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The Inequities Embedded in Measures of Engagement in Science Education for African American Learners from a Culturally Relevant Science Pedagogy Lens

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Abstract: Although African American educators strive to ameliorate racist and/or sexist barriers to learners' science engagement in U.S. education, examples of applications of culturally relevant science instruments to measure African American learners' engagement in science are hard to find in the literature. Inaccurate perceptions about student engagement in science education continue to exist, including assumptions about the prevalence and effects of low socioeconomic status, limited content knowledge, and a lack of interest or motivation of African American learners compared to white learners. Most exemplars of student engagement in science focus on the cognitive, behavioral, and social mores of white, male, cisgender, middle-class learners and their reactions to teacher pedagogy. This article reports on a qualitative study of three African American female and male secondary science educators' narratives of "engagement" in science amongst systemic inequities in the northeastern and southeastern U.S. regions. To better understand African American learners' science engagement, I combined socially transformative science curriculum approaches for African American students using five types of mastery with the concepts of culturally relevant science pedagogy as the facilitator of racial equity. A critical-arts-based research methodology was used to craft participants' autobiographical data and drawings into a literary métissage of the participants' experiences, memories, and culturally relevant pedagogical strategies. Themes included: (1) teachers' recognition that their interest and positionality impacted their engagement in science; (2) their understanding of how identifying as scientists informed their career choices and modes of participation; and (3) their observations about how mentoring and vision influenced students' attitudes about engaging in science. The major finding was that critical incidents that teachers experienced when they were students in K-20 schools influenced how they became engaged in science and constructed their culturally relevant practices as science educators. The implications of this finding for pre-service and teacher leadership development for equitable teaching and learning will be discussed, and recommendations for using culturally relevant science practices and navigating power dynamics will be provided.

Keywords: secondary science teachers; culturally relevant science pedagogy; science engagement; African American; critical arts-based methods; literary métissage

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1. Introduction

African American learners' expressions of engagement are narrowly understood in science education beyond mainstream psychological indicators (i.e., behavioral, emotional, and cognitive measures) rooted in a non-scientific context [1,2]. The problem is that standardized methods to evaluate science engagement for African American learners stem from a disregard for the sociocultural-political contexts' impact on how African Americans engage in science education. Since the early 2000s, research on African American students addressing the inequities embedded in measures of science engagement from a culturally relevant lens, and the acknowledgement of racially diverse students' sociocultural norms, have not gained traction. Empirical studies on student engagement in science education, for

example, tend to use different approaches to determine which variables influence engagement; variables have included self-concept or locus of control [3]; cognitive and affective subtypes [4]; individual and developmental differences [2]; motivation; [5] motivational and contextual factors [6]; domain-specific aspects like topics students find interesting [2]; and multidimensional perspectives [7]. Although research acknowledges the challenges and shortcomings of interpreting students' engagement in science education [2], African American students' expressions of engagement continue to be assessed within a framework that does not take cultural specificity (including gender, race, and class background) into account [8,9]. Engagement is considered a predictor of student achievement and enrollment in advanced science courses [10,11]; therefore, methods of evaluating science engagement for students of color, and African American students particularly, directly impact the advancement of racial equity in science education.

Few studies examining science engagement have critiqued the role of racial background in determining African American student engagement [6]. Instead, conclusions based on indicators such as self-concept or locus of control of African American learners' engagement in science education have long defined the scientific field's assumptions regarding science achievement for culturally and linguistically diverse learners [3]. Wright [12], for example, discusses the academic disconnect that African American students experience in education when their everyday activities like talking and seeing the world inform how they learn and achieve, yet, seldom does this inform teacher pedagogy. Mainstream concepts for engagement have facilitated gatekeeping in science education based on Eurocentric norms, which negatively affects students of African descent whose behavioral, emotional, and cognitive patterns do not align with engagement scales lacking a multidimensional framework [7]. Left unchallenged, such practices become accepted conventions for characterizing engagement in science, resulting in a lack of consideration of African American students' cultural norms. Additionally, the oversimplification of engagement in science education using non-domain-specific descriptors borrowed from the field of psychology [1,7] inhibits progress in general by discouraging nuanced expressions of engagement in science by African American students.

Interpretations of African American student engagement in science rarely take into account the life experiences, values, beliefs, and logic of those observed (i.e., African American learners) [12]. The field of science education is predominantly made up of white males, a reality that influences the cultural norms characterizing the learning environment [13]. In 2019, the percentage of students earning science and engineering bachelor's degrees, by race and ethnicity, reflected a disproportionately low number of African American students (14% of the total population of 20–34-year-olds attending college) of 9%, compared to the 54% of their white counterparts, who earned 58% of degrees [13]. An examination of participation in science and engineering by gender shows that women of color comprise over 50% of the population earning bachelor's degrees for their ethnic group. However, white and Asian women lag behind the males in their ethnic groups [13]. Although Black women tend to earn bachelor's degrees in biological sciences (72%) and physical sciences (57%) at a higher rate than white and Asian women, the factors that support their engagement in science are not known [13].

In the early 2000s, educational policies like the No Child Left Behind Act (NCLB, 2001) resulted in high-stakes science assessments for students and comprehensive teacher performance evaluations. The practice of reporting student test scores and not disaggregating the school data by race had hindered any progress toward closing the achievement gaps, necessitating the NCLB policy. In 2010, amid a growing concern that STEM (science, technology, engineering, mathematics) jobs were outpacing qualified workers to fill the positions, then President Obama's Council of Advisors on Science and Technology (PCAST) proposed a strategy to improve K-12 STEM education. Like NCLB, the PCAST strategy to prepare and inspire future STEM workers did not explicitly focus on the role of engagement. Instead, science engagement was understood as synonymous with learning and achievement [2,3,7], which gave rise to informal learning spaces to encourage

STEM engagement for minoritized groups. Such learning environments tend to focus on the interests of the individual by making students' lived experiences the curriculum source to amplify learning. Informal learning environments in STEM that support girls of color, like the culturally responsive computing camp Compugirls, exemplify diverse ways to nurture student engagement by defining the purpose of engagement toward social change outcomes through technology [14]. The success of after-school STEM programs in increasing Black and Hispanic/Latinx students' engagement in STEM shows that engagement requires factors beyond content knowledge development, especially because an overemphasis on certain kinds of content knowledge can perpetuate dominant views and exclusionary mentalities [15,16]. Therefore, achievement being tied to engagement implies the sociocultural need to utilize a racial lens when reporting on science engagement.

This qualitative study describes the conceptualization and measurement of science engagement through the lens of race. By centering the narratives of African American science educators' journeys to become engaged in science and foster other African American learners' engagement, the study expands on how engagement is articulated and nurtured. African American teachers' engagement in science education is framed as a social movement, as a critical arts-based methodology, and as a fundamental part of the teachers' life stories. Each of these elements is used for data generation. The resulting literary métissage, Hasebe-Ludt et al. [17] define literary métissage as a strategy "to generate, represent and critique knowledge through writing and braiding autobiographical text," demonstrates the complex and nuanced meaning of African American student engagement in science and how forms of oppression—namely racism—influence students' science engagement (p. 34). To gain insight into the understandings and practices that determine African American learners' engagement in science, this article addresses the following research questions:

1. How have African American educators become, and led others to become, engaged in science?
2. How are African American educators' understandings of engagement related to in/equity?

In this article, I define engagement in science using two distinct approaches to African American students' learning: culturally relevant science pedagogy (CRSP) [18], an offshoot of CRP within a science context, and the five types of mastery [19], a socially transformative science curriculum model. At their intersections, CRSP articulates the instructional method for enacting equity and the five types of mastery supports the practice of equity through a curricular checklist approach to meet African American students' social and engagement-in-science needs. Collectively, these two variables establish conditions for self-directed engagement aligned with the pursuit of racial equity in science education. I use CRSP to emphasize the impact of teaching styles on African American student engagement, and I use the five types of mastery to exemplify curricular approaches' ability to nurture self-directed engagement for African American students, using specific goals to dismantle colonial structures in science education.

This research is grounded in critical conceptions of science engagement, science education, and race that challenge non-culturally relevant approaches to the study of science engagement among African American students. Taking CRSP as the foundation for examining how standardized measurements of science engagement promote racial inequities, I present in the background section an overview of the literature on racism in science education, research on science engagement, and socially transformative science curricula.

2. Background

2.1. Racism and Science Education

Many studies equate retention issues and student performance problems among racially underrepresented groups of learners in science education to negative classroom experiences [20], teacher instruction, course designs that inadequately prepare them to succeed in higher education [21], or failure to foster growth mindsets [22]. Even with race as a key measure to foreground the need for actionable steps that broaden participation,

the solutions rarely implicate racism as the cause or purpose of African American student disengagement in science education [23–25]. Concerns that African American students' experiences in science education substantially differ from white students' experiences have been framed in a variety of ways. For example, Seiler and Gonsalves' [26] study highlights the need to reform science education for African American students through liberatory pedagogy. Utilizing Freirean perspectives and transformative practices for social change to re-envision science teaching, the researchers changed the learning environment to address unequal power dynamics using a co-teacher model at an inner-city high school with African American students. Inspired to teach science in a way that improves marginalized students' lives, the co-teachers in the study identify the pedagogical problem undergirding African American high school student disengagement as a lack of investment in promoting student agency and motivation and student-centered approaches. Although they used a critical framework (i.e., Freirean perspectives) to explore the impact of liberatory pedagogy on "racially and economically marginalized youth", a recognition of race and racism's influence on African American science students is overshadowed by an emphasis on teacher pedagogy [26] (p. 88).

Some scholars explicitly focus on racism and anti-Blackness as the root causes of systemic inequities. These inequities, in turn, are understood as being responsible for barriers to racial literacy and a lack of justice for African American and Black learners in science education because of anti-Black pedagogy, anti-Black curricular frameworks, and educational policies that uphold anti-Blackness racism [19,25,27–30]. Increasing efforts to identify root causes for racial inequities in science education are exemplified by Mutegi and Atwater's [25] call for theorizing racism in science education. Seeking to understand the science education of people of African descent, they describe how the formulation of research questions informed by the theorization of racism may encourage culturally responsive methodological innovations. More specifically, their review of scholarship exploring teaching and learning for people of African descent suggests three ways to achieve the goal: paying attention to how racism is enabled by ideas, spaces, and research. Although shifts are being made in how we frame the problem when it comes to learning and opportunity gaps, more needs to be done to challenge narratives that African American students disengage from science education for reasons unrelated to racism.

A racial equity agenda in science education must be implemented during the development of curricula and pedagogical methods, rather than being used as a measurement to rate effectiveness retroactively. For example, studies in science education to promote socially transformative curricula [19]; sociocultural consciousness [31]; culturally relevant teaching [18]; the inclusion and amplification of Black girls' voices in learning settings [32]; and awareness in teacher education programs of pre-service teachers' experiences in culturally diverse contexts [33] offer unique insights to confronting racism. Such studies define the purpose of and strategies for centering racial equity in science education.

Racial justice work requires one to be unapologetically committed to the abolishment of racism. In science education, achieving racial justice involves the practice of critical race dialogue in the curriculum [34]. Racial justice science educators center race, racism, and whiteness to expose a number of systemic issues, including barriers to equitable science education and careers, colorblind racism, and the perpetuation of dominant norms [34–40]. To prepare for racial justice work, individuals must study critical theories on race, societies, and whiteness. In highlighting the violence of colorblind racism, Matias [41], for example, describes how, when the concept of whiteness is made invisible in curricula, the work of racial justice is impeded. As a result, curricula become instrumental in establishing a culture of racial dialogue that includes critical race objectives. Once critiquing for evidence of race, racism, and whiteness is normalized in science education, efforts to promote racial justice and equity become viable.

2.2. Research on Science Engagement

The dilemma of measuring science engagement [2] exposes the limitations in adjusting pedagogical guidelines to identify and nurture student displays of engagement. Most studies seeking to create instruments that measure student engagement disregard the sociocultural and political influences at the program and community levels [9]; instead, examples like measuring what worked or did not work become the standard to inform broadening participation initiatives for groups underrepresented by race and gender [42]. Student learning, another important indicator of student engagement [43,44], shapes curricula and instruction guidelines. Although studies exploring what incites student engagement in K-12 science education identify data sources including behavioral markers, such as analyses of interaction rituals or emotional energy [45,46]; subjective guidelines based on physical behaviors; and structural, contextual, and social prompts [44–46], the analytical process of measuring engagement under the previously named markers while using a race/racism lens is absent. For decades, the field of education has used psychological labels (behavioral, emotional, cognitive, physical, and, more recently, agentic) to describe engagement. However, a critique of the feasibility of such labels to accurately represent the diversity of student experiences caused by race/racism in terms of its promoting or hindering science engagement is yet to be explored. Despite the reliance on race/ethnicity as the category to document racial inequities in science education, no adjustments to the analysis and interpretation of science engagement along the dominant indicators (i.e., behavioral, emotional, cognitive, and agentic signals) [2] have been made.

Inquiries in science education seldom apply a sociopolitical lens to make sense of how science teachers understand student engagement. Instead of studying science teachers, some scholars have focused on engaging students' sociopolitical lenses to combat science inequities [47–49], which calls into question how teachers understand student engagement. For instance, research performed to develop math and science engagement surveys from a sample composed of 54.7% female and 67% white students to construct its instruments [6] does nothing to increase Black student science engagement, with its majority of white students as the reference for engagement markers and its incomplete understanding of engagement. Therefore, when we look at the research on science engagement specific to African American/Black students to date, given that the underrepresentation-in-science problem is categorized by race, makes the sociopolitical lens in science research imperative.

2.3. Socially Transformative Science Curricula

According to Mutegi [19], traditional science education lacks curricular goals that liberate African American students and encourage scientific achievement for all. He goes on to offer an alternative, socially transformative science curriculum that dismantles sustained colonial structures that socially hinder African American students. The implementation of a socially transformative approach, Mutegi states, requires an understanding of three contrasting assumptions:

(1) Science teaching and learning of African Americans (and African people in general) can be characterized as pervasively deficient, and the scope of the disparity touches every area of human activity. (2) (a) All human cultures have had means of studying nature, and (b) Western modern science refers to the means of studying nature that is predominant in Western (and Westernized) societies. Additionally, the worldview that supports and reinforces Western modern science is the same worldview that supports and reinforces colonialism. (3) Race is centrally important to a socially transformative curricular approach for African Americans [19] (p. 309).

Solutions intended to overcome learning disparities for African American students must accurately define the problem (systemic racism) and construct a plan to fix the structural inequities in science education hindering equitable teaching and learning.

From the literature, it is clear that race matters in science education, whether we are observing, encouraging, interpreting, or defining student engagement. Science educators must reframe the purpose of science education toward social change and engage in profes-

sional development in culturally relevant pedagogy. Next, I will provide a literature review that supports CRSP and the five types of mastery for engagement in science.

3. Conceptual Framework

The following framework challenges non-culturally relevant science approaches to the study of engagement among African American students. As a standard, equitable engagement in science should acknowledge nuanced expressions (i.e., cognitive, emotional, behavioral, agentic representations) related to learning and the barriers to engagement formed by social inequities. While instruments exist to measure science engagement, they are not designed to consider the roles of race, culture, and equity [2,8,9].

For the purposes of this study of equitably investigating students' engagement, I combined Mutegi's [19] idea of socially transformative science curricular approaches for African American students using five types of mastery (The five types of mastery can be found in Mutegi, J.W. (2011). The inadequacies of "Science for Al" and the necessity and nature of a socially transformative curriculum approach for African American science education [19] with the concepts of CRSP as a facilitator of racial equity. I then incorporated these two concepts into an engagement in science (EIS) framework (see Figure 1). A racial equity lens foregrounds the important ways in which CRSP positions African American students' culture. Alongside Mutegi's five types of mastery, this framework deepens teacher purpose regarding student engagement in science education as a social justice movement. Next, I elaborate on the two distinct entities making up the engagement in science framework that work together to change perceptions about how to measure and nurture African American student engagement.

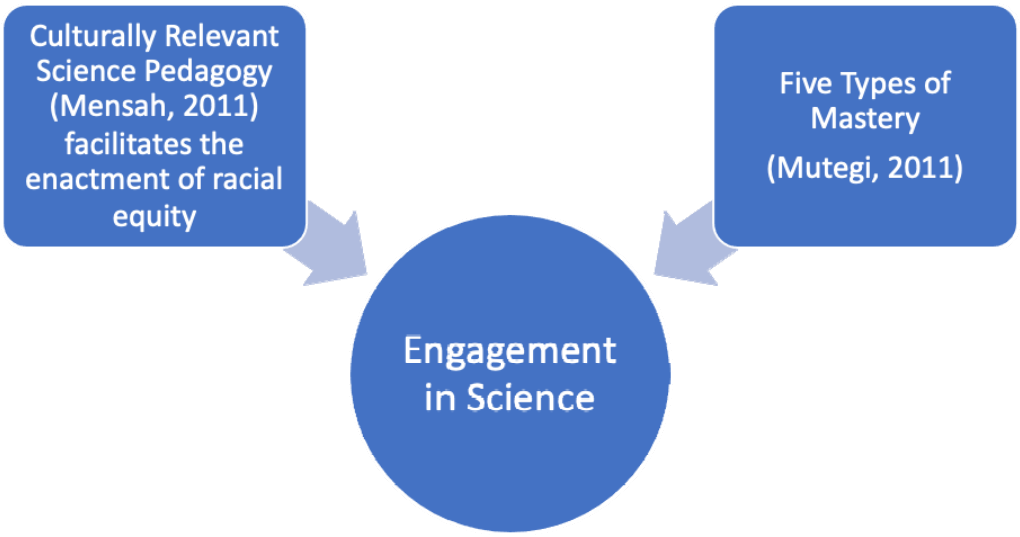

Figure 1. Culturally relevant science pedagogy and five types of mastery in support of engagement in science (EIS) [18,19].

3.1. Culturally Relevant Science Pedagogy (CRSP)

Building on Ladson-Billings' [50,51] theoretical descriptions of an educational framework for multicultural classrooms, CRP, science education researchers formed an adaptation, CRSP. CRSP is a style of teaching noted for "increasing higher-order thinking skills, student achievement, and democratic citizenship for students of color and all students" [52]. Adjusting teacher pedagogy to utilize students' cultures as an instructional strategy for a culturally diverse K-12 student population provides students with authentic opportunities to connect with the science concepts taught in schools [18,53,54]. Individuals are shaped by influences and beliefs learned through culture. However, traditional science instruction underutilizes cultural capital in diverse classrooms when it comes to engaging and maximizing student learning [55,56].

In the last decade, more CRSP studies have responded to Sleeter's [57] call for comprehensive and usable research on culturally responsive education that demonstrates CRSP's impact on outcomes among ethnically diverse groups of students [58,59]. This call has given rise to research in science education that examines culture, race and racism, and teacher preparation programs' applications and interpretations of CRSP [37,59–63]. Empirical evidence of CRP's impact on science students [60,61] helps to illuminate reasons why students of color underperform and/or fail to see the relevance of science on a personal level. For instance, Hubert's [64] study highlighted a gap in the literature regarding outcomes from this population; there is an absence of research on African American math students' perceptions of how CRP informed their experiences of learning math. Examples of students' perceptions of CRP (like teachers' perceptions) make the inequities in science education visible. To this point, CRSP studies have revealed sources of inequity, which involve exclusive instructional practices such as failing to recruit underrepresented groups and not creating a department culture where students from non-dominant groups can be themselves [65]. Another example involves underdeveloped or absent understandings and implementations of CRP; for example, ending the achievement gap was a teacher goal, but they could not articulate ways to close the gap [52].

However, some CRSP studies have made attempts to offset racial inequities by creating models that prepare pre-service teachers to use culturally relevant practices to teach students from culturally diverse backgrounds. The aim of these models is to disrupt inequitable science education [59], potentially nurturing African American student engagement in science. Notably, the importance of acknowledging race is another major determinant of achievement and engagement outcomes for racially diverse students in science and math education [37,63], which adds to the urgency of transformative resolutions to end racism.

When we look for models of teaching and learning that are informed by notions of equity, we find CRSP. Mensah [29] argues that diversity and equity in science teaching occur through a teacher mindset in which science education is seen as a right that should be accessible to all and where desired outcomes include student empowerment and educational advancement. In addition, CRSP frames equitable teaching and learning as a process in which science teachers reflect on how they instruct and engage students. While an explicit aim of CRSP is to dismantle barriers that racially marginalized science students face [52,58], research has also highlighted science educators' successful execution of CRP's sociopolitical consciousness tenets in a middle school class by positioning students' sociopolitical realities as central to their knowledge and practice of science [37]. Pointing to the need to examine pre-service teacher perceptions of math and science being taught using a CRP framework, Mark & Id-Deen [59] have expanded how engagement for African American science students is understood, explained, and practiced through the analysis of teacher instructional plans.

3.2. Five Types of Mastery

Mutegi [19] proffers a five-point mastery checklist for a socially transformative curricular approach in science education for African American students. Based on five categories—content, currency, context, critique, and conduct—science teachers can support African American students' science engagement using the curriculum guidelines that assess for mastery in each. The five types of mastery illuminate the inequities in traditional science curricula and the corrective measures to apply to secure social uplift. A brief description of each mastery type follows.

1. Content mastery requires a deep understanding of scientific concepts. Presumably, social transformation occurs when students know the dominant Eurocentric science codes and cultural mores needed to inform social change.
2. Currency mastery is an ability to connect science and social issues. Here, student engagement involves applying science content to lived experience.

3. Context mastery allows students to personalize learning and fosters inquiry into non-Western approaches to science practices. Marginalized students who take a broader look at scientific knowledge, habits, and traditions expand the utility of science work.
4. Critique mastery reflects critical consciousness. Science becomes a medium to analyze systemic forms of oppression through cultural analyses—like the use of food as a social weapon.
5. Conduct mastery sets expectations for activist outcomes. Fully equipped at the close of the learning process, students are expected to reflect on, question, and formulate ideas to improve social conditions, which further defines the purpose of science engagement.

4. Methodology

I used a qualitative approach developed by Hasebe-Ludt et al. ([17], called literary métissage, which allowed me to weave together African American educators' stories of science engagement and science in/equity, including life writing and arts-based methods. Through a CRSP, racial equity, and five types of mastery lens, I used arts-based methods as a self-reflexive tool [66] to help participants identify ways teachers promote, consider, ignore, conceptualize, and understand science engagement for African American students. This study centers on life writings, with a focus on literary métissage, to illuminate a research strategy for describing, interpreting, and combining African American science educators' experiences without erasing difference [17].

4.1. Methods

For each science educator, I conducted two audio-recorded, semi-structured interviews. I then conducted a third interview after educators received a draft of the literary métissage, so that they could respond to what they read. The first 60 to 90 min interview was in person. I asked participants to make a drawing, or artifact, from the prompt's instructions to "draw the ideal science teacher—NOT" on an eight-by-twelve-inch sheet of white copy paper. The drawing activity was modified from Mensah's [67] study with pre-service teachers on science teaching and teacher identity. I utilized the artifact during the interview and afterward for further analysis. Participants also responded to guiding prompts to recall being engaged, like: "Think back to a time in science when you were engaged and describe that experience". From notes from the first transcribed interview, I conducted a second 30 min interview via Google Hangouts two weeks after the face-to-face interview. I asked participants to respond to follow-up questions based on my analysis of the initial interview. The third interview, also via Google Hangouts, occurred four months later for 15–20 min. This artistic approach was intended to stimulate conversations about underutilized opportunities to represent knowledge through art in science education research to generate data on science engagement.

4.2. Data Analysis

All interviews were voice-recorded and professionally transcribed. The data was organized into two categories for analysis.

Category 1 involved interview questions that were divided into subsets A and B. Subset A included questions about the participants' engagement in science, and subset B included questions about current endeavors related to equity in science education. To identify emerging themes in respondents' answers to the interview questions, I read through the transcripts and field notes, and I open-coded them [68–70]. The iterative coding process included using the in-person interview questions as reference points to formulate themes across the three participants' responses. The coding process of matching responses to related interview questions by topic and analyzing them both separately and collectively resulted in three themes. I referred to these themes as "braids" in keeping with the concept of weaving together separate parts into one to construct a literary métissage. Derived from the Latin mixticius, métissage is the intentional weaving of cloth from different fibers.

According to Hasebe-Ludt et al. [17], literary métissage is the description and interpretation of interwoven personal experiences. The shared knowledge of repressed cultural traditions becomes potential a platform to present tensions without offering assimilation or incorporation solutions. To highlight the complexity of understanding science engagement in the participants' interview data, and to construct a métissage that can foster critical conversations around differences linked to socio-historical formations (i.e., language, nation, colonization, and globalization), I modified Hasebe-Ludt et al.'s model by changing the autobiographical format to a biographical one that recounted three African American science educators' journeys to engage in science and education.

Category 2 data included the artifact drawings. I examined the details of each drawing based on two categories: symbols and reasoning. The first level of analysis focused on symbolic depictions of "the ideal science teacher—NOT" (ISTN). This process coded for images; in other words, people, furniture, text, and objects were featured as descriptive markers in the drawings [67,71]. The positioning of people and the use of labels, gender identifiers, and arrangements of furniture were compiled into the symbol category. For example, each participant added people in the artwork (sometimes specifying gender and sometimes not) to characterize whom they considered to embody undesirable teacher attributes. Each symbol was independently listed and critiqued based on its function. The second level of analysis focused on participants' reasoning regarding the attributes included in the drawing. A list of common phrases was used to organize participants' articulation of the ISTN as a reference point for engagement in science. For example, phrases like "teachers who lack vision" supported participants' reasons for undesirable teacher behavior. Thus, the reasons provided revealed participants' strategies for engagement in science. Figure 2 provides a graphic representation outlining the process of analyzing and constructing data into a literary métissage.

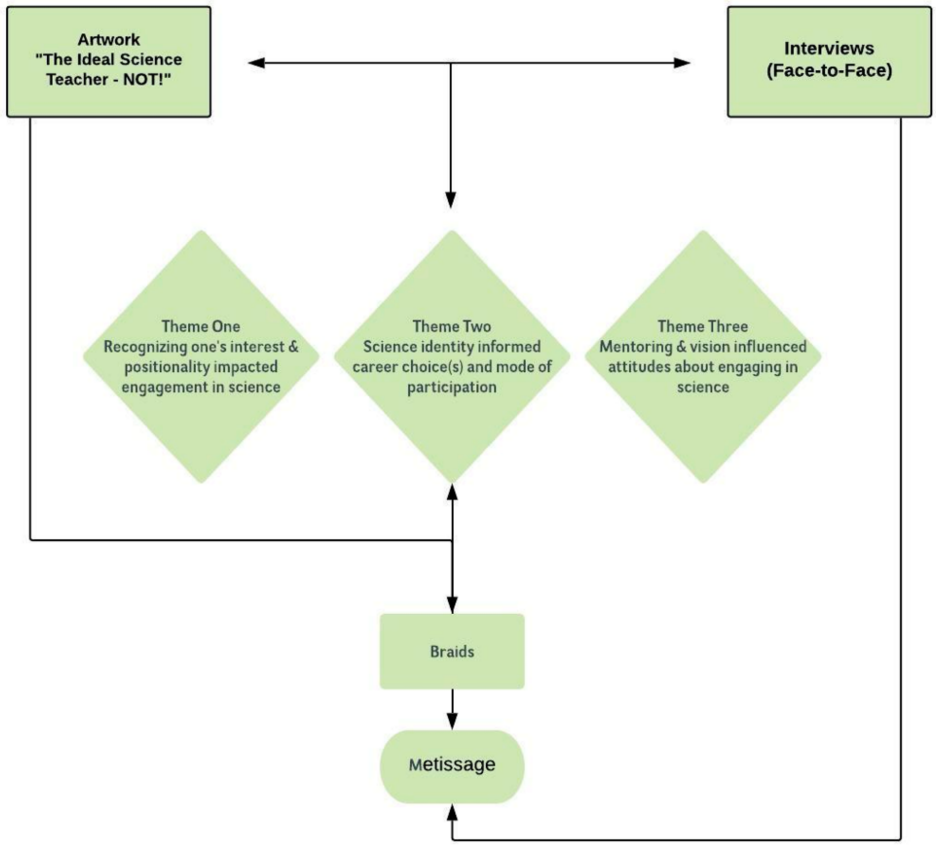

Figure 2. Flowchart of data analysis and construction process for literary métissage.

The literary métissage contains three braids (themes) under a single topic derived from the coding process. For instance, "Engaging (as) Science Educator" represents the main topic contextualizing the braids. Under each braid, I retold science educators' narratives about science engagement. Collectively, each braid revealed the participants' practices of engaging themselves and others in science.

4.3. Participants

To gain an understanding of African American science educators' narratives about engagement in science, I recruited participants using an advertisement describing the study with these qualifying criteria: is African American; has a science degree; taught at predominantly Black and Brown schools; received awards related to diversity/equity in science education; and/or published on topics focused on science equity. The call resulted in three participants: one middle school teacher and two high school teachers. All three were veteran science educators (between 36 and 44 years old) with more than a decade of experience in the field; two identified as Black women, and one as a Black man, serving youth between the ages 12 and 18 in underperforming schools (See Table 1). Additionally, the participants for this study reflected three attributes: (1) an ability to provide narratives (personal or situational) about engagement, (2) a willingness to describe characteristics for engagement in science education, and (3) an ability to provide personal narratives about people instrumental in developing and/or hindering science engagement in their lifetimes.

Table 1. Demographics of study participants.

Name/Pseudonym	Gender	Race	Teaching Level/Position	Years of Experience	State
Keisha	Female	Black	High school/Teacher	13.5	Texas
Claudia	Female	Black	High school/Teacher	13.5	Texas
Tye	Male	Black	Middle school/Teacher	17	Washington

5. Results

Analyzing the ISTN artwork and interviews and constructing a literary métissage revealed two key factors that promoted science engagement for the African American participants. First, as learners, there were formal and/or informal examples of CRSP in K-16 that cultivated their science identity. Second, as educators, they witnessed African American student disengagement and designed equitable science learning environments to disrupt racial and/or gender inequity in science education. I use the African American science educators' ISTN artifacts and a literary métissage to reveal the reasons why the science educators characterized science engagement in these ways, in order to re-imagine learning and applying scientific content. My aim is to illustrate how culturally relevant methods to measure engagement in science education for African American learners advance racial equity.

5.1. ISTN Artwork to Explore Understandings of Engagement and In/Equity

5.1.1. Keisha's Artifact: "Intention and Impact"

My first of three K-12 science educator interviewees, Keisha, energetically shared her nearly 14 years of teaching experience with me. Teaching in a large public school district in the southeastern United States, she has always held appointments at predominantly Black schools. Keisha chose the number two pencil to represent her thoughts about the ISTN and shared these words about her drawing:

> I have two pictures that refer to two scenarios that I think of as teachers I don't wanna be. The teacher who actually is in the room, but not mentally or academically present 'cause they're distracted with their own task. In the end, the teacher who is literally not in the room for a variety of reasons, typically because they're

> avoiding teaching. And then I have a list of characteristics that, to me, describe teachers that I definitely don't ever wanna become. A teacher who doesn't care about kids or their improvement, the teacher who is in inappropriate relationships with students, the teacher who's trying to be popular by befriending the students, the teacher who lacks classroom management, and then the teacher who's just there because it's a great schedule as far as off time.

Adept teachers prioritize communicating a purpose for learning science that is relevant and encourages social change (see Figure 3).

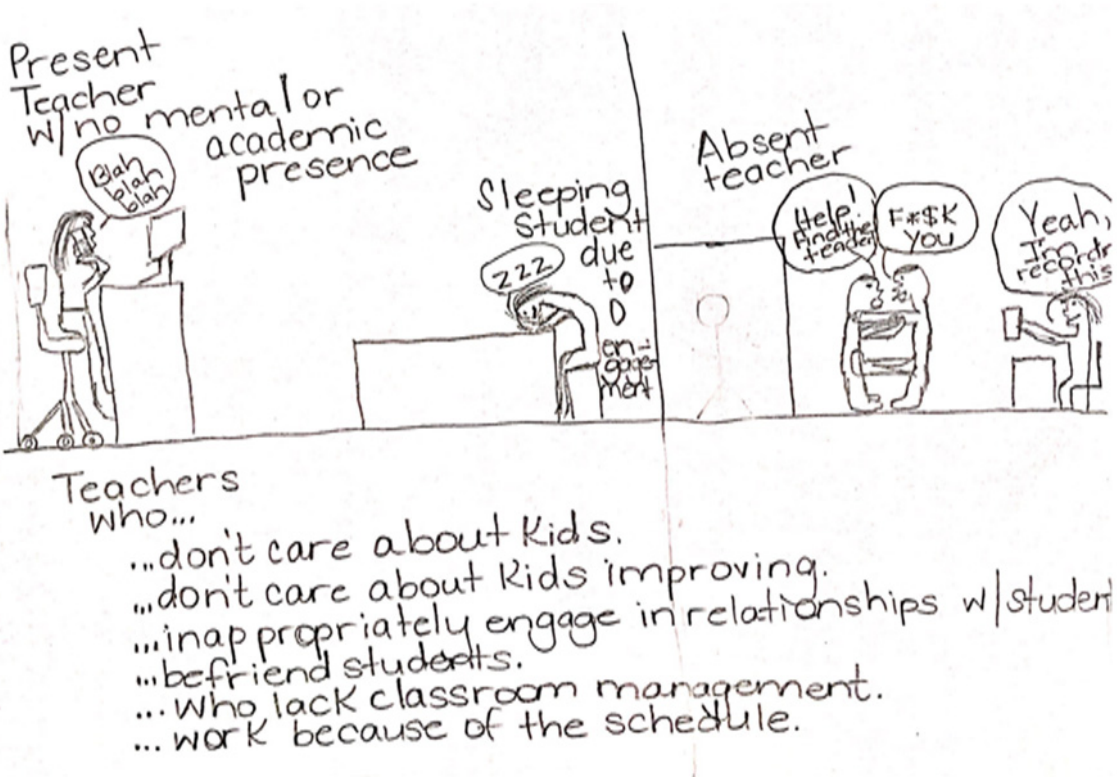

Figure 3. Keisha's artifact depicting the ISTN.

Each image reflects representations of extreme student behavior in different settings. One example shows a teacher who is physically present but mentally absent and the other shows a teacher who is physically absent from the classroom. Collectively, the images suggest that engagement in science depends on teacher behavior. In the scene where the teacher is present, the teacher's disengagement fosters student disengagement in science. Even when the teacher and student physically occupy the same classroom space, they do not interact. Further, in the drawing, the student sleeping on the desk facing the teacher suggests that student engagement is externally motivated. Because the teacher relies on the banking system model [72], a one-way instructional practice of teachers depositing into the student information and skills, the student is trained to be complacent.

To encourage student engagement in science, participants pursued student and/or teacher alliances through mentoring. Beginning with building teacher/student relationships, mentoring offered access and achievement denied to members of marginalized groups in science education. Making science relevant to students' lived experience in order to bolster achievement requires more than providing students with examples. Participants discussed the responsibility of mentors to include sociocultural factors. Keisha outlines her approach to mentoring this way:

> So, I had been very purposeful in, number one, engaging in relationships, specifically with young Black women who tend to have a greater need for structure, support, and/or encouragement because they lack those things at home.

Bolstering Black women's ability to engage in science extends beyond CRSP. For instance, success in science/STEM for Black women demands more than content proficiency. It requires navigating sociocultural norms through mentorships and community support systems (i.e., sister circles, church) [73,74].

Teacher disengagement, exemplified by the ISTN, led Keisha to increase science engagement for underrepresented groups in her role as a mentor. This impact was evident in her efforts to find students summer internships, in contradiction to her representation of the absent teacher whose students engage in destructive acts. Moreover, according to Keisha, conditions were no better for students when teachers were physically present but mentally absent in class and lacked an agenda to build relationships, improve proficiency, or express care.

Trusting teacher intentions, Keisha's drawing implies that teacher engagement determines the level of science engagement for students. A mixture of teacher purpose and values held about science education undergirds classroom culture. In Keisha's examples of teacher disengagement, students express bad attitudes about the content and demonstrate a lack of empathy for others. Keisha also indicates that blind trust in education ignores the banking model's limitations when it comes to developing students' critical consciousness. In turn, this limitation hinders student ownership of knowledge production and obscures student agency in the classroom. In fact, Keisha's comic strip suggests that both students and teachers have been taught that only teachers, not students, are responsible for cultivating engagement in science. This classroom scene clearly expresses science engagement as conditional and not driven by individual purpose.

The two images represent a multiplicity of issues faced by members of marginalized groups in science education. The comic design exhibits Keisha's perception that care and mentoring are pedagogically absent. In her description of characteristics that she does not want to emulate as a teacher (not caring about students, acting inappropriately, trying to be popular, etc.), she implies that these factors limit students' engagement in science. By contrast, in her own work as a teacher, Keisha invests in mentoring relationships with students to connect self and science. Motivated by care, Keisha encourages students to build their capacity to think critically and understand scientific content.

5.1.2. Tye's Artifact: "Do Not Disturb"

Tye teaches at an affluent private school in the northeastern United States and has 17 years of experience as a science educator. While he created his artifact, his facial expressions mirrored the impassive expression of the person in his drawing, which he created with a black pen. His assignment to construct the ISTN created a unique opportunity for him to represent his story. When asked to explain what he drew, Tye said:

> I think my artifact represents most of the science teachers I had. White male. For whatever reason, they liked to have beards. Majority of them wore glasses. Couldn't relate to me at all, but not just to me—they couldn't relate to most of the kids that they were teaching. What else? Then some of the words that I wrote, you know—cold, like I don't want to become somebody that was cold or arrogant. Condescending, unapproachable. Always abstract. It's like they didn't do a good job of taking their ideas and making it real for students, like relating it to their life. They carried too many pens, a lot of them, like just too many. Why do you have all those pens you don't need? There's like 20 in your pocket.

In his words, Tye reveals the impact of teacher demeanor on perspectives about science education and the importance of care and fostering relationships with students (see Figure 4).

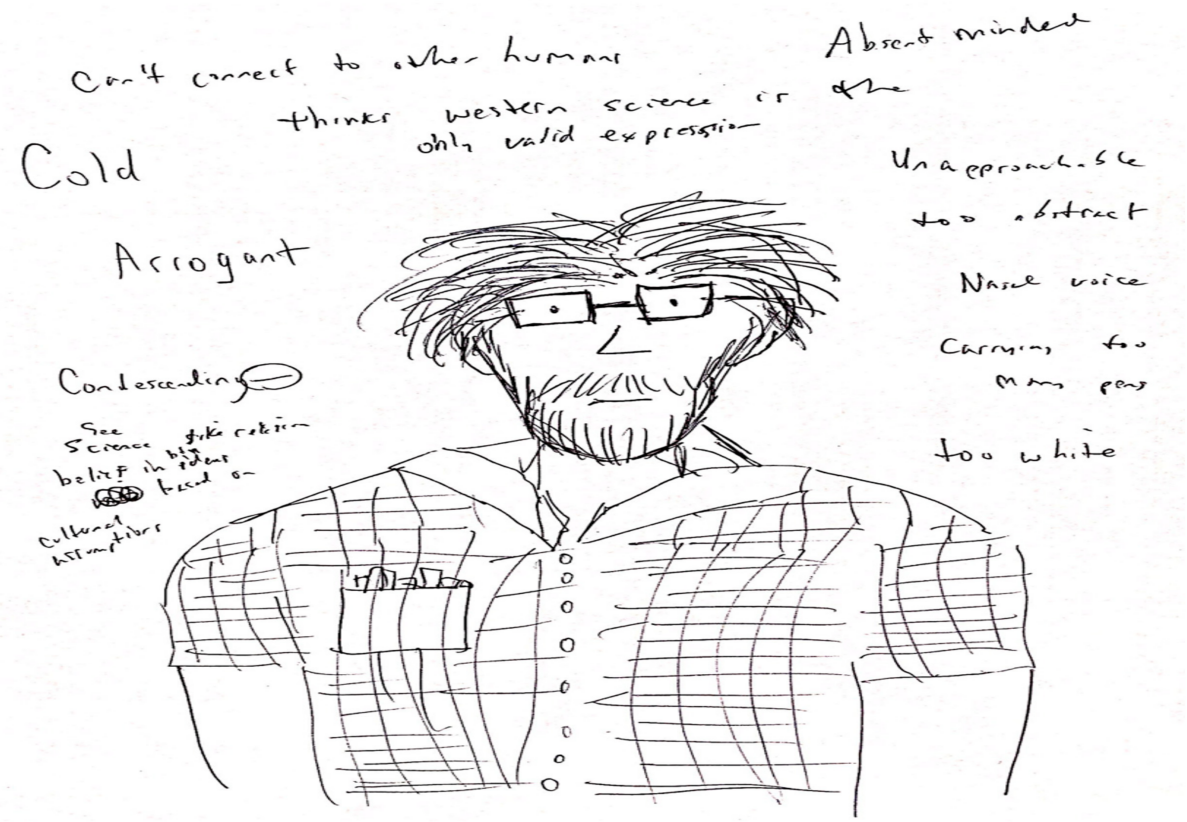

Figure 4. Tye's artifact depicting the ISTN. The descriptive text written around the image includes—Cold, Can't connect to other humans, Thinks western science is the only valid expression, Absent minded, Unapproachable, Too abstract, Nasal voice, Carrying too many pens, Too white, Condescending, See science like religious belief based on cultural assumptions.

Tye described an incident that he experienced as a student: surprised by a white science professor's compliment of his work, he blurted, "You see me"? His question contextualized his negative associations with the white male that he drew. That white male appeared to be the gatekeeper of scientific knowledge. Tye focused on the positionality of self and others in science. He applied stereotypical indicators for a science teacher and highlighted Western standards that marginalized indigenous science, particularly for underrepresented groups. The drawing's details depict how science education in schools is socially constructed. Tye demonstrates how, even in diverse classrooms where he has taught, dominant assumptions about race and gender norms devalue non-Western scientific thought and practice. Tye's art and narrative suggest that his personal experiences engaging in science education and encountering Western social mores have taught him the importance of persevering and teaching oneself how to engage with content.

Tye's drawing reflects the notion that adhering to dominant norms is a necessary prerequisite for occupying the role of teacher, and ultimately, he suggests that the ISTN's teaching habits incite disengagement. He further centers teacher attitude and appearance as critical to the learning process for students. Reflections like this one allow teachers to develop a critical consciousness, which in turn allows them to promote equitable science education.

Having emerged from emotional memories absent of joy and belonging, Tye's artifact symbolizes the exclusivity of science engagement. Descriptive terms like "absent minded", "too abstract", and "cold", heavily inform Tye's pedagogy. He prioritizes being approachable, encouraging diverse ways of knowing, and facilitating processes for the underserved to achieve positive science identities. Seeing fear as a barrier to engagement in science, particularly for underserved groups, he said:

> So for my kids one of the things I try to help them with—and I've always done that, even though I've had different demographics—is create an environment where they can feel like they can take a risk and not be punished by their peers or be punished by me.

In explaining strategies to maintain science engagement, Tye described ambiguous classroom procedures as a barrier to content mastery. As a solution, he suggested that teachers should explicitly state behavioral and academic expectations, saying:

> I try to give them access, information as far as expectations. What I learned is that is countercultural in this school, [while] in public school, that was pretty much standard. In here, people don't like to do that. Kids who come from different environments have a hard time navigating the space because they're guessing, right? They're playing a culture game. What flies here? What flies here? I don't know. I don't know.

Positive classroom culture was central. Tye's experiences of being excluded in school because of racism led him to create his agenda to increase engagement for underserved groups. Tye enforces student-centered learning, uses theater to promote inclusivity, and mentors.

5.1.3. Claudia's Artifact: "Certification Is Not Enough"

Claudia taught in a large public school district in the southeastern region of the United States. In her words, after the first experience "that gave me the teaching bug that I always desired", she remains a science teacher nearly 14 years later. Seeing the profession as a calling, Claudia drew what appeared to be a blueprint for effective science engagement. Also issuing a warning, she shared this insight on the ISTN:

> The first thing that I would not want to be as a teacher is one who lacks a vision for their classroom. Before you even get into the education field, you have to decide what type of teacher you wanna be and what you want your students to be. These teachers who lack vision typically come with a lack of planning. So you see the students sitting at the desk and I have the question marks next to their heads. They don't plan properly, so the students become so confused. So, over here, where you see the eye going toward the vision, they don't have worldview of education. Schools aren't one-sided anymore, where you have one demographic of students there. There are so many different demographics. And I think if you don't understand a worldview and how different cultures, or different demographics of students, or students with disabilities navigate through the world, then all of that kind of spills over into the classroom.

Emphasis on teachers having a vision, cultural competency, and lesson-planning ability that tap into student interests are foundational to helping them engage in science (see Figure 5).

Claudia's drawing represents a collage of consequences from the ISTN attributes. Focusing on the ISTN's character as the root cause for confused students with unmotivated demeanors, Claudia connects the negative student outcomes to science teachers' absence of vision, collaboration, and communication. The perspective of science teachers controlling knowledge production suggests Claudia prioritized collaboration between teachers and/or between teacher and administrator for curriculum planning and instruction. From the apparent top-down approach, engagement for students in science depends on the teacher's behavior more than students' funds of knowledge, an assets-based framework [75]. Implied deficit mindsets, a belief that students from disadvantaged circumstances don't excel academically in school as a result of their circumstances, suggest that student pathways to science achievement emerge directly from teacher demeanor. Therefore, regarding the chance that students would know science content, Claudia described it as unlikely.

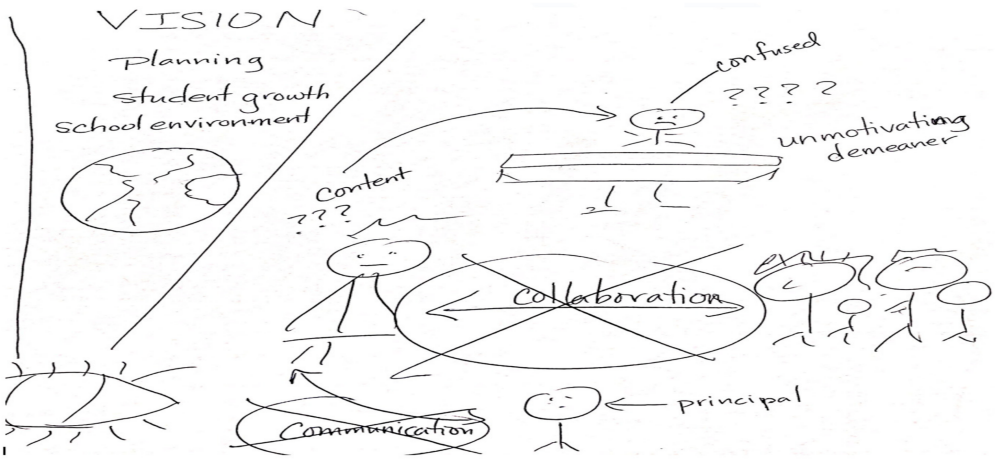

Figure 5. Claudia's artifact depicting the ISTN.

Members of marginalized student groups experience difficulties with science content mastery because teacher expectations are not explicit or differentiated, and they solely reflect dominant social norms. For instance, socialization hinders learning scientific concepts for members of non-dominant groups when those members have not been equipped to understand the dominant scientific culture taught in schools [19]. Claudia echoed these specific challenges:

> We have to learn to teach African American kids because they learn through time. They don't have the experiences that everybody else have. So, you have to make sure you're constantly drilling the information for them because that's through time. And so, we find that the African American students will tend to not go toward science or not go toward math because we don't take the time to ensure that they have certain fundamentals.

A collage of topics—vision, planning, student growth, and school environment—represent educational components that are necessary to engage in science. Claudia's drawing depicts a cause-and-effect scenario: one side serves as a roadmap and the other side serves as a warning. Her articulation of bad teacher characteristics also reveals a desire to teach diverse populations. Claudia attributed disengagement to a lack of teacher planning, stating:

> Planning lessons. So, starting with understanding how the curriculum is designed and putting that into your content, and making—you know, bringing that over to the students. But the planning in terms of how things go in your classroom, the procedures that students follow every day. I think most teachers who fail, or do the education system or the students an injustice, are the ones who don't plan for everything that involves the student.

The reference to teachers not planning for everything showed up in Claudia's attitude about addressing students' socio-emotional well-being [76]. For Claudia, the inability to center the needs of students beyond content development diminished teacher effectiveness. Therefore, being able to motivate students required having information (i.e., interests, lived experience, family background) about them to draw from to contextualize scientific content [60].

In Claudia's drawing, vision and lesson planning are the backdrop for student growth and inclusivity in science classrooms [59]. She demonstrates that when these values are omitted, student learning is disrupted, and students become disengaged and confused about the content.

Claudia used descriptors like "unmotivating demeanor" and crossed out words like "collaboration" and "communication" to illustrate multiple variables impacting engagement. Not limiting engagement to the realm of the classroom, she constructed a web that focuses less on student contributions in the process. This dynamic characterizes how the

ISTN teacher unconsciously discourages students from engaging, independent of external factors (i.e., experience, interest).

5.1.4. Literary Métissage, Theme: Recognizing That One's Interest and Positionality Impact Engagement in Science

From the artwork and face-to-face interview data, this section presents the participants' life stories as first-person accounts made into a métissage. Using the braid metaphor, Keisha, Claudia, and Tye's life experiences as three individual strands become a braid (theme) to better understand the concept of science engagement from the perspective of African American science educators. Taken from the three participants' collective memories, diverse and nuanced, came the theme of recognizing that one's interest and positionality impact engagement in science, for the métissage. The memories of critical incidents at home and/or school helped to define the participants' academic interests in science to engage and cultivate expertise in the field while resisting racism. This métissage gives an account of Keisha, Claudia, and Tye's memories exploring scientific concepts and the messaging they received as learners about science engagement and/or their response to inequities.

Chemistry Set: Keisha

Since childhood, I loved the subject science. As early as fourth grade, vivid memories confirm my science passion through examples of special requests made to my parents for a chemistry set at Christmas. Knowing how scientific concepts affect real life fostered my pursuit toward deeper content knowledge. Situated in environments (home, school) that nurtured my curiosity, I learned how to naturally respond to the things that piqued my interest. Most important was I learned to recognize the role of science in all aspects of one's life. This became obvious in ninth-grade biology class. My favorite K-12 teacher's example of using a personal experience most people would never publicly share helped us connect content to our lives. I respected her courage and talent demonstrating the ways we could apply science in making life choices.

In school, I was labeled a quick learner. I could easily pick up concepts delivered. For instance, I could read a text and re-read it just before a test and then perform successfully on it. I captured the attention of most K-12 teachers with my high aptitude levels, [which] resulted in teacher campaigns to have me enrolled in their class. Despite one physics teacher lacking social skills, never once did I experience discouragement by K-12 science educators to indulge in the learning of science. In fact, the example of the ninth-grade science teacher really cultivated my understanding of science as the basis for every decision I make. I believe science represents the process to make logical sense of things in and out of the classroom. I've developed a theory about science in my life: if I can't figure out a solution to a problem utilizing aspects of the scientific method then it becomes a complaint, not a problem. I rely on science for everything in my life. I am science.

Advice from Others: Claudia

Dad enrolled me in a math and science summer camp my seventh-grade year. He was a math professor at Wood State University (pseudonym), where I later attended. For two summers, I participated with other young kids getting first-hand experience in the field. My initial leaning toward science, however, occurred in high school. The way this science teacher always told us "we could do this" had an effect on me. In college, when it came time to determine a major, I remembered him. I initially thought I would be a marketing major, but objections from my dad led me to consider other options. Being reminded of dad's words, "You're too good to major in anything other than science and math" brought back memories of how I was always good in science. With all arrows pointing toward science, I studied chemistry in college.

I caught the science bug early on in life. Growing up in Jackson, Mississippi, with parents who were agriculturally inclined, laid the groundwork for firsthand knowledge of nature and mankind. The first time I used an outhouse was in Boyle, Mississippi. Dad and

his brothers would sometimes rent farmland I converted into academic playgrounds about nature. Those unique experiences cultivated my independent thinking skills. As a student, I paid attention, went to class, and did homework when required. Even though I didn't study a lot, I still excelled academically because I followed along in class with the teacher.

On two different occasions, fourth and eighth grade, something happened to alter the way I approached education. In fourth grade, I let my mom help with a social studies homework assignment. When it was checked the next day in school, every answer was wrong. From that incident, I vowed to myself never again to allow another person to influence anything I knew I learned. Then, in eighth grade, my algebra teacher, Ms. Anderson (pseudonym), who spoke with a Mississippi dialect that was hard to follow if you had not read the book, kept repeating, "You have to put the vurable" to highlight my error. After several failed attempts to make sense of her instructions, I opened the book to read. Her words became clear as I read the term "variable" in the text. From that incident, I made a second important vow to read for myself if I want to know something. In both cases, I learned the option of relying on everybody else for my own progress limits my academic growth.

Plan B: Tye

I hated the uncomfortable feeling. I attended a small, predominantly white university in the northeast region of the US to study computer science. In due time, I switched majors, abandoning the option to ask for help to pursue what I remembered being my best subject in school. As a kid, life science fascinated me. Regularly, I would occupy my time between watching nature shows and playing with bugs. I had associated doing science in my formative years with a natural process led by one's curiosity. Being unaccustomed to structures that limited the way I interpreted and interacted with the world put me at ease with my development as a scientist. The more I spent time in school, however, the less I was able to enact self-directed science explorations that fueled my true interests.

I believe several factors interrupted my development in science. Mostly, reasons related to having a number of science teachers fail to connect the content to my life. I felt forced in school to think about science in a certain way. By middle school, science became less fun, and it progressively got worse by the time I reached high school. Eventually, I questioned my interest in science. My resistance to how science was presented often got me into trouble. After repeat bad experiences, I started to not like it as much.

I set the terms for how I learned science. In spite of the teacher (dis)encouragement, the roots of my love for science were deeply planted. When it came to life science, I thrived. Recognizing my natural propensity to become captivated by the content alone, despite teacher delivery that lacked relevance and excitement, unconsciously taught me to author my own knowledge. For me, this became evident in Dr. Klein's (pseudonym) high school science class. Despite the fact Dr. Klein is the driest, most robotic, most cold person, I really liked the life science content. So, although as a teacher I was removed from him, I did not let that interfere with my learning. Many times, I focused on the content, not the teacher, in science when I did not receive the instruction necessary for my growth as a scientist. Instead, I relied on personal passions to understand animals, nature, and life systems to teach me the habits of a scientist.

6. Discussion

The purpose of this study is to expand how science engagement for African American learners should be interpreted and nurtured amidst racial inequities. Major findings reveal critical incidents that influence the African American educator's decision to engage with science and, in turn, help others engage. Underdeveloped instruments to measure student engagement in science that ignore race are apparent in the data. The targeted action of measuring how engaged or not engaged a science student is implies that they have an ability to be one or the other; therefore, engagement becomes a response to scientific content contextualized within the social norms. Arguably, assessing student engagement in science

through a race/ethnicity lens instead positions the culture of science education as the object of critique for the failure to develop African American learners' science identities.

The first research question asked, "How have African American educators become, and led others to become, engaged in science"? The African American educators' reasons for engaging in science and helping others become engaged differed. The differences underscore how science engagement, if measured and represented from a non-culturally relevant instrument, perpetuates inequities through decontextualized strategies to address the problem of science disengagement. The participants presented three distinct purposes for self-engagement and supporting the engagement of others in science. Keisha associated engagement in science with acquiring a science identity not related to a career path, but rather tied to the well-being of the individual. Tye engaged in science as an act of resistance to negative perceptions about his academic talent and to construct a learning environment that welcomed multiple expressions of knowledge for others. Claudia viewed engagement in science as a planned phenomenon occurring through deliberate and customized experiences awakening the individual's curiosity about that field. Measuring science engagement using variables counter to the typical indicators for career choices or curriculum and/or pedagogy, which are disconnected from African American students' lived experiences, confirms the need for transformative approaches to properly interpret and nurture African American student science engagement.

The second research question asked, "How are African American educators' understandings of engagement related to in/equity"? All participants had specific rationales for the lack of African American student engagement. Keisha interpreted the individual's connection to science as an indication of healthy living. Therefore, if students' experiences in science did not encourage them to understand themselves and others through a cultural lens, and exercise critical consciousness, science engagement would be absent. On the other hand, Tye understood that student science disengagement happened in cases where there was fear, impersonal teacher interactions, and a lack of clarity about the teachers' expectations. His engagement was defined by the absence of these things; therefore, Tye encouraged student engagement by constructing a science learning environment that removed these obstacles. Meanwhile, Claudia saw science engagement as a dynamic and comprehensive process for African American students who are unsupported by the current structures in science education. Consequently, the data show there is likely an expectation that teachers are collaborating to fulfill this goal of developing students' mindsets to see the relevance of science in their daily lives.

The conceptual framework—made up of CRSP and the five mastery types—illuminates the racial inequities embedded in non-culturally relevant methods for measuring African American learners' engagement in science education by ignoring the influence of racism. Although this is only one study, the evidence provided supports the idea that CRSP fosters science engagement, science identity development, and actions to confront science inequities for African American learners.

6.1. Science Engagement and CRSP

This arts-based interview study found omissions of culturally relevant practices pertinent to engagement in science for underserved groups in science education. The exclusion of diverse (non-dominant) scientific practices served as reasons for students to disengage [58]. For members of non-dominant groups, science education is a socialization process embedded in decontextualized learning, lacking relevance to lived experience [77]. Standardized systems for sharing scientific knowledge and codifying scientific practice, derived from white middle-class norms, promote understandings that devalue indigenous scientific knowledge [65]. According to Zuss [78], student awareness of differences manifests in conscious decisions to either apply dominant cultural norms or reject them for alternative options. Therefore, studying science disengagement acknowledges marginalized students' awareness of their exclusion from the creation of scientific knowledge and practice. Tye, for instance, suggested that teachers should explicitly state behavioral and

academic expectations to avoid ambiguous classroom procedures becoming barriers to student content mastery. This aligns with previous CRP research, which recommends bridging student learning gaps by emphasizing the role of culture and cultural resources in learning science [62].

Science curricula originate from a perspective not relatable to non-white students; therefore, skill-building to connect self and science has not been developed [77]. Instead, marginalized students are exposed daily to decontextualized science content that conditions them to view science as abstract [60]. Because science is socially constructed, science's meaning and utility vary at social, cultural, and political levels [61]. Many teachers who are cognizant of these issues acknowledge the diversity of student conceptualizations of science with, for instance, workshops on differentiation [79]. Although many teachers understand that scientific interpretations of content are diverse, the predominant standards for differentiating scientific content reflect Western traditions and values [52]. Culturally relevant approaches to teaching science are a direct result of African American educators' resistance to the white culture of science education. Disengagement occurs when non-dominant student groups must relate to their lived experiences from a Western science perspective [12]. Similarly, connections to science content mastery are rooted in culturally relevant practices [62]. Engagement is thus associated with the integration of diverse perspectives in science/STEM education.

6.2. CRSP and Identity

Science teachers' expectations of African American students' academic competency often dictate curriculum design and pedagogy. Marginalized students are impacted most by curricular and pedagogical decisions made about student ability levels [80]. Science teacher perceptions of students' abilities—high or low—have an influence on student outcomes. Keisha, for instance, had dreams of specializing in lions. Being the only African American woman enrolled in the undergraduate program for wildlife and fisheries at a southeastern university came with two initial challenges. First, the program's wildlife focus was on ducks, deer, and alligators, not lions. Despite her confidence that studying lions was her career purpose, the notable program limitation negatively impacted Keisha's interest in that particular field. Second were several instances of racism. Although underrepresented in science, her intersecting identities as a Black woman scientist did not require external factors to encourage her engagement [24,27]. Instead, Keisha describes how "the racist demeanor of my white male professor merely dampened my excitement about the class, not the content." Ultimately, it is not the content that hinders student progress for marginalized groups; it is the Eurocentric dominant representation of science that narrows participation [52,63]. Therefore, science teaching, for participants, is about dismantling negative stereotypes, racism, and portrayals of science knowledge as exclusive to white middle-class males [37]. Building content knowledge and expertise to overcome sociocultural and political injustices are important aspects of teaching science to African American students [19].

6.3. CRSP and Actions

The African American science educators I interviewed strive to uplift marginalized groups using scientific knowledge. This study revealed actions taken by Keisha, Claudia, and Tye to operationalize a certain type of engagement for social change. Not motivated by pointless activity or passive participation, the study participants incite students to think critically and actively contribute to the production of scientific knowledge. As the five mastery types represent a framework for defining the parameters to equitably position African American learners in science education, it also promotes meaningful science engagement.

Keisha, Claudia, and Tye followed certain aspects of the five types of mastery in their instructional methods. Explicit in the data was the participants' reliance on currency, critique, context, and conduct to foster students' engagement in science education. With references to building critical thinking skills, connecting science and self, and applying

subject matter to a social issue, participants worked to bolster African American learners' competencies in science for better job opportunities and representation [19,81]. Yet, less obvious were participants' actions to enhance African American students' competency in order to name and confront inequities. Overall, participants relied on skill-building techniques to foster student engagement at the expense of directly preparing students to disrupt racism.

7. Limitations

Although the initial interview was conducted face to face, the second interview was held virtually through Google Hangouts. This mode made a difference in my observations; when participants situated the camera from the shoulder up, I was only permitted to observe facial features. The fact that participants were given interview protocol questions prior to the first face-to-face interview potentially allowed them to prepare a response that made them appear in ways not representative of their true practice, belief, or values.

Journaling before and after interviews helped me identify emotions and ideas, and to pose questions on what I witnessed during the interview. I did not require study participants to journal their experiences before and after interviews. Because narrative inquiries are dependent on memory, including pre and post journal, prompts could have enhanced their engagement with the process and provided more insight into the symbolism represented in their drawings. The absence of participants representing other categories, such as sexuality and religion, may have narrowed the range of perspectives.

I interpreted participant responses from two semi-structured interviews, an artifact drawing, and observations to re-narrate their story. Although the information was firsthand from participant interviews, the métissage was a creative product I wrote using their responses to represent how I made sense of their narratives. Additionally, my interpretation of what was drawn and explained by the participants was reflected in the drawing analyses and does not include the participants' analyses of their drawings.

The five types of mastery introduced steps to identify and enhance engagement in science for African Americans. This effort to expand on how engagement is conceptualized beyond psychological indicators presented a teacher checklist for engaging students. This model lacks empirical evidence to suggest a method to prevent shortcomings. It also might encourage standardized perceptions rather than alternative outcomes to define engagement based on a student's unique lived experience.

8. Conclusions

Through life writings, this study contributes to existent literature on African American educators' academic experiences that shape their science identity and the circumstances defining their purposes for engaging or disengaging in science. Most attempts to measure science engagement lack a CRSP lens, which reflects negatively in their analyses of culturally diverse learners. African American science educators must resist the exclusionary practices embedded in standardized teaching and learning to develop the process for becoming and remaining engaged. Overwhelmingly, a critical incident embedded in racial or gender norms prompted participants to recognize and engage in science's social and political dimensions. Notably, engagement in science for pleasure became secondary in the context of systemic forms of oppression. Likewise, engagement in science involved mentoring to heal and bring awareness of inequities. Participants were motivated to engage in science for social equity reasons. Apparent in the study was the correlation between CRSP and racial equity initiatives for participants and their students' engagement in science. The science educators' narratives suggest that encountering inequities at the social level had a greater impact on science engagement for self and others. As such, becoming a science educator positioned them to re-imagine a culturally relevant science educational experience supportive of African American student engagement.

9. Implications and Recommendations

The following are implications for science teacher professional development, sociocultural and political dynamics of teaching science, and the use of arts-based methods for science research. For teacher professional development to foster engagement in science for African American students, there needs to be a focus on preparing teachers to gain a philosophical understanding of culturally relevant teaching in science education, and then to put that framework into practice (see Mensah, [67]). In a 2019 study, Mark, Id-Deen, and Thomas [33] identified some barriers for pre-service teachers—e.g., pedagogical theory and practice—that hinder culturally relevant teaching in culturally diverse educational contexts, thus requiring teacher training. With regard to the sociocultural and political dynamics of teaching science, teachers need to merge scientific concepts with sociocultural consciousness development [31] and socially transformative curricula [19]. Traditional science education does not represent science for all—or, in Mutegi's words, science for all becomes a slogan that is "inherently misleading and consequently dangerous" when social, cultural, and political factors are overlooked [19] (p. 302).

Science education research on African American students should involve techniques that acknowledge diversity of thought, expression, and conceptions of engagement. Arts-based research techniques like critical response pedagogy elicit reflexivity [82] and engagement that represent the perspective of the individual. While this study finds that CRSP fosters science engagement and actions to ameliorate inequity for African American learners and educators, more research is needed on K-12 science teachers' journeys to help members of other underrepresented groups engage in science. Recommendations for arts-based approaches (i.e., theatre of the oppressed, storytelling, drawing) to CRSP for science teachers include transferring theory into practice, identifying unequal power dynamics, and advancing social equity as the purpose of engagement.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

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Conflicts of Interest: The author declares no conflict of interest.

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