

Article

Claiming Your Own Identity and Positionality: The First Steps toward Establishing Equity and Social Justice in Science Education

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Abstract: If there is one major aspect that calls for science education reform in both Costa Rica and the United States have in common is that in both countries, science teachers are expected to establish an inclusive environment where students feel free to engage in discussions and investigations of real-world (socially relevant) issues. However, one aspect that teacher education programs in both countries have also in common is taking for granted the complexity of developing a teacher identity with the kind of cultural awareness, relevant pedagogy and content knowledge, and positionality necessary to meet the ambitious calls for science education reform. In our study, we sought to contribute to the understanding of these issues by assisting 17 pre-service high school science teachers in Costa Rica explore how their identity development and positionality might impact their abilities to establish culturally inclusive and socially relevant science classrooms. To this end, we offered participants culturally and socially relevant science teaching and curriculum development workshops for the last year and a half of their teacher professional program. Findings from the project's first phase of analysis indicate significant growth in the participants' identity development as culturally inclusive teachers responsible for making the science curriculum relevant for everyone.

Keywords: identity; positionality; social justice; pre-service teacher education; sociotransformative constructivism (sTc)



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1. Introduction

While the construct of identity continues to gain more attention in science education research [1–3] there is still much we can learn from other scholarly fields that have studied this topic extensively. More specifically in science education, there is a need to consider more critical and feminist conceptualizations of teacher identity development in terms of the multiplicity of identities that teachers (or anyone) can inhabit—especially in culturally diverse spaces, such as today's schools [4–6]. In addition, we argue that if we are to better prepare teachers to become culturally inclusive and effective professionals in response to reform efforts (e.g., Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas [7] in the US, and Education for a New Citizenry [8] in Costa Rica), teacher education programs need to better understand how to assist pre-service teachers (PSTs) identify and critically engage with their own identities and positionalities (we acknowledge the multiplicity associated with the constructs of identity and positionality and will elaborate on our conceptualizations of these terms; however, for the sake of clarity, from this point onward, we will use these terms only in the singular). To this end, our study reports on how a group of pre-service teachers' enhanced identity awareness and espoused positionality influenced their professional development as culturally inclusive science teachers.

We begin with a brief discussion of research on science teacher identity. We then explain how critical and feminist post-structuralist frameworks inform our conceptualizations of identity, positionality, and other related social constructs. This is followed

by a description of how we connected our insights about identity and positionality with sociotransformative constructivism—a theory of teaching and learning for social change [9]. Overall, preliminary analysis of the quantitative and qualitative data shows significant gains in the PSTs' perceptions of their abilities to integrate cross-cultural science/STEAM (science, technology, engineering, arts, and mathematics) education in their practice. However, for this manuscript, we focus on insights gathered on the PSTs' identity development and its impact on their curriculum and pedagogical choices as they sought to become effective and culturally inclusive science/STEAM teachers. We conclude with recommendations for teacher preparation programs interested in supporting their PSTs' identity and positionality development as culturally inclusive teachers, and as teachers who are committed to addressing science education reform efforts.

2. Theoretical Framework

2.1. Supporting Teacher Identity Development in Science Education

In the United States, the low representation of Indigenous Peoples, Afro-descendants/Black, Latinos/as/Hispanic, and Mestizos/as (individuals from mixed ethnic/cultural backgrounds) in STEM-related fields [10] and in science teacher education programs [11] has been a source of concern for decades. Therefore, various reform efforts, policies, and programs have been proposed to monitor and address this issue. While well-intended, most of these programs rely on truncated conceptualizations of equity, diversity, and social justice that seek to “fix” the Other without critiquing the institutional and historical practices that created and sustain inequities in the first place [12,13]. Aggravating this omission is the absence of critical self-reflection on how those in privilege positions are implicated in the very systemic oppression they might be describing in their research and/or reform reports [14,15]. Thus, effective science/STEAM education and teacher preparation reform efforts need to shift from well-intended notions of seeking to establish equity policies and practices *for the Other* to *working with the Other* to establish social justice together [16]. To this end, teacher education programs should make teacher identity development a more central aspect of professional and personal development. In other words, how can teachers make their curriculum and pedagogy more culturally inclusive (as expected by various reform efforts) without assisting teachers to become more critically aware of their own identity and positionality?

While we continue to gain new insights into teacher identity development in science education, most studies have focused on: gaining strong science subject matter knowledge [17,18] gaining access to a distinct science community of practice [1,19]; documenting one's process of becoming a science teacher in the form of narratives or storied identities [20]; or investigating how the participants' gendered experiences impact their professional development [3,21]. Some critical scholars, on the other hand, point out that fewer science teacher identity studies explore how ethnicity, or the intersectionality of ethnicity and gender, impact professional development [22,23]. Furthermore, and ironically, science teacher educators/researchers often do not disclose or problematize their own identities and positionalities even when working in contexts that are culturally very different from their own.

To better understand the state of the field in science teacher identity research Avraamidou [1] conducted an analysis of 29 studies published over the span of 12 years (2001–2013). She found three key areas in need of attention: (1) The lack of “a clear and concrete conceptualization of science teacher identity, which would support our efforts in supporting its development” (p. 165); (2) a disconnect between research on identity development and science education reform efforts; and (3) how science teacher identity development is actualized in classroom practice. In our study, we begin to address these gaps by engaging participants in a critical exploration of their own identities and positionalities, and by supporting them in their efforts to make their science curriculum and pedagogy culturally and socially relevant. Avraamidou [1] also posed a critical question in her literature review: “What constitutes a reform-minded science teaching identity? How do teachers

construct reform-minded identities? What kinds of programmes and experiences can support teachers?" (p. 167). While we do not claim to have all the answers for these important questions, our study begins to provide some insights on the productive challenges and possible approaches to support the identity development of *reform-minded and culturally inclusive science teachers*.

2.2. Identity vs. Ethnicity vs. Culture vs. Race vs. Positionality

Our study in the Costa Rican context helped us realize that one of the aspects that makes the integration of identity development challenging in teacher preparation programs in the US and in Costa Rica is the pervasive colonial terminology still used for individuals to identify themselves and others. These colonial approaches for categorizing individuals into mostly skin-color-coded boxes mainly serve to commodify and politicize groups of peoples, and they dominate our discourse and sense of self. This is compounded by the multiplicity of definitions across scholarly fields and government agencies for key concepts, such as identity, ethnicity, race, positionality, and culture. Therefore, in our study, we draw attention to how obsolete colonial categorizations of 'race' and modern, neoliberal definitions of culture obfuscate the study and support of identity development in teacher education programs. This is further discussed in the Findings section, but we articulate next how feminist poststructuralist scholarship guided our use of key social constructs in the study of teacher identity

Feminist poststructuralist perspectives on identity, positionality, and intersectionality articulate that these constructs represent multiple complexities of becoming and being [24,25]. Thus, researchers/teacher educators could at the very best use these constructs as analytical/pedagogical tools that can assist research participants/teachers to better understand their identity development in a given social context and time. In our study, we are particularly mindful of colonial and racialized social categories, such as those traditionally used in school contexts. Thus, we heed the advice of critical feminists who caution social scientists to avoid the entrapments of binary and essentializing demarcations (e.g., oppressed vs. oppressor, rich vs. poor, race categories, etc.) [24,25]. Therefore, we refuse to use terms such as 'race' to denote an individual's ethnic and cultural heritage. It is well known that this term has no basis in the natural sciences when it comes to describing diversity among human beings. Our skin color diversity is no more than valuable adaptations to protect us from the sun and to produce vitamin D [26]. Yet, the construct of race, and the use of its skin color-coded categories, still endure. Thus, for our study, we prefer to define culture broadly to include an individual's multiple identities manifested by the individual's ethnicity, gender expression, socioeconomic status, gender, sexual orientation, language(s), and physical abilities in a given context. Ethnicity and culture are closely related terms, but for us ethnicity involves the individual's shared ancestral roots, language(s), familial associations, and shared traditional foods, art, music, and social customs. Therefore, no individual has a single identity, but a multiplicity of identities that often intersect and manifest based on social interactions [27]. We argue that an individual's critical awareness of their own multiple identities and how this awareness impacts their identity (personal and professional), as well as their interactions with others, represents that individual's positionality. Therefore, we view positionality not just as an individual's self-declared locations (e.g., middle-class, conservative, environmentalist, pro-choice, etc.), but positionality as an espoused and public disposition to act, or the specific actions (or inactions) that reveal who we are.

Hoping to avoid the entrapments of (mis)representation that may arise from fears of 'speaking for others' even when aspects of our identity as teachers or as teacher educators/researchers align with those of other individuals, we must consciously and often interrogate our taken-for-granted assumptions [4]. To this end, we agree with Alcott's more fluid notion of identity "as a political point of departure, as a motivation for action" (p. 431). Given the transformative focus of our study, we embraced whatever terms participants preferred to identify themselves, and we were more interested in how the participating

PSTs enacted their critical understanding of identity and positionality into their curriculum and pedagogical practice. Thus, we used sociotransformative constructivism as the guiding framework for assisting PSTs' experience and practice culturally and socially relevant science teaching and curriculum development.

2.3. Sociotransformative Constructivism

Sociotransformative constructivism (sTc) is an ideal framework for the study of teacher identity in our increasingly pluralistic society because it merges critical cross-cultural education (as a theory of social justice) with social constructivism (as a theory of learning) [9]. sTc draws heavily from Lev Vygotsky's [28] conceptualization of learning as a social activity dependent on the context and experiences of participants. This implies that an individual's culture (broadly defined, as mentioned earlier), language (in whatever form and including symbolic language), and experiences mediate what and how that person learns during social interactions with others. This perspective is particularly important for teacher education programs to consider in assisting PSTs' identity development. In other words, if we believe that learning is influenced by the participants' prior experiences, language, culture, and social interactions, then the construct of power must be considered as one of the key mediating factors. This is where sTc serves as a bridge between social constructivism and critical cross-cultural education because an individual's identity awareness and espoused positionality determine their access to (and influence upon) the culture of power, or existing dominant discourses in any given context. For example, a female Mexican American with dark skin, who teaches advanced high school physics courses with a focus on gender equity in STEM in predominantly Anglo male high school classrooms, might experience different power dynamics than an Anglo male counterpart. Thus, sTc seeks to raise critical awareness about how an individual's multiple identities might intersect (intersectionality) to determine one's course of action (positionality) to establish a productive, respectful, and inclusive learning environment for all students. In other words, sTc problematizes teacher identity development beyond gaining access to a community of practice, or having strong subject matter and pedagogical knowledge, or investigations of one's gendered or racialized experience in becoming an effective teacher. All these explorations are of course important, but sTc is a framework that unapologetically promotes transformative action.

This agentic approach for enacting social constructivism is congruent with critical approaches to multiculturalism [14]. That is, sTc rejects neoliberal notions of "inclusion", "belonging", "acceptance", "tolerance", "diversity", "awareness", "equality", etc., which are often associated with commodified notions of ethnic or gender representation for institutions, schools, or even individuals to make claims about diversity or cultural competence or representation.

On the other hand, sTc encourages teachers not only to identify how webs of oppression might obstruct their own identity development as culturally inclusive teachers, but also how these same webs of oppression obstruct access to meaningful learning for everyone. Thus, sTc helps guide difficult conversations on how to effect meaningful social change in educational systems that are so recalcitrant to change and often contradictory to their own calls for reform [12,13].

sTc is composed of four interconnected elements: *the dialogic conversation, authentic activity, metacognition, and reflexivity*, and these will be briefly described here. More details about the sTc framework are provided elsewhere [9,29,30], and for other examples of how sTc has been deployed in various teaching, learning, and other contexts, see: [31–35].

It is important to note that the four components of sTc are not linear "stages" or "phases". These components are simply conceptual tools meant to embrace and facilitate the complexity of teaching and learning through culturally and socially relevant pedagogical strategies and curriculum. Thus, any one or more of sTc's four elements can be enacted at any time in response to the challenges and opportunities typically found in educational contexts.

In our study with Costa Rican PSTs, we enacted all four elements of sTc; however, because we are focusing on science teacher identity development and positionality in this manuscript, we will draw more attention to *reflexivity* and the *dialogic conversation*.

The dialogic conversation is primarily based on Mikhail Bakhtin's [36] construct of *dialogicality*. This construct enables us to better understand the complex process of meaning-making among individuals because it problematizes taken-for-granted assumptions about listening and speaking or 'just engaging in dialog.' The dialogic conversation helps teachers constantly keep in mind the question "who is doing the talking?" For example, in educational research and science education reform reports [7,8], it is common to hear about the importance of promoting students' collaborative work in groups, the open discussion of their findings, the development of their scientific-argumentation-from-evidence skills, and so on. However, this approach assumes that all that is needed is for teachers to organize students in small groups, and then complex meaning-making will simply happen. We believe this process is much more complicated. Using Bakhtin's dialogicality construct, we argue that teachers and students also need to understand how their identities (i.e., culture, ethnicity, gender expression, sex, gender expression, language, etc.) and multiple positionalities (their dispositions to act or actions associated with their chosen identities) influence what and how they think. In short, a dialogic conversation does not involve just listening, reading, or deciphering words or symbolic language, it involves understanding how the speaker's and the listener's voices harmonize (construct meaning together) or collide (creating tension and dissonance). This is where sTc advances the notion of dialogicality by directly addressing issues of power dynamics. In other words, teachers (with their privileged, authoritative voices) are perfectly poised to guide and encourage dialogic conversations through which students (and their teachers) engage in meaningful and respectful conversations. In these dialogic conversations, participants are not just hearing words, they are listening and paying attention to what is being said, as well as who the speaker is (i.e., the speaker's positionalities). For the dialogic conversation to work effectively, additional efforts are needed to ensure that everyone in the dialogic context (e.g., classroom community) knows one another well, and all are interested in building trust and respect for each other.

Therefore, we argue that for teachers to be able to promote dialogic conversations in their classrooms—especially in culturally diverse classrooms—they also need to have a strong sense of their own identities and multiple positionalities. Similarly, we pose that identity and *reflexivity* are closely linked and always influenced by one another. Thus, for sTc, *reflexivity* involves engaging in an on-going process of critical self-reflection on how one's own espoused positionalities show who we are through our actions (or inactions) [9,29].

Metacognition is another sTc element, and it involves critical epistemic and ontological awareness by asking questions, such as: what, how, and why am I learning the prescribed or official knowledge represented in the science standards? What agency do I have in this process, and whose interests are represented by being required to learn the prescribed curriculum? [30,37,38]. For teachers to be able to encourage this level of agency and understanding in their classrooms, they need to be able to answer these questions for themselves. To accomplish this, science teachers need to recognize the important role they play in developing their students' abilities to become the kind of critical consumers and producers of knowledge who actively engage with the world around them—as expected by the various calls for science education reform [7,8]. This implies that teachers should encourage students to ask questions about their learning, such as: "What am I meant to be doing? What is the purpose of this task? Why am I doing it this way? What control do I have in how to proceed?" [29]. Similarly, teachers need to also reflect on what, how, and why they teach a certain subject matter in a particular way, as well as the ways by which they allow students' voices and creativity to be represented in the teaching/learning enterprise.

Finally, authentic activity in sTc goes beyond hands-on and minds-on science activities to ensuring that these activities are culturally and socially relevant to students. This

involves incorporating students' funds of knowledge (i.e., cultural and home/community knowledge and experiences [37]), as well as connecting the prescribed science curriculum to real local/world issues [9,30–33,38]. This is obviously a challenging task for PSTs, both in the US and in Costa Rica, because they are mostly members of the predominant culture and most likely experienced transmissive, teacher-centered, and decontextualized science learning in their school and university science courses [7,39,40]; in other words, the exact opposite of how major science education reform efforts expect PSTs to teach to motivate the 'next generation of creative scientists and engineers' [7,8].

To counter this pervasive contradiction, we engaged the PSTs in various sTc science activities that modeled culturally and socially relevant curriculum and pedagogy across the three required science methods courses of their teacher preparation program. After completing each sTc activity, we also offered multiple opportunities to deconstruct them using dialogic conversations. In short, as Avraamidou [3] suggested previously, we sought to prepare "reform-minded" PSTs, and to accomplish this, we believe that PSTs (and in-service teachers in general) also need support in developing their own identity and positionality as culturally and socially relevant teachers.

3. Methodology

Our project involved the participation of seventeen secondary pre-service science teachers. Nine of them self-identified as women (52.9%), seven as men (41.2%), and one as non-binary/other (5.9%). Given that the focus of this manuscript is on identity development and positionality, the participants' and researchers' cultural backgrounds are discussed in more detail in the Findings section. However, it is useful to highlight here that fourteen (82.4%) of the PSTs self-identified as Mestizas/os; two (0.12%) as Mulatos/as; and one (0.06%) as Other. The first author is Latino (male), and the second author and research assistant identify as Mestizas (female).

The PSTs were followed during three consecutive methods courses over a period of a year and half. The courses were: (1) *Methodology in the Teaching of Sciences* (which have the same focus on science pedagogy and curriculum as methods courses in the US); (2) *Teaching Experience in Sciences* (which included a weekly seminar and the PSTs' school-based teaching placements); and (3) *Seminar in the Teaching of Sciences* (which involved learning about research methodologies and conducting a small research project in school-based placements). During each course, PSTs participated in multiple activities that modelled how to make science more culturally and socially relevant using the sTc framework. These were followed by dialogic conversations aiming to deconstruct these activities, as well as to assist PSTs in examining the role they could play as reform-minded teachers. The dialogic conversations also sought to promote reflexivity; that is, critical reflections on how their own identity and positionality (e.g., as a woman in science, or coming from a rural community, or from modest SES, etc.) have influenced their own personal and professional growth, as well as how these realizations might impact the pedagogical and curriculum choices they will (should) make as culturally inclusive teachers.

In addition to modelling and engaging PSTs in authentic activities, we also used a variety of quantitative and qualitative research tools that included pre–post surveys (with Likert scales and short answers). These were administered at the beginning of the project, and then at the end of the second and third course. Same-gender focus group interviews (4 females and 4 males) were conducted three times over the course of the project. In addition, we gathered data from teaching observations, review of artifacts (lesson plans and students' class work), and field notes across three semesters. For this manuscript, we are only reporting findings from the first phase of analysis using mostly qualitative data (i.e., short answers from surveys, focus group interviews, students' artifacts, and field notes).

The research team used an ethnographic approach to investigate the PSTs' changes in conceptions over time, as well as their shared meaning-making [41]. To this end, the team independently read and re-read interview transcripts and the short answers from surveys, and contrasted emerging trends with field notes and students' artifacts for triangulation [42]. For

the overall study, we are developing various themes and categories, and for this manuscript we focus on the aspects related to the PSTs' identity and positionality development.

4. Findings and Discussion

4.1. Identity Starts with I, but Who Am I?

The first author is conducting a similar study with US pre-service teachers (PST) to the one reported here in the Costa Rican context, and in all our projects, it is common practice to ask participants to disclose their ethnic/cultural identity associations. However, to move away from colonial categorizations of race and shades of skin color, we use a more open-ended question: *What ethnic/cultural group(s) do you identify with?* The goal is to encourage research participants to reflect on their ethnic heritage and culture and indicate how they identify themselves without feeling 'boxed' into the pre-designated racial categories one often finds in the US context. For example, the first author often struggles with traditional demographic questions that offer forced choices of colonial and color-coded (Black and white) binaries, as well as odd choices or too broad 'race' categorizations, such as Hispanic or Latino, Asian, American Indian or Alaska Native, Black or African American, Native Hawaiian or Other Pacific Islander, and white. Furthermore, for the first author, who identifies himself as Latino (originally from South America), this category represents a broad ethnic/cultural identity, not a 'race'.

The second author, Dr. Navarro, identifies herself as Mestiza and born in Costa Rica, and she argued that including the aforementioned cultural identity question in this study—although seemingly innocuous—would be too confusing for pre-service teachers in the Costa Rican (CR) context. She explained that this type of question is not often asked. "Here, we would not know what to answer, and we don't have Indigenous or Afro-descendant students in our program". (Dr. Navarro, field notes, Year 1). This dialogic conversation among members of the research team (that also included a research assistant who identifies as Mestiza) prompted Dr. Navarro—who is the Director of Secondary Science Education program—to reflect on the persistent absence of Afro-descendant (Afro-Caribbean) and Indigenous students in her program. She then sought to investigate whether her university had any recruitment and retention programs for students from these ethnic groups. She found out that the university does not offer any support programs for marginalized students, and did not monitor students' ethnic backgrounds in general.

This long-standing lack of pre-service teachers from Afro-descendant or Indigenous cultural backgrounds enrolled in the University of Costa Rica's (UCR) teacher education program is not a unique phenomenon to Costa Rica. The first author observed the same pattern at his former and current institution in the US, even though these universities are within, or close to, major urban centers with significant Afro-descendants and Indigenous populations.

Thus, to pursue the ethnic/cultural identity question as a more prominent subject of study and not just as another demographic question, we decided to use the same ethnic/cultural categories as those deployed by the Costa Rican (CR) National Institute of Statistics and Census (INEC 2011) (see Table 1). We thought that these 'official' categories could avoid the possible confusion that the above-mentioned open-ended question might produce. Interestingly, this was not the expected outcome. In other words, the CR Government's choice of color-coded and colonial racial categories (e.g., Mulatto, Black, and White, see Table 1) provoked a strong and negative reaction from all the participants that indirectly helped us achieve our main objective; that is, engaging them in a dialogic conversation about their cultural identity, as well as how this identity awareness might impact their reflexivity, positionality, teaching practice, and their relationships with students.

All the PSTs struggled with the CR census-based ethnic/cultural identity question we included in our baseline survey. The most troublesome was the CR Government's "White or Mestizo(a)" category. This became more evident during our focus group interviews when we asked students to elaborate on their answers. For example, Luis explained:

I had a problem with the ambiguity because in the option of white, it also said Mestizo [see Table 1]; that is, I do not consider myself white because I am Latino, let's say but I wanted to mark Mestizo, so I wanted to mark both.

(Luis, FG I, p. 4)

Table 1. Costa Rican official ethnic categories *.

Ethnic Category	Definition
Black or Afro-descendant	People who mainly recognize in their identity the cultural roots of African descent and their diaspora.
Mullato(a):	The people who recognize mainly in their identity the root cultures of African descent and their diaspora from one of their parents.
Chinese	People with ancestry from the People's Republic of China, including Taiwan and Hong Kong. Does not include people of other Asian ancestry.
White or Mestizo(a)	People who mainly identify with the legacy of Hispanic American culture and history. This also includes people who identify with the legacy of European or Anglo-Saxon culture and history.
Indigenous	Any person identifying as a member of one or more of the various indigenous ethnic groups of Costa Rica. (These are explained in more detail in the next section.)
Other	People who self-identify with any ethnic group not mentioned in the previous categories.

* Categories translated directly from those indicated in the INEC, 2010 (Census Taker Manual, p. 142).

Pedro—another student in the same focus group—agreed: “I was also confused because I didn't know how to classify myself in relation to the categories in the survey, so I chose Mestizo” (FG I, p. 4). Javier—who also has dark skin—did not find a category that best represented him, so he chose Mestizo as he understood this category to involve the mixing of multiple ethnicities, and added:

I have a great grandmother who is from China from my father's side, and from my mother's side I have a great grandmother who is from Germany, so for me it is more the mixing of everything.

(Javier, FG I, p. 4)

To explore any potential gender-based issues, we conducted separate focus group interviews by gender (gender expression) across the project. However, regarding this question, we found the same level of frustration and difficulty among the female students. Veronica illustrated well the challenge (and complexity) of verbalizing one's ethnic/cultural identity when presented with pre-determined 'boxes' (choices):

I believe that the classification made by the INEC (the CR census institute) is not the one with which I feel most identified, because there is no specific classification with which I identify myself, which is between Mulatta and Mestiza in our education program, they do not teach us how to identify with something specific. We know that we are a mixture and I think that knowing that we are a mixture, we do not identify with something specifically. I think that because of social networks and because of the information bombshell, I think that being Latino is very important first and I think that is what most people classify into, but between Mulatto and Mestizo, taking into account that we have more part, let's say, of America than from the other continent but I do not feel that it is an accurate classification.

(Veronica, FG I, p. 3)

Another student, Maria, expressed less hesitation:

Well, I think that regarding this question I have had no doubt that I classify myself as Mestiza, I have always had that very present, and there is even a curious story

in my family where there is a great-great-grandmother who was completely an Indigenous person. That's why I have that certainty that there is Indigenous blood in my veins, so I qualify myself as Mestiza.

(Maria, FG I, p. 4)

To highlight the importance of encouraging PSTs to explore their own cultural identity, when we contrast the responses from US PSTs' who have participated in the first author's on-going project to those of PSTs from Costa Rica, we can observe interesting results. Participating US PSTs do not seem to struggle in selecting any of the color-coded and broad identity categories when asked the open-ended ethnic/cultural identity question. As indicated in Table 2, the percentage distribution of the pre-service teachers' self-described ethnic/cultural identities in the US study is representative of the overall ethnic/cultural identity of teachers across the US (even when using the official US government-designated race/ethnic categories). In addition to showing the low representation of African Americans/Afro-descendants, this table also shows the low representation of Peoples of Color across ethnic groups. However, an important point to note here is that participants in the US study struggled to explain what their chosen ethnic/cultural identity meant to them. For example, when asked to explain why they have chosen White, they could only state that their response is based on their skin color. In other words, they struggled to make connections to cultural/ethnic roots. "I'm just White", some students said. Other students wrote "American" as their response, and when asked to explain their choice, they said "I was born here (in the US), so I'm American".

While we accept and respect all the participants' identity choices, our goal again was to promote dialogic conversations about a taken-for-granted construct: their *chosen* ethnic/cultural identity. As Table 2 indicates, when the ethnicity/cultural association question is left open, participants are free to name their chosen ethnic/cultural association, which in turn provides more meaningful spaces to discuss ethnic roots and cultural identity. While we appreciate that government agencies need to have convenient social categories to make funding decisions and/or provide specific services, our findings suggest that when it comes to identity research and professional development, cultural/ethnic identity questions should be left as open as possible to avoid nudging participants to fall into pre-conceived and convenient social boxes. In addition, color-coded ethnic/identity categories serve to their unquestioned reproduction when they may be perceived as the norm when authoritative figures (e.g., teacher, government official, researcher, etc.) offer them as the only self-identifying choices [43].

During our class discussions and interviews, we also noticed that some students were puzzled about why they were discussing topics such as cultural identity, ethnicity, positionality, equity, and social justice in a science methods course. Carmen elaborates:

It is curious because until you asked me this question, no one had asked me, I had never thought about it, I have always considered myself a mixture of everything and very similar on what Veronica said, it would be like a Mestiza, is what I, through the education I have received over the years, is the word I find to describe myself according to that.

(Carmen, FG I, p. 3)

Interestingly, all three of these female students, based on their physical appearance, would be perceived as white in the US or in Costa Rica, but their chosen identities are Mestizas. These pre-service teachers' responses, and in particular, Carmen's response, support the importance of providing pre-service teachers with multiple opportunities across their teacher preparation program to name and explore their own identities and positionalities [2,23,29]. To this end, our research projects—including this one—seek to assist pre-service teachers meet the expectations put forward by current science education reform policies, such as those laid out by the *Education for a New Citizenry*, Ministry of Education [8], the *Next Generation Science Education Standards* [44], and the *Framework for K-12 Science Education* [7] in the United States. All these initiatives expect science teachers

to promote critical thinking to address real-world problems, cultural understanding, sustainability, equity, and global citizenship. However, we argue that to promote all of these collaborative goals, teachers must first have a well-grounded and critical understanding of their own cultural identities. Similarly, we argue that the same strong sense of identity awareness can better inform their positionalities, their teaching practice, and ultimately their relationships with students.

Table 2. Participating US students' chosen ethnic/cultural identity vs. the overall percentage distribution of teachers by US designated race/ethnic categories.

US Study—PSTs' Chosen Ethnic/Cultural Identity	Number of Participants	Percentage %	Percentage of Teachers' Race/Ethnicity across the US *	US Designated Race/Ethnic Categories *
White	17	48.56	79.3	White, non-Hispanic
Caucasian	12	34.30	-	-
American	1	2.86	-	-
Sub-Total	30	85.71	79.3	White, non-Hispanic
Asian	2	5.71	2.1	Asian, non-Hispanic
Hispanic	2	5.71	9.3	Hispanic regardless of race
African American	1	2.86	6.7	African American/Black
			0.2	Native Hawaiian/Pacific Islander, non-Hispanic
			0.5	American Indian/Alaska Native, non-Hispanic
			1.8	Two or more races, non-Hispanic

* US Department of Education, Public School Teacher Data File 2017–2018.

To facilitate this process of critical reflection and transformative action, we modelled multiple culturally and socially relevant science activities (informed by sTc). That is, PSTs carried out standards-based science activities that were inclusive and culturally relevant, centered on inquiry and problem-solving of real (socially relevant) issues. The following section provides some examples of the curriculum projects pre-service teachers produced because of their involvement in the study.

4.2. The Dialogic Conversation and Reflexivity in Action

Given that participants expressed that they had very limited exposure to university courses with a focus on cross-cultural education, and much less knowledge on the critical integration of equity, diversity, and social justice issues in science/STEAM, we took steps to engage them in multiple activities throughout the three science methods courses that did just that. For an example of a complete activity that also modeled how to integrate a culturally responsive and responsible engineering design process, see [38]. In addition, we used insights from the students' cultural identity comments/struggles discussed above to assist them in making relevant connections between the contributions of Indigenous and Afro-descendants individuals to STEAM.

To this end, PSTs participated in a field trip to an organic coffee farm that illustrated the integration of place-based knowledge for sustainable farming, as well as a presentation on various endemic plants and their uses by indigenous people. Another field trip involved a

visit to a rural Maleku school (Maleku is one of the eight indigenous groups of Costa Rica). During this visit, PSTs met with the school principal and some students, conducted field water quality tests using Vernier probes, and discussed issues affecting this community—including access to clean water. The PSTs found these field trips enlightening, and several commented that this was the first time they met Indigenous people from their country and heard them speak in their own language.

We used these first-hand experiences to encourage PSTs to reflect on their own cultural identities as future teachers who would most likely be placed in spaces where such a diversity of students will be present. It is important to point out that in Costa Rica, graduates of teacher education programs are assigned to available teaching posts around the country. This means that some postings could be in rural communities with higher numbers of Indigenous students, or in more populated areas with a higher population of Afro-descendants.

While our project is on-going, preliminary quantitative and qualitative data analysis continue to show significant growth in the PSTs' perceptions of their ability to integrate critical cross-cultural and STEAM education. The quantitative analysis will be reported elsewhere; however, additional qualitative evidence of the PST's growth is demonstrated by the culturally and socially relevant focus of their teaching units. That is, the major project for their second science methods course required PSTs to prepare a unit (or set of lessons and activities) that demonstrated what they had learned in the course and that they were expected to teach during their school placements. Table 3 provides three examples of these units, and it is important to note how PSTs moved from a canonical and socially neutral perspective of science and science teaching to a more culturally and socially relevant (sTc) emphasis. Given the limited access to resources in local schools, we made the Vernier equipment (see Vernier.com), apps, and other materials we used during our model activities in the methods courses available to PSTs who wished to use them at their school placements. As can be observed, one team of PSTs—who have a strong interest in health sciences—used insights gained from the water quality activity in the methods class and the field trip to the Maleku community to extend this activity. As a result, they developed more detailed lessons to assist Indigenous students living in rural communities better monitor and care for their own drinking water.

Even though the PSTs' cultural awareness and understanding of the critical role they can play in making their science teaching and curriculum more inclusive and connected to students' lives were evident in their lesson plans and activities, several of them explained that integrating equity, diversity, and social justice issues was very challenging because this was the first time they were exposed to this approach. This concern is the same as that often expressed by PSTs in the research literature due to their similar prior academic preparation in science as mostly canonical, Western, and decontextualized [7,40]. These are valid concerns that speak to the need for teacher education programs everywhere to integrate culturally and socially relevant practices more purposely and broadly *across courses*—and especially across core method curriculum subjects (i.e., social studies, mathematics, and language literacy). In this way, PSTs will have multiple opportunities to experience first-hand how their own cultural awareness and positionalities are the first steps to making their classrooms more inclusive and responsive to all students.

In the next analysis phase of this study, we are triangulating the self-efficacy quantitative data with the participants' short answers from surveys and focus group interviews to further investigate how the PSTs' identity and cultural awareness informed their positionalities as science teachers. In the same vein, we are also seeking to identify the experiences that facilitated and/or obstructed the PSTs' efforts to make their science/STEAM curriculum and pedagogy culturally and socially relevant.

Table 3. Examples of pre-service teachers' culturally and socially relevant (sTc) units.

Unit Title	Description
STEAM Lab: Making recyclable paper from pineapple peels	Using the sTc framework, these lessons engaged students in an engineering design activity to explore the environmental impact of the production of white paper, the importance of recycling and reuse of resources, and the role they can play in exercising environmentally sustainable citizenship. In the activity, students are challenged to produce a viable paper using pineapple peels. In addition, the social and environmental consequences of pineapple production in Costa Rica are analyzed within a culturally relevant framework. For example, pineapple photosynthesis requires a great deal of radiation, which leads to high deforestation; therefore, students are guided in a discussion to explore alternatives that include indigenous agricultural knowledge.
Exploring water quality and safety at an indigenous rural school.	For this activity, students extended a similar sTc activity modeled in the science methods course, and they also used the same Vernier probes and water quality test kits for the field-based tests. Participants became concerned about the quality of water at indigenous rural schools where reliable infrastructure for clean water is limited, requiring community members to rely on natural fresh water sources. Based on the water quality values detected, the two pre-service teachers working on this unit developed following lessons designed to help their students understand the care and consumption of drinking water at their school. As another result of these socially relevant lessons, one of the high school students who participated in the unit won in the National Science and Technology Fair for her investigation on parasite problems associated with water consumption in her community.
Building a Mariposario: Breeding of butterflies in a controlled environment (mini-butterfly enclosure) as a tool to demonstrate the ecological, cultural, and socioeconomic importance of these insects.	Using the sTc framework, this STEAM unit guided students in the exploration of the ecological and socioeconomic importance of butterflies. To this end, students are challenged to build a mini-butterfly enclosure that would resemble all the ecological niches occupied by each of the stages of a butterfly during its life cycle. The cultural role and economic importance of butterflies in Costa Rica and in other countries and cultures are also studied. In Costa Rica, many families have seen in these insects an opportunity to improve their quality of life from the economic activities that revolve around these insects. These opportunities have been mainly led by women in rural communities; therefore, students are guided in a discussion that helps them recognize the entrepreneurial and place-based knowledge of women using science in everyday life contexts.

5. Conclusions and Recommendations

While major science/STEAM education reform documents in both the US and Costa Rica call for making these subjects more inclusive and connected to students' cultures and everyday lives [7,8], an aspect taken for granted in this process is the identity and cultural awareness development of teachers. We have shown that the participating Costa Rican PSTs (just like those participating in similar studies in the US with the first author) expressed that they had very limited exposure to university courses with a focus on cross-cultural education, and even much less exposure to courses where the critical integration of equity, diversity, and social justice issues with core curriculum subjects (i.e., science/STEAM, social studies, mathematics, and language literacy) is modelled. In addition, the exploration and development of teachers' identity and cultural awareness development across their teacher education programs is not facilitated, yet teachers are expected to make their curriculum and pedagogy inclusive and relevant to students who often come from different cultural/ethnic and socioeconomic backgrounds.

Our study sought to address this gap by first facilitating dialogic conversations on the PSTs' chosen ethnic/cultural identities and by assisting them to reflect on how their chosen identities and positionalities impact their curriculum choices and pedagogy. These dialogic conversations, combined with hands-on, minds-on culturally and socially relevant science/STEAM activities modelled in the methods courses provided PSTs with practical applications.

The first analysis phase of our study reported here shows that the project had a positive impact on all participants' identity and cultural awareness development. This awareness

helped them explore how to make their curriculum and pedagogy more culturally inclusive and socially relevant. This was especially observed in their efforts to integrate various equity issues in their curriculum that they had not previously considered (e.g., SES, gender, and/or the contribution of Afro-descendants and local Indigenous Peoples to science/STEAM). Table 3 provides an illustration of the units (set of lesson plans and activities) participants developed as part of their second methods course. This table also shows how PSTs moved from seeing science as canonical and “as just science” to “to be taught,” to science/STEM as opportunities to engage their students in culturally meaningful and socially contextualized learning.

A small group of PSTs commented that they conceptually understood the importance of exploring their own positionality to become more culturally responsive teachers, but that they still struggled to put this understanding in action due to the lack of resources and limited time to carry out inquiry-based activities (institutional constraints). More details on these institutional constraints and events that facilitated participants’ abilities to make science/STEAM more culturally and socially relevant are being explored in the second analysis phase of this project. However, one common theme identified thus far is the participants’ wish to be exposed to more culturally and socially relevant science/STEAM pedagogical approaches earlier in their university education.

In short, our study indicates that if we are interested in assisting prospective teachers in becoming effective culturally inclusive teachers, teacher education programs should provide multiple opportunities for them to:

1. Critically reflect on their *chosen* identities and positionalities, as well as how their identity and cultural awareness development impact their curriculum choices and pedagogy.
2. Engage in various culturally and socially relevant science/STEAM activities that provide hands-on and minds-on examples of the same kinds of inclusive activities they can (should) do in their own classrooms. In other words, teacher educators need to model what “reform-minded” science teaching and learning looks like.
3. Develop curriculum/lessons that demonstrate their understanding of how to make science/STEAM culturally and socially relevant for all students.
4. Experience different ways of doing and understanding science from culturally diverse perspectives, such as ways of knowing from Indigenous, Afro-descendants, and other traditionally marginalized peoples. For example, student teaching placements in culturally diverse schools, and/or visits to sites where students can gain new insights (e.g., visiting an Indigenous Peoples’ school; visiting museum exhibits on Indigenous Peoples’ rich place-based knowledge of metallurgy, agriculture, conservation, engineering, and so on).

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