Tripp *et al.*
Disciplinary and Interdisciplinary Science Education Research (2024) 6:21
https://doi.org/10.1186/s43031-024-00110-y

Disciplinary and Interdisciplinary Science Education Research

RESEARCH

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Paradoxical perceptions: minoritized high school students' stereotypical and expansive views of science and scientists at an urban, inclusive STEM-focused high school (ISHS)

Jennifer N. Tripp[1*], Noemi Waight[1] and Xiufeng Liu[1]

Abstract
Existing research on inclusive STEM-focused high schools (ISHSs) has focused on the design and implementation of ISHSs at the school-level, along with the positive effects of ISHSs on STEM course taking, college majoring, and STEM career orientations. Missing from the literature are studies that foreground the perspectives and voices of students of color and their perceptions of science and scientists from asset-based, critical perspectives. Thus, the purpose of this qualitative case study is to document the perceptions of science and scientists among racially, ethnically, and linguistically minoritized ninth graders at an urban, inclusive STEM-focused high school in a mid-sized, northeastern city in the United States, along with the contexts, sources, and associated experiences informing these perceptions. Iterative cycles of inductive and deductive coding and domain analysis, informed by theoretical perspectives on ecological systems and Discourses, revealed paradoxical perceptions. Students viewed science as a body of knowledge, testing and experimenting, a life-enhancing discovery, building on background information, and connected with other disciplines and everywhere. Students' perceptions of scientists were both stereotypical and expansive, including that scientists are smart and serious; use science equipment and gear in traditional lab contexts; and are creative, curious, and open-minded. While students primarily identified deceased White males as scientists, three girls of color mentioned counter-stereotypical women and people of color when they thought of science. Students noted that science field trips and after school programs, as well as science in the media and school, informed their perceptions. These findings suggest that despite reform efforts such as Science for All, very little has changed regarding conceptions of science and scientists. What is more, these findings are troubling when minoritized students at an ISHS continue to replicate status quo perceptions of science and scientists. This study has implications for practice, research, and policy related to building on and extending these views in more critically conscious and equity-oriented ways.

Keywords STEM schools, Inclusive STEM-focused high schools (ISHS), Science, Scientists, Perceptions, Discourses, Contexts, Stereotypes, Equity, Inclusion

*Correspondence:
Jennifer N. Tripp
jntripp@buffalo.edu
[1]Department of Learning and Instruction, University at Buffalo, State University of New York, Buffalo, NY 14260-1000, USA

Introduction

The focus on science, technology, engineering, mathematics, and medicine (STEM) has continued to heighten globally (Liu & Wang, 2023), amongst calls to augment and better prepare a STEM workforce. Beyond an economic vision, however, the importance of cultivating 21st century skills and STEM competencies lies in informed decision making and activism to address grand challenges, such as climate and food justice, where racially and ethnically minoritized working class communities are most adversely burdened due to interlocking systems of injustice. It is within this international context that education initiatives, from early childhood to graduate school, have increasingly advocated for STEM.

In the United States, disparities in STEM participation persist along lines of race, ethnicity, disability, and gender statuses (NCSES, 2023). Recognizing that this inequitable participation has roots in axes of oppression such as racism, ableism, and sexism, precollege programs have called for equitable visions of STEM education, in terms of access and less often, transformation (Burgess & Patterson Williams, 2022). Among such programs that have been at the intersection of STEM education and equity conversations are STEM schools, which have been promoted as structures that increase and concentrate STEM opportunities that, in turn, improve STEM outcomes. However, there are a variety of STEM schools, located from rural to urban areas, and great variation exists within and across STEM schools, with mixed results (Tripp, 2023).

Likewise, access to STEM schools is an equity issue, given that who these schools serve varies depending on the school's location and admission procedures; in an effort to address these concerns, schools known as inclusive STEM-focused high schools (ISHSs) have been created. ISHSs actively recruit students traditionally underrepresented in STEM, particularly along lines of race, ethnicity, gender, and socioeconomic status and do not have traditional standardized entrance exam requirements as compared with selective STEM schools (Lynch et al., 2018). Through an amalgam of opportunity structures, ISHSs are uniquely positioned to support students through business and industry partnerships and rigorous STEM curricula and research opportunities, among other features.

Existing literature on ISHSs has focused on the design and implementation of ISHSs at the school-level. There have been cross-case analyses of ISHSs as compared with comprehensive, non-STEM schools (Weis et al., 2015), across STEM elementary, middle, and high schools (Lesseig et al., 2019), or only among ISHSs (Lynch et al., 2018), in addition to single instrumental case studies of ISHSs (Peters-Burton et al., 2014). These studies have highlighted key features of ISHSs, particularly exemplary schools, and the ways in which these schools offer unique opportunities that prepare students for STEM pathways or have failed to sustain these opportunities over time (Eisenhart & Weis, 2022). There is also research on the effects of ISHSs on STEM course taking, college majoring, and STEM career orientations. For example, in a meta-analysis conducted by Means and colleagues (2021), there were positive effects for ISHSs regarding the completion of key STEM courses and the likelihood of engaging in self-selected STEM activities. Students who attended an ISHS identified more strongly with math and science, and high school seniors were more likely to be interested in one or more STEM careers. There was also a small positive effect on students' science test scores.

Largely missing from the ISHS literature, however, are racially, ethnically, and linguistically minoritized students' experiences—that foreground their own perspectives and voices (Tripp & Waight, 2024)—along with their perceptions of science and scientists in their first year at these schools from critical, asset-based lenses. We focus on ninth graders because it is the first year that they are in high school, particularly an ISHS—the focus of this case study. Additionally, in the second half of the school year in which data collection for this study occurred, ninth graders have had informal and formal science education experiences at the ISHS, and they have also had various prior K-8 experiences. By centering our study on ninth graders, we were able to gauge a sense of the STEM experiences and perspectives minoritized youth had at this unique point directly after middle school and at the beginning of high school, a crucial time for youth's exploration of their present and future selves and identity development (Archer et al., 2015). Given the marginalization of formal science education for students of color in K-8 formal school settings and more research on the science and scientist perspectives among elementary students and preservice teachers, this choice to focus on ninth graders at an urban ISHS addresses a unique gap (Mensah & Bianchini, 2023).

Eliciting and foregrounding minoritized students' perspectives is an equity issue. It is aligned with counterstorytelling and counterrnarratives that center the stories of people of color, their experiential knowledge, and unique voices (Solórzano & Yosso, 2002). Moreover, ISHS students' science and scientist perspectives are important as they inform students' science aspirations, which also mediate student ISHS outcomes, including participation in STEM extracurricular activities, course taking patterns, attendance, academic performance, and STEM majoring (Means et al., 2021). Exploring students' perceptions of science and scientists is also essential given that such perceptions are intertwined with how students see themselves represented in science, which can also be preserved, broadened, and/or challenged through ISHS curriculum, pedagogy, and assessment practices. If ISHSs are to be truly inclusive, as their name suggests—and as purported by the "Inclusive STEM Mission" critical component—such programming should epitomize, promote, and sustain students' cultures, which would entail moving beyond a traditional White masculine culture of STEM. Rather, such curricula should be grounded in nuanced understandings and recognition of the multifaceted racial, ethnic, linguistic, gender, and other identities, cultures, experiences, and contributions of communities of color, which heretofore has not been central nor directly and deeply woven into the design, role, and vision of ISHSs (Tripp, 2023).

Additionally, from elementary school (Blagdanic et al., 2019) to college (Schinske et al., 2016), research has shown that students across the globe harbor stereotypical, narrowed, often contradictory views of science and scientists, reflecting societal discourses and racialized and gendered inequities (Archer et al., 2012; Chionas & Emvalotis, 2021; Varelas et al., 2011). Science is stereotypically viewed as culture free, objective, in search of truth, methodical, focused on a single scientific method, and primarily experimental (Avraamidou & Schwartz, 2021; Settlage et al., 2018). The prevailing image of scientists is that they are White and male, supremely clever, anti-social, and confined to their labs in basements, secretly and methodically engrossed in search of breakthroughs, such as medical cures; donning white lab coats and glasses, they pour chemicals into test tubes, which sometimes leads to explosions and other threats to humanity (Chambers, 1983; Christidou & Kouvatas, 2013; DeWitt et al., 2013; Yilmaz-Na & Sönmez, 2023).

These representations of science and scientists are common in textbooks that devote little attention to the epistemic dimensions of scientific knowledge and practices (Abd-El-Khalick et al., 2017; Kapsala et al., 2022; Li et al., 2020; Ju et al., 2023) and depict mostly White men of European descent as scientists (Yacoubian et al., 2017). Such prevalent, public images of science and science professions are also fostered by photos of scientists and their work environments on university and research institution websites (Christidou & Kouvatas, 2013). Such portrayals have also been common in cartoons, children's books, and mass media (Brown, 2019; Brunner & Abd-El-Khalick, 2020; Rawson & McCool, 2014; Steinke, 2017). While there have been alternatives to these images that are less stereotypical, altogether, these representations cultivate distorted, superficial perceptions of science and scientists.

Despite an ostensibly widespread base of literature and subsequent awareness of these collective representations and perceptions of science and scientists, there are notable limitations and gaps. First, White participants have been the majority racial group under study (Walls, 2016, 2022), thereby missing the firsthand perspectives and views of science and scientists among Asian, Black, Indigenous, and Latinx students and teachers in a majority of nature of science and Draw-a-Scientist-Test (DAST) studies. Second, studies have harbored problematic, deficit, "othering" terminology and conceptions of people of color, where race, ethnicity, and gender, along with racism and sexism have been conflated, if considered or mentioned at all (Walls, 2022).

Indeed, dubbed as a seminal work in studying students' images of science and scientists, the Mead and Metraux (1957) study inspired Chambers's (1983) 1966–1977 DAST research with elementary school children. While both studies have been cited as foundations of DAST studies in the decades thereafter and have uncovered stereotypical science and scientist images that still persist today, both are examples of studies containing deficit, problematic lenses and discourses evident in their designs and recommendations, that have materialized in subsequent DAST research building on their work (Walls, 2022). Thus, there are a range of methodological limitations in many DAST studies, including instructions to draw a picture of *a* scientist—which might privilege depictions of single scientists, suggesting solitary views of scientists' work—to coders' obscure and inconsistent interpretations of the race and gender of scientist pictures, without consulting the student drawers. Finally, none of these studies center the perspectives of students of color, who are high school students, within STEM schools, including ISHSs. Given the unique nature of ISHSs, with explicit claims toward inclusivity in STEM as part of their mission statements that drive their formation and implementation, research on the perceptions of science and scientists among students of color at ISHSs is essential.

As such, the purpose of this exploratory qualitative case study is to document the perceptions of science and scientists among racially, ethnically, and linguistically minoritized ninth graders at an urban ISHS in a mid-sized, northeastern city in the United States, along with the contexts, sources, and associated experiences informing these perceptions. Specifically, this study examines the following research questions among ninth graders who attend an urban ISHS:

1) What are racially, ethnically, and linguistically minoritized high school students' perceptions of science?
2) What are racially, ethnically, and linguistically minoritized high school students' perceptions of scientists?
3) What are the identified contexts, sources, and associated experiences that inform racially,

ethnically, and linguistically minoritized high school students' perceptions of science and scientists?

This study's focus is significant for several reasons. First, Walls (2022) pointed out the ways in which the extant research on students' views of science and scientists has reproduced harm: "Harm in research happens when people of color are by general rule, left out of research. Left out of participating, left out of discussions, and left out of decision making" (p. 166). In turn, he argued for researchers to center the views of science and scientists among students of color, and African American students in particular, to intentionally privilege their voices in this research, and to "identify where and how race is present in their study" (p. 166). Science education research that has centered racially and ethnically minoritized participants' perspectives has contested deficit thinking and pervasive, flawed narratives about people of color corresponding with colorblind ideology, White privilege, and structural racism (Mensah & Bianchini, 2023). Towards addressing this call and aligning with critical, asset-based stances of minoritized students' conceptions in ISHSs, this study privileges the perspectives of students of color in their first year of attending an ISHS. Specifically, it explores their views of science and scientists, which have not been previously foregrounded and documented.

Furthermore, students' perceptions of science and scientists are connected with perceptions of their past, present, and future selves in science (Kang et al., 2019). As DeWitt et al. (2013) remark, "any narrow perceptions of science held by young people may be problematic because they may restrict the possibilities for individuals to find a place for themselves in science" (p. 1456). These perceptions have significant implications for students' self-recognition as a science person (Brickhouse et al., 2000), aspirations towards science careers (Archer et al., 2015), and their sense of belonging (Gormally & Inghram, 2021). Ultimately, restricted views can lead students to "doubting the relevance of scientific claims" and perpetuating "inequities and false narratives about whose science is valued" (Avraamidou & Schwartz, 2021, p. 342). In these ways, this study has potential to shed new insights on students' perceptions of science and scientists, which can inform the design, implementation, and evaluation of STEM education programming that transforms students' views of, identification with, and redefinition of science.

Theoretical framework

Bronfenbrenner's (1979, 1986) ecological systems theory offers a useful framework for exploring minoritized students' perceptions of science and scientists, along with the contexts, sources, and associated experiences informing them. Bronfenbrenner's framework emphasizes the dynamic, nested contexts and interactions between individuals and others that contribute toward human development across the lifespan. In the context of this study, the most immediate and influential environment for the individual is the microsystem, where students learn about science and scientists from the home, family, and community, along with school and other out-of-school science education programs, offered in conjunction with industry and university partners (Shaby et al., 2021).

Interconnections among the microsystems of science experiences, messaging, and interactions create the mesosystem, which are connected with and indirectly influenced by the exosystem. Thus, students' perceptions may also be influenced by cartoons, videos, curricular materials and other mass media (Steinke, 2017), along with standards documents (Park et al., 2020) such as the *Next Generation Science Standards* (*NGSS*) (NGSS Lead States, 2013). The messages communicated within these materials can inform students' science education experiences at the micro- and meso- levels, and their perceptions of science and scientists, either consciously or unconsciously, including their beliefs about science, science careers, and scientists overall (DeWitt et al., 2013). The macrosystem comprises macro-level societal ideologies and structures, which tend to disproportionately reflect Eurocentric, White masculine cultures of science and scientists' contributions and perspectives (Harding, 1991). The chronosystem recognizes the patterns of life events that occur over time, which we represent as connecting the past time and space with the present and future. Thus, students' prior experiences inform their perceptions of science and scientists, and we also recognize that students' future perceptions might change with changing contextual layers of interacting systems and opportunities therein. Figure 1 includes a depiction of this framing.

We combine the above framing of embedded contexts shaping students' perceptions with Gee's (1990) conceptualization of Discourses, which consists of repertoires of knowledge, beliefs, dispositions, and relationships, that can be assembled into an "identity kit" to be taken and drawn upon in other contexts (p. 142). These Discourses may be normalized, celebrated, and/or marginalized and therefore recognized differently in various contexts (Carlone et al., 2015). As Gee (1990) explains, big "D" Discourse is more than little "d" discourse of language—it refers to the "ways of being in the world" (p. 142), such as constructions of what it means to be a scientist or a student of biology, along with the associated ways in which scientists think, behave, and speak. Thus, science and scientist Discourses are "always embedded in a medley of social institutions" and often involve various "props" including the contextual settings like "laboratories, classrooms, buildings of various sorts, various technologies,

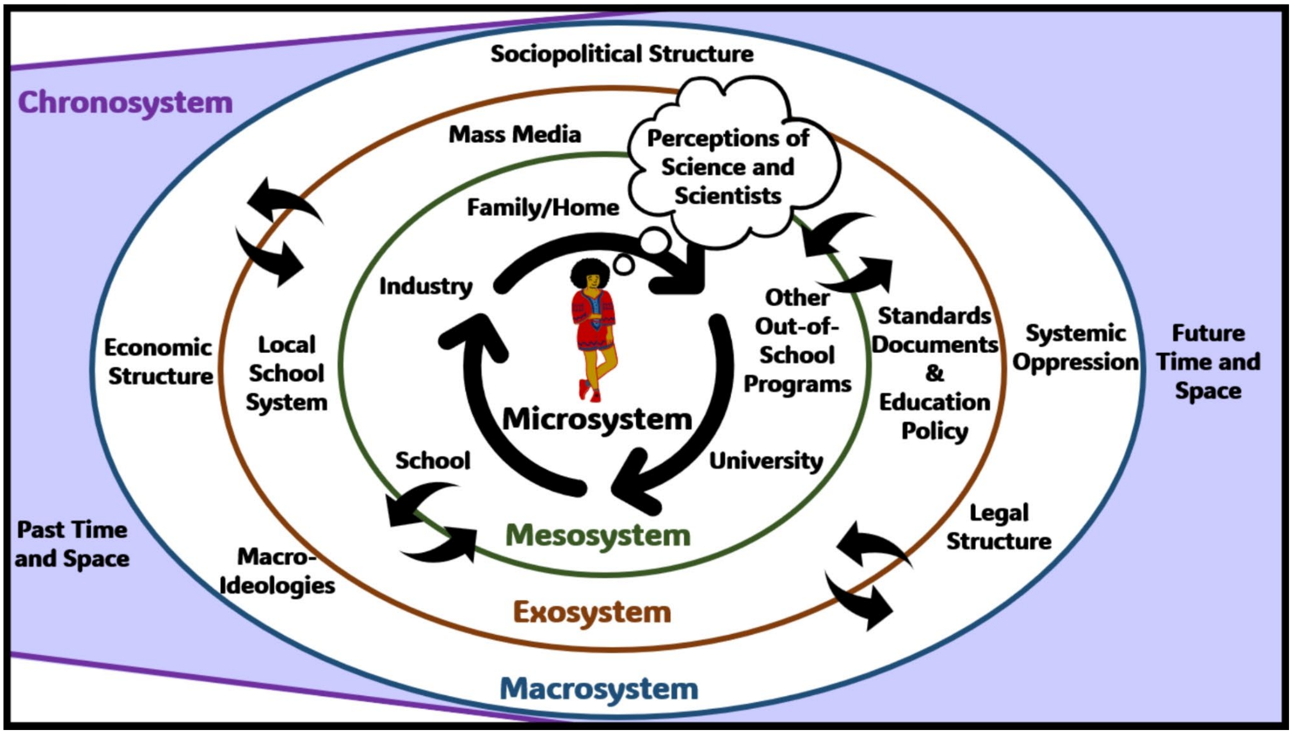

Fig. 1 Theoretical framework of contexts informing students' perceptions of science and scientists. Adapted from Bronfenbrenner (1979, 1986)

and a myriad of other objects" (p. 143). Within science and scientist Discourses are tacit rules about membership, governing what is considered appropriate ways for scientists to think, feel, believe, value, and act.

Consequently, Discourses are "inherently 'ideological'" as they "crucially involve a set of values and viewpoints about the relationships between people and the distribution of social goods" that govern these norms of participation (p. 144). As such, they are also "intimately related to the distribution of social power and hierarchical structure in society" (p. 144), including racist and sexist constructions of science and scientists. Mastery of dominant Discourses can lead to status and power in society, which are "products of history, whether these be Discourses connected with academic disciplines like physics…or other school-based practices…or other social institutions" (p. 145). Students could critique other Discourses, such as the stereotypical White male scientist assiduously working alone in a lab, yet to do so, they have adopted some sort of Discourse. Given that Discourses are taken up in relation to others, a Discourse will inevitably "*marginalize* viewpoints and values" of other Discourses (p. 144, emphasis in original). Students can also be members of multiple, sometimes contradictory Discourses, as the Discourses the individual chooses to take up can be in "conflict and tension between the values, beliefs, attitudes, interactional styles, uses of language and ways of being in the world which two or more Discourses represent" (p. 145). In this way, a science student might have both narrowed and expansive perceptions of science and scientists. They might also be able to adopt a Two-Ways or Two-Eyed Seeing with epistemic insight approach to making sense of and simultaneously valuing Indigenous and Western knowledge in science (Michie et al., 2023).

Combined, these frameworks suggest that a variety of Discourses about science and scientists exist and inform one another across time and space. From macrosystem-level ideologies, norms, and values that can inform education standards and policy, such Discourses can be communicated through mass media and school textbooks. They also exist in familial, school, and community cultures, reinforced through microsystem-level interactions that, in turn, shape the perceptions of science and scientists among individuals. The science and scientist Discourses might align or be in tension with one another.

Methodology

This study emerges from a larger study and followed an exploratory qualitative case study design (Yin, 2009) to explore students' perceptions of science and scientists, along with the associated contexts, sources, and experiences informing these perceptions. As a case study, it was bounded by ninth graders taking both Regents Living Environment (biology) and Scientific Research courses at an urban ISHS, along with the teachers of these courses.

Study context and participants

The research site, STEM Scholars Academy, is an ISHS in an urban public school district in a mid-sized city in the northeastern United States. There were 18 student participants, all of whom were ninth graders who took both Regents Living Environment and Scientific Research courses and provided parent/guardian consent and their assent to participate in this study, which was approved by the Institutional Review Board; all names are pseudonyms. The school was chosen because it shared critical components of ISHSs (Lynch et al., 2018), and the courses were chosen since they were the science courses that students took as ninth graders at STEM Scholars Academy.

Regents Living Environment was an introductory high school-level science course offered to students throughout the state, which followed a curriculum based on state standards and prepared students for a state standardized exam that students took as part of their high school graduation requirements; its content is similar to what would be found in a traditional high school biology class. Scientific Research, on the other hand, was designed to expose students to practices involved in scientific research, from obtaining information from various databases and citing sources, to learning about experimental design and controlled science experiments, to analyzing and communicating results to others. An important outcome of this course was a capstone project where students were expected to design and implement their own science investigations to present at the school's annual science research symposium.

The focus was on ninth graders because it was the first year that they were in high school, and in the second half of the school year, they had various science experiences, informal and formal, including in the two abovementioned science courses. Students were asked how they identified according to race, ethnicity, gender, pronouns, and languages they speak. The self-reported demographics of student participants are 61% female and 39% male; 6 students identified as multiracial, 5 as Black or African American, 3 as Latinx or Hispanic, 3 as Middle Eastern, and 1 as Asian. Students identified Afghani, Eritrean, Filipino, Irish, Kenyan, Native American (unspecified tribal affiliation), Nigerian, Portuguese, Puerto Rican, Russian, Somali, Thai, Turkish, West Indian Trinidadian, and Yemeni heritage. In addition to varieties of English, student participants collectively spoke Arabic, French, Karen, Mai Mai, Spanish, Somali, Swahili, Thai, Tigrigna, Turkish, and Russian. School-reported demographics reveal that 28% of students were classified as multilingual learners of English; 17% of students were formerly classified as multilingual learners of English and have since been reclassified; 17% of students were classified with disabilities; and all students were eligible for free and reduced-price lunch.

Teachers in both courses were also consulted, although their voices in this study are backgrounded and used primarily for triangulation purposes. Mrs. Clark taught Regents Living Environment, Ms. Allen was the integrated co-teacher in Regents Living Environment, and Mrs. Turner was the Scientific Research teacher. All teachers were White females, certified in the areas in which they taught, earned both bachelor's and master's degrees, and had teaching experience ranging from 4 to 14 years at the time of the study.

Data collection

Drawing from a larger study, this exploratory case study primarily relies on student interviews, with observations and artifacts for triangulation purposes (Creswell & Poth, 2018), which diverges from existing studies of views of science and scientists that have relied on surveys and the DAST. Unless otherwise noted, quotes are from the first of two semi-structured interviews, averaging 30–45 min each, which included open-ended questions and follow-ups (Seidman, 2013), to elicit yet minimize researcher influence on students' perceptions of science and scientists. Observations are documented by the class followed by the month and date such that an observation of a Regents Living Environment Class on Pi Day, March 14th would be documented as: (Regents Living Environment Observation, 3.14). The first author conducted the semi-structured interviews with participants individually in a quiet room at the school, conducted observations, and took field notes.

Interviews occurred when participants were available, during free periods, lunch, and/or after school. Given that these interviews were semi-structured, the first author asked follow-up questions to elicit more details and examples from participants. Statements such as, "Tell me more," "Please explain," and "What do you mean by…?" were used to elicit more information and detail (Glesne, 2011, p. 122). Individual interviews allowed a forum for participants to share their thoughts and make meaning of their experiences and perceptions. As opposed to focus groups, individual interviews elicited responses from participants in ways that minimized the influence of groupthink or conversations potentially dominated by more vocal participants.

Interview questions and follow-ups pertaining to the results in this study included: "When you think about science, what comes to mind?" and "What does science mean to you?", which aligned with the first research question exploring students' perceptions of science. Questions corresponding to the second research question included: "When you think of a scientist, what do you think?", "How would you describe a scientist?", "What do scientists do?", "Are there any scientists that you know?", and "Who do you think of as scientists?" Interview questions that addressed the third research question on the contexts, sources, and associated experiences informing these perceptions of science and scientists include, "What makes you say that?" and, "Where have you seen, heard, and learned that?"

Daily observations occurred in the science courses and out-of-of school events, totaling over 50 h, attending to activities and interactions that followed an ethnographic approach, consistent with Spradley's (1980) descriptive question matrix. This approach entailed attending to major components and activities of the observed lesson and overall patterns of science teaching and learning over time to get a sense of the culture of the science learning context. After observations, field notes were expanded, descriptions were separated from inferences, and when possible, adhered to the concrete principle within 24 h to maintain trustworthiness in data collection (Spradley, 1980). Associated artifacts, including lesson materials and student work samples, were collected whenever possible and when teacher and student participants consented to share this information.

Data analysis

Data analysis was iterative, beginning with reading and memoing emergent ideas of interview responses (Creswell & Poth, 2018) related to the research questions, followed by developing initial codes through descriptive and in vivo coding (Saldaña, 2021), such as "smart" and "serious" to describe scientists or "testing things" to describe the methods of science, which grounded analysis in participants' own words. The second stage was deductive, informed by perspectives from the literature, such as "counter stereotypical scientists" (Nguyen & Riegle-Crumb, 2021), to the theoretical framework pertaining to different microsystem, mesosystem, exosystem, and macrosystem contexts and experiences such as field trips and school courses informing students' (Bronfenbrenner, 1986) scientist and science Discourses (Gee, 1990), including that scientists are "curious" and "open-minded" and science involves "experimentation and testing." Spradley's (1980) domain analysis offered an additional interpretative lens. An example is a cover term of "scientist" with the semantic relationship being "an attribute of" and "remembers things, knows things fast, creative, curious, and open-minded" as some of the included terms. After multiple reads across participants and questions, along with observations and artifacts, codes were merged and collapsed into categories.

As an example, for the theme that *Scientists Work in Traditional Lab Contexts*, Brianna's interview statement, "I think tubes, you know, putting things together…and like a lab coat, with the goggles" was in vivo coded as *tubes*, *lab coats*, *and goggles*, which were later subsumed by the deductive code of *traditional lab Discourses* (Gee, 1990) from the theoretical framework. Similarly, Jada's interview statement, "it's actually like everywhere, like I watch science movies at home, or I used to watch it in middle school" was deductively coded as part of the *microsystem* (e.g., home) and *exosystem* (e.g., mass media, cartoons, videos, and curricular materials) that tend to normalize and celebrate *traditional lab Discourses*, aligned with our theoretical framework (Bronfenbrenner, 1986; Gee, 1990). Observations revealed instances when students used flasks or test tubes for their science experiments (e.g., Regents Living Environment, 3.26) or were watching the movie, GATTACA (e.g., Scientific Research Observation, 4.3), where individuals were working in a lab environment, and these instances were likewise coded as *traditional lab Discourses* and *exosystem – mass media and curricular videos*, just as the artifact shown in Fig. 3, from a Scientific Research course handout showcasing flasks and test tubes, was coded. Spradley's (1980) domain analysis was used as another lens to synthesize this information where *tube*, *flask*, *lab coat*, *and goggles* were "a kind of" *traditional lab equipment and gear* that were examples of the *traditional lab Discourses* (Gee, 1990). Altogether, these codes and examples across data sources contributed to the theme that students perceived scientists as working within traditional lab contexts. Triangulation of data, reflective memoing, and awareness of researcher subjectivities as a woman of color, who had established rapport with participants through informal STEM education programming and member checking, along with data interpretation consultation with study co-authors, helped to enhance this study's trustworthiness (Creswell & Poth, 2018).

Findings

Research question 1: Students' perceptions of science

In this section, we highlight the main themes of students' perceptions of science, in response to the first research question. Regarding students' perceptions of science, students identified science as (1) a body of knowledge, (2) as experimentation and testing, (3) a life-enhancing discovery, (4) researching to build on background information, and (5) connected with other disciplines and present everywhere. That is, students identified a range of perceptions about what science entails.

Science as a body of knowledge

Out of all science content mentioned, 56% of students highlighted topics in a traditional biology course. In particular, 33% of students mentioned the "human body," "body systems," and the "study of the body." For instance, Jada explained that she feels like biology is "everything about like the human body" and "how everything works and how we use it." Carissa echoed a similar response when she stated that biology is "people's bodies and the human…I think of the human body and the way it works." In addition, Malia stated, "Science is obviously about like body parts." Students' notions of science were associated with their immediate science course, which was biology. Indeed, the emphasis on science as biology, and in particular, the study of the human body, was prominent. Students also listed topics that they had studied in Regents Living Environment earlier in the year or during the time of their interviews, which included DNA, cells, bacteria, viruses, HIV, genes, and reproduction. Having recently finished a series of units on human body systems, ending with the immune system, students' emphasis on the human body and pathogens makes sense.

Only two students, Anton and Kareem, mentioned that science is "the study of life." Anton elaborated on the diversity of life beyond the study of the human when he said, "Anything that's living you will learn it in science, from tiny, from bacteria, from the human body, from anything that's living." Here, Anton's view of science was aligned with biology topics, which he learned in the Regents Living Environment course. Teachers also described biology in this way, but instead of equating the study of life with science in general, they ascribed it to biology. For example, the biology teacher, Mrs. Clark, remarked that biology was "studying living things and their surroundings." Likewise, Ms. Allen, the integrated co-teacher, said that biology is "the study of living things." In these ways, when students thought of science content, they primarily thought of biology-related topics and specifically the human body. Overall, their definition of biology as the study of life was consistent with the definition that their Regents Living Environment teachers provided, and what they learned as ninth graders in this biology course.

Moreover, 33% of students identified science as working with chemicals, mixing them, and/or making "potions." As students spoke of mixing chemicals, they indicated blowing things up, explosions, and fire. Fewer students, or 22%, mentioned fossils, rocks, planets, and space, which is typically aligned with topics taught in earth science, which they would have learned in middle school and more extensively the following year in tenth grade. For example, Jayla remarked, "rocks is part of the Earth, which is science" and that the rocks are "a lot of stuff together, that's science." Lastly, 39% of students mentioned gravity, forces and motion, and electricity, topics traditionally found in a physics course, or partly in middle school science. In this way, students perceived science as a mélange of topics traditionally taught in biology, chemistry, earth science, and physics, though biology content learned in their Regents Living Environment course was most prominent.

"…experiment people, they got to test it like a lot": science as testing and experimentation

An overwhelming majority or 72% of students stated that science involves doing experiments and repeating them or conducting multiple trials and tests. For instance, Jeremiah mentioned taking samples of grass, while Daniel commented on collecting samples of bacteria from different locations. However, neither Jeremiah nor Daniel elaborated on why they would do this except that scientists do this to "test" the grass and bacteria. Jemal also said, scientists "test stuff like three times" and added that "experiment people, they got to test it like a lot and try different thing." Indeed, for his authentic science inquiry project, Jemal conducted three trials.

The importance of conducting multiple trials was also communicated by Amaya who said, "when you first do an experiment, it's not gonna work like it's gonna work like after you do it many times, and you get like the hang of it." The importance of multiple trials was also documented on students' "Scientific Research Reference Sheet," which was distributed in their Scientific Research class. The document stated: "A valid experiment will use the average of several trials to eliminate outliers and show more consistency in the data," and "Be sure to find ways to increase the validity of your experiment. Two simple ways to this are: 1. Increase sample size 2. Repeat your experiment, increase trials." On another handout, entitled, "What You Should Do the Day of the Science Fair," there was a statement that said, "Be sure to show you tested your experiment at least 3 times. Show your data (graphs and charts)." In these ways, students maintained a view that scientists test things and do so multiple times, which was also communicated by the handouts distributed in the Scientific Research class and evidenced in teacher-student interactions (e.g., Scientific Research Observations, 3.18, 3.21). Interestingly, while students understood the need for multiple trials, the rationale to engage in testing and multiple trials was not immediately evident to them. The need for more robust evidence, which is supported by the process of testing and multiple trials, was a missing link in students' understandings of the experimentation process.

In addition, students explained that experimentation involved several components. Jemal's explanation of experimentation was similar to the work of his scientific research project: "doing the procedure and what you think, first like question, like what you think is gonna happen, then like at the end when you do the experiment, did it work, or didn't it work." In this way, Jemal mentioned aspects of a typical science investigation beginning with asking a question and then forging a hypothesis, performing a procedure, and evaluating a hypothesis based on results. Similarly, Malachi explained that an experiment is "like experiment method" and science is about figuring out "how did it work or like how did they mutate." Thus, Malachi thought of science activity as involving a particular way of doing things, such as an experiment, which he learned about in his Scientific Research class. Science also involved figuring things out and developing explanations for how something functioned or mutated, which he learned about through participation in Bioinformatics Club.

Likewise, Mrs. Clark mentioned that students learned about "the scientific method" earlier in the year. Although *The* Scientific Method has been debunked as a myth (Settlage et al., 2018), it is still the case that *The* Scientific Method is part of the Regents Living Environment curriculum, standards, and state final exam associated with the course. The Scientific Research Reference Sheet also showed a similar stepwise procedure for scientific research, as seen in Fig. 2, although there were some bidirectional arrows and feedback loops that suggest reflection and unpredictability in the process. In speaking about scientists, Zion added, "They have to collect data for their science experiments and make sure they have all the right dependent, independent variables and constants…so their experiment won't go wrong." Although Zion did not mention control groups, he recognized several components of controlled science experiments.

In these ways, students perceived science to be an endeavor meant to better understand the natural world, and in their view, through experimentation and testing, aligned with the focus in their Scientific Research class. However, experiments are one of many methodological approaches in science, and scientific investigations are not as linear and straightforward. Not all sciences aim to test hypotheses through controlled science experiments nor can they. For example, astronomy may rely more on observations or systematic collection of data and interpretation of evidence in relation to models. Indigenous knowledge systems also contribute variations of this scientific method, built on generations of ancestral wisdom and experiential and relational knowledge systems informing observations and interpretations of the natural world (Medin & Bang, 2014).

Science as life-enhancing discovery

Furthermore, 56% of students emphasized science as a quest to find answers to questions or discover cures for cancers and diseases. Brianna remarked, "you're discovering something new, or you're trying to find out something different." Similarly, Ana said that scientists "want to try something new, like they want to explore new things, and find new results for everybody." While describing her perception of what scientists do, Jayla said, "They're not gonna come in and do the same exact thing. It's gonna be different every day." Thus, as Brianna, Ana, and Jayla considered, underlying this discovery component was searching for something different and novel, that nobody currently knows. Jeremiah gave an example where scientists "look into the planets and how far up to see how things are going, and if there's anything living on it." In this way, he commented on how scientists wanted to find out more about the universe in which we live and alluded to the ongoing interest in search for extraterrestrial life or conditions which would support it.

Related to this quest for discovery was the tentative nature of science. Students mentioned competing worldviews and explanations of phenomena. Referencing the Earth and how it was created, Jeremiah said:

> *Every time I think about science, I think about the Earth. So the fact there's so many theories about it. People say Jesus – people say God made it, people say that it was just a Big Bang. People say that it was a meteor…we got all this, we're like no other planet. We got life, we got plants, we got water, we got normal temperatures, we got our season changed, we got all this, and if you go on a different planet you ain't got none of this…so for the fact that we got this, there got to be something that happened in order for this to happen, so like science is like the thing to get at, like people say rocks are living, people say rocks are non-living and then some people say it's living. And science is science, so find out.*

Here, Jeremiah emphasized his awe over the uniqueness of Earth as we know it as compared with other planets in the universe. He pointed out how there were various explanations for how the Earth was created and that Earth differed from other planets. He also suggested that some people had different claims about whether rocks were living or not, that the role of scientists was to discover the answer to one's questions, and that science is a way of knowing, like religion, among others, that did not necessarily have to be in tension. While Jeremiah did not explicitly point out how Indigenous knowledge systems regarding living things differs from the Regents Living Environment's characterization of water and rocks as non-living according to Western, Eurocentric definitions of life, he did bring up the tensions that exist and alluded to argumentation based on evidence as part of science. Jada offered a similar perception of science as the search for "truth," yet she emphasized the tentativeness in explanations of the world and pushed back against the notion of whether arriving at "Truth" was possible:

> *Everything's a mystery in science…things are gonna be right, things are gonna be wrong, but everything's*

> *a mystery cause you never know like the truth cause we haven't been on this planet for a very long time, and the people that did, it's just like they based it on…artifacts…and we're not 100% sure, but we're like 85%, so I guess everything is a mystery.*

As such, Jada's response posited that 100% certainty is not something science can achieve, even if there is a lot of evidence supporting a scientific explanation.

Like Jada, from Carissa's perspective, scientists are busy with "finding the answer to things," yet "not all scientists can find the answer to a question" since scientists "just find another question to replace the answer." In other words, through the quest of searching for answers to their questions, scientists develop more questions, and therefore the process is unending. At the same time, there remains an element of mystery in the ongoing endeavor of science.

Just as science as experimentation can be an oversimplistic rendering, so too is science as discovery. Surely, scientists can be motivated by possibilities to observe something new or to devise new ideas and questions. Yet, new questions, ideas, and discoveries do not emerge instantaneously. Scientists can be viewed as trying to make sense of the natural world rather than searching to discover Truth. Indeed, students hedged their statements regarding scientific discoveries, suggesting that they are situated and subject to change. To further extend these ideas, such 'discoveries' can be viewed as part of a long history of prior research, collaborations, and lines of evidence, embedded within particular paradigms, ways of interpreting phenomena, and reconciling anomalies (Kuhn, 1970). Often, the role of creativity, imagination, cooperation, and competition, along with critical and exploratory thinking in this process of discovery is hidden (Dai et al., 2021; Li et al., 2020; Settlage et al., 2018). There are also social, cultural, economic, and political structures that might constrain or expand scientists' work and recognition (Gandolfi, 2021; Kapsala et al., 2022), which are often not reflected in accounts of these scientific discoveries, including appropriation and exploitation of Indigenous knowledge (Medin & Bang, 2014).

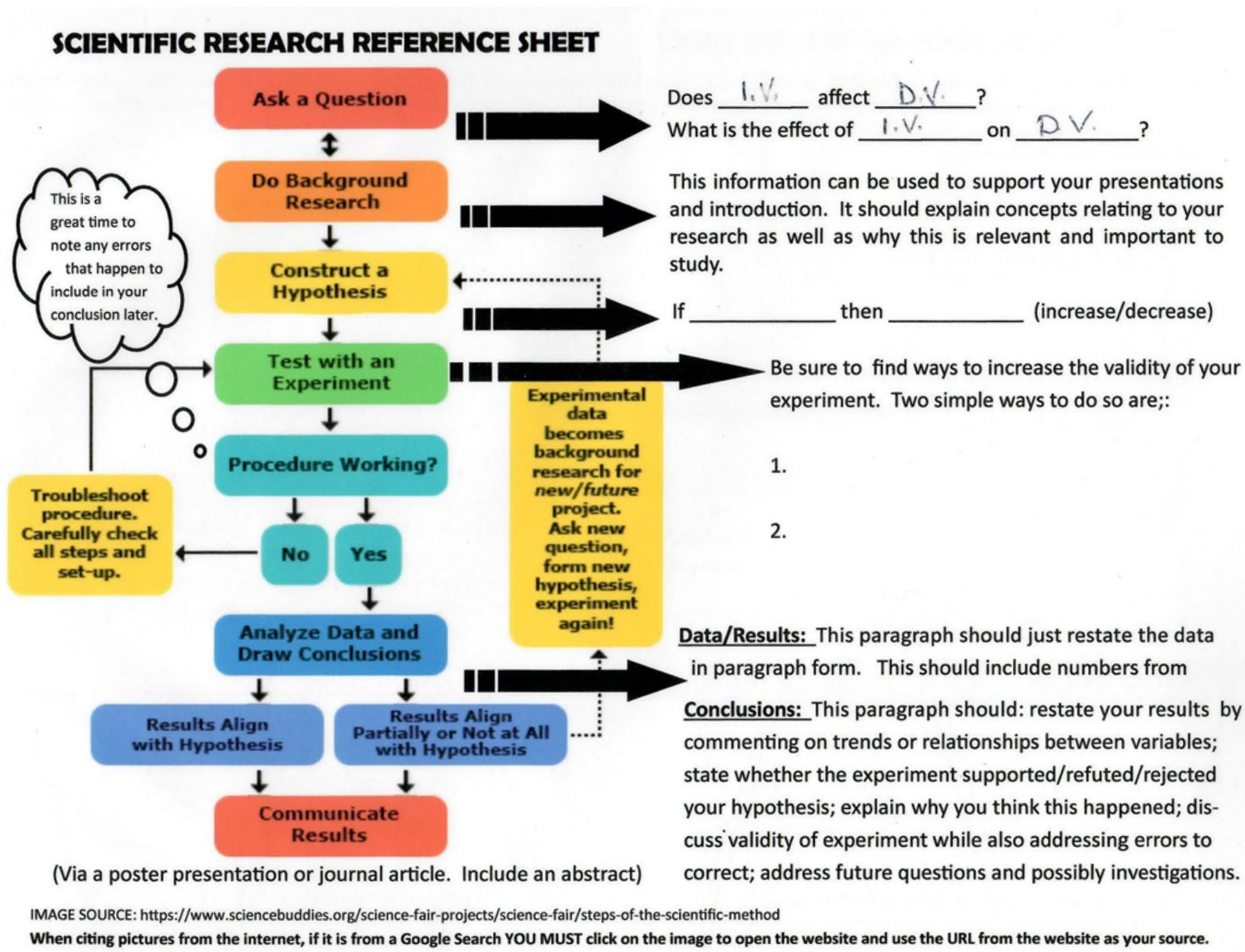

Fig. 2 Scientific research reference sheet depicting scientific method

Connections to medicine Related to this idea that science involves discovery, 28% of students also commented on breakthroughs in the medical realm that were life-enhancing. Identifying herself as someone who wanted to be a doctor someday, Alicia said, "When I hear science, I think of hospital. I think of heart transplants, I think of stuff that got to do with the human body." To be clear, although Alicia thought of hospitals, heart transplants, and the human body when she first hears 'science,' she recognized that there were differences between science and medicine, as evidenced by her contextualization of that statement:

> *The science that I'm like interested in, it's not really like science. It is kinda because it ties into what I need to know to help do what I want to do, but it's not really like the experiment type…it's like stuff in the science field that you need to know, and you have to be able to do in order to be one…so I wasn't really like looking at scientists. I was actually just looking at like doctors and how they use science to like do stuff…so it's not really like, when I hear science, I think about experiments and types of things…I don't really think about the chemicals and stuff.*

In this way, in contrast to what Alicia believed others think of when they hear 'science'—experiments and chemicals—she thinks of science serving medicine; she thinks of the "stuff that got to do with the human body" that she would have to learn on her path to becoming a doctor, along with the science body of knowledge and practices she would rely on as a doctor. While it might appear that Alicia conflates science with medicine in stating that she thinks of a hospital when she thinks of science, her other statements suggest recognition of their differences. Perhaps Alicia thinks of the hospital because she envisions herself working there as a doctor. In essence, Alicia envisioned science as a practical tool—as a field of study required to realize her career aspirations and a domain that encompasses the knowledge she would need to use in her practice as a future doctor.

Malachi shared that scientists "discover a lot of good thing, different thing…like medicine." Likewise, Jayla said, "Like they work in labs and um, find out new things, like cancer, like they try to find out like diseases or trying to find the medicine." Similarly, Daniel commented that "science can help with like medicines…so like if you're sick, you can take it to not become sick no more." He also added that vaccines "can help prevent diseases" and that a "scientist is just like a pharmacist that can help with medicines and stuff." While Daniel's statement suggests equating scientists with pharmacists, his subsequent statements signal an acknowledgment of a difference:

> *But as a scientist, you have to do like lots of research. You gotta have some tests, you gotta have some problems, you're gonna end up getting some results and like, not the right results, so you'll have to do the entire thing over again.*

Here, Daniel seemed to refer to research scientists testing, such as certain pharmaceutical drugs, and repeating their tests when they encountered unexpected results. In this regard, while not explicitly stated, scientists could "help with medicines and stuff" through doing research.

Furthermore, referring to what scientists do, Kareem said, "I think like they help people get better, make cures, like that," and when asked what he meant by "help people," Kareem shared, "to be a doctor, you need to go through a lot of science to like know what type of medicine a certain person needs." In each of these ways, students perceived science as necessary for knowing how to create cures and an integral part of pharmacists' and doctors' training to know what medicines their patients need. Carissa shared:

> *Humans have to be researched…you need to research a human because say if one human has a type of disease, you have to research that, and the question for that human that everybody asks when they're sick, 'Am I either going to live, or am I either going to pass?'*

Here, Carissa, who also had personal experiences with family members experiencing health challenges, conveyed the need to better understand the human body and related diseases. In each of these ways, students drew connections between science and finding cures for cancers, diseases, and making vaccines, as they were personally relevant experiences and applications of science in their own lives.

What is more, as students mentioned this vision of science for the good of overall public health and wellbeing of family members, they shared personal examples. Daniel said, "my grandpa's brother actually got cancer and then science actually helped make some sort of backup towards something to actually help it…he got rid of the cancer." This same personal connection made Daniel interested in learning more about diabetes, which he was glad to learn more about in his Regents Living Environment class, as he remarked, "I want to know what diabetes actually was, cause my grandpa had it, and I didn't know what it was." Daniel also shared that an everyday science connection example is when he had strep throat:

> *I was sick. You can have strep throat. I didn't know what it was. I asked my mom, 'Can I go to the doctor's?' She said I probably have strep throat, and I*

> *wondered what strep throat was, but we didn't learn about strep throat, so this, but strep throat turns out to be like some sort of bacteria that's in your throat, and it sort of makes these really, really bad swelling.*

Thus, while diabetes was explicitly discussed in his Regents Living Environment class earlier in the year, Daniel did not learn about strep throat through class, but he found out from a visit to the doctor's office through his own firsthand experiences.

When Cory thought about science, he also thought of research on cancer and diseases and "how you can cure them" because of articles he read in middle school and what he saw on the news. As he explained, "it's mostly been scientists on you know, researching how to find cures for cancer, breast cancer, or, or them seeing what the problem is, what occurs that makes that specific person get that type of cancer or disease." In many ways, these references to science as furthering more robust understandings of medical ailments and developing medicines were connected to medical issues and discoveries that students personally experienced in their own families, read about in articles, or saw in the media. As Jeremiah summarized, "I think scientists are just here to help us discover more about ourselves." In other words, students harbored an overwhelmingly positive perception of science as discovering new information to answer questions, many of which would contribute to human health and wellbeing, which were informed by familial health experiences and learning more about what it means to be human.

Nevertheless, the ways in which students spoke of science and medicine or scientists and doctors almost interchangeably require more interrogation; although students acknowledge differences and connections between the two, the boundaries between them were somewhat blurred. Students' perceptions signal more room for sophistication, especially when considering research scientists' work as extending beyond researching diseases or finding new therapeutics. Similarly, doctors can also conduct research as clinical research physicians or physician scientists, although most doctors whom students encounter might rely on this research in their practice but not necessarily conduct it. Overall, these findings offer evidence towards students' thoughts about the relationships between the science and medicine dimensions of STEM, perhaps in more transdisciplinary ways, and the connections between these disciplines and students' lives and desires.

Scientific research as researching to support understanding of background information

In addition to science as experimentation, testing, and an endeavor to better understand and explain the world and find cures, 33% of students highlighted the role of conducting background research, including searching for information on the Internet. As Jeremiah said, "When I think about research, I think about looking something up. Like, find out the background of whatever I'm doing an experiment or testing." Jemal similarly mentioned, "When you go to Google like, you research, you get some information of that thing, of like, like, you know like, we did experiment in lab." Thus, students used the term "research" primarily as searching for background information to inform their experiments through Internet searches.

Mrs. Clark also used similar language, as she said, "We use the computers a lot for research, researching things." For example, in discussing a project where students chose a different pathogen to study and recreate an antibody-antigen model with play doh earlier in the year, Mrs. Clark said, "They did a little bit of research on it. They did a couple of facts about it, and they presented it." Similarly, Mrs. Clark also described another project students did where they searched for information on the Internet, as she said, "So they had to research each type of asexual reproduction, find the picture, and a quick definition in their own words, and give an example" (Interview 2). These ways of talking about searching information on Google as research were also evident in observations (e.g., Regents Living Environment Observations, 3.13, 3.14).

Likewise, in Scientific Research, although students had class sessions on how to use the Gale Database to find reliable information (Scientific Research Observations, 4.29, 5.1), there were other instances when students were encouraged to search for information on Google, such as how to properly cite sources if they were unsure (Scientific Research Observation, 5.1). In fact, Mrs. Turner mentioned that one of the goals in spending class sessions on teaching students how to use the Gale database was "because we're trying to get them away from Google" and that there are "scientific journals and publications that we want them to use" instead. She explained that one of the main goals for the course was to "make sure they all know how to find good sources on the Internet, not really using Google" where "the algorithms are different for everybody" and to ensure that students have "examples of like what is good and what is not."

Moreover, while Jada did not mention searching for information through Google or specific databases, she shared that scientific research involves "finding out like background information" for experimentation. She further explained:

> *If you want to do an experiment, you need to know about like...if a different scientist did the experiment, what they did right, what they did wrong, so*

> *you could research about it, and do it a different way. If it doesn't work out, put that research out and then someone else can find out.*

As such, Jada explained that searching for background information allowed her to recognize what works well and what does not to inform the design of an experiment; relatedly, regardless of the experiment's outcome, it is important to publish the findings so that others can learn from and modify their experimental designs as appropriate.

Indeed, one Scientific Research handout mentioned discussing possible sources of error for an experiment in the results and conclusion sections, as it said: "Note: THIS IS OK TO WRITE! IT WILL NOT LOSE YOU POINTS. ADMITTING MISTAKES AND ERRORS ALLOWS FOR IMPROVEMENT AND MAKES YOU A GREAT RESEARCHER AND SCIENTISTS!" Therefore, in all caps, it was made clear that it is ok to make mistakes, that errors are part of doing research and science, and more importantly, that making mistakes makes one a better researcher and scientist. As Mrs. Turner shared while reflecting on the authentic science inquiry project, it was important to "[let] the kids kind of struggle and falter…because a big thing that…we want them to experience is that failure is still a success in science." Through these statements, students were also positioned as researchers and scientists, and failure was constructed as positive and productive (Silvestri et al., 2023). Jada also mentioned that if "you want to like learn about something, there's other people that tried or that did your experiment, so you could just research about it online or ask somebody, and they will help you out." In these ways, students perceived scientific research as building on previous research and a collaborative, social endeavor, where ideas are shared that inform one's own research (Settlage et al., 2018).

Overall, however, the term "research" was generalized. Researching information about a topic in science class was not explicitly distinguished from the processes of scientific research, nor did students mention the importance of evaluating sources of information through search engines like Google. Thus, students came to think of experimentation and testing as separate from scientific research, which they equated primarily with finding background information on a topic, thereby reinforcing a misconception that knowledge and understanding can be achieved through searching for information on the Internet. Such dictionary definitions found on the Internet fail to help students understand the subtleties and complexities of science phenomena.

"… everything on the Earth is scientific": linking science with other disciplines

Indeed, 28% of students mentioned other disciplines when they thought about science. Carissa explained:

> *When I think of science, I think of math because math and science are equivalent to each other because you need math to deal with science. So like science is not just one thing by itself. You need ELA, you need social studies, cause, like when people, they want to go like ancient artifacts on like bones and stuff, you need social studies because it's history. And then you need ELA to identify who that person is because it has something to do with words…And then you need math of all because an equation is always in a science question. So like density is a part of science and it's a part of math…That's technically science. Biology is science, like earth science, you go biology, you go earth science, you go environmental science, you go chemistry.*

That is, Carissa pushed back against disciplinary silos in that she believed that science is connected to other disciplines, such as math, ELA, and social studies. Furthermore, Carissa shared that there were subareas within science, as she named typical science courses and progressions – biology, earth science, environmental science, and chemistry.

While Carissa mentioned disciplines such as ELA and social studies, other students focused more on disciplines traditionally included in the STEM acronym. For example, Jayla concentrated on technology, science, and math, as she remarked, "Technology's science cause they got to put things together and understand. Math is science—math is part of science, or science is part of math." In addition, Ana said that when she thinks of science "sometimes I hear math. I don't like math, but it comes up cause like it's not always about testing chemicals, but you gotta know the measurements and how much you're gonna put in and everything." Out of all of the disciplinary connections to science, students mentioned math the most, whether it be the use of equations to determine an object's density or to measure the amount of a substance for an experiment. In these ways, although students were asked what they thought about when they heard of science and what science meant to them, they suggested orientations towards STEM and other disciplines, including medicine as abovementioned, all of which were unprompted.

Along with these perceptions of science as related to different subject areas is that "science is everywhere" or that "everything is science." For instance, Jayla shared a story about science embedded in activities that she did as a child, observing and trying to understand what she observed: "When I was little, I would go in the dirt and dig, find rocks, and like look at 'em. That's science, cause you're, you're looking at it, that's science, and trying to understand it…Everything is science." Similarly, Carissa remarked:

> *Electrical engineers does work with chemicals. They work with different types of glass and electricity, and electricity is science. So, glass is science. Everything, let's just say everything on this Earth is scientific. We got wood, we got concrete, we got buildings, we got drinks and foods and like everything on the Earth is scientific, even humans.*

In this way, Carissa not only recognized that electrical engineering, the field which she wanted to go into, involved science, but she also saw science existing all around her. She explained this belief further when she shared: "Everything in everyone has a question…questions go with science…that's how everything's scientific because everything has to be researched." Carissa shared that science was everything and that everyone could be a scientist because "everyone has a question," and when she thinks of science, she thinks of questions and engaging in explorations to find answers to questions. From her perspective, from the materials that are used, to what humans eat, humans have connections to science.

Ms. Allen also commented that science is "happening all around us all the time," such as with plants growing; moreover, she connected this statement with encouraging students to notice and be more mindful of science existing everywhere as part of her goals for students as an integrated co-teacher to support students classified with disabilities in the science classroom. She gave the example of how her students "look at plants all the time, but they don't stop to think how plants grow" and how having these conversations with students encourages them to "stop and realize what's happening in the world around them," which "creates a passion in them, and it makes them more mindful." Thus, both Carissa and Ms. Allen recognized that wondering about and attempting to ask questions about natural phenomena are central to science, which exist in everyday encounters.

Research question 2: Students' perceptions of scientists

In this section, we discuss students' perceptions of scientists as well as scientists whom students identified. Students perceived scientists as (1) smart (knowing everything) and serious (always working hard), (2) working in traditional lab contexts, and (3) creative, curious, and open-minded. Most students could not identify scientists, but the scientists who they did identify were primarily deceased White males. They also emphasized scientists' discoveries and idiosyncratic elements of stories about them. Notably, only girls of color identified counter-stereotypical role models when they thought of science, such as women and scientists of color.

Scientists are smart (know everything) and serious (always work hard)

In describing scientists, 33% of students mentioned that scientists are "smart," which meant that they knew everything and could quickly memorize, learn, and recall information. As Jada commented, "they are very smart" and elucidated, "Like physically and mentally…cause like they have to deal with a lot on an everyday basis," which she explained as doing different experiments every day. Hana also pointed out that scientists "learn something fast, like if you teach them something, they catch up very fast." Hana referenced Mrs. Clark, her biology teacher, as a scientist and justified this with, "She knows a lot," and "it seems like when she learns something she would get it like right through her head." Thus, smart meant learning information quickly and knowing a lot of information. Amaya said, "I would describe someone that's a scientist as smart" because "they'll stay on science like the whole day." This perception of scientists staying on task was related to students envisioning scientists as working in labs, stationary, and focused on their work without breaks.

This sentiment was also communicated by Jayla who said, "I like to go out and explore things. I don't like to be locked up in a place for hours, like, it's boring to me." In other words, Jayla believed that scientists are so focused on their work that they remain indoors, working the entire day. She did not consider, for example, that there are scientists who also "go out and explore," such as ornithologists doing fieldwork in outdoor settings, or that even scientists who work in labs do not remain in place all day; as humans, they will take breaks from their work, too. In fact, 28% of students mentioned that scientists are focused and organized. As Ana specified, "They're very focused on one thing, and if they get it wrong, they stress out too much." Overall, this perception of scientists as smart meant knowing a lot of information, remembering and recalling it quickly, and persistently working hard at a task, often in a lab, with the goal of getting things "right." With this line of thinking, there was a lot of pressure and seriousness involved with being and becoming a scientist.

Scientists work in traditional lab contexts

Moreover, 28% of students envisioned traditional laboratory equipment and gear when they described science and scientists. Students mentioned test tubes, microscopes, beakers, lab coats, and goggles. Brianna stated that when she thinks of science, "I think tubes, you know, putting things together…and like a lab coat, with the goggles." Likewise, 28% of students also envisioned traditional laboratory equipment and gear when they described science and scientists, some of which are visible in Fig. 3, found on a Scientific Research handout about what an abstract is, what to include in an abstract, and sentence starters to support students in writing abstracts for their experiments.

Consistent with the literature, students mentioned emblems of science such as test tubes, microscopes, beakers, lab coats, and goggles (Christidou & Kouvatas, 2013). For instance, Ana stated, "Chemicals and beakers and the lab coats and goggles, yeah, that's what comes up to me when I hear science." Likewise, Hana explained, "wearing like those goggles…like from those movie, like they test out those tubes and stuff." Brianna added, "I think tubes, you know, putting things together…and like a lab coat, with the goggles, so I think of that, and fire. We use a fire, the gas and stuff like that." Jada also commented on these materials as she said, "I like see a lab and like lab coats, like, a lot of liquid things." Carmen similarly noted, "A lab coat, glasses, a little notepad in their hand, or now, nowadays a tablet." In each of these ways, students described scientists wearing lab coats, goggles, using scientific equipment such as test tubes and beakers to mix and heat chemicals, and a notepad or tablet to record data. Students envisioned scientists working in traditional lab contexts and using science equipment and gear.

Scientists are creative, curious, and open-minded

While the abovementioned might coincide with more traditional, narrowed views of science and scientists, 22% of students shared that scientists are creative, curious, and open-minded. Brianna explained that a scientist is "curious" because "of course they want to find out something, try to find, try to crack a code to something, so anybody could be a scientist." Further, Ana recounted that she used to watch the TV show, *Bill Nye the Science Guy*, in sixth grade science every day. As she spoke of Bill Nye, the excitement in her voice was evident, through faster speech and a higher pitch, as she said, "I like him a lot because you know scientists like…they're busy, like they're so busy focusing on one thing" whereas Bill Nye "just goes everywhere, and he just sees something interesting, and he just tries to test it out, or he like mixes up something…like an open-minded person."

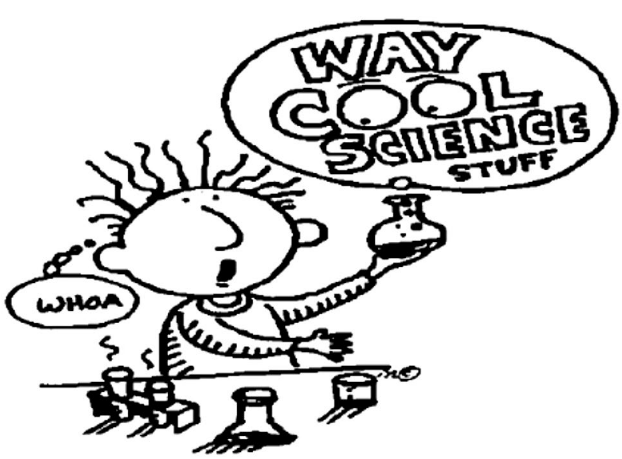

Fig. 3 Scientist graphic on scientific research "How to Write an Abstract" handout

In contrast, according to Ana, typical scientists are "very focused on one thing, and if they get it wrong, they stress out too much" whereas "Bill Nye, he doesn't care if he gets it wrong or not, he just like does it." At the same time, Ana qualified this statement with: "some scientists are like that too, so it depends on the things, the person." In other words, while she perceived that scientists typically stress out if their experiments fail, not every scientist is like this, as in the case of Bill Nye. She also added, "everyone can be a scientist, you just have to be like, have an interest in it, like you just want to do it," as opposed to wanting to be a scientist only for monetary gain. In sum, Ana liked Bill Nye because she viewed him as someone who is open-minded, willing to explore and try things without stressing too much, and someone who is fine with making mistakes.

In addition to being open-minded, several students pointed to curiosity and creativity as critical habits of mind for scientists. Malia added that science is "for people who are very like interested in finding out more things that are, who are very curious." Likewise, Carissa shared, "When I think of science, I think of creativity and people answering questions in their own valuable way" and elaborated:

> *Like not all scientists can discover a question or based it on a fact that they have. They need multiple facts, so let's just say the world is just a big experiment. And the people are the facts of the experiment. And like, it's a question that we all have to answer with one fact. Want to know what that one fact is? (pauses for dramatic effect) Personality!*

As such, Carissa emphasized the human component of doing science. She recognized science as a human endeavor, where multiple scientists are necessary, and the personality and creativity of scientists are critical for discovering answers to questions (Settlage et al., 2018).

White males as dominant representations of scientists

Students primarily identified White male scientists, many of whom have long been deceased, as scientists who they knew of or about. Albert Einstein was named the most, with 28% of students mentioning him. Students also referenced Isaac Newton (11%), Bill Nye (11%), Stephen Hawking (6%), Benjamin Franklin (6%), Ben Carson (6%), Neil DeGrasse Tyson (6%), and Rosalind Franklin (6%). Only one student, Anton, elaborated the most about scientists he knew:

> *I've heard of lots of scientists. I've heard of Isaac Newton. Isaac Newton was the one that found gravity. Um, the story goes that an apple fell on his head, and he was like, 'I wonder how that apple fell on my head?' and so bam. Then a further study and that he said, boom, gravity's holding us down on Earth, so we're not flying all over the place…Albert Einstein, he was the one that made um, uh, 3D time travel. $E = mc^2$. Uh, he made that one…Isaac Newton because he made a theory of every reaction equals an equal or opposite reaction.*

Here, the scientists that Anton recalled, Isaac Newton and Albert Einstein, were both dead White males. As he told the story of Isaac Newton's contributions, Anton emphasized words like "the one that found," or "he made that one," which signaled solo discoveries, and "bam" and "boom," which suggested that scientists arrive at ideas, theories, and explanations about how the world works, instantly, alone, and without struggle.

This emphasis on individual scientists making or creating was also shared by Carissa, who stated, although incorrectly, "Albert Einstein, I mean the man created, didn't he create electricity?" and "without electricity, I wouldn't become an electrical engineer." Thus, students often mentioned these White male scientists in conjunction with what they alone discovered or created. Similarly, Anton recalled the famous equation, $E = mc^2$, but he was not able to elaborate on what it meant. This equation is also likely why Zion mentioned that Albert Einstein was a "scientist for math" and that he helped other scientists learn math. In this way, Zion acknowledged relations between science and math, even if at the surface.

While students highlighted scientists' perceived contributions with respect to discoveries, they also recalled stories. For example, although Jeremiah forgot Isaac Newton's name because "I haven't heard the name in so long," like Anton, he also mentioned that Newton discovered "something about gravity when the apple fell on his head." Kareem, while referring to Albert Einstein said, "They took out his brain when he died, or something like that…I forgot his name though…they always talk, he was just a famous scientist back then…they have like articles about him." Moreover, Cory shared that although he could name Albert Einstein:

> *I never really heard about these experiments that Albert Einstein would do, but I could talk about Benjamin Franklin that like, you know, I've seen, I've seen a few videos, and you know, read about it, how he did the experiment on light. And if I'm not mistaken, I think it was, I think it was outside that he did that.*

Indeed, students recalled idiosyncratic events such as an apple falling on Newton's head or the preservation of Albert Einstein's brain. At the same time, they often indicated that these "famous" White male scientists "discovered" things, seemingly without struggle, which they read or watched videos about in middle school. These findings reveal the kinds of information and details that resonate with students about scientists' stories, which indicates the importance of what is shared in scientists' stories as well as how these stories are told (Hu et al., 2020; Lin-Siegler et al., 2016; Ovid et al., 2023; Schinske et al., 2016). Yet, it is particularly troubling that students of color at an ISHS would primarily identify only deceased, well-known White scientists and view them as exceptional geniuses who made scientific discoveries alone.

Counter-stereotypical scientists and science-related role models Notably, only three girls of color mentioned individuals besides White males as scientists or associated with science, who they learned about on their own or through their science courses at STEM Scholars Academy. For example, Alicia could not identify a scientist, though she described an African American male doctor as an example of a role model:

> *I forgot his name, but it's this one doctor, and they actually made a movie about him, and he was the first doctor to ever successfully separate conjoined twins, and they both lived. So, he, that's really my role model. I can't think of his name. I forgot it cause its kinda hard, but it was him, and the fact that he did that, and he was African American, so I really look up to him.*

Here, Alicia commented on how she looked up to Ben Carson because he was African American and had a major accomplishment in the medical field. As an aspiring doctor and someone who identifies as multiracial Black, Puerto Rican, and White, this contribution was especially important to Alicia, who learned about Carson through an Internet search while she was looking up requirements for becoming a doctor. Alicia mentioned that she "wasn't really like looking at scientists, I was actually just looking at like doctors."

Similarly, Carmen, who identifies as Latina Puerto Rican, mentioned an African American male scientist whom she learned about from a video in Regents Living Environment lab. She recounted the video that put her in awe, which was one of her favorites:

> *Like the other day, we did this, I think it was genetics. It was like this video about like this really cool video about this guy. He's a scientist, and he went – he said we're related with a tree, and I believe him cause DNA don't lie. And we're like long, cause like far cousins from a tree, and a butterfly and all these things, and that was so cool. And like, I learned from that! And I still remember it, and I liked it because like I'm learning, but like I don't even realize I'm learning.*

In describing the scientist, Carmen added, "he turned tiny, and he went in somebody's body…I just know he's a famous scientist, he kinda look like Martin Luther King… he has a mustache." Mrs. Clark similarly recounted:

> *All the kids, which they never say, were like, 'I really like this video. This video's informative,' and I'm like, 'Wow!'...But he just is good, you know, he's a good narrator. And I told them like, 'He's an astrophysicist,' and he was talking about evolution, so it's really cool. (Interview 2)*

From these quotes, it is evident that students were intrigued by what they learned from the video—that they were related to other non-human living things—and that Dr. Neil deGrasse Tyson was an inspiring, captivating narrator. Carmen's statement also provokes interrogation into why she referenced Dr. Martin Luther King Jr. and what other African Americans Carmen might know as key leaders and contributors.

Similarly, referring to Rosalind Franklin, Jayla, who identifies as Hispanic Puerto Rican, said, "She discovered, um, chromosomes and DNA stuff" and that "They took it, they took her credit" (Interview 2). Although she did not remember Rosalind Franklin's name or specific details about Photo 51 and X-ray crystallography, after a lesson as part of the genetics unit in Regents Living Environment, Jayla recognized that Rosalind Franklin did not get credit for her discovery like she deserved because individuals like Francis Crick and James Watson "took her credit" which "was lame" (Interview 2). Although this lesson was not observed, a review of teacher artifacts reveals one slide, entitled, "The Structure of DNA" that says, "James Watson and Francis Crick are credited with the discovery. They used X-ray images produced by Rosalind Franklin." It was followed by a slide with a multiple-choice question related to these notes in that it asked who was given credit for discovering the double helix model, as depicted in Fig. 4.

Furthermore, there were also posters in the classroom where students had their Regents Living Environment and Scientific Research courses. These posters highlighted mostly STEM people of color, including scientists of color such as Benjamin Banneker, May Jemison, Katherine Johnson, Severo Ochoa, Charles Henry Turner, and Chien-Shiung Wu, as shown in Fig. 5a, on the left. During the time of observations, however, teachers did not mention any of the scientists on the wall, nor were students observed looking at or reading the posters. Representation and presence of scientists of color was not only visible on posters in the science classroom environment, but in the school hallway as well. Depicted in Fig. 5b, on the right, there was also a bulletin board in the school hallway that said, "Who runs the world? GIRLS," and there were pictures of women in STEM, including Cynthia Breazeal, Maria Da Penha, Rosalind Franklin, and Hayat Sindi. That students did not reference these scientists is

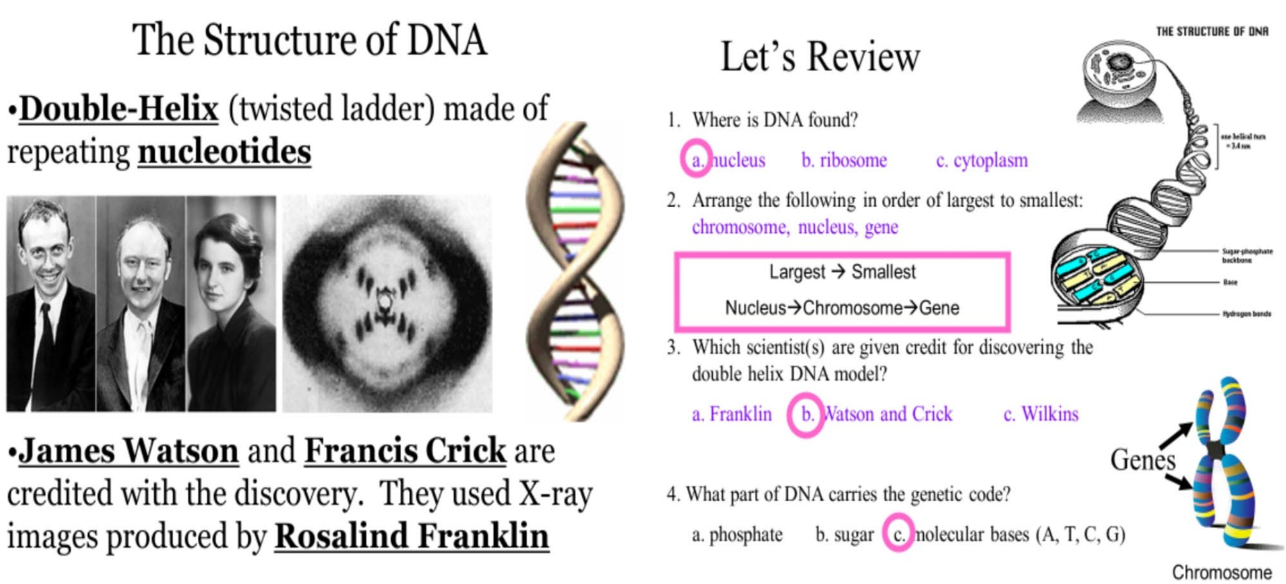

Fig. 4 Regents living environment powerpoint slides on Rosalind Franklin

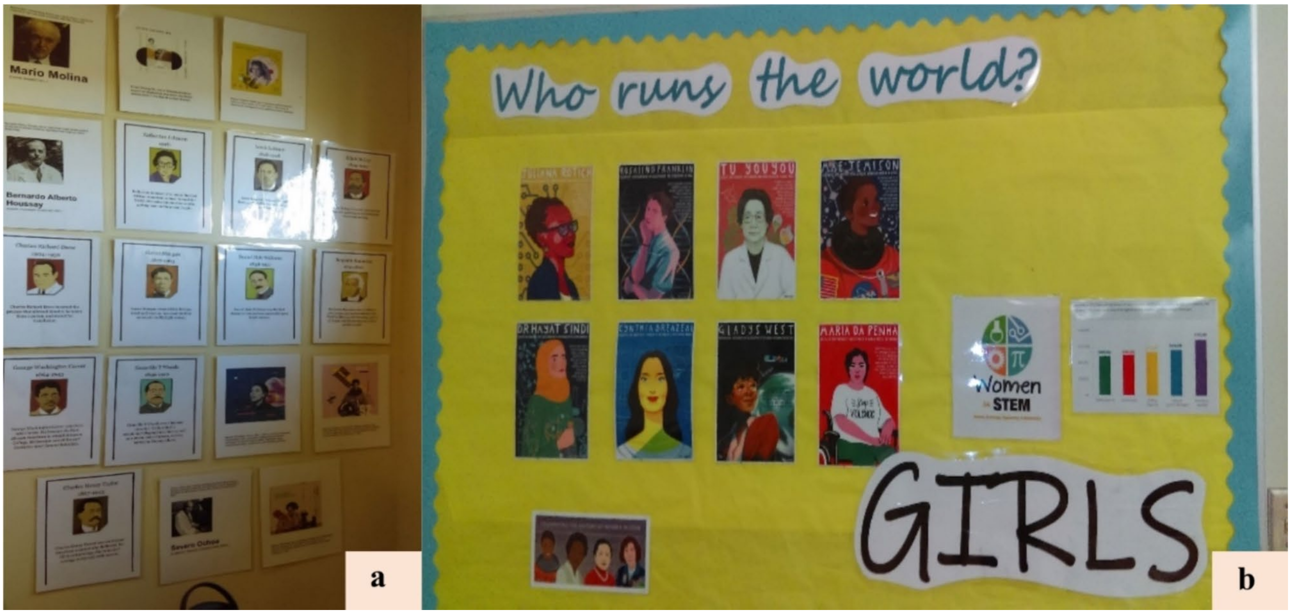

Fig. 5 Posters of scientists in the science classroom (**a**) and school hallway (**b**)

telling. Perhaps these posters remained static, inanimate representations of scientists who were not explicitly addressed in the curriculum in ways like Albert Einstein and Isaac Newton have been in students' previous learning encounters.

Ana, Brianna, and Carissa pointed out that "anybody" or "everyone" could be a scientist. As Carissa shared, "anybody can be a scientist." Likewise, Ana noted that:

> *Everyone can be a scientist, you just have to be like, have an interest in it, like you just want to do it. You can't be a scientist and just be like, "Oh, I'm just gonna get money and just do it because I need money."*

Each of these young women of color, however, did not consider themselves as scientists in the present nor aspire to be scientists. Ana wanted to be a nurse; Brianna wanted to be a surgeon, and Carissa wanted to be an electrical engineer. Each explained that they would need or use science in their future career, but science was not a field they were going into. Overall, students' initial visions of scientists were not themselves. An exception is Daniel who shared:

> *I can consider my classmates and us one since we're learning about scientists. Sciences not scientists, but like, we're learning lots of different things. Like, cells, we're learning about cells. We learned about diseases, HIV, the ones that could actually kill us off.*

Thus, only Daniel immediately thought of himself and his peers as scientists, though notably because he was learning about science content, rather than counter-stereotypical scientists.

Research question 3: Contexts and experiences informing students' perceptions

In this section, we document the salient contexts and associated experiences which participants identified as informing their perceptions of science and scientists. These included science field trips and after school programs, media in home and school spaces, and science courses in the past and present.

Science field trips and after school programs

Indeed, 39% of students mentioned learning about what science was and what scientists do from science field trips while attending STEM Scholars Academy. One notable field trip that students mentioned was a trip to a local public university for Science Exploration Day, where students participated in various STEM-related sessions offered by professors and local community organizations on the university campus. For example, Carmen mentioned that the reason why she envisioned scientists wearing goggles and lab coats was because she was given this labware to wear during one of the sessions: "They do it on us sometimes when we do like projects. They give us like little – when we went to [local university]! They gave us like glasses, lab coats, and gloves, and it was cool." In other words, Carmen associated lab gear with science given her field trip experience, where she engaged in science inquiry practices and interacted with scientists.

Jada also shared that she learned about what science is and what it means to be a scientist from Science Exploration Day. She explained that before the field trip, "I thought it was all numbers and medicine, and like hard stuff, but now, when I went to the field trip, it could be more than just numbers, medicine, and stuff like that." In other words, her views of science broadened to mean more than numbers and medicine. In particular, Jada added that she now perceived scientists doing different things every day because a scientist at Science Exploration Day "said that he's happy to come to work because… he doesn't do the same things every day." Jada elaborated on what she meant by this:

> *Like one day he would like do something with genes or DNA and then another day he would do something like completely different like research or do something else like I don't really know, but he'll do something else, and he'd say like he's happy every day cause it's like a new adventure cause he does everything different, every day.*

In this way, how students came to perceive science and the work of scientists was at least partly due to what they learned from scientists they met on field trips and how scientists talked about what they did. Carissa, who also participated in the Science Exploration Day field trip, shared:

> *We went on this field trip yesterday, to the [local public university]…they taught us about scientists. We went to this building, and it was like this people in two separate rooms…And then we saw scientists in there, so scientists were testing out one chemical in one room and another chemical in another because the lighting affects the chemical and how it works, that's what the lady tells us.*

Here, Carissa shared that during the field trip, she observed scientists testing the effects of light on certain chemicals, which led her to think that scientists test things and do experiments.

Moreover, Hana shared that during a Science Exploration Day forensics session, she learned about "criminal crime, fingerprints, and how they can figure out if the person did this, or who got involved in the crime scene." She also participated in another session on animals, where she learned "how the animal affect our environment" and elaborated on what she saw:

> *We got to see snakes, and it was cool. It was cute, and it was sleeping, and we got to see three types of birds…I think it was one with the world's fastest bird. And the second one was, um, he had like a heart shaped face, and it's like night vision. Like he could see in the night.*

Thus, on this field trip, Hana was exposed to different domains of science, which also expanded her perceptions of science. Notably, despite this exposure, Hana attested that experiments, goggles, and test tubes persisted in her mind when she first heard the word "science."

Science after school programs

Apart from field trips, students also mentioned that their participation in after school programs influenced their perceptions of science and scientists. For example, several participants were members of Bioinformatics Club, which was open to all students who were interested in joining. The club was developed in partnership with scientists at a local public university with the help of a national grant. Both Mrs. Clark and Mrs. Turner were advisors who actively recruited students to participate, including multilingual learners. Each year, as Mrs. Clark explained, students visited the local public university to "present authentic research" on "proteins and genes and a bacterial genome," which they worked on in the club. Jeremiah shared that his perception of science as discovery and finding out something new was informed by his experiences in Bioinformatics Club, where he researched "a gene that nobody ever searched or researched about."

Moreover, Daniel noted that experiences he was exposed to in an after school science program at STEM Scholars Academy influenced his perceptions as well. Referring to an experience with testing the water quality of samples, he remarked:

> *You can actually learn about tiny specimens, like for example, you took the swamp water, we looked through it, we determined what it was, and then we had a tiny swamp monster that we were so eager to look at.*

Indeed, Daniel noticed the tiny organism that he called a "swamp monster" in one of the water samples for students to examine in one after school session. This experience made Daniel think about collecting samples and testing as central to what it means to do science. In these ways, science after school programs also contributed to students' perceptions of science and scientists.

Science in the media

In addition to science field trips, 28% of students identified media as contributing to their perceptions of science and scientists. In fact, 28% of students referenced past experiences watching TV shows and commercials or reading articles about scientists, like Albert Einstein, and their "discoveries." For instance, Cory shared how he used to watch cartoons like *The Fairly Oddparents*: "I remember growing up, watching cartoons, in my house, and it's like, sometimes in those cartoon episodes it would actually like show them, you know, mixing chemicals, and that just looked fun for some reason." This led him to associate the work of scientists with mixing chemicals.

What is more, some of these media-related encounters originated at school. Hana explained that in middle school science class, she used to watch the show, *Bill Nye the Science Guy* virtually every day, which she found fascinating. Hana explained how her teacher "put it on every single day, and like different one, it talks about the compass and stuff and magnet and stuff, so like it was cool" and that "the experiment that he did, it was quite cool." Ana also echoed Hana as she shared that her middle school science teacher showed her episodes of *Bill Nye the Science Guy* in class, which were also "cool." This feeling of intrigue was similar to how Cory felt when seeing cartoon characters mix chemicals on *The Fairly Oddparents*, which he would watch at home as a child. Indeed, these portrayals of scientists mixing and testing things and doing experiments was ubiquitous, as Jada remarked, "it's actually like everywhere, like I watch science movies at home, or I used to watch it in middle school."

Students' also identified materials and media produced and introduced by STEM Scholars Academy as contributing to their perceptions of science and scientists. For example, Jayla associated scientists with traditional lab accessories and lab gear due to what she saw on a STEM Scholars Academy informational pamphlet that she reviewed when applying for schools. She explained, "Cause I saw it on the paper…the little paper about the school, like what the school was about…I saw the kids with the lab coat and the glasses." In other words, Jayla shared that when she saw pictures of students wearing lab coats and protective glasses while engaging in science inquiry, she thought to herself, "Oh, that's what they do?" which motivated her to apply to the school. However stereotypical, students were intrigued by the Discourses of scientists wearing lab coats, glasses, and goggles while mixing chemicals in a traditional lab context, which entails further investigation, especially when considering ways to support students' seeing themselves as scientists.

Besides informational materials about STEM Scholars Academy, students also watched media in their science classes. For instance, Jada mentioned that "videos that we watch about like the lab" at STEM Scholars Academy contributed to her perceptions. Indeed, after the completion of the research symposium, students watched the movie, GATTACA, in their Scientific Research class (Scientific Research Observation, 4.3). Jada explained how the movie portrayed scientists testing things in labs:

> *Cause I saw science, like I saw a lab, and it had a lot of things, and like him scraping himself, and all that, so I feel like scientists work in the labs most of the times. I might not be right, but I feel like, when I see scientists, they're in labs.*

That is, the movie GATTACA that students watched in Scientific Research conveyed to Jada that scientists work in labs, which was consistent with other portrayals. Notably, Jada also conveyed hesitancy about her perceptions of science and in particular, scientific research, when she said:

> *To be honest, till this day, I still don't know what that is because I never took it in like middle school, and now I'm starting to learn about it, but it's still kind of confusing, like I don't really know the full definition of it.*

Thus, it is important to acknowledge that as ninth graders, students' perceptions of science and scientific research are still emergent and tentative. In many ways, however, students' previous and current exposure to science and scientists—at home, in the community via field trips, or at school—were mainly consistent with traditional perceptions of science and scientists as mixing and testing chemicals and working in labs while wearing lab coats, goggles or protective glasses, and gloves.

Science courses

Students' perceptions of science and scientists were also influenced by their previous and current science courses. Jada's abovementioned remarks reveal the role of prior science experiences—or lack of them—in informing students' perceptions. Unfortunately, prior to joining STEM Scholars Academy, she did not have many science experiences, as she stated at another time in her interview: "I did not know *any* of this when I was in middle school, but since I came here, I learned so fast and like a lot." In contrast, Hana had fond memories of middle school science, as she explained:

> *I think in middle school I had the best science teacher. Yeah, um, he taught us a lot of stuff, and we learned about friction, force, and stuff. Yeah, we did like ramp, like balls, we tested. We had like a meeting, like we had two group, it was like two group meeting, and like we test out each type of ball, the weight, and like how friction conduct that, like how far the ball rolls, and we measured that, so I thought it was cool.*

Thus, these experiences in middle school in which Hana "tested" how friction on a ramp and the weight of a ball affected how far the ball moved after rolling down a ramp were not only "cool" and noteworthy, but they also informed her ideas about science. Likewise, Ana believed that scientists worked in labs and did experiments because of her middle school science experiences, as she shared, "in eighth grade, we used to do like a lot of labs, and we be dealing with a lot of chemicals and testing out things."

Additionally, Daniel felt that observation was part of science, as he recalled a Regents Living Environment lab at STEM Scholars Academy, where he examined cheek cells to learn about nuclei. Students' ideas about science and research were also informed by their Scientific Research course and in particular, the authentic science inquiry project that spanned about four months of the course, where they designed and implemented their own science experiments. This experience expanded their previous notions of science. The discourses regarding "research" as abovementioned in both Regents Living Environment and Scientific Research also contributed to students' conflation of research as searching for information online, even if it was to inform their experimental designs. Thus, students' prior and present experiences, whether originating in school, at home, or in the community, contributed to their current views of science and the work of scientists.

Discussion

These findings add to the ISHS literature and suggest a range of contexts that collectively contribute to the perceptions of science and scientists among students of color. The results surfaced students' traditional, stereotypical perceptions as well as more expansive, broadened perceptions of science and scientists. While students held onto more traditional views of science as doing experiments, or science as a body of knowledge that consists primarily of biology topics, these findings make sense given students' experiences as ninth graders at STEM Scholars Academy. Students each devised their own science inquiry investigations for their Scientific Research class and were enrolled in Regents Living Environment, where they spent the previous months learning about the human body and other biology content areas.

Research question 1: Students' perceptions of science

At STEM Scholars Academy, all ninth graders experienced science as both disciplinary core ideas and practices, which is a strong foundation to build upon in subsequent years. Students were able to identify science in a variety of ways, such as its tentative nature and the role of background information and creativity in formulating questions for science inquiry (Settlage et al., 2018). At the same time, it is important to note that, at times, students blurred the boundaries between science and medicine, simplified science as discovery in nascent ways, and condensed scientific research to searching for information online, separate from experimentation and testing.

Another unique insight is the emerging idea of science as present in students' everyday lives, located everywhere, and connected with other disciplines. This finding has important equity implications for ISHSs and for STEM educators elsewhere to ensure that science is culturally sustaining and revitalizing for students while also defining, unpacking, and teaching socioscientific issues of consequence (Paris & Alim, 2017). When students come to recognize science embodied in their past and present practices and lives, the possibilities of seeing themselves and their communities as science people, knowledge possessors, and contributors to science and related community-based practices and problems expands. They begin to recognize other science Discourses (Gee, 1990) that reside within and extend from generations of communities of color.

As students identified connections of science to math, engineering, technology, medicine, ELA, and history, they also indirectly communicated that science is something central to many domains of life. While students' identification of these connections among the disciplines and their individual characteristics were emergent, their statements reveal an acknowledgement of these disciplines as assemblages and related. Parsing out the similarities and differences between science and medicine, and that of research scientists and clinical physicians is also important. The relationship between mathematics and physics, for example, differs from that between mathematics and other disciplinary areas, such as biology, and these relationships also differ from anatomy to epidemiology. Students' views of these disciplines have potential for further sophistication and extension with future experiences that center integrated STEM education programming, such as project-based learning.

Students overwhelmingly viewed science as a positive endeavor, mostly in terms of finding cures for cancer and illnesses that they and family members experienced. In contrast to a barrage of deficit discourses about African American communities as mistrusting science and vaccines, students in this study pointed to vaccines as being one of the positive contributions to human wellbeing (Waight et al., 2022). This finding brings attention to the roles of medical professionals as educators of science and STEM and how learning occurs beyond the traditional school classroom walls; learning becomes more meaningful with personal, firsthand experiences and problems, often situated in local microsystem and mesosystem interactions of the school, home and family, and community contexts (Bronfenbrenner, 1979, 1986).

A STEM learning ecosystem (Shaby et al., 2021) that connects what students learn in the science classroom with what they learn from other life contexts has great power and potential to bolster learning even further. For example, efforts to broaden students' perceptions of science and scientists through a coordinated learning ecosystem might entail (1) biology teachers drawing on case studies and role play scenarios based on medical conditions that are situated in students' lives, biomedical research, and stories from global histories and sociologies of science; (2) medical internship opportunities for students to authentically learn about medical careers through participation in medical practices and research; and (3) medical professionals considering their roles as science and medical educators as they converse with patients. Integrating historical cases in student-centered ways, that promote ongoing dialogue and reflection, can contribute towards critical thinking and skepticism in scientific practice, while offering more insights into the social, cultural, economic, and political factors that shape science and its relationship with other disciplines and society (Dai et al., 2021; Gandolfi, 2021; Ju et al., 2023).

Positive views toward science and its potential to transform human life in revolutionary, beneficial ways are important, especially for students who might align with altruistic science identities (DeWitt et al., 2013). There is a need for students to view science's potential towards building more equitable futures, where they can contribute to justice-centered science projects in transformatively constructive ways in the present, such as through youth participatory action science projects (Morales-Doyle & Frausto, 2019)—as opposed to only envisioning others as science contributors or that they have to become a "scientist" with the official, institutionally-designated career title to be a scientist or to do science. Such experiences and intentional, explicit, science and scientist Discourses (Gee, 1990), arising from and situated within communities of color and Indigenous knowledge systems, are necessary to counter the overwhelming status quo Discourses where most students identified deceased White men, instead of themselves and others within communities of color as doers of science.

Notably, given a lack of explicit instruction targeting such criticality, students did not perceive science and scientists as detrimental and destructive, contributing towards militarization, environmental degradation, and with histories that have perpetuated racist, sexist, ableist, and colonizing myths and practices (Harding, 1991; Sheth, 2019; Reinholz & Ridgway, 2021; Vossoughi & Vakil, 2018). As students mentioned the promises of science as it pertains to medicine, they did not consider the role of toxic heavy metals, industrial byproducts and wastes, and pollutants that disproportionately affect communities of color, especially as it relates to cancer-causing mutagens (Bigelow & Swinehart, 2014).

From our theoretical framework situated in Bronfenbrenner's (1979, 1986) ecological systems theory and Gee's (1990) perspectives on Discourses, we recognize that the science curriculum, pedagogy, and assessment practices that students were exposed to from before and within their first year at an ISHS, along with associated field trips and mass media, did not help to substantively counteract, and in some cases, reified students' stereotypes and partial conceptions of science and scientists. As such, students were not provided with meaningful, transformative opportunities to consider medicines as technologies or the relationship between science and technology in more critical ways, including racism and colonization embedded in medical technologies or in the histories and structures of these disciplines themselves (Author, 2022).

Therefore, science educators—from schoolteachers to medical professionals—can become more aware of and include in their practices a recognition and attempt to redress unjust structures on health outcomes, including the Two-Eyed Seeing approach that privileges Indigenous worldviews in medical curricula (McKivett et al., 2020). Liberatory opportunities for science education in ISHSs that foster more critical consciousness raising around science, particularly around hegemonic conceptions of science and STEM, and the promotion of Indigenous knowledges and community-based science among communities of color, are important for critical science praxis (Tripp, 2021).

Research question 2: Students' perceptions of scientists

Additionally, this study also elucidated students' perceptions of scientists. While students identified scientists in stereotypical, more narrowed ways such as being smart and serious and using science equipment and gear in traditional lab environments, students also mentioned scientists as creative, curious, and open-minded. Regarding the former, students underscored the role of scientists being able to memorize and recall information quickly and to know what they are doing. With respect to the latter, students spoke about scientists as creative, curious, and open-minded in idealistic ways, suggesting that not all scientists have these qualities, though these are aspirational, valuable characteristics. Students seemed to promote conceptions of scientists as a part of, and more exceptional than regular people, which can lead to precarious beliefs that becoming scientists is unfeasible.

Exactly *who* does science matters and shapes the domain of science itself, while also contributing to how students perceive themselves in relation to science and scientists. Students' characterization of scientists as smart, which entails memorizing and quickly regurgitating a lot of information, is not only erroneous, but it can also undermine students' visions of possible futures in science and STEM if students do not see themselves as such. As our theoretical framework suggests, these science Discourses (Gee, 1990) do not arise out of a single context but are intertwined and embedded in multiple systems, from interacting microsystems such as in- and out-of-school STEM learning programs that forge the mesosystem, to the exosystem of mass media and standards, to the larger ideologies and systemic oppression that have shaped the field of science and science education across the chronosystem's time, space, and scale (Bronfenbrenner, 1979, 1986). If students experience the bulk of their science instruction—and interactions with others whom they consider science people as memorization and recall—they will take up such perceptions of science and scientists. These conceptions of scientists call into question how and which scientists were prominently featured in students' teaching and learning prior to, within, and beyond the ISHS.

Not all students identified or referenced scientists, but among those mentioned, students primarily highlighted deceased White males, such as Albert Einstein and Isaac Newton. Students at STEM Scholars Academy were exposed to a variety of scientists symbolically in the school hallways and in the science classroom, but they did not mention these scientists in their interviews. This finding suggests that the posters remained static representations, detached from students' science curriculum and learning. Only two young women of color mentioned Rosalind Franklin and Neil deGrasse Tyson as scientists, who they learned about in their Regents Living Environment class, while the remainder of students did not mention them. This finding underscores the importance of and need for intentional, explicit science instruction and curricular materials that uncover the range of counter-stereotypical scientists who have contributed and will continue to contribute to science.

Contextualized, explicit, and reflective history of science cases can be particularly integral in order to move beyond a focus on individual scientist achievements and a false portrayal of the scientific research process as linear (Kapsala et al., 2022). For example, Dai and colleagues (2021) utilized historical narratives in an undergraduate biology course, based on the history of research on the structure of DNA and the contributions of Rosalind Franklin, using an explicit and reflective approach, that exposed the role of creativity, imagination, and social and cultural biases in scientific development. It is important for students to have multiple, consistent, and coordinated opportunities to interact with a range of scientists of varying intersectional identities, across a broad array of STEM disciplines and careers, along with role models, elders, and community members from communities of color to share their science knowledge and expertise.

Previous research has revealed the significant positive impacts of combatting narrowed, traditional, deficit, and stereotypical images of science and scientists, especially with assignments that involve students in creating these scientist spotlights themselves, while also incorporating opportunities for personal and collective reflections (Schinke et al., 2016). Most of this work has occurred at the college level, although more recently, secondary school students have been exposed to these counter-stereotypical scientist spotlights (Ovid et al., 2023); after at least three spotlight assignments, especially in conjunction with in-class discussions, students used more non-stereotypical, inclusive descriptors of scientists. Whose stories are told, how they are told, and to whom they are told matter; thus, incorporating scientists' struggles and humanizing them in ways that individuals can relate to are promising directions forward (Hu et al., 2020; Lin-Siegler et al., 2016; Ovid et al., 2023).

Indeed, this study offers evidence of the significance of students' relatability to spotlighted scientists. For example, students like Ana pointed to facets of Bill Nye the Science Guy that she could relate to because she characterized him as open-minded and willing to make and learn from mistakes. She believed he diverged from other scientists to whom she did not relate. Ensuring that students are part of co-creating and sharing these stories and materials, such as through comics, podcasts, posters, and videos, along with serving as counter-stereotypical role models themselves, are encouraging ways forward to support students' science agency and identification in more personally meaningful, experiential, and creative ways. Such opportunities are necessary across the lifespan and the chronosystem's future time and space (Bronfenbrenner, 1986) to counteract an avalanche of stereotypical White male scientist Discourses from TV shows, movies, and advertisements to textbooks and curricular materials (Brown, 2019; Gee, 1990).

Research question 3: Contexts, sources, and associated experiences informing students' perceptions

This study also documented the salient contexts, sources, and associated experiences that participants identified as informing their perceptions of science and scientists. These included science field trips and after school programs, media in home and school spaces, and science courses in the past and present that formed the immediate micro- and mesosystems, which in turn were influenced by the surrounding exosystem and macrosystem (Bronfenbrenner, 1979, 1986). In this way, students' perceptions were influenced by a variety of contexts, sources, and experiences, many of which we will not be privy to, including those in the past, those which were not observed as part of this study, and those which students did not consider nor share in their interviews. At STEM Scholars Academy, some of the influences could be the generalized use of the term "research," documented in science class observations. These contexts, sources, and associated experiences also include science influences from the family, home, and community that students might not recognize as science because systemically oppressive structures and ideologies extending from the macrosystem have conditioned students not to value them (Bronfenbrenner, 1979, 1986; Dou & Cian, 2022; Gee, 1990).

The contexts, sources, and experiences that students mentioned, however, can be documented as significant. At STEM Scholars Academy, informal science learning experiences were created in conjunction with partnerships with the local public university and other organizations. For example, experiences associated with the Science Exploration Day field trip at a local university reinforced for some students that scientists work in labs, test chemicals, and wear lab coats and goggles. For some students, the exposure to different domains of science, such as forensic science and animals, broadened their perceptions of science to be more than "numbers" and "medicine." These findings speak to the messaging—whether intentional or not—which emerges from field trips and interactions with guest speakers in industry and universities that communicate to students what science is and who does science; it is important for such institutions and stakeholders, connected with ISHSs and embedded across the STEM learning ecosystem, to also challenge stereotypical and false narratives about science and scientists.

Conclusion

As this study is a qualitative case study, findings reveal contextualized richness but cannot be generalizable to all ninth graders or ISHSs. Moreover, as previously noted, it is possible that there are contexts, sources, and experiences that have informed students' perceptions of science and scientists that have not been captured in this study through student interviews and observations of contexts connected to the ISHS, STEM Scholars Academy. As our theoretical framework suggests, students' perspectives of science and scientists are informed across time and space, which can be stable yet shift with new experiences. Though our study spanned almost half a school year, we recognize that capturing students' perceptions takes a long time.

Thus, we recommend that future studies attend to students' perspectives longitudinally, from elementary to high school, as well as across contexts, to explore whether students have different perceptions of science and scientists at different times, with emphasis on the conditions that influence their development and the processes of their development. As these factors that influence students' perceptions of science and scientists are examined—such as the nature of scientific field visits, after school STEM programs, and scientific projects—it is important to study the factors and their characteristics that are critical for students' understanding of science and their views on scientists.

Although the voices of students of color have been centered in this study, students' perceptions of science and scientists did not primarily foreground themselves nor people of color with other intersecting, minoritized identities as doers of science—nor did they center the cultures of science that are representative of communities of color. These findings are troubling, especially when considering that ISHSs, by design, offer unique, STEM-focused opportunities, including more STEM coursework and science research experiences, along with connections with STEM industry and university partners. ISHSs and their opportunity structures need to do more to help students develop more expansive conceptions of science and scientific research practices that are inclusive of scientists of color. ISHSs must live up to their names and mission statements of inclusion through fostering more critical, expansive, and sophisticated understandings of science and scientists.

An ecological systems theory perspective (Bronfenbrenner, 1979, 1986) helps us recognize that the reasons for these perceptions are distributed across levels of interacting systems and time. These perceptions do not arise out of nowhere—nor only from within students' current experiences at an ISHS as ninth graders. Rather, they are formed, reproduced, reinforced, extended, and confronted by a range of prior and current experiences in science programming in and out of school, at the doctor's office, field trips, and from watching cartoon videos. Certainly, these ideologies embedded in experiences are a small selection among many others, which we and students might not be privy to, as they are often hidden, implicit, and/or missing from science curricula, pedagogy, and assessment Discourses at large (Brown, 2019; Gee, 1990). From this framing, students' immediate experiences and interactions at the micro- and mesosystems had strong influences on their perceptions of science and scientists (Bronfenbrenner, 1979, 1986). Students' personal experiences with illness, seeing commercials of scientists searching for cancer cures—which also aligned with recent biology class units—contributed to their perceptions of science. Generalized terminology of "research" that were present in students' science courses also informed students' perceptions.

An ecological systems theory perspective also ensures that onus of responsibility to challenge, broaden, and educate in ways that transform such perceptions is distributed across the system, thereby decentering any one individual. For example, while science teachers indubitably have responsibility to teach in ways that promote more criticality in students' perceptions of science and scientists, they also work within and are influenced by interactions with other stakeholders within and beyond ISHSs. Science teachers require critical, asset-based, contextually meaningful, and reflective structures to do this work successfully, coherently, and consistently, including robust prior teacher education opportunities, ongoing collaborative professional development, and aligned state standards, assessments, and district-provided curricular materials and administrative leadership that allow for the countering of status quo, misleading, and inaccurate science and scientist ideas.

There is rarely criticality along these dimensions, such as opportunities to grapple with the economic, ethical, institutional, political, and social aspects of scientific development, along with the role of diverse, intercultural exchanges, collaborations, and contributions to science from many individuals across the world, beyond Europe (Gandolfi, 2021). For true change to occur, candid introspection, aligned progressions, and sharing and redistribution of resources across institutions are imperative; teachers must have continued access and supports to make and implement these changes that are aligned with science education research. Too often, there are competing priorities and Discourses in tension with one another across chrono-, macro-, exo-, meso-, and micro-systems (Bronfenbrenner, 1979, 1986; Gee, 1990). Examples abound with opposing Discourses, from science textbook and curricular materials, standards documents like the *NGSS*, and among nature of science education research traditions—all of which have different visions and portrayals of science and scientists, from implicit to explicit (Brunner & Abd-El-Khalick, 2020; Li et al., 2020; NGSS Lead States, 2013). Indeed, researchers have recognized the importance of such supports and alignment, so as not to solely rely on teachers and their own partial understandings and lack of resources (e.g., planning time and suitable curricular materials) to teach beyond a hidden curriculum (Kapsala et al., 2022).

Moreover, adequately defining science and scientists is challenging in and of itself. There is great variation among science subdisciplines, especially when considering peculiarities among different institutional cultures and diverse emphases and methods used. College STEM students, preservice and in-service science teachers, and scientists harbor various views and naïve conceptions as well, which they might inadvertently convey to students in their own teaching and interaction practices (Ju et al., 2023; Woitkowski & Wurmbach, 2019; Yacoubian, 2021). For example, a study conducted by Woitkowski and Wurmbach (2019) found that German physics professors' views of science aligned with naïve empiricism, where more emphasis was placed on the value of the experiment and verifiability of scientific knowledge, which was pragmatically consistent with their daily work. These professors also deemphasized the importance of diverse cultural contributions to science. Yet, perspectives among sociologists, philosophers, historians, psychologists, and education researchers of science offer various other perspectives on science and scientists; their views are also reflective of different cultural traditions and understandings, including Indigenous knowledge systems (Harding, 1991; Medin & Bang, 2014; Michie et al., 2023; Kapsala et al., 2022).

Consistent with decades of conceptual change research (Aleknavičiūtė et al., 2023), we recognize how stubbornly persistent misconceptions regarding science and scientists can be, even after explicit, reflective instruction, and especially after the passage of time, without consistent efforts to directly counter them. Yacoubian (2021) explored the long-term retention of four students' views of the nature of science, over a 13-year period, after a high school biology course utilizing a contextualized consensus framework and explicit-reflective method. While there were positive results in the short-term, students' patterns of retention varied over the long-term, including the extent to which there was continued exposure in students' college and career experiences. From these perspectives, as disconcerting as these findings may be, it is not a complete conundrum as to why perceptions of science and scientists among students of color in this study continued to be incomplete, nascent, inaccurate, and stereotypical; after less than one year at an ISHS as ninth graders, students required more coordinated, intentional learning experiences that explicitly target and counteract such perceptions that have developed across their lifetimes and across multiple systems levels.

Overall, students at STEM Scholars Academy harbored paradoxical perceptions of science and scientists—seemingly contradictory and in tension at times—yet might partially speak to reality. Students both aligned with and rejected certain visions of science and scientists, including those that were stereotypical, traditional, and narrowed. These perceptions should be broadened and extended so that they are not regarded as the *only* views of science and scientists. Moreover, it is necessary for the contributions of minoritized cultures and communities of color to be recognized, which would capture a more panoramic, complex, and complete picture of science and scientists.

Ultimately, limited, stereotypical perceptions of science and scientists are stubbornly persistent, which can include misconceptions, alternative conceptions, and partial conceptions, though incomplete or inaccurate. These ideas can shift and serve as a foundation from which to build. It is incumbent upon multiple stakeholders across society to collectively contribute, directly and indirectly, to shifting the narrative of science and scientists. Policymakers impact science and science education policies and standards, which inform curricula and assessments that adopt and communicate perspectives on the nature of science, its connections to other STEM disciplines, and the role of scientists (Park et al., 2020). Among others, teachers and scientists in the broader sense (i.e., not only teachers and scientists with these formally designated titles and positions in society, but also parents and community members as they engage in education and science practices) have important roles as well.

In conclusion, we take an asset-based perspective, acknowledging that these ideas from ninth grade students are foundations from which to work, challenge, broaden, and expand—across subsequent years in an ISHS and beyond. At the same time, we take a critical one that underscores the responsibility of ISHSs to live up to a truer sense of inclusion. This responsibility necessitates intentional coalitions and alignment with other systems, institutions, policies, and practices across the STEM learning ecosystem to critique a status quo Eurocentric masculine culture of science as the one and only culture of science and to honor generations of Indigenous knowledge systems and ethnoscience wisdom as well.

With the rise of STEM schools globally, researchers can explore the experiences and perspectives of students across a trajectory of attending inclusive STEM-focused elementary, middle, and high schools, along with multiple lines of evidence signaling their impact through asset-based, equity-focused lenses. Future studies can critically reflect on the ways that teachers, family and community members, business and industry, and colleges and universities might marginalize, reproduce, celebrate, and/or challenge these perceptions through their programming, across space and time. Altogether, a concerted, coordinated, and tenacious effort to promote diverse ways of knowing, thinking, feeling, being, and identifying in science across contexts and stakeholders is necessary to counteract these messages that as Jada aptly pointed out, is "actually like everywhere." Such endeavors are vital in the images of science and scientists project of reform; let us make such a turn for a more diverse, inclusive, equitable, and justice-centered future of STEM education research, practice, and policy.

Abbreviations

DAST	Draw-a-Scientist-Test
ELA	English Language Arts
ISHS	Inclusive STEM-Focused High School
NGSS	*Next Generation Science Standards*
STEM	Science, Technology, Engineering, Mathematics, and Medicine

Acknowledgements

The authors are grateful to the STEM Scholars Academy community, who graciously shared their time, expertise, and opportunity to learn from them. Acknowledgements also go to Dr. Mary McVee and Dr. Felicia Moore Mensah for their thoughtful questions and perceptive feedback towards the larger project from which this article emerges. Lastly, we thank the anonymous reviewers for their constructive feedback.

Author contributions

JT contributed to the study's design, implementation, and manuscript writing. NW and XL participated in study discussions and provided insightful questions and feedback that guided the development and revisions of this manuscript. All authors read and approved the final manuscript.

Funding

This study was not supported by any external funding sources.

Data availability

Data are not shared for individual participant privacy.

Declarations

Ethics approval and consent to participate

As noted in the Methodology section, participants in this study provided informed consent and assent, and this study was approved by the university's Institutional Review Board.

Consent for publication

All authors have provided consent for publication of this manuscript.

Competing interests

JT and NW declare that they have no competing interests. XL declares a competing interest as Editor of *Disciplinary and Interdisciplinary Science Education Research*; thus, another Editor or member of the Editorial Board was assigned to assume responsibility for overseeing the peer review process for this manuscript.

Author informations

JT is a Postdoctoral Research Associate, NW is an Associate Professor of Science Education, and XL is a SUNY Distinguished Professor of Science Education at the University at Buffalo, SUNY.

Received: 8 February 2024 / Accepted: 19 September 2024
Published online: 09 October 2024

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