.

Analysis was also performed in order to assess the frequency of themes of each of the question-answering strategies across all responses to questions with associated open-ended questions (N = 325). The most used question-answering strategy was identified as effective knowledge organization (n = 97). The next most used strategy was recognition of elements of scientific method/experimental design (n = 60). The least number of instances for question-answering strategy was keyword thinking (n = 31) (see Table 38).

Table 38

Emergent Themes from All Science Literacy Assessment Combined

Emergent Themes	Number of Instances		Correct Responses		Incorrect Responses	
	Frequency	%	Frequency	%	Frequency	%
Effective knowledge organization	97	29.85	60	18.46	37	11.38
Guesswork	32	9.85	17	5.23	15	4.62
Keyword thinking	31	9.54	22	6.77	9	2.77
Process of elimination/deductive reasoning	51	15.69	42	12.92	9	2.77
Recognition of elements of scientific method/experimental design	60	18.46	53	16.31	7	2.15
Word knowledge	54	16.62	33	10.15	21	6.46

Note. N = 325.

Further analysis identified that the use of the theme recognition of scientific method/experimental design resulted in the highest percentage of correct response relative to the frequency of the strategy employed (99.33%) (see Table 39).

Table 39

Percent of Instances of Correct versus Incorrect Responses for Emergent Themes

Emergent Themes	Number of Instances	Correct Responses	Incorrect Responses
	Frequency	%	%
Effective knowledge organization	97	61.86	38.14
Guesswork	32	53.13	46.88
Keyword thinking	31	70.97	29.03
Process of elimination/deductive reasoning	51	82.35	17.65
Recognizes elements of scientific method/experimental design	60	88.33	11.67
Word knowledge	54	61.11	38.89

Note. N = 41.

Critical Discourse Analysis

Following initial qualitative analysis of all open-ended survey responses, critical discourse analysis (CDA) was performed. For this round of CDA, all rounds of coding as well as the original responses were assessed specifically for words or phrases that could be related to instances of identity, agency, and/or power (IAP). Within the previous science experience section as well as the sociocultural experience section, CDA was applied in a manner to carefully identify the participants' responses where language used could be representative of IAP. In regard to the science literacy assessment section, CDA was applied to identify instances where participants recognized IAP in the science literacy questions and/or answer choices themselves. For deeper understanding and the ability to concretely separate out relations to identity, agency, or power, per the participants' responses, follow-up data collection would be necessary. As follow-up data collection was not possible due to the nature of this study, all responses that had words or phrases related to IAP were coded collectively as such. All instances of IAP that resulted from this analysis are reported below.

Identity, Agency, and Power in Previous Science Experiences

In the previous science experiences block of the survey, responses to the two open-ended questions were included. The questions asked participants from their experience what the attitudes toward science were in their household and community. Each response was carefully assessed for IAP (N = 41). The first question which asked, “In your experience, what was the attitude toward science in your household?” resulted in nine instances of IAP. The second question asked, “In your experience, what was the attitude toward science in your community?” and had 12 instances of IAP (see Table 40).

Identity, Agency, and Power in Sociocultural Experiences

Responses to the two open-ended questions in the sociocultural experiences block of the survey were assessed for instances of IAP following the same method that was employed for the previous science literacy responses (N = 41). The questions asked participants from their experience what their household and/or community attitudes as well as their own attitudes toward education were. The first question which asked, “How was education viewed in your household and/or community?” resulted in 16 instances of IAP. The second question asked, “What are your views on education?” and had 15 instances of IAP (see Table 41).

Table 40

Instance of Identity, Agency, and Power in Previous Science Experience Responses

Previous Science Experience	Language from Participants' Responses
Question 1	
	...both of my parents are in the science field
	Computer Scinece [sic] was a win…
	Lots of pseudoscience and incorrect science
	Learning science...was very important
	...to be looked at as truth…
	I was about the only one good at it.
	extremely praise-worthy, typical indian [sic] household mindset
	My family was full of religious nuts who believe science is a hoax made up by liberals.
	...everyone supports science and the CDC as well as my major.
Question 2	
	Limited and untrusted
	a mixture of pro scientific and pseudoscientific people.
	very in touch with natural sciences
	Science is big in my community, especially agricultural science
	Somewhat skeptical
	More on the positive, but a little frightened on how science is advancing.
	very impressive and praised
	Not very good.
	Very negative
	More religious based then science
	...in Christian school, there they actively denied it…
	Passionate

Table 41

Instance of Identity, Agency, and Power in Sociocultural Experience Responses

Sociocultural Experience	Response
Question 1	
	Self led [sic] education...Bible study.
	...valued towards our future and getting further in life…
	very pro education
	Very important for success
	It was viewed as very important/highly valued
	An opportunity or indoctrination…
	Very important to pursue in order to gain better opportunities for oneself.
	Important to be successful
	It’s a gateway to a better career
	...high importance...it was almost a requirement to attend college
	continue onto the college style
	Highly sought after
	...a priority
	... viewed as something that is important and very much needed
	Top priority
	...schools indoctrinate kids into being gay/liberal/etc. I do not believe them.
Question 2	...very important to your future…stepping stone [sic] towards jobs and to an extent, money…
	...very important, but the system in the US is trash.
	For specialized success it can open a lot of doors in your future
	...extremely important and should be accessible to all
	I want to become educated so I can become a doctor and prove my family wrong, as well as help people. I love going to school!
	...very important, for both the individual, the community, and the world
	...necessary and important
	...it is important to always learn new things so that you as a person are able to better understand the people around you and their situations.
	Positive, everyone should have a right to good education
	beneficial and necessary to survive
	everyine [sic] should be able to reach some type of higher education after completing highschool [sic] or obtaining their GED...very important for every individual…
	...very important in order to be successful
	...important and is integral to society
	...completely necessary for everyone to have at least a highschool [sic] education...higher education should be more accessible and affordable.

Identity, Agency, and Power in Science Literacy Assessment Responses

In this section, CDA was applied as it was in the previous two sections, however, a different approach was employed to account for instances of identity, agency, and power that participants identified in the science literacy questions associated with open-ended responses. The responses were evaluated for each question that had an associated open-ended response option (N = 325). Instance of IAP were tallied across each respective question (see Table 42). A total of 56 instances of IAP identification were found across all responses.

Table 42

Instance of Identity, Agency, and Power in Open-ended Science Literacy Responses

Science Literacy	Number of Instances	Example of Identified IAP
Question 1a	0	n/a
Question 2a	4	sometimes the way they represent the news is skewed towards their way of thinking or as a way to garner public attention.
Question 3a	9	The other ones weren't based on solely science, there were other political factors as well…
Question 4a	4	Going to a private institution in a region known for it's [sic] religiousness is a great way to skew results.
Question 8a	0	n/a
Question 11a	17	Reputation is subjective, publishers can be bought, data can be forged or mislabeled
Question 12a	22	Using science to prove something to advance someone's political beliefs make the data biased and it is corruption on the government.
Question 13a	0	n/a

Chapter 5 Discussion

In this chapter I discuss the findings of my survey which examined previous science experiences, sociocultural experiences, and science literacy assessment outcomes of traditional first-year college students. I will discuss the findings for each individual section of the survey employed. Furthermore, I discuss the relationships found within the results from this study which address the proposed research questions. I present implications for future research within this area of study. Additionally, I provide limitations of this research to be considered.

Review of the Purpose of Research and Research Questions

The purpose of this study was to gain a deeper insight into factors that may play a role in how students and citizens engage with scientific information. Factors examined were previous science experiences, as well as social and cultural factors from participants' lived experiences. This study aimed to assess what sociocultural factors may influence aspects of science literacy. Some of the sociocultural factors explored were environments in which the student was raised, cultural experiences, traditions, and beliefs within the community, at home, and at school. Due to the limited amount of research has been done on influences of sociocultural experience in science education as well as the lack of any published studies that have utilized critical sociocultural research in science literacy to date, the findings of this study can be applied to more directed areas of study in order to gain even greater insight and understanding of the roles sociocultural factors, and instances of identity, agency, and power, play a role in relation to science literacy. To evaluate the relationships between previous science experiences, sociocultural experiences, and science literacy assessment outcomes, the following research questions were asked:

A. *How do previous science experiences relate to students' science literacy?*

B. *What sociocultural factors correlate to students' science literacy scores?*

Participants' Demographics

The nature of this study was to assess differences in previous science experiences as well as social and cultural experiences of traditional first-year college students and how they relate to science literacy assessment. Due to the limitations of this study being conducted at a single university in one region of the country, and data collection being performed through anonymous survey, there was no way to ensure a diverse sample group of participants representative of the population. First it was important to establish whether or not there was a variety of demographic identities represented within the research. It has been identified that historically underrepresented groups do not seek out STEM-related studies at the same frequency as those who hold dominant identity characteristics (Ketenci et al., 2020). Additionally, it has been found that difference in demographics have played a role in retention within STEM-related disciplines, whereas individuals who hold non-dominant identities do not obtain degrees in STEM at the same rate as those whose demographics align with the dominant group (Costello et al., 2023).

The findings from the demographic section of this study did show a variety of demographic information for participants who completed the survey which allowed for confidence in overall results due to a more overall representative sample ($N = 41$). While the majority of participants were enrolled in an introductory biology course ($n = 26$) and were science majors ($n = 22$), there were still nearly half of participants who selected that they were pursuing majors that were not science. This was valuable, as participants were given a science literacy assessment. If an overwhelming number of students had been strictly science majors, the potential outcome of how science literacy related to other factors investigated within this study could have been unfairly biased due to a larger number of participants being more geared toward a future that involved a science endeavor. This also added to the richness of this study as it expanded on the previous understanding of science literacy by including roughly half of the sample who were non-science majors. In regard to identity demographics, the majority identified as white (n = 30), not of Hispanic, Latino/a/x, or of Spanish origin (n = 35), American nationality (n = 31), female (n = 22), apolitical (n = 11), and able-bodied (n = 40). For the non-majority demographic results, other than ability, there were a variety of different demographic responses identified which supported evidence of a diverse sample group for this study.

There were a few participants identified as holding more than one identity when it came to race (n = 5) and nationality (n = 1). Because of the location of the university from which participants were pooled for this study, it was expected that the majority of participants would identify as having American or U.S. citizens nationality. Having several participants identify as holding nationalities other than American or U.S. citizen was able to enrich the findings of this study due to a greater possibility of various social and cultural experiences (Gipps, 1999).

The expanded response options for the demographics section of this survey also allowed for greater representation of both gender identity and sexual orientation within these findings. By including greater selection options in an anonymous survey, participants may have felt more inclined to answer honestly about gender identity and sexual orientation without fear of social repercussions (Dillbary, & Edwards, 2019; Schmader & Block, 2015; Wood & Eagly, 2015).

Participants' Previous Science Experiences

Previous science experiences were examined in order to gain a greater understanding of areas in which may account for science literacy assessment outcomes and how these may be in relation with sociocultural experiences. Also, data collected within this section aimed to ensure that there was not a monolith of previous science experiences represented by the participants of this study. The majority of participants identified as being a science person (n = 28) as well as having been an active participant in previous science classes on occasions (n = 26). Most participants had taken three to four science courses during their high school career (n = 23), which is the average amount of courses typically expected if a student takes one science course per year in a typical four-year high school duration. The majority had never had a negative experience while discussing science, either inside or outside of the classroom (n = 25). In regard to the extent in which the participants perceived that their views of science were influenced by their household and/or community's views toward science, the majority reported that they felt that their views had not much been influenced by their household and/or community, however, approximately one-third of participants felt strongly that their views had been influenced by their household's and/or community's views on science. This is reflected by work done by Dabney et al. (2013) that identified that family influence does play a role in whether or not a child within the household becomes interested in science. However, their research was limited to younger children and did not identify if early childhood interest resulted in a lifelong interest in science. This study added to the understanding of how young adults perceived influence from their families and communities on their own views of science.

Further examination of the previous science experiences probed in this study showed that the majority of participants felt as though creativity was fostered (n = 22) and that critical thinking was valued (n = 27) in previous science courses. Daud et al. (2012) identified the importance of science education to foster greater creativity in both its discipline and its implementation in order to keep up with global demand as a factor to generating new knowledge.

Creativity has also lent itself to engagement within science learning. As there has been a push to include art, moving STEM to STEAM, studies have shown that creativity can be a motivating factor for engagement, enjoyment, critical thinking, and problem solving within science (Blatti et al., 2019; Conradty & Bogner, 2019; Elvianasti & Dharma, 2021). High school resulted in the highest-ranking outcome for both overall science experience (M = 7.61) as well as the extent to which participants found science courses to be the most engaging (M = 7.63). This could indicate that science teachers are better equipped to teach science in a more impressionable way than elementary and middle school science. This has implications in pre-service teacher education where confidence in science teaching and exploration into more engaging activities can be.

Household attitudes toward science were mostly identified as supportive (n = 24). There was a slight shift in community attitudes toward science when compared to household attitudes toward science. Community attitudes toward science differed in that they were identified to be mostly favored (n = 19), while there were more instances of unfavored, untrusted, or indifferent attitudes toward science. Less than 50% of community attitudes favored science, while the equivalent amount had attitudes toward science that were unfavored, indifferent, and mixed. Sentiment analysis of attitudes toward science reflected thematic analysis in that there were more responses that aligned with positive and very positive sentiments within household attitudes toward science and a shift was seen to more neutral or negative attitudes toward science within community attitudes toward science. A perception of more negative attitudes toward science in communities as opposed to household may be a result of the digital age, where there is a large amount of negative rhetoric surrounding certain scientific topics, such as global warming and pandemics. Households may be able to insulate against negative rhetoric, especially if topics such as science are discussed in home environments.

There were also reports of communities being untrusting toward science. This has become an increasing trend that has become much more visible since the beginning of the COVID-19 pandemic (Del Corona, 2021; Priniski & Holyoak, 2022). Negative feelings and sentiments surrounding science and scientific data that is being reported have continued to be a hot-button issue. There are also reports that have shown that there is an overall growing trend in distrust of media and news outlets (Ladd, 2013; Suiter & Fletcher, 2020; Ternullo, 2022). Further complicated by the growing trend for people to rely solely on social media for their news and information, this could lead to an even greater drastic increase in mis- and disinformation (Johnson & Kaye, 2015; Shu et al., 2017).

For students that are between the ages associated with early childhood education to Grade 12, there is more of a potential influence from their household than their community (Dabney et al., 2013). Households environments have the capacity to insulate negative influence from the outside world. However, household attitudes that differ greatly from, may also have a negative impact on feelings/ relevance toward science, especially if the core values within the household align with a religious, political, or cultural group that does not advocate for or actively denies science.

Participants' Sociocultural Experiences

Sociocultural experiences play a role in our everyday lives, whether we are aware of it or not. They influence our identity, our decisions, and how we see and interact with the world around us (Jessee, 2016; Simonton, 2014). I examined sociocultural experiences of participants in order to identify factors that may play a role in science literacy. Similar to the previous science experiences section, findings from the data collected within this section showed that there was a variety of different sociocultural experiences represented in this study. By ensuring a diverse set of sociocultural experiences, I was better situated to identify areas where there were relationships with sociocultural experiences and science literacy assessment outcomes.

The majority of participants identified as Christian (n = 21). This was expected as Christianity is the reported as the largest religion in the United States. Results from this study showed that 22% of participants reported as being atheist, which is a much higher percentage than what has historically been reported for the United States. A study conducted by Van Tongeren et al. (2021) reported that people who report as non-religious now make up the third most populated group regarding religious identities. However, caution is taken to note that shifts in attitudes toward religion, or those departing religion-affiliated groups, do not indicate religious intolerance. Religious intolerance tends to be most represented between different religious groups and can lead to escalated violence and acts of harm (Dauda, 2020). While some findings from the previous science experience section of this study did have elements of intolerance for science due to religious beliefs, which I discuss below.

In regard to the household environments of participants, it was found that the majority of participants lived in a household where only one language was spoken (n = 32), had household responsibilities such as chores (n = 24), and did not live in a multigenerational home (n = 33). While multigenerational households used to be more commonplace, the increase in the single nuclear family model has become the standard of living for a large proportion of residents within the United States (Lesthaeghe, 2014; 2020). The decline of multigenerational households may influence the degree to which cultural traditions are practiced or passed down among generations. However, multigenerational households are not the sole way in which cultural traditions and understandings that impact ways of knowing are imparted onto younger generations (Taber, 2020; Wetzel et al., 2019).

Further household environment findings determined that most participants came from a household where the highest level of education within their household was either a Bachelor's degree (n = 14) or a Graduate or Professional degree (n = 14). The extent to how much a caretaker within a household who holds a higher degree influence whether or not the student matriculates to college themselves is not well understood. However, Hung et al. (2019) showed that in the South and Southwest, race disparities in alignment with household education contributed to educational achievement gaps. There have been reports that discuss the influence that parents or caretakers have on student's decision to continue on to college after completing high school, such as socioeconomic resources or ideas about a more prosperous future for the student (Blandin & Herrington, 2022; Ruiz Alvarado et al., 2020).

Community aspects of sociocultural experiences identified that the majority of participants lived in suburban communities (n = 22) and were involved along with their families in community activities (n = 27). School aspects of participants sociocultural experiences shared commonalities of the community aspects reported as the majority of participants identified that the type of community that the school they attended was located in a suburban community (n = 23) and most participants attended a traditional public school (n = 34). The majority of participants were involved in extracurricular activities. Extracurricular activities may be another area where students' ideals and beliefs can be influenced or reinforced, such as an after-school science program, sports program, or language club.

Participants' views on education appeared to shift to a more positive overall view as opposed to results of household or community views on education. While in both cases, views on education were deemed to be important by the majority, instances of indoctrination were mentioned in response to household or community views on education, where the participants' views on education did not reflect that. Sentiments within household or community's views toward education were found to range from very negative to very positive, however, participant sentiments toward education showed to only range from neutral to very positive. The shift may be due to the fact that all participants are enrolled in their first year of college and so by pursuing higher education, they may hold higher esteem for education in itself. There were also many instances where participants identified education as important to their future success. One participant responded,

> My views on eduaction [sic] is that everyine [sic] should be able to reach some type of higher education after completing highschool [sic] or obtaining their GED. I think that education is very important for every individual no matter what their future career may end up being

and another wrote "It's there for a reason. To learn and apply those practices to outside sources. Without education, the world doesn't continue to survive and evolve. It' extremely important to do good in education". However, not all participants identified education as being the end-all for every person, as there were multiple instances where responses indicated that education was good for those who wanted to pursue it, such as one participant who answered, "if you want it go for it if not that's fine too" and another reported, "It's a good thing to pursue, but it may not be for everyone". It was also recognized that a four-year college was not the only type of educational avenue that was available as one participant responded, "It is extremely important although there are many different avenues towards a quality education (college, trade school, apprenticeship)". In a landscape where the importance of education has seemed to be reinforced by the transition of high school education programs to be almost exclusively college-track programs, the idea that college is not for everyone from this group of students indicates that there may be a shift in perspective for future generations.

Participants' Science Literacy Assessment Outcomes

Results from the science literacy assessment showed a very wide range of science performance. The overall outcome of science literacy assessment scores out of 14 possible ranged from the lowest score being one and the highest score being 14 with a mean score of 9.5. It should be taken into consideration the very real impact and disruption that the COVID-19 pandemic had on learning gains across all levels of education (see Grewenig et al., 2021; Kwakye & Kibort-Crocker, 2021; Middleton, 2020). Students that were evaluated in this study would have been impacted by the pandemic due to their age and the fact that they were traditional first year college students during the 2022-2023, or 2023-2024 academic year.

The scientific literacy skill area that resulted in the highest percentage of correct responses was evaluation of use and misuse of scientific information (92.68%) followed by problem solving using quantitative skills. The scientific literacy skills area that resulted in the lowest percentage of correct responses was justification of inferences, predictions, and conclusions based on quantitative data (43.90%).

Question-answering strategies were identified in all responses to the embedded question which asked participants why they answered a specific question the way they did (N = 325). Strategies identified were 1) effective knowledge organization, 2) guesswork, 3) keyword thinking, 4) process of elimination/deductive reasoning, 5) recognition of elements of scientific method/experimental design, and 6) word knowledge. While the most used strategy varied per individual question, it was found that the most used question-answering strategy overall was effective knowledge organization (29.85%). This strategy also resulted in the highest percentage of correct responses overall (18.46%). Recognition of elements of scientific method/experimental design was the strategy that was employed at the second highest percentage (18.46%) and resulted in the second highest percentage of correct responses (16.31%). This highlights the importance of increasing science literacy in how it helps to approach scientific information. Furthermore, this gives insight into how students approach assessments. The use of multiple other strategies, such as keyword thinking or process of elimination showed the use of test-taking strategies, which does not result in a clear picture of science literacy outcomes based on assessment results alone. Test-taking strategies are often taught through tutoring sessions or test preparation courses that tend to be costly, which implies another source of inequity where people with greater means are able to perform better on assessments.

Relationships between Science Literacy Assessment Scores and Previous Science Experiences

When previous science experience data were analyzed against science literacy assessment scores, there were five previous science experience categories that resulted in no relationship with science literacy assessment. Those were 1) overall previous middle school science experience, 2) overall elementary school science experience, 3) engaging high school science experience, 4) engaging middle school science experience, and 5) whether or not a participant had ever had a negative experience while discussing science. According to the Cohen (1988) stipulations, a Pearson's correlation value of less than 0.3 indicated a weak relationship, a Pearson's correlation value of 0.3-0.49 indicated a moderate relationship, and a Pearson's correlation value of 0.5 or greater indicates a strong relationship. When science literacy assessment scores were analyzed against previous science experiences using bivariate correlation analysis, no strong relationships were identified. There were seven instances of weak relationships identified. Those were 1) whether or not the participant considered themself a science person, 2) the number of science courses taken during high-school, 3) Whether or not the participant was an active participant in previous science courses, 4) overall high school science experience, 5) engaging elementary school science experience, 6) whether or not the participant felt that critical thinking was valued in previous science courses, and 7) the extent to which the participant felt that their household and/or community influenced their own views on science. Only one area resulted in Pearson's correlation of 0.3 or greater with a p-value of 0.02, indicating a moderate relationship with statistical significance. The moderate relationship identified was between science literacy assessment scores and previous science experiences that fostered creativity. General linear regression analysis confirmed these findings as the ANOVA generated a significance value of 0.02, which indicates statistical significance, and the R-square value that resulted was 0.13. This may indicate that when creativity is employed in science learning spaces, a stronger understanding of the processes that are being explored is allowed to take shape. When students are able to approach problems with creativity, this could indicate that curiosity is also more welcomed in those learning spaces. Encouraging creativity in science learning spaces may lead to deeper and more meaningful explorations of science topics by our students. This relationship should be further explored as there is evidence that employment of creativity within school instruction supports stronger learning outcomes (see Benedek & Fink, 2019; Daud et al., 2012; Hanif et al., 2019; Supena et al., 2021). The findings within this section contribute to a deeper understanding that previous science experience alone cannot account for science literacy outcomes.

Relationships between Science Literacy Assessment Scores and Sociocultural Experiences

Cohen (1988) stipulations were also applied to Pearson's correlation values that resulted from bivariate correlation analysis when science literacy assessment scores were analyzed against sociocultural experiences. Similar to analysis against previous science experiences, no strong relationships were identified. Only three sociocultural aspects resulted in no relationship to science literacy assessment. Those were 1) the number of languages spoken within the household, 2) whether or not the participant grew up in a multigenerational household, and 3) household responsibilities of the participant. There were eight sociocultural aspects that resulted in a weak relationship with science literacy. Those were identified as 1) race, 2) ethnicity, 3) nationality, 4) political affiliation, 5) the highest household education level, 6) the type of community in which the participant was raised, 7) participant and family involvement in community activities, and 8) the type of community the school in which the participant attended was located. However, among all sociocultural variables analyzed, six identifiers resulted in a Pearson's correlation of 0.3 or greater. Only three identifiers resulted in a p-value of < 0.05, which indicated a strong confidence in the relationship, while the other three identifiers resulted in p-values between 0.06 and 0.12 indicating medium confidence in the resulting Pearson's correlation values. The moderate relationships with high confidence identified were sexual orientation, ability, and religious affiliation. All participants except for one indicated that they were able-bodied, and therefore correlation analysis was not reliable for that variable. Purposeful sampling and a deeper investigation into ability and how it relates to science literacy should be investigated. Both sexual orientation and religious affiliation resulted in positive correlations with science literacy. Results indicated that science literacy assessment scores were higher for participants who identified as something other than straight/heterosexual. Similarly results suggested that science literacy scores are lower for students who identified as Christian. Moderate relationships with medium confidence identified were gender, type of school attended, and extracurricular activity involvement. Gender and type of school resulted in positive correlations while involvement in extra-curricular activities resulted in a negative correlation. Similar to sexual orientation outcomes, there was a relationship of an increase in science literacy outcomes participants who identified as having a gender identity other than male. Gender and sexual orientation results may indicate that those who hold identities other than heteronormative may be inclined to question or push back against the status quo and not just accept information as is. The positive relationship between the type of school attended and science literacy outcomes showed higher scores were associated with participants who attended private school. This is supported by our understanding that higher socioeconomic status has been shown to be positively related to science and mathematics outcomes (Broer et al., 2019). As private schools tend to be costly and not an option for all students, this highlights a continued perpetuation of inequity in education. The negative correlation of the relationship between extra-curricular activities and science education could point to participants having interests other than science and therefore spending more of their time engaged with activities that did not support science literacy. While we know that science education is Eurocentric in nature and science spaces have been designed to uphold the ideals of the dominant culture, evidence from this study suggests that certain dominant identity characteristics could negatively impact science literacy. This could indicate that in a world that is designed for the success of those whose identities align with the dominant culture, there is a negative impact on the skills required for science literacy. In contrast, those who attended private schools, and therefore are more likely associated with higher social classes may have an advantage in regard to their science education. This provides additional evidence that there is still inequity in science education, as well as a need for more inclusive and representative science education. Similar to how it has been shown that sociocultural experiences have contributed to differences in science education, these findings provide evidence that sociocultural experiences also impact science literacy outcomes as well (Allum et al., 2018; Anaya et al., 2022; Rivera Maulucci, 2010).

When identity characteristics were grouped as dominant (white, cis, heteronormative, an American citizen, not of Hispanic, Latino/a/x, or of Spanish origin) and non-dominant characteristics and analyzed against science literacy assessment outcomes, bivariate correlation analysis resulted in a weak relationship. Interestingly, when Christianity was added to the dominant identity characteristics group, analysis resulted in a positive moderate relationship, that is participants who identified as Christian had lower science literacy outcomes than participants who did not identify as Christian. Furthermore, general linear regression analysis confirmed these findings. These results provided greater evidence that students who hold dominant identity characteristics, to include Christianity are at a disadvantage to science learning, even in a system where curriculum was designed to give advantage to those who hold dominant identities (Le & Matias, 2019; Martin, 2019; Sawyer & Waite, 2021). This is further supported as it has been identified that religious beliefs within a household do influence science beliefs, however, the type of influence differs based on religious denomination or affiliation (Jensen et al., 2021).

Identity, Agency, and Power within Previous Science Experience, Sociocultural Experiences, and Science Literacy

Critical discourse analysis (CDA) was carefully applied to all open-ended responses embedded within the survey. A reflexive and reflective process was used to identify words and phrases within participants' responses that conveyed any instance of identity, agency, and/or power (IAP). Within the responses investigated, instances of both micro-relational and macro-relational influences of IAP were identified. As there was no way to follow-up with the participants and further analyze the meaning of their responses, or to a greater extent separate out what could be identified as identity versus agency versus power, all instances identified within were grouped together. As systems of power often operate invisibly to the general public, perpetuation of harm and oppression continues to occur in everyday life with limited understanding or interference. In order to make effective changes within any system or institution, critical evaluation and critique is necessary. Social and cultural environments, such as education, legal systems, and churches are examples of areas that have more often leant themselves to critical analysis and critique as they have long been identified to be spaces that maintain the status quo and have of extensive elements of power associated with them. Science spaces should be no exception. While often thought to be objective in nature, science education and science disciplines have continued to uphold Eurocentric ways of knowing as well as perpetuate harm.

Within previous science experiences, a total of 21 instances of IAP were identified within responses to the question, "In your experience, what was the attitude toward science in your household?" and "In your experience, what was the attitude toward science in your community?". Examples of words and phrases flagged for instances of IAP include, "...in Christian school, there they actively denied it…" as well as "My family was full of religious nuts who believe science is a hoax made up by liberals", which demonstrates active denial of science due to religion powers, which can also be associated with identity as well as affect a student's agency over their own beliefs or expression. Other examples were "…extremely praise-worthy, typical indian [sic] household mindset" as well as "Science is big in my community, especially agricultural science". While the latter two example do not necessarily represent a negative view on science, there are elements of IAP shown in that a community as a whole, that represents certain feelings and attitudes toward a subject can have unintended consequences of power assertion.

Responses to the questions in the sociocultural experiences section of the survey "How was education viewed in your household and/or community?" and "What are your views on education?" resulted in a total of 31 instances of IAP. Instances if IAP were recognized in responses such as "Self led [sic] education...Bible study" and "...schools indoctrinate kids into being gay/liberal/etc. I do not believe them". While these showed very clear instances of IAP that perpetuate oppression and harm, there are also less innocuous responses such as "top priority", "Very important to pursue in order to gain better opportunities for oneself", and "Highly sought after". Pressure and ideas of success based on education alone can also perpetuate harmful believes and practices, especially given the influence of educational institutions and the ever-increasing pressure to be successful in ways that seemingly align solely with Eurocentric ways of recognizing success. These examples showed that there was a presence of IAP, however, it is unclear as to whether the participants recognized the potential influences that they were describing in most instances.

The science literacy assessment open-ended responses (N = 325) were evaluated slightly differently, as the question prompt did not ask specifically about participant views, experiences, or perceptions, but simply why they answered a science literacy question the way that they did. Responses that contained language that could be related to the participant identifying instances of IAP within the science literacy questions themselves were identified and separated out for further analysis. Responses were then meticulously evaluated against the science literacy question itself to ensure the response was flagged appropriately for IAP. There were 56 instances of IAP identified in participant responses. Examples of words and phrases which were identified as being associated with IAP were when participants pointed out potential bias due to political affiliation, corruption, or religion.

It is important to remember that science funding, education, and research is not immune to pressures from systems of power. Just as it is important for researchers to identify and critique systems of power and oppression, it should also be considered and an important skill for students to be able to recognize these as well (Catalano & Waugh, 2020). Recognition of instances of IAP in play within real-world situations could be a valuable tool to help combat mis-and disinformation (Igwebuike & Chimuanya, 2021).

Implications for Future Research

Findings from this research lay the groundwork for future studies into how sociocultural experiences influence science literacy. Additionally, findings from areas of strengths and weaknesses in responses can help guide science educators in areas within science education that could use greater attention. Relationships were identified among multiple sociocultural factors and science literacy outcomes. In this study, those factors were identified as gender, sexual orientation, religious affiliation, type of school attended, and involvement in extra-curricular activities. Studies that employ a greater qualitative approach to the identified relationships could expand our understandings of the nuanced influences that play a role in how our students make meaning of scientific knowledge. Further research that includes more collaborative methods with participants involved, such as interviews, follow-up questions, and/or inviting the participant to work with the researcher in the analysis phase could ensure a more complete representation of participant responses and lead to a deeper understanding of the nuances of sociocultural experiences.

Due to the limitations of this research, strong associations were unable to be identified. It could be argued that by employing the methods described within this research to a larger, more diverse sample group, stronger associations between sociocultural factors and science literacy could emerge. Furthermore, initial findings of this study could guide researchers to employ purposeful sampling methods and more thoroughly investigate the sociocultural factors that were identified to be in relation to science literacy outcomes.

Limitations of this Research

Limitations of this research include that data was only collected at single public university in one region of the United States. The pool of potential participants may have had similar upbringings and backgrounds based on where they decided to attend college due to location, admission, and/or convenience, as most students who attend public universities are from the same state in which the university is located. Employing this research at multiple different universities across the United States could garner greater insight into sociocultural factors that could influence science literacy.

This study was also limited in size in that it only had 41 participants who completed the entire survey. A larger sample size could provide a richer data set with which to answer the questions posed in this study. Additionally, as the survey deployed was anonymous, there was no way to follow-up with the participants to ask deeper probing questions in regard to their responses, or to follow-up to can clarity and confirmation of how their results were interpreted. Lastly, this research was limited to a single point in time in the students' academic career, as only traditional first-year students were eligible to participate in this research. A longitudinal study of participants over time as their college journey continues could lend itself to identifying if shifts from household influences on students' attitudes toward science and education to a greater influence from the surrounding community occur over time, or how the knowledge gained in post-secondary school contributed to their science literacy.

Conclusion

This research provided evidence that while there was one moderate relationship area identified between previous science experiences and science literacy outcomes, there were a greater number of relationships identified between sociocultural factors and science literacy. Findings from this research indicate that influences that affect the science literacy of our students are not solely based on classroom learning. Social and cultural factors such as gender, sexual orientation, religion, type of school the student attended, and involvement in extracurricular activities were found to correlate to science literacy outcomes. However, due to the small sample size and limited nature of this study, care should be taken not to generalize these results to a greater population. Furthermore, instances of identity, agency, and power at both the micro-relational and the macro-relational level were identified within participants responses. Systems of power may have differing influences and impact depending on geographical location, socioeconomic status, or other things related to persons' position of privilege. Findings from the critical analysis within should not be used as a blanket critique of the systems within which participants operate. Follow-up studies should be accomplished in order to further explore the impact of these findings.

REFERENCES

Ahenakew, C. (2016). Grafting Indigenous ways of knowing onto non-Indigenous ways of being: The (underestimated) challenges of a decolonial imagination. *International Review of Qualitative Research*, *9*(3), 323-340. https://doi.org/10.1525/irqr.2016.9.3.323

Allcott, H., Gentzkow, M., & Yu, C. (2019). Trends in the diffusion of misinformation on social media. *Research & Politics*, *6*(2).

Allen, K. A., Butler-Henderson, K., Reupert, A., Longmuir, F., Finefter-Rosenbluh, I., Berger, E., Grove, C., Heffernan, A., Freeman, N., Kewalramani, S., Krebs, S., Dsouza, L., Mackie, G., Chapman, D., & Fleer, M. (2021). Work like a girl: Redressing gender inequity in academia through systemic solutions. *Journal of University Teaching & Learning Practice*, *18*(3), 03.

Allum, N., Besley, J., Gomez, L., & Brunton-Smith, I. (2018). Disparities in science literacy. S*cience*, *360*(6391), 861-862.

American Association for the Advancement of Science. (1990). *Science for all Americans*. Oxford University Press.

American Association for the Advancement of Science. (1994). *Benchmarks for science literacy*. Oxford University Press.

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9-16.

Anaya, L., Stafford, F., & Zamarro, G. (2022). Gender gaps in math performance, perceived mathematical ability and college STEM education: The role of parental occupation. *Education Economics*, *30*(2), 113-128.

Anyon, J. (1980). Social class and the hidden curriculum of work. *Journal of Education*, *162*(Winter 1980),*67*-92.

Anyon, J. (1981). Social class and school knowledge. *Curriculum Inquiry*, *11*(1), 3-42.

Apple, M. W. (1993). The politics of official knowledge: Does a national curriculum make sense? *Discourse*, *14*(1), 1-16.

Apple, M. W. (2012). *Education and power*. Routledge.

Ardiyanti, Y., Suyanto, S., & Suryadarma, I. G. P. (2019, October). The role of students science literacy in Indonesia. In *Journal of Physics: Conference Series* (Vol. 1321, No. 3, p. 032085). IOP Publishing.

Armitage, K. C. (2005). State of denial: The United States and the politics of global warming. *Globalizations*, *2*(3), 417-427.

Auld, G. W., Diker, A., Bock, M. A., Boushey, C. J., Bruhn, C. M., Cluskey, M., Edlefsen, M., Goldberg, D. L., Misner, S. L., Olson, B. H., Reicks, M., Wang, C., & Zaghloul, S. (2007). Development of a decision tree to determine appropriateness of NVivo in analyzing qualitative data sets. *Journal of Nutrition Education and Behavior*, *39*(1), 37-47.

Bakker, I., & Gill, S. (2019). Rethinking power, production, and social reproduction: Toward variegated social reproduction. *Capital & Class*, *43*(4), 503-523.

Banks, J. A. (1993). Multicultural education: Historical development, dimensions, and practice. *Review of Research in Education*, *19*(1), 3-49.

Banks, J. A. (2002). Race, knowledge construction, and education in the USA: Lessons from history. *Race Ethnicity and Education*, *5*(1), 7-27.

Banks, J. A. (2008). An introduction to multicultural education. Pearson Education.

Banks, J. A., & Banks, C. A. M., (Eds.). (2019). *Multicultural education: Issues and perspectives*. John Wiley & Sons.

Berk, R. A. (2017). Microaggressions trilogy: Part 3. Microaggressions in the classroom. *The Journal of Faculty Development*, *31*(3), 95-110.

Benedek, M., & Fink, A. (2019). Toward a neurocognitive framework of creative cognition: The role of memory, attention, and cognitive control. *Current Opinion in Behavioral Sciences*, *27*, 116-122.

Berry, E. (2022). The right climate: Political opportunities for religious engagement with climate policy. In *Climate Politics and the Power of Religion*. Indiana University Press.

Bianchini, J. A. (1997). Where knowledge construction, equity, and context intersect: Student learning of science in small groups. *Journal of Research in Science Teaching*. *34*(10), 1039-1065.

Blandin, A., & Herrington, C. (2022). Family heterogeneity, human capital investment, and college attainment. *American Economic Journal: Macroeconomics*, *14*(4), 438-478.

Blatti, J. L., Garcia, J., Cave, D., Monge, F., Cuccinello, A., Portillo, J., Juarez, B., Chan, E., & Schwebel, F. (2019). Systems thinking in science education and outreach toward a sustainable future. *Journal of chemical education*, *96*(12), 2852-2862.

Boehme, H. M., Cann, D., & Isom, D. A. (2022). Citizens' perceptions of over-and under-policing: a look at race, ethnicity, and community characteristics. *Crime & Delinquency*, *68*(1), 123-154.

Bourdieu, P. (2018). Cultural reproduction and social reproduction. In *Knowledge, education, and cultural change* (pp. 71-112). Routledge.

Bowden, M., Bartkowski, J. P., Xu, X., & Lewis Jr, R. (2018). Parental occupation and the gender math gap: Examining the social reproduction of academic advantage among elementary and middle school students. *Social Sciences*, *7*(1), 6.

Broćić, M., & Miles, A. (2021). College and the "culture war": assessing higher education's influence on moral attitudes. *American Sociological Review*, *86*(5), 856-895.

Broer, M., Bai, Y., & Fonseca, F. (2019). *Socioeconomic inequality and educational outcomes: Evidence from twenty years of TIMSS*. Springer.

Brown, L. (2010). Nurturing relationships within a space created by "Indigenous Ways of Knowing": A case study. *The Australian Journal of Indigenous Education*, *39*(S1), 15-22.

Bratman, E. Z., & DeLince, W. P. (2022). Dismantling white supremacy in environmental studies and sciences: an argument for anti-racist and decolonizing pedagogies. *Journal of Environmental Studies and Sciences*, *12*(2), 193-203.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77-101.

Bucchi, M., & Saracino, B. (2016). "Visual Science Literacy" images and public understanding of science in the digital age. *Science Communication*, *38*(6), 812-819.

Butler, J. (2002). *Gender trouble*. Routledge.

Bybee, R., McCrae, B., & Laurie, R. (2009). PISA 2006: An assessment of scientific literacy. *Journal of Research in Science Teaching*, *46*(8), 865-883.

Bybee, R. W., & McInerney, J. D. (1995). Redesigning the Science Curriculum: A Report on the Implications of Standards and Benchmarks for Science Education.

Byrne, D. (2022). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & quantity*, *56*(3), 1391-1412.

Carey, J. (2012). Global warming: faster than expected? *Scientific American*, *307*(5), 50-55.

Castells, M. (1996). The net and the self: working notes for a critical theory of the informational society. *Critique of Anthropology*, *16*(1), 9-38.

Catalano, T., & Waugh, L. R. (2020). *Critical discourse analysis, critical discourse studies and beyond*. Springer International Publishing.

Ceci, S. J., Williams, W. M., & Barnett, S. M. (2009). Women's underrepresentation in science: sociocultural and biological considerations. *Psychological Bulletin*, *135*(2), 218.

Champagne, A. B., Lovitts, B. E., & Calinger, B. J. (Eds.). (1989). *Scientific Literacy: Papers from the 1989 AAAS Forum for School Science* (Vol. 89). AAAS Press.

Chen, C. T. A., Lui, H. K., Hsieh, C. H., Yanagi, T., Kosugi, N., Ishii, M., & Gong, G. C. (2017). Deep oceans may acidify faster than anticipated due to global warming. *Nature Climate Change*, *7*(12), 890-894.

Cho, S., Crenshaw, K. W., & McCall, L. (2013). Toward a field of intersectionality studies: Theory, applications, and praxis. *Signs: Journal of Women in Culture and Society*, *38*(4), 785-810.

Chou, W. Y. S., Oh, A., & Klein, W. M. (2018). Addressing health-related misinformation on social media. *Jama*, *320*(23), 2417-2418.

Christensen, J. E., Larson, K. E., & Dykes, F. O. (2021). Using a school-wide coaching framework to create safe and inclusive spaces for students who identify as LGBTQ. *Preventing School Failure: Alternative Education for Children and Youth*, *65*(4), 371-378.

Cobern, W. W., Adams, B. A., Pleasants, B. A., Bentley, A., & Kagumba, R. (2022). Do we have a trust problem? Exploring undergraduate student views on the tentativeness and trustworthiness of science. *Science & Education*, 1-30.

Costello, R. A., Salehi, S., Ballen, C. J., & Burkholder, E. (2023). Pathways of opportunity in STEM: comparative investigation of degree attainment across different demographic groups at a large research institution. *International Journal of STEM Education*, *10*(1), 46.

Crabtree, L. M., Richardson, S. C., & Lewis, C. W. (2019). The gifted gap, STEM education, and economic immobility. *Journal of Advanced Academics*, *30*(2), 203-231.

Crall, A. W., Jordan, R., Holfelder, K., Newman, G. J., Graham, J., & Waller, D. M. (2013). The impacts of an invasive species citizen science training program on participant attitudes, behavior, and science literacy. *Public Understanding of Science*, *22*(6), 745-764.

Crenshaw, K. (1990). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review*, *43(6)*, 1241-1299.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Cronin, D. P., & Messemer, J. E. (2013). Elevating adult civic science literacy through a renewed citizen science paradigm. *Adult Learning*, *24*(4), 143-150.

Cronje, R., Rohlinger, S., Crall, A., & Newman, G. (2011). Does participation in citizen science improve scientific literacy? A study to compare assessment methods. *Applied Environmental Education & Communication*, *10*(3), 135-145.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage Publications.

Dabney, K. P., Chakraverty, D., & Tai, R. H. (2013). The association of family influence and initial interest in science. *Science Education*, *97*(3), 395-409.

Daneshfar, S., & Moharami, M. (2018). Dynamic assessment in Vygotsky's sociocultural theory: Origins and main concepts. *Journal of Language Teaching and Research*, *9*(3), 600-607.

Daud, A. M., Omar, J., Turiman, P., & Osman, K. (2012). Creativity in science education. *Procedia-Social and Behavioral Sciences*, *59*, 467-474.

Dauda, K. O. (2020). Islamophobia and religious intolerance: Threats to global peace and harmonious co-existence. *Qudus International Journal of Islamic Studies*, *8*(2), 257-292.

Davidson, M. N. (2011). *The end of diversity as we know it: Why diversity efforts fail and how leveraging difference can succeed*. Berrett-Koehler Publishers.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, *37*(6), 582-601.

Del Corona, L. (2021). Distrust in science as a threat to scientific freedom. Some considerations in light of Covid-19 emergency. *CERIDAP*, *2021*(2), 1-14.

Delgado, R., & Stefancic, J. (2007). Critical race theory and criminal justice. *Humanity & Society*, *31*(2-3), 133-145.

Dillbary, J. S., & Edwards, G. (2019). An empirical analysis of sexual orientation discrimination. *The University of Chicago Law Review*, *86*(1), 1-76.

Dimitriadis, G., & Carlson, D. (Eds.). (2003). *Promises to keep: Cultural studies, democratic education, and public life*. Routledge.

Dimitriadis, G., & Kamberelis, G. (2006). *Theory for education: Adapted from theory for religious studies, by William E. Deal and Timothy K. Beal*. Routledge.

Dimock, M. (2019). Defining generations: Where Millennials end and Generation Z begins. *Pew Research Center*, *17*(1), 1-7.

Drummond, C., & Fischhoff, B. (2017). Individuals with greater science literacy and education have more polarized beliefs on controversial science topics. *Proceedings of the National Academy of Sciences*, *114*(36), 9587-9592.

Durante, F., & Fiske, S. T. (2017). How social-class stereotypes maintain inequality. *Current Opinion in Psychology*, *18*, 43-48.

Duarte, B., Teixeira, C. M., Martins, I., Engelen, A. H., Costa, R. L., Adams, J. B., Bebianno, M. J., Melo, R. A. & Fonseca, V. F. (2022). Editorial: Emerging Topics in Coastal and Transitional Ecosystems: Science, Literacy, and Innovation. *Frontiers in Marine Science*, *9*, 953-967.

Eagly, A. H. (2021). Hidden in Plain Sight: The Inconsistent Gender Gaps in STEM and Leadership. *Psychological Inquiry*, *32*(2), 89-95.

Elshahed, H., & Tyson, N. D. (2020). Communicating science in the new media environment: The advancement of science literacy. *Arab Media & Society*, *28*, 1-18.

Elvianasti, M., & Dharma, A. P. (2021, May). Correlation Between Students Creative Thinking Ability in Solving Environmental Problem with Achievement of Environmental Education. In *1st Annual International Conference on Natural and Social Science Education (ICNSSE 2020)* (pp. 275-281). Atlantis Press.

Evans, D. K., Akmal, M., & Jakiela, P. (2020). *Gender gaps in education: The long view* (No. 523). Center for Global Development.

Fardouly, J., Pinkus, R. T., & Vartanian, L. R. (2017). The impact of appearance comparisons made through social media, traditional media, and in person in women's everyday lives. *Body Image*, *20*, 31-39.

Federici, S. (2019). Social reproduction theory. *Radical Philosophy*, *2*(4), 55-57.

Feinstein, N. (2010). Salvaging science literacy. *Science Education,* 169-185.

Fernandez, T., Godwin, A., Doyle, J., Verdin, D., Boone, H., Kirn, A., Benson, L., & Potvin, G. (2016). More comprehensive and inclusive approaches to demographic data collection. *School of Engineering Education Graduate Student Series*. Paper 60. Purdue.

Fives, H., Huebner, W., Birnbaum, A. S., & Nicolich, M. (2014). Developing a measure of scientific literacy for middle school students. *Science Education*, *98*(4), 549-580.

Forst, R. (2001). Towards a critical theory of transnational justice. *Metaphilosophy*, *32*(1-2), 160-179.

Freeman, J. B. (2020). Measuring and resolving LGBTQ disparities in STEM. *Policy Insights from the Behavioral and Brain Sciences*, *7*(2), 141-148.

Funk, C., & Parker, K. (2018). Women and men in STEM often at odds over workplace equity. Pew Research Center, Washington, D.C.

Gay, G. (2018). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press.

Gergan, M., Smith, S., & Vasudevan, P. (2020). Earth beyond repair: Race and apocalypse in collective imagination. *Environment and Planning D: Society and Space*, *38*(1), 91-110.

Gilbert, A., & Yerrick, R. (2001). Same school, separate worlds: A sociocultural study of identity, resistance, and negotiation in a rural, lower track science classroom. *Journal of Research in Science Teaching*, *38*(5), 574-598.

Giroux, H. A. (1986). Critical theory and the politics of culture and voice: Rethinking the discourse of educational research. *Journal of Thought*, *21*(3), 84-105.

Goldsmith, T. E. (1995). Standards and benchmarks in science education: Requiem or revolution? In Bybee, R. W., & McInerney, J. D. (Eds). *Redesigning the Science Curriculum: A Report on the Implications of Standards and Benchmarks for Science Education.* (p. 116). BSCS.

Gormally, C., Brickman, P., & Lutz, M. (2012). Developing a test of scientific literacy skills (TOSLS): Measuring undergraduates' evaluation of scientific information and arguments. *CBE—Life Sciences Education*, *11*(4), 364-377.

Gough, A. (2014). Beyond Eurocentrism in science education: Promises and problematics from a feminist poststructuralist perspective. In *Curriculum* (pp. 185-209). Routledge.

Grammatikopoulos, V., Tsigilis, N., & Gregoriadis, A. (2019). Assessing the Science Learning Assessment (SLA) instrument in Greek early childhood education using the Item Response Theory framework. *Frontiers in Education, 4*(123), 1-10.

Grasswick, H. (2017). Epistemic injustice in science. In *The Routledge Handbook of Epistemic Injustice* (pp. 313-323). Routledge.

Gravetter, F. J., & Wallnau, L. B. (2004). Statistics for the behavioral sciences. Belmont. *CA: Thomson Wadsworth*.

Greene, M. (1988). *The Dialectic of Freedom*. Teachers College Press.

Grewenig, E., Lergetporer, P., Werner, K., Woessmann, L., & Zierow, L. (2021). COVID-19 and educational inequality: How school closures affect low-and high-achieving students. *European Economic Review*, *140*(103920), 1-21.

Grimson, A. (2010). Culture and Identity: Two different notions. *Social Identities., 16*(1), 61.

Hahs-Vaughn, D. L., & Lomax, R. G. (2020). *An introduction to statistical concepts*. Routledge.

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing Students' Creativity through STEM Project-Based Learning. *Journal of Science Learning*, *2*(2), 50-57.

Harrison, C., & Tanner, K. D. (2018). Language matters: Considering microaggressions in science. *CBE—Life Sciences Education*, *17*(1).

He, L., Chen, Y., Xiong, X., Zou, X., & Lai, K. (2021). Does science literacy guarantee resistance to health rumors? The moderating effect of self-efficacy of science literacy in the relationship between science literacy and rumor belief. *International Journal of Environmental Research and Public Health*, *18*(5), 2243.

Herlanti, Y., Mardiati, Y., Rahmawati, R., Putri, A. M. K., Jamil, N., Miftahuzzakiyah, M., ... & Sugiarti, S. (2019). Finding learning strategy in improving science literacy. *Jurnal Penelitian dan Pembelajaran IPA*, *5*(1), 59-71.

Hodson, D., & Hodson, J. (1998). From constructivism to social constructivism: A Vygotskian perspective on teaching and learning science. *School Science Review*, *79*(289), 33-41.

Horkheimer, M. (1972). *Critical theory: Selected essays* (Vol. 1). A&C Black.

Howell, E. L., & Brossard, D. (2021). (Mis) informed about what? What it means to be a science-literate citizen in a digital world. *Proceedings of the National Academy of Sciences*, *118*(15).

Huang, J. P., & Benson, P. (2013). Autonomy, agency and identity in foreign and second language education. *Chinese Journal of Applied Linguistics*, *36*(1), 7-28.

Hurd, P. D. (1958). Science literacy: Its meaning for American schools. *Educational Leadership*, *16*(1), 13-16.

Hwang, J., Choi, K. M., Bae, Y., & Shin, D. H. (2018). Do teachers' instructional practices moderate equity in mathematical and scientific literacy? An investigation of the PISA 2012 and 2015. *International Journal of Science and Mathematics Education*, *16*(1), 25-45.

IBM Corp. Released 2022. IBM SPSS Statistics for Windows, Version 29.0. Armonk, NY: IBM Corp.

Igwebuike, E. E., & Chimuanya, L. (2021). Legitimating falsehood in social media: A discourse analysis of political fake news. *Discourse & Communication*, *15*(1), 42-58.

James, C. E. (2021). Racial inequity, COVID-19 and the education of Black and other marginalized students. *Impacts of COVID-19 in Racialized Communities*, 36.

Janks, H. (1997). Critical discourse analysis as a research tool. *Discourse: Studies in the Cultural Politics of Education*, *18*(3), 329-342.

Jensen, J. L., Manwaring, K. F., Gill, R. A., Sudweeks, R. S., Davies, R. S., Olsen, J. A., Phillips, S., & Bybee, S. M. (2019). Religious affiliation and religiosity and their impact on scientific beliefs in the United States. *BioScience*, *69*(4), 292-304.

Jessee, M. A. (2016). Influences of sociocultural factors within the clinical learning environment on students' perceptions of learning: An integrative review. *Journal of Professional Nursing*, *32*(6), 463-486.

Johnson, T. J., & Kaye, B. K. (2015). Site effects: How reliance on social media influences confidence in the government and news media. *Social Science Computer Review*, *33*(2), 127-144.

Ketenci, T., Leroux, A., & Renken, M. (2020). Beyond student factors: A study of the impact on STEM career attainment. *Journal for STEM Education Research*, *3*, 368-386.

Kim, B. (2001). Social constructivism. *Emerging Perspectives on Learning, Teaching, and Technology*, *1*(1), 16.

Kincheloe, J. L. (2011). Critical ontology and indigenous ways of being: Forging a postcolonial curriculum. In *Key works in critical pedagogy* (pp. 333-349). Brill.

Kitson, R., & Bowes, J. (2010). Incorporating Indigenous ways of knowing in early education for Indigenous children. *Australasian Journal of Early Childhood*, *35*(4), 81-89.

Klasik, D., Blagg, K., & Pekor, Z. (2018). Out of the education desert: How limited local college options are associated with inequity in postsecondary opportunities. *Social Sciences*, *7*(9), 165.

Koppal, M., & Caldwell, A. (2004). Meeting the challenge of science literacy: Project 2061 efforts to improve science education. *Cell Biology Education*, *3*(1), 28-30.

Korda, H., & Itani, Z. (2013). Harnessing social media for health promotion and behavior change. *Health Promotion Practice*, *14*(1), 15-23.

Kortenkamp, K. V., & Basten, B. (2015). Environmental science in the media: Effects of opposing viewpoints on risk and uncertainty perceptions. *Science Communication*, *37*(3), 287-313.

Kristyasari, M. L., Yamtinah, S., Utomo, S. B., & Indriyanti, N. Y. (2018). Gender differences in students' science literacy towards learning on integrated science subject. *Journal of Physics: Conference Series, 1097*(1).

Kwakye, I., & Kibort-Crocker, E. (2021). Facing Learning Disruption: Examining the Effects of the COVID-19 Pandemic on K-12 Students. Education Insights. *Washington Student Achievement Council*.

Kyza, E. A., Varda, C., Panos, D., Karageorgiou, M., Komendantova-Amann, N., Coppolino Perfumi, S., ... & Hosseini, A. S. (2020). Combating misinformation online: re-imagining social media for policy-making. *Internet Policy Review*, *9*(4), 1-24.

Ladd, J. M. (2013). The era of media distrust and its consequences for perceptions of political reality. In *New Directions in Media and Politics*, (pp. 24-44). Routledge.

Ladson-Billings, G., (1995). But That's Just Good Teaching! The Case for Culturally Relevant Pedagogy. *Theory into Practice*, *34*(3), 159-165.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, *32*(3), 465-491.

Ladson-Billings, G., & Tate, W. F. IV. (1995). Toward a critical race theory of education. *Teachers College Record, 97*(1), 47-68.

Laugksch, R. C. (2000). Scientific literacy: A conceptual overview. *Science Education*, *84*(1), 71-94.

Lantolf, J. P. (2000). Introducing sociocultural theory. *Sociocultural Theory and Second Language Learning*, *1*, 1-26.

Lavalley, M. (2018). Out of the Loop: Rural Schools Are Largely Left out of Research and Policy Discussions, Exacerbating Poverty, Inequity, and Isolation. *Center for Public Education*.

Laurence, J., & Bentley, L. (2016). Does ethnic diversity have a negative effect on attitudes towards the community? A longitudinal analysis of the causal claims within the ethnic diversity and social cohesion debate. *European Sociological Review*, *32*(1), 54-67.

Layzer, J. A. (2007). Deep freeze: How business has shaped the global warming debate in Congress. *Business and Environmental Policy*, *93*, 126.

Le, P. T., & Matias, C. E. (2019). Towards a truer multicultural science education: How whiteness impacts science education. *Cultural Studies of Science Education*, *14*, 15-31.

Lee, M. J., Collins, J. D., Harwood, S. A., Mendenhall, R., & Huntt, M. B. (2020). "If you aren't White, Asian or Indian, you aren't an engineer": racial microaggressions in STEM education. *International Journal of STEM Education*, *7*(1), 1-16.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296-316.

Lemke, J. L. (2001). Articulating communities: Sociocultural perspectives on science education. *Journal of Research in Science Teaching*, *38*(3), 296-316.

Leonardo, Z. (2009). *Race, whiteness, and education*. Routledge.

Lesthaeghe, R. (2014). The second demographic transition: A concise overview of its development. *Proceedings of the National Academy of Sciences*, *111*(51), 18112-18115.

Lesthaeghe, R. J. (2020). The second demographic transition: Cohabitation. In *Cross-cultural family research and practice* (pp. 103-141). Academic Press.

Lewis, C., Enciso, P. E., & Moje, E. B. (Eds.). (2020). *Reframing sociocultural research on literacy: Identity, agency, and power*. Routledge.

Lewis, C., & Moje, E. B. (2003). Sociocultural perspectives meet critical theories. *International Journal of Learning*, *10*, 1979-1995.

Lier, L. V. (2007). Action-based teaching, autonomy and identity. *International Journal of Innovation in Language Learning and Teaching*, *1*(1), 46-65.

Liu, X. (2009). Beyond science literacy: Science and the public. *International Journal of Environmental & Science Education, 4*(3), 301-311.

Liu, H., Zeng, H., Shen, Y., Zhang, F., Sharma, M., Lai, W., Zhao, Y., Tao, G., Yuan, J., & Zhao, Y. (2018). Assessment tools for health literacy among the general population: a systematic review. *International Journal of Environmental Research and Public Health*, *15*(8), 1711.def

Lotz, C. (2022). *Marx and classical studies.* The Classical Review. Cambridge.

Lupton, D. (Ed.). (1999). *Risk and sociocultural theory: New directions and perspectives*. Cambridge University Press.

MacDonald, N. E. (2018). When science meets Google: reflections on research and evidence in the age of science deniers. *Clinical and Investigative Medicine*, *41*, 35-37.

MacDonald, N. E. (2020). Oral Health in Canada: Fake news and science denier attacks on vaccines. What can you do? *Canada Communicable Disease Report*, *46*(1112), 432.

Mansour, N., & Wegerif, R. (2013). Why science education for diversity. In *Science Education for Diversity. Theory and Practice*. Springer.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2013). Science literacy in school and home contexts: Kindergarteners' science achievement and motivation. *Cognition and Instruction*, *31*(1), 62-119.

Martin, D. B. (2019). Equity, inclusion, and antiblackness in mathematics education. *Race Ethnicity and Education*, *22*(4), 459-478.

Master, A., & Meltzoff, A. N. (2016). Building bridges between psychological science and education: Cultural stereotypes, STEM, and equity. *Prospects*, *46*(2), 215234.

Master, A., & Meltzoff, A. N. (2020). Cultural stereotypes and sense of belonging contribute to gender gaps in STEM. *International Journal of Gender, Science and Technology*, *12*(1), 152-198.

McGee Banks, C. A., & Banks, J. A. (1995). Equity pedagogy: An essential component of multicultural education. *Theory Into Practice*, *34*(3), 152-158.

McGee, E. O. (2020). Interrogating structural racism in STEM higher education. *Educational Researcher*, *49*(9), 633-644.

McPhetres, J., & Zuckerman, M. (2018). Religiosity predicts negative attitudes towards science and lower levels of science literacy. *PloS ONE*, *13*(11).

Mesarović, M. M. (2019). Global warming and other climate change phenomena on the geological time scale. *Thermal Science*, *23*(Suppl. 5), 1435-1455.

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Metallic, J. (2009). Exploring Indigenous ways of knowing, being, and doing in developing a cross-cultural science curriculum. In *Indigenous knowledges, development and education* (pp. 97-108). Brill.

Mezirow, J. (1981). A critical theory of adult learning and education. *Adult Education Quarterly,* 32(1), 3-24.

Mezirow, J. (1990). *Fostering critical reflection in adulthood: A guide to transformative and emancipatory learning*. Jossey-Bass.

Mezirow, J. (1994). Understanding transformative theory. *Adult Education Quarterly, 44*(4), 222-232.

Mezirow, J. (1996). Contemporary paradigms of learning. *Adult Education Quarterly, 46*(3), 158-173.

Mezirow, J. (1998). On critical reflection. *Adult Education Quarterly, 48*(3), 185-198.

Michell, D., Szabo, C., Falkner, K., & Szorenyi, A. (2018). Towards a socio-ecological framework to address gender inequity in computer science. *Computers & Education*, *126*, 324-333.

Middleton, K. V. (2020). The longer-term impact of COVID-19 on K–12 student learning and assessment. *Educational Measurement: Issues and Practice*, *39*(3), 41-44.

Miethe, T. D., & Gauthier, J. F. (2008). *Simple statistics: Applications in social research*. Oxford University Press.

Mijs, J. J. (2016). The unfulfillable promise of meritocracy: Three lessons and their implications for justice in education. *Social Justice Research*, *29*(1), 14-34.

Moje, E. B., & Lewis, C. (2020). Examining opportunities to learn literacy: The role of critical sociocultural literacy research. In *Reframing sociocultural research on literacy* (pp. 15-48). Routledge.

Moutsios, S. (2010). Power, politics and transnational policy-making in education. *Globalisation, Societies and Education*, *8*(1), 121-141.

Mullet, D. R. (2018). A general critical discourse analysis framework for educational research. *Journal of Advanced Academics*, *29*(2), 116-142.

Narvaez, D., Arrows, F., Halton, E., Collier, B., & Enderle, G. (2019). *Indigenous sustainable wisdom: First-nation know-how for global flourishing*. Peter Lang.

National Academies of Sciences, Engineering, and Medicine. (2018). Sexual harassment of women: Climate, culture, and consequences in academic sciences, engineering, and medicine. *Policy and Global Affairs.* National Academies of Sciences.

National Commission on Excellence in Education. (1983). A nation at risk: The imperative for educational reform. *The Elementary School Journal*, *84*(2), 113-130.

National Research Council. (1989). *Everybody counts: A report to the nation on the future of mathematics education*. National Academies Press.

National Research Council [NRC]. (1996). National Science Education Standards, Washington, DC: National Academy Press.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Noddings, N. (2013). *Education and democracy in the 21st century*. Teachers College Press.

Nohl, A. M. (2015) Typical phases of transformative learning: A practice-based model. *Adult Education Quarterly, 65*(1), 35-49.

Nuhfer, E. B., Cogan, C. B., Kloock, C., Wood, G. G., Goodman, A., Delgado, N. Z., & Wheeler, C. W. (2016). Using a concept inventory to assess the reasoning component of citizen-level science literacy: Results from a 17,000-student study. *Journal of Microbiology & Biology Education*, *17*(1), 143-155.

NVivo qualitative data analysis. Version 14 [software]. QSR International Pty Ltd. 2018. https://support.qsrinternational.com/nvivo/s/.

Office of Regulatory Affairs and Research Compliance (ORARC) at Harvard Longwood Campus. (2020). *Inclusive demographic data collection*. https://www.hsph.harvard.edu/ohra/

Otto, S., Kaiser, F. G., & Arnold, O. (2014). The critical challenge of climate change for psychology. *European Psychologist*, 19(2):96–106.

Ozanne, J. L., & Murray, J. B. (1995). Uniting critical theory and public policy to create the reflexively defiant consumer. *American Behavioral Scientist*, *38*(4), 516-525.

Paine, L. W. (2019). Missing voices and possible dialogues: Problems and possibilities for teacher education. *Teachers and Teaching*, *25*(6), 684-702.

Peca, K. (2000). *Critical theory in education: Philosophical, research, sociobehavioral, and organizational Assumptions*. Eastern New Mexico University.

Pete, S., Schneider, B., & O'Reilly, K. (2013). Decolonizing our practice: Indigenizing our teaching. *First Nations Perspectives*, *5*(1), 99-115.

Pishghadam, R., Noghani, M., & Zabihi, R. (2011). The construct validation of a questionnaire of social and cultural capital. *English Language Teaching*, *4*(4), 195-203.

Posselt, J. R. (2020). *Equity in Science: Representation, Culture, and the Dynamics of Change in Graduate Education*. Stanford University Press.

Posselt, J. R., & Grodsky, E. (2017). Graduate education and social stratification. *Annual Review of Sociology*, *43*, 353-378.

Posselt, J., Porter, K. B., & Kamimura, A. (2018). Organizational pathways toward gender equity in doctoral education: chemistry and civil engineering compared. *American Journal of Education*, *124*(4), 383-410.

Prabowo, C. A., & Fidiastuti, H. R. (2017). Measuring First Year Student Scientific Literacy Skills using Test of Scientific Literacy Skills (TOSLS). *Bioeducation Journal*, *1*(2), 78-86.

Priniski, J. H., & Holyoak, K. J. (2022). A darkening spring: How preexisting distrust shaped COVID-19 skepticism. *PloS ONE*, *17*(1).

Quellmalz, E. S., Silberglitt, M. D., Buckley, B. C., Loveland, M. T., & Brenner, D. G. (2020). Simulations for supporting and assessing science literacy. In *Learning and performance assessment: concepts, methodologies, tools, and applications* (pp. 760-799). IGI Global.

Rachmatullah, A., Diana, S., & Rustaman, N. Y. (2016, February). Profile of middle school students on scientific literacy achievements by using scientific literacy assessments (SLA). In *AIP Conference Proceedings* (Vol. 1708, No. 1, p. 080008). AIP Publishing LLC.

Rekker, R., Pardini, D., Keijsers, L., Branje, S., Loeber, R., & Meeus, W. (2015). Moving in and out of poverty: The within-individual association between socioeconomic status and juvenile delinquency. *PLOS One*, *10*(11).

Reveles, J. M., Cordova, R., Kelly, G. J. (2004). Science literacy and academic identity formulation. *Journal of Research in Science Teaching, 41*(10), 1111-1144.

Reyna, V. F. (2021). A scientific theory of gist communication and misinformation resistance, with implications for health, education, and policy. *Proceedings of the National Academy of Sciences*, *118*(15).

Reichelt, M., Collischon, M., & Eberl, A. (2019). School tracking and its role in social reproduction: Reinforcing educational inheritance and the direct effects of social origin. *The British Journal of Sociology*, *70*(4), 1323-1348.

Rivers, E. (2017). Women, minorities, and persons with disabilities in science and engineering. *National Center for Science and Engineering Statistics*. NSF.

Rivera Maulucci, M. S. (2010). Resisting the marginalization of science in an urban school: Coactivating social, cultural, material, and strategic resources. *Journal of Research in Science Teaching*, *47*(7), 840-860.

Ritonga, A. H., & El Widdah, M. (2021, July). The Role of Science Literacy Based Ta'lim Andragogy as an Alternative Media in Strengthening Covid-19 Awareness. In *5th Asian Education Symposium 2020 (AES 2020)* (pp. 21-26). Atlantis Press.

Robert, S. A., & Yu, M. (2018). Intersectionality in transnational education policy research. *Review of Research in Education*, *42*(1), 93-121.

Rodriguez, A. J. (1998). Busting open the meritocracy myth: Rethinking equity and student achievement in science education. *Journal of Women and Minorities in Science and Engineering*, *4*(2&3).

Rogers, R. (2004). An introduction to critical discourse analysis in education. In *An introduction to critical discourse analysis in education* (pp. 31-48). Routledge.

Rogers-Chapman, M. F. (2014). Accessing STEM-focused education: Factors that contribute to the opportunity to attend STEM high schools across the United States. *Education and Urban Society*, *46*(6), 716-737.

Romberg, T. A. (1989). *Curriculum and evaluation standards for school mathematics*. National Council of Teachers of Mathematics.

Ross, K., Hooten, M. A., & Cohen, G. (2013). Promoting Science Literacy through an Interdisciplinary Approach. *Bioscene: Journal of College Biology Teaching*, *39*(1), 21-26.

Royal Society (1985). *The public understanding of science*. Royal Society.

Rubin, G. S. (2002). Thinking sex: Notes for a radical theory of the politics of sexuality. In *Culture, Society and Sexuality A Reader* (pp. 143-178). Routledge.

Ruiz Alvarado, A., Stewart-Ambo, T., & Hurtado, S. (2020). High school and college choice factors associated with high-achieving low-income students' college degree completion. *Education Sciences*, *10*(6), 153.

Rusilowati, A., Kurniawati, L., Nugroho, S. E., & Widiyatmoko, A. (2016). Developing an Instrument of Scientific Literacy Assessment on the Cycle Theme. *International Journal of Environmental and Science Education*, *11*(12), 5718-5727.

Rusilowati, A., Nugroho, S. E., Susilowati, E. S. M., Mustika, T., Harfiyani, N., & Prabowo, H. T. (2018). The development of scientific literacy assessment to measure student's scientific literacy skills in energy theme. In *Journal of Physics: Conference Series*. IOP Publishing.

Saatcioglu, B., & Corus, C. (2014). Poverty and intersectionality: A multidimensional look into the lives of the impoverished. *Journal of Macromarketing*, *34*(2), 122-132.

Sadler, T. D., & Zeidler, D. L. (2009). Scientific literacy, PISA, and socioscientific discourse: Assessment for progressive aims of science education. *Journal of Research in Science Teaching*, *46*(8), 909-921.

Samarapungavan, A., Mantzicopoulos, P., Patrick, H., & French, B. (2009). The development and validation of the science learning assessment (SLA): A measure of kindergarten science learning. *Journal of Advanced Academics*, *20*(3), 502-535.

Samuels, A. J., Samuels, G. L., & Self, C. (2019). Champions of equity: Fostering civic education to challenge silence, racial inequity, and injustice. *Multicultural Perspectives*, *21*(2), 78-84.

Santiago, C. D., Wadsworth, M. E., & Stump, J. (2011). Socioeconomic status, neighborhood disadvantage, and poverty-related stress: Prospective effects on psychological syndromes among diverse low-income families. *Journal of Economic Psychology*, *32*(2), 218-230.

Sawyer, L., & Waite, R. (2021). Racial and ethnic diversity in higher education: White privileged resistance and implications for leadership. *Education Policy Analysis Archives*, *29*(January-July), 38-38.

Sawyer, R. K. (2002). Unresolved tensions in sociocultural theory: Analogies with contemporary sociological debates. *Culture & Psychology*, *8*(3), 283-305.

Scarborough, W. J., Pepin, J. R., Lambouths III, D. L., Kwon, R., & Monasterio, R. (2021). The intersection of racial and gender attitudes, 1977 through 2018. *American Sociological Review*, *86*(5), 823-855.

Scheepers, D., & Ellemers, N. (2019). Social identity theory. *Social psychology in action: Evidence-based interventions from theory to practice*, 129-143.

Schiro, M. (2013). *Curriculum theory: Conflicting visions and enduring concerns*. Sage.

Schmader, T., & Block, K. (2015). Engendering identity: Toward a clearer conceptualization of gender as a social identity. *Sex Roles*, *73*, 474-480.

Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nature Human Behaviour*, *3*(9), 931-939.

Scott, S., & Palincsar, A. (2013). Sociocultural theory. *The Gale Group.* 1-10.

Segarra, V. A., Hughes, N. M., Ackerman, K. M., Grider, M. H., Lyda, T., & Vigueira, P. A. (2018). Student performance on the Test of Scientific Literacy Skills (TOSLS) does not change with assignment of a low-stakes grade. *BMC research notes*, *11*(1), 1-5.

Şentürk, C., & Sari, H. (2018). Investigation of the contribution of differentiated instruction into science literacy. *Qualitative Research in Education*, *7*(2), 197-237.

Sharon, A. J., & Baram-Tsabari, A. (2020). Can science literacy help individuals identify misinformation in everyday life? *Science Education*, *104*(5), 873-894.

Shu, K., Sliva, A., Wang, S., Tang, J., & Liu, H. (2017). Fake news detection on social media: A data mining perspective. *ACM SIGKDD explorations newsletter*, *19*(1), 22-36.

Singh, G., & Richards, J. C. (2006). Teaching and learning in the language teacher education course room: A critical sociocultural perspective. *Religion Language Center Journal*, *37*(2), 149-175.

Simonton, D. K. (2014). Studying Sociocultural Influences. *Historical Social Psychology*, 139.

Snow, C. P., & Smoluchowski, R. (1961). The two cultures and the scientific revolution. *Physics Today*, *14*(9), 62.

Soares, A. E., & Lopes, M. P. (2020). Are your students safe to learn? The role of lecturer's authentic leadership in the creation of psychologically safe environments and their impact on academic performance. *Active Learning in Higher Education*, *21*(1), 65-78.

Stefancic, J., & Delgado, R. (Eds.). (2000). *Critical race theory: The cutting edge*. Harvard: Temple University Press.

Suiter, J., & Fletcher, R. (2020). Polarization and partisanship: Key drivers of distrust in media old and new? *European Journal of Communication*, *35*(5), 484-501.

Sundin, O., & Johannisson, J. (2005). Pragmatism, neo-pragmatism and sociocultural theory: communicative participation as a perspective in LIS. *Journal of Documentation*, *61*(1), 23-43.

Supena, I., Darmuki, A., & Hariyadi, A. (2021). The influence of 4C (Constructive, Critical, Creativity, Collaborative) learning model on students' learning outcomes. *International Journal of Instruction*, *14*(3), 873-892.

Taber, K. S. (2020). Mediated learning leading development-the social development theory of Lev Vygotsky. In *Science Education in Theory and Practice: An Introductory Guide to Learning Theory*. Springer.

Taylor, S. P. (2018). Critical realism vs social constructionism & social constructivism: application to a social housing research study. *International Journal of Sciences: Basic and Applied Research*, *37*(2), 216-222.

Teemant, A., & Hausman, C. S. (2013). The relationship of teacher use of critical sociocultural practices with student achievement. *Critical Education*, *4*(4).

Ternullo, S. (2022). "I'm not sure what to believe": Media distrust and opinion formation during the COVID-19 pandemic. *American Political Science Review*, *116*(3), 1096-1109.

Terry, G., & Hayfield, N. (2020). 38. Reflexive thematic analysis. *Handbook of Qualitative Research in Education*. Edward Elgar Publishing Limited, 430-441.

Tolbert, S., & Bazzul, J. (2017). Toward the sociopolitical in science education. *Cultural Studies of Science Education*, *12*(2), 321-330.

Tollefson, J. W. (2006). Critical theory in language policy. An introduction to language policy: Theory and method, *Teaching English as a Second or Foreign Language, 10*(2), 42-59.

Toomey, A. H., & Domroese, M. C. (2013). Can citizen science lead to positive conservation attitudes and behaviors? *Human Ecology Review*, 50-62.

Torres, S. A., Santiago, C. D., Walts, K. K., & Richards, M. H. (2018). Immigration policy, practices, and procedures: The impact on the mental health of Mexican and Central American youth and families. *American Psychologist*, *73*(7), 843.

U.S. Department of Education. Institute of Education Sciences, National Center for Education Statistics, National Assessment of Educational Progress (NAEP), 2019 Science Assessment.

Utami, A. U. (2021). The effectiveness of the online-based test of scientific literacy skills (tosls) assessment to measure science literacy ability during the covid pandemic. In *Proceeding of International Conference in Education, Science and Technology* (pp. 322-328).

Van Tongeren, D. R., DeWall, C. N., Chen, Z., Sibley, C. G., & Bulbulia, J. (2021). Religious residue: Cross-cultural evidence that religious psychology and behavior persist following deidentification. *Journal of Personality and Social Psychology*, *120*(2), 484.

Vandegrift, E. V., Beghetto, R. A., Eisen, J. S., O'Day, P. M., Raymer, M. G., & Barber, N. C. (2020). Defining science literacy in general education courses for undergraduate non-science majors. *Journal of the Scholarship of Teaching and Learning*, *20*(2).

Waldo, J. T. (2014). Application of the test of scientific literacy skills in the assessment of a general education natural science program. *The Journal of General Education*, *63*(1), 1-14.

Walker, D. F., & Soltis, J. F. (2009). *Curriculum and aims*. Teachers College Press.

Weinstein, M., Blades, D., & Gleason, S. C. (2016). Questioning power: Deframing the STEM discourse. *Canadian Journal of Science, Mathematics and Technology Education*, *16*(2), 201-212.

Wetzel, M. M., Vlach, S. K., Svrcek, N. S., Steinitz, E., Omogun, L., Salmerón, C., Batista-Morales, N., Taylor, L. A., & Villarreal, D. (2019). Preparing teachers with sociocultural knowledge in literacy: A literature review. *Journal of Literacy Research*, *51*(2), 138-157.

Wiggins, B. L., Eddy, S. L., Wener-Fligner, L., Freisem, K., Grunspan, D. Z., Theobald, E. J., ... & Crowe, A. J. (2017). ASPECT: A survey to assess student perspective of engagement in an active-learning classroom. *CBE—Life Sciences Education*, *16*(2), ar32.

Williams, R., & Agosto, V. (2012). Missing and shrinking voices: A critical analysis of the Florida textbook adoption policy. In *The New Politics of the Textbook* (pp. 17-39). Sense.

Wilson, H. E. (2022). Resolving the conflict in gifted education: The missing piece in discussions of inequity of identification, service, and achievement for advanced learners. *Gifted Child Quarterly*, *66*(2), 134-135.

Wood, W., & Eagly, A. H. (2015). Two traditions of research on gender identity. *Sex Roles*, *73*, 461-473.

Woodward, R. (2009). *The organisation for economic co-operation and development (OECD)*. Routledge.

Xu, Y., Ramanathan, V., & Victor, D. G. (2018). Global warming will happen faster than we think.

Yang, Y., & Carroll, D. W. (2018). Gendered Microaggressions in Science, Technology, Engineering, and Mathematics. *Leadership and research in Education*, *4*, 28-45.

Young, M. (2017). *The rise of the meritocracy*. Routledge.

Zandalinas, S. I., Fritschi, F. B., & Mittler, R. (2021). Global warming, climate change, and environmental pollution: recipe for a multifactorial stress combination disaster. *Trends in Plant Science*, *26*(6), 588-599.

APPENDIX A

Student Survey of Sociocultural Experience and Science Literacy

Sociocultural Experiences & Science Literacy

Start of Block: Demographics

Demographics Q1 Would you like to be involved in research at the Central University? I am kristen shelton, a doctoral candidate from the Department of Instructional Leadership and Academic Curriculum. I invite you to participate in my research project entitled Assessing the Impact of Sociocultural Experience on Science Literacy Among First Year College Students. This research is being conducted at the Central University via an online survey. You were selected as a possible participant because you are a Central University student and may be or have been enrolled in a 1000-level introductory science course at the Central University during the 2022-2023 or 2023-2024 academic year. You must be at least 18 years of age to participate in this study. Please read this document and contact me to ask any questions that you may have BEFORE agreeing to take part in my research. What is the purpose of this research? The purpose of this research is to evaluate past science experiences, sociocultural experiences, student perspective and science literacy among first year college. We want to know how your previous experiences and sociocultural background influenced your relationship with science and scientific information. How many participants will be in this research? About 350 people will take part in this research. What will I be asked to do? If you agree to be in this research, you will need to follow the Qualtrics survey link sent to you and complete the survey. All responses are anonymous and there is no identifiable information in the survey or data to be collected. How long will this take? Your participation will take approximately thirty (30) minutes. What are the risks and/or benefits if I participate? There are no risks and no benefits from being in this research. Will I be compensated for participating? You will not be reimbursed for your time and participation in this research. Who will see my information? In research reports, there will be no information that will make it possible to identify you. Research records will be stored securely, and only approved researchers and the OU Institutional Review Board will have access to the records. Data are collected via an online survey system that has its own privacy and security policies for keeping your information confidential. Please note no assurance can be made as to the use of the data you provide for purposes other than this research. What will happen to my data in the future? After removing all identifiers, we might share your data with other researchers or use it in future research without obtaining additional consent from you. Do I have to participate? No. If you do not participate, you will not be penalized or lose benefits or services unrelated to the research. If you decide to participate, you do not have to answer any question and can stop participating at any time. Who do I contact with questions, concerns, or complaints? If you have questions, concerns or complaints about the research or have experienced a research-related injury, contact me via email at kristen.k.shelton-1@ou.edu. You can also contact the Central University – Norman Campus Institutional Review Board (OU-NC IRB) at 405-325-8110 or irb@ou.edu if you have questions about your rights as a research participant, concerns, or complaints about the research and wish to talk to someone other than the researcher(s) or if you cannot reach the researcher(s). Please print this document for your records. By providing information to the researcher(s), I agree to participate in this research. This research has been approved by the Central University.

IRB. IRB Number: _15653__ Approval date: _02/24/2023_

◯ Yes, I consent to participating in this research (1)

◯ No, I do not consent to participating in this research (2)

Skip To: End of Survey If Would you like to be involved in research at the Central University? I am kristen shelton, a... = No, I do not consent to participating in this research

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Demographics Q2 Are you within your first year of college?

◯ Yes (1)

◯ No (2)

Skip To: End of Survey If Are you within your first year of college? = No

---

Demographics Q3 What is your age range?

◯ 18-22 (1)

◯ 22 or older (2)

Skip To: End of Survey If What is your age range? = 22 or older

---

Demographics Q4 Are you currently enrolled in a 1000-level introductory science course (Spring 2023) or were you enrolled in a 1000-level introductory science course last semester (Fall 2022/Fall 2023)?

- ◯ Yes, currently (Spring 2023) (1)
- ◯ Yes, previously (Fall 2022/Fall 2023) (2)
- ◯ No (3)

Demographics Q4a Which 1000-level or 2000-level introductory science course(s) are/were your enrolled in during Fall 2022, Spring 2023, or Fall 2023?

Demographics Q5 What is your intended major field of study?

- ◯ Science (1)
- ◯ Technology, Engineering, or Math (TEM) (2)
- ◯ Non-Science/Non-STEM (3)
- ◯ Have not yet chosen a major (4)

Demographics Q6 What is your race? (choose all that apply)

- ☐ Native American or Alaskan Native (1)
- ☐ Asian (2)
- ☐ Black or African American (3)
- ☐ Native Hawaiian or Other Pacific Islander (4)
- ☐ White (5)
- ☐ Some other race, ethnicity, or origin (6)
- ☐ Prefer to self-describe (7)
- ☐ Prefer not to say (8)

Demographics Q7 What is your ethnicity? (choose all that apply)
Are you of Hispanic, Latino/a/x, or of Spanish origin? (one or more categories may be selected)

- ☐ No, not of Hispanic, Latino/a/x, or of Spanish origin (1)
- ☐ Yes, Mexican American, Chicano/a/x (2)
- ☐ Yes, Puerto Rican (3)
- ☐ Yes, Cuban (4)
- ☐ Yes, Another Hispanic, Latino/a/x, or Spanish origin (5)
- ☐ Some other race, ethnicity, or origin (6)
- ☐ Prefer to self-describe (7)
- ☐ Prefer not to say (8)

Demographics Q7 What is your nationality?

Demographics Q8 What is your gender identity?

- ○ Male (1)
- ○ Female (2)
- ○ Non-binary / third gender (3)
- ○ Transgender (4)
- ○ Prefer to self-describe (5)
- ○ Prefer not to say (6)

Demographics Q9 What is your sexual orientation?

- ○ Straight/Heterosexual (1)
- ○ Gay or Lesbian (2)
- ○ Bisexual (3)
- ○ Pansexual (4)
- ○ Asexual (5)
- ○ Prefer to self-describe (6)
- ○ Prefer not to say (7)

Demographics Q10 What is your political affiliation?

- ○ Not Political (1)
- ○ Republican (2)
- ○ Democrat (3)
- ○ Libertarian (4)
- ○ Independent (5)
- ○ Prefer to self-describe (6)
- ○ Prefer not to say (7)

Demographic Q11 How do you identify your physical ability?

○ Disabled (1)

○ Able-bodied (2)

○ Prefer to self-describe (3)

○ Prefer not to say (4)

End of Block: Demographics

Start of Block: Science Experiences

Science Exp Q1 Do you consider yourself a science-person?

○ Yes (1)

○ No (2)

○ Do not know (3)

Science Exp Q2 How many science courses did you take in high school/secondary school (grades 9-12)?

○ 1-2 (1)

○ 3-4 (2)

○ 5-6 (3)

○ 7 or more (4)

Science Exp Q3 Would you consider yourself to have been an active participant in your previous science course? (e.g., often engaging in discussion, asking questions in class, etc.)

- ◯ Yes, frequently (1)
- ◯ Yes, occasionally (2)
- ◯ Yes, rarely (3)
- ◯ No, never (4)

Science Exp Q4 How would you rank your previous science experiences? (0=poor; 5=mediocre; 10=excellent)

	Not Applicable 0 1 2 3 4 5 6 7 8 9 10
High School (9-12) ()	
Middle School/Mid-High (6-8) ()	
Elementary School (K-5) ()	

Science Exp Q5 How engaging did you find your previous science classes? (0=Not at all engaging; 10=Very engaging)

Not Applicable

0 1 2 3 4 5 6 7 8 9 10

High School (9-12) ()	
Middle School/Mid-High (6-8) ()	
Elementary School (K-5) ()	

Science Exp Q6 Do you feel your previous science courses fostered creativity?

- Yes (1)
- No (2)
- Do not know (3)

Science Exp Q7 Do you feel like critical thinking was valued in your previous science experiences?

- Yes (1)
- No (2)
- Do not know (3)

Science Exp Q8 Have you ever had a negative experience while discussing scientific topics (in or outside of school)?

- ◯ No (1)
- ◯ Yes (2)
- ◯ Do not know (3)

Science Exp Q9 In your experience, what was the attitude toward science in your household?

____

Science Exp Q10 In your experience, what was the attitude toward science in your community?

____

Science Exp Q11 To what extent do you perceive that your household's or community's attitude toward science influenced your attitude toward science? (0=No influence at all; 100=Very influential)

	0 10 20 30 40 50 60 70 80 90 100
Influence on your attitude toward science ()	

End of Block: Science Experiences

Start of Block: Sociocultural Experience

Sociocultural Q1 What is your religious affiliation? (choose all that apply)

- ▢ Judaism (1)
- ▢ Islam (2)
- ▢ Christianity (3)
- ▢ Hinduism (4)
- ▢ Jainism (5)
- ▢ Buddhist (6)
- ▢ Baha'i (7)
- ▢ Confucianism (8)
- ▢ Shinto (9)
- ▢ Sikhism (10)
- ▢ Taoism (11)
- ▢ Zoroastrianism (12)
- ▢ Atheist/Agnostic (13)
- ▢ A religion not listed (14)
- ▢ Prefer to self-describe (15)
- ▢ Prefer not to say (16)

Sociocultural Q2 How many languages were spoken in your household?

- 1 (1)
- 2 (2)
- 3 or more (3)

Sociocultural Q3 Did you grow up in a multigenerational household?

- Yes (1)
- No (2)
- Do not know (3)
- Prefer not to say (4)

Sociocultural Q4 In what type of community did you grow up? (choose all that apply)

- [ ] Rural (1)
- [ ] Suburban (2)
- [ ] City (3)

Sociocultural Q5 What was the highest level of education in the household in which you grew up?

- ○ Middle school (1)
- ○ Some high school (2)
- ○ High school (diploma or GED) (3)
- ○ Some college (4)
- ○ Bachelor's degree (5)
- ○ Graduate or professional degree (6)
- ○ Do not know (7)
- ○ Prefer not to say (8)

Sociocultural Q6 Before attending college, were you and/or your family involved in community activities?

- ○ Yes, both myself and my family (1)
- ○ Yes, just me (2)
- ○ Yes, just my family (3)
- ○ No (4)
- ○ Prefer not to say (5)

Sociocultural Q7 In what type of community did you attend school? (choose all that apply)

- ☐ Rural (1)
- ☐ Suburban (2)
- ☐ City (3)

Sociocultural Q8 What type of school(s) did you attend? (choose all that apply)

- ☐ Traditional public school (1)
- ☐ Public charter school (2)
- ☐ Public magnet school (3)
- ☐ Private school (4)
- ☐ Online academy (5)
- ☐ Homeschool (6)
- ☐ Learning pod (7)
- ☐ Prefer not to say (8)

Sociocultural Q9 Before attending college, were you involved in extra-curricular activities such as sports or clubs?

○ Yes, a lot (1)

○ Yes, a few (2)

○ No (3)

○ Prefer not to say (4)

Sociocultural Q10 Before attending college, did you have household responsibilities such as chores or caretaking? (choose all that apply)

▢ Yes, household chores (1)

▢ Yes, caretaking (2)

▢ Yes, responsibilities other than household chores or caretaking (3)

▢ No household chores or caretaking responsibilities (4)

▢ Prefer not to say (5)

Sociocultural Q11 How was education viewed in your household and/or community?

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Sociocultural Q12 What are your views on education?

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End of Block: Sociocultural Experience

Start of Block: Science Literacy

Science Literacy Q1 Which of the following is a valid scientific argument?

- ○ Measurements of sea level on the Gulf Coast taken this year are lower than normal; the average monthly measurements were almost 0.1 cm lower than normal in some areas. These facts prove that sea level rise is not a problem. (1)
- ○ A strain of mice was genetically engineered to lack a certain gene, and the mice were unable to reproduce. Introduction of the gene back into the mutant mice restored their ability to reproduce. These facts indicate that the gene is essential for mouse reproduction. (2)
- ○ A poll revealed that 34% of Americans believe that dinosaurs and early humans co-existed because fossil footprints of each species were found in the same location. This widespread belief is appropriate evidence to support the claim that humans did not evolve from ape ancestors. (3)
- ○ This winter, the northeastern US received record amounts of snowfall, and the average monthly temperatures were more than 2°F lower than normal in some areas. These facts indicate that climate change is occurring. (4)

Science Literacy Q1a Briefly explain why selected your answer to Science Literacy Question 1.

Science Literacy Q2 **Use the excerpt below** (modified from a recent news report on MSNBC.com) for this question.
"A recent study, following more than 2,500 New Yorkers for 9+ years, found that people who drank diet soda every day had a 61% higher risk of vascular events, including stroke and heart attack, compared to those who avoided diet drinks. For this study, Hannah Gardner's research team randomly surveyed 2,564 New Yorkers about their eating behaviors, exercise habits, as well as cigarette and alcohol consumption. Participants were also given physical check-ups, including blood pressure measurements and blood tests for cholesterol and other factors that might affect the risk for heart attack and stroke. The increased likelihood of vascular events remained even after Gardener and her colleagues accounted for risk factors, such as smoking, high blood pressure and high cholesterol levels. The researchers found no increased risk among people who drank regular soda."

The excerpt above comes from what type of source of information?

- ◯ Primary (Research studies performed, written and then submitted for peer-review to a scientific journal.) (1)
- ◯ Secondary (Reviews of several research studies written up as a summary article with references that are submitted to a scientific journal.) (2)
- ◯ Tertiary (Media reports, encyclopedia entries or documents published by government agencies.) (3)
- ◯ None of the above (4)

Science Literacy Q2a Briefly explain why selected your answer to Science Literacy Question 2.

Science Literacy Q3 Which of the following actions is a valid scientific course of action?

- ◯ A government agency relies heavily on two industry-funded studies in declaring a chemical found in plastics safe for humans, while ignoring studies linking the chemical with adverse health effects. (1)
- ◯ Journalists give equal credibility to both sides of a scientific story, even though one side has been disproven by many experiments. (2)
- ◯ A government agency decides to alter public health messages about breast-feeding in response to pressure from a council of businesses involved in manufacturing infant formula. (3)
- ◯ Several research studies have found a new drug to be effective for treating the symptoms of autism; however, a government agency refuses to approve the drug until long term effects are known. (4)

Science Literacy Q3a Briefly explain why selected your answer to Science Literacy Question 3.

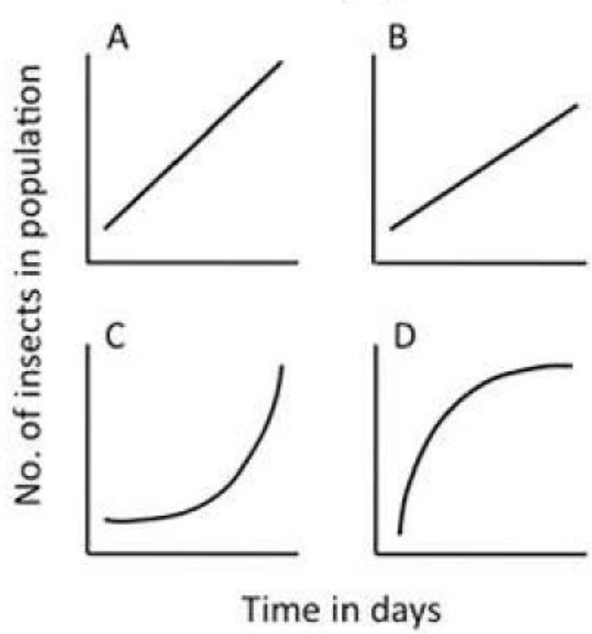
Science Literacy Q4 Which of the following research studies is least likely to contain a confounding factor (variable that provides an alternative explanation for results) in its design?

- ◯ Researchers randomly assign participants to experimental and control groups. Females make up 35% of the experimental group and 75% of the control group. (1)
- ◯ To explore trends in the spiritual/religious beliefs of students attending U.S. universities, researchers survey a random selection of 500 freshmen at a small private university in the South. (2)
- ◯ To evaluate the effect of a new diet program, researchers compare weight loss between participants randomly assigned to treatment (diet) and control (no diet) groups, while controlling for average daily exercise and pre-diet weight. (3)
- ◯ Researchers tested the effectiveness of a new tree fertilizer on 10,000 saplings. Saplings in the control group (no fertilizer) were tested in the fall, whereas the treatment group (fertilizer) were tested the following spring. (4)

Science Literacy Q4a Briefly explain why selected your answer to Science Literacy Question 4.

Science Literacy Q5 While growing vegetables in your backyard, you noticed a particular kind of insect eating your plants. You took a rough count (see data below) of the insect population over time. Which graph shows the best representation of your data?

Time (days)	Insect Population (number)
2	7
4	16
8	60
10	123



- ○ A (1)
- ○ B (2)
- ○ C (3)
- ○ D (4)

Science Literacy Q6 A gene test shows promising results in providing early detection for colon cancer. However, 5% of all test results are falsely positive; that is, results indicate that cancer is present when the patient is, in fact, cancer-free. Given this false positive rate, how many people out of 10,000 would have a false positive result and be alarmed unnecessarily?

- ○ 5 (1)
- ○ 35 (2)
- ○ 50 (3)
- ○ 500 (4)

Science Literacy Q7 Why do researchers use statistics to draw conclusions about their data?

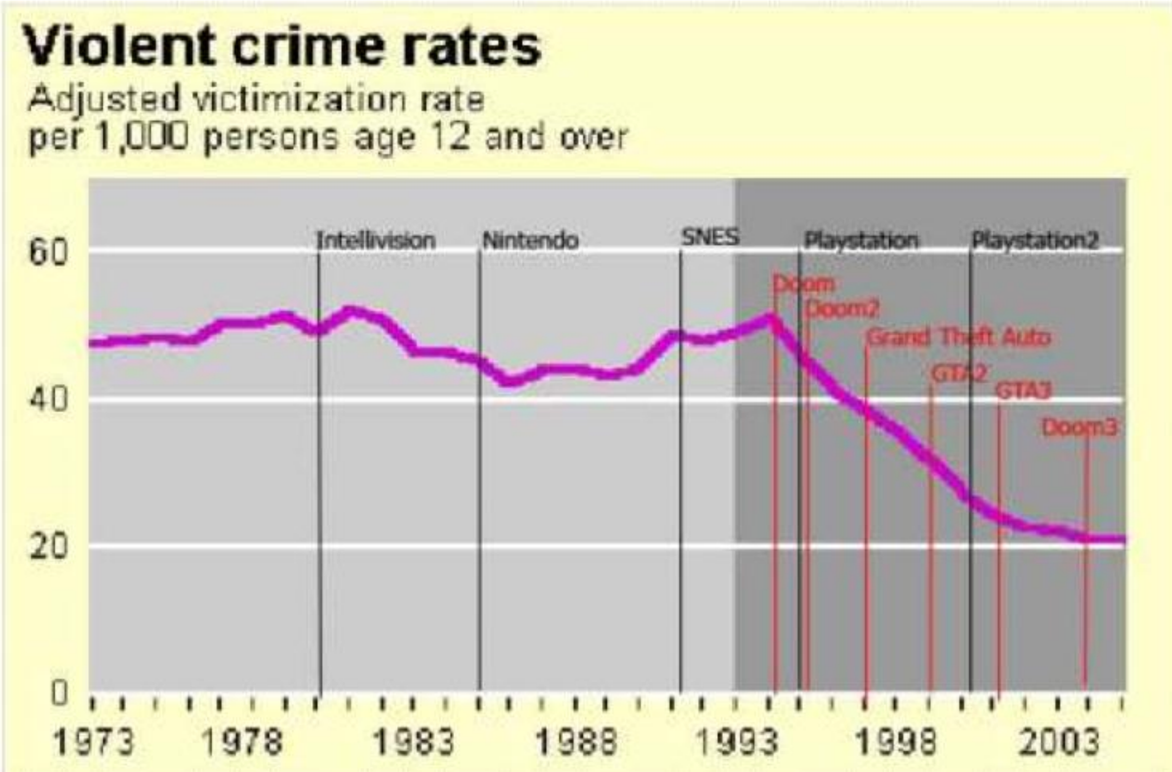
- ○ Researchers usually collect data (information) about everyone/everything in the population. (1)
- ○ The public is easily persuaded by numbers and statistics. (2)
- ○ The true answers to researchers' questions can only be revealed through statistical analyses. (3)
- ○ Researchers are making inferences about a population using estimates from a smaller sample. (4)

Science Literacy Q8 Creators of the Shake Weight, a moving dumbbell, claim that their product can produce “incredible strength!” Which of the additional information below would provide the strongest evidence supporting the effectiveness of the Shake Weight for increasing muscle strength?

- ◯ Survey data indicates that on average, users of the Shake Weight report working out with the product 6 days per week, whereas users of standard dumbbells report working out 3 days per week. (1)
- ◯ Compared to a resting state, users of the Shake Weight had a 300% increase in blood flow to their muscles when using the product. (2)
- ◯ Survey data indicates that users of the Shake Weight reported significantly greater muscle tone compared to users of standard dumbbells. (3)
- ◯ Compared to users of standard dumbbells, users of the Shake Weight were able to lift weights that were significantly heavier at the end of an 8-week trial. (4)

Science Literacy Q8a Briefly explain why selected your answer to Science Literacy Question 8.

Science Literacy Q9 **Background for question**: A videogame enthusiast argued that playing violent video games (e.g., Doom, Grand Theft Auto) does not cause increases in violent crimes as critics often claim. To support his argument, he presents the graph below. He points out that the rate of violent crimes has decreased dramatically, beginning around the time the first “moderately violent” video game, Doom, was introduced.



Considering the information presented in this graph, what is the **most critical flaw** in the blogger's argument?

- ◯ Violent crime rates appear to increase slightly after the introduction of the Intellivision and SNES game systems. (1)
- ◯ The graph does not show violent crime rates for children under the age of 12, so results are biased. (2)
- ◯ The decreasing trend in violent crime rates may be caused by something other than violent video games. (3)
- ◯ The graph only shows data up to 2003. More current data are needed. (4)

Science Literacy Q10 **Background for question:** The following graph appeared in a scientific article1 about the effects of pesticides on tadpoles in their natural environment.

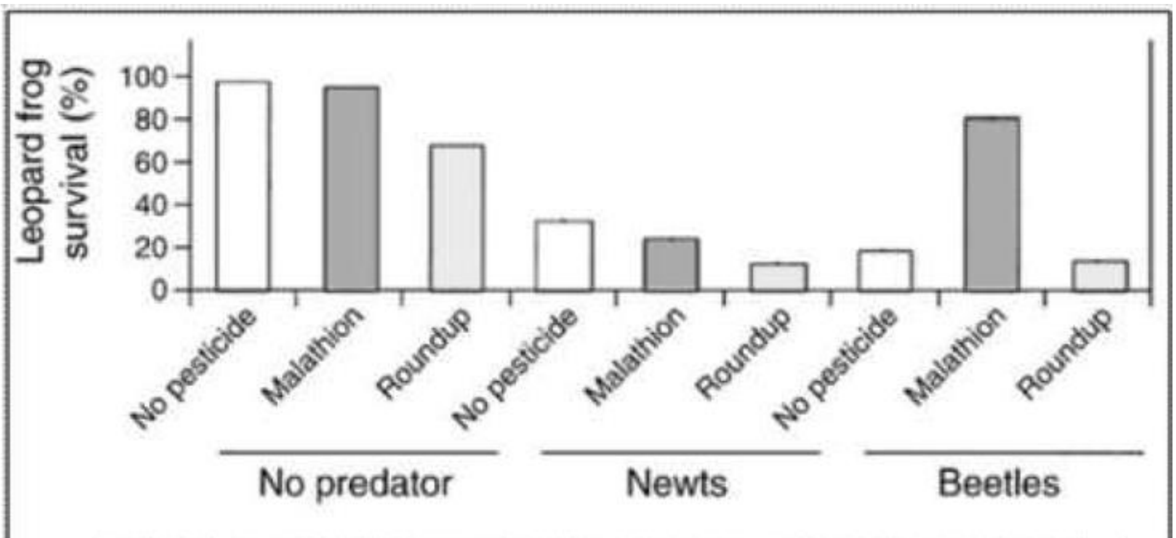


Fig. 2. Total survival of Leopard frog tadpoles living in ponds with 2 pesticides added (Malathion and Roundup) and 2 tadpole predators present (newts and beetles).

When beetles were introduced as predators to the Leopard frog tadpoles, and the pesticide Malathion was added, the results were unusual. Which of the following is a plausible hypothesis to explain these results?

- ○ The Malathion killed the tadpoles, causing the beetles to be hungrier and eat more tadpoles. (1)
- ○ The Malathion killed the tadpoles, so the beetles had more food and their population increased. (2)
- ○ The Malathion killed the beetles, causing fewer tadpoles to be eaten. (3)
- ○ The Malathion killed the beetles, causing the tadpole population to prey on each other. (4)

Science Literacy Q11 The most important factor influencing you to categorize a research article as trustworthy science is:

- ○ the presence of data or graphs (1)
- ○ the article was evaluated by unbiased third-party experts (2)
- ○ the reputation of the researchers (3)
- ○ the publisher of the article (4)

Science Literacy Q11a Briefly explain why selected your answer to Science Literacy Question 11.

Science Literacy Q12 Which of the following is not an example of an appropriate use of science?

- ○ A group of scientists who were asked to review grant proposals based their funding recommendations on the researcher's experience, project plans, and preliminary data from the research proposals submitted. (1)
- ○ Scientists are selected to help conduct a government-sponsored research study on global climate change based on their political beliefs. (2)
- ○ The Fish & Wildlife Service reviews its list of protected and endangered species in response to new research findings. (3)
- ○ The Senate stops funding a widely used sex-education program after studies show limited effectiveness of the program. (4)

Science Literacy Q12a Briefly explain why selected your answer to Science Literacy Question 12.

Science Literacy Q13 A researcher hypothesizes that immunizations containing traces of mercury do not cause autism in children. Which of the following data provides the strongest test of this hypothesis?

○ a count of the number of children who were immunized and have autism (1)

○ yearly screening data on autism symptoms for immunized and non-immunized children from birth to age 12 (2)

○ mean (average) rate of autism for children born in the United States (3)

○ mean (average) blood mercury concentration in children with autism (4)

Science Literacy Q13a Briefly explain why selected your answer to Science Literacy Question 13.

Science Literacy Q14 **Background for question**: Researchers interested in the relation between River Shrimp (Macrobrachium) abundance and pool site elevation, presented the data in the graph below. Interestingly, the researchers also noted that water pools tended to be shallower at higher elevations.

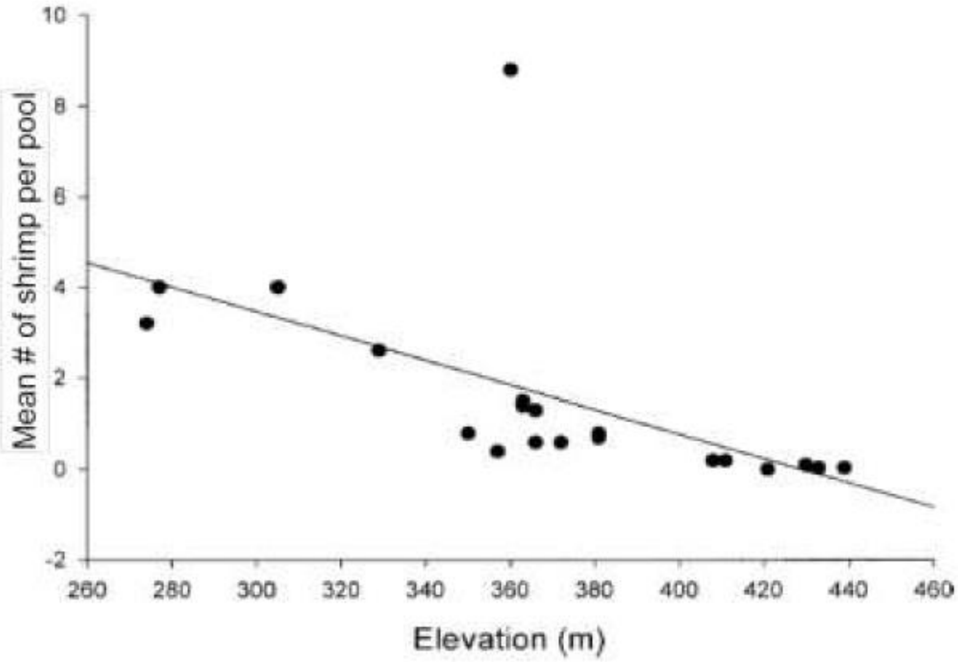


FIG. 3. Relationship between total abundance of *Macrobrachium* (1988–2002) and elevation in Quebrada Prieta.

Which of the following is a plausible hypothesis to explain the results presented in the graph?

◯ There are more water pools at elevations above 340 meters because it rains more frequently in higher elevations. (1)

◯ River shrimps are more abundant in lower elevations because pools at these sites tend to be deeper. (2)

◯ This graph cannot be interpreted due to an outlying data point. (3)

◯ As elevation increases, shrimp abundance increases because they have fewer predators at higher elevations. (4)

End of Block: Science Literacy