# 'Using my education to fight for my communities': understanding how an equity-based STEM experience cultivated equity ethic and STEM identity development among women of colour in STEM

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## How to cite

Yeldell, J., Wilkins-Yel, K., Bharaj, P.K., Cross Francis, D., Mahmud, A., Walters, R. and Bryson, T. (2024) '"Using my education to fight for my communities": understanding how an equity-based STEM experience cultivated equity ethic and STEM identity development among women of colour in STEM'. *London Review of Education*, 22 (1), 28. DOI: https://doi.org/10.14324/LRE.22.1.28.

## Peer review

This article has been peer-reviewed through the journal's standard double-anonymous peer-review process, where both the reviewers and authors are anonymised during review.

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# Abstract

The pervasive myth that science, technology, engineering and mathematics (STEM) are purely objective subjects fosters significant disconnects between Black, Latinx, Asian, Brown and Indigenous students and K–12 STEM education, as the curriculum is often detached from their lived experiences. This disconnect leaves many students of colour feeling alienated in undergraduate and graduate STEM classrooms. Traditional STEM programmes rarely incorporate culturally responsive curricula that would allow students to connect more deeply with the content and develop their STEM identities. According to Carlone and Johnson's framework of STEM identity development, students must view themselves as 'doers' of STEM. Without experiences that allow under-represented students to demonstrate competence and engage in disciplinary performance, their STEM identities are hindered. The I CAN PERSIST Initiative, a culturally responsive, evidence-based programme, aims to advance academic and career persistence among women and girls of colour in STEM. It seeks to reshape narratives about who can participate meaningfully in STEM through a curriculum designed to enhance students' STEM identity development. This programme provides Black and Brown women and girls with opportunities to become 'doers' of STEM while integrating their lived experiences. Specifically, Black and Brown undergraduates and graduates facilitate lessons with local secondary school girls of colour interested in STEM, focusing on socio-scientific issues from a critical perspective. This article details the engagement of undergraduate and graduate women of colour in the I CAN PERSIST STEM Initiative through equity-based outreach activities that support their STEM identity development.

**Keywords** STEM identity; equity ethic; higher education; STEM outreach; culturally responsive; women of colour

# Introduction

Research shows that women of colour are significantly under-represented within the spaces of science, technology, engineering and mathematics (STEM) (Miles et al., 2020; Wilkins-Yel et al., 2022). This pervasive under-representation is amplified in predominantly White upper- and middle-class male-dominated STEM milieux. These spaces have been shown to contribute to feelings of isolation and marginalisation among women of colour in STEM (McGee, 2021a; Ong et al., 2011). Such experiences not only take a significant toll on their psychological well-being (Wilkins-Yel et al., 2022); they also impact their abilities and decisions to persist in STEM (Hodari and Johnson, 2019). Hence, improving recruitment and retention among women of colour in STEM fields is a critical undertaking in academic spaces (Ong et al., 2011). To support women of colour's STEM persistence and mental well-being, a team of researchers designed a multigenerational counterspace called the I CAN PERSIST STEM Initiative (hereafter referred to as the Initiative). The Initiative is a call to counter the deficit-based narratives often experienced by women of colour in STEM and to create avenues to promote their STEM persistence.

   In designing the activities, we intentionally positioned undergraduate and graduate women of colour enrolled in this initiative – referred to as 'scholars' – as experts and engaged them in interdisciplinary teams to design and implement justice-centred, community-based STEM outreach activities with secondary school girls of colour. The focus of these activities was also tied to scholars' values and deeper motivations to pursue STEM pathways via their equity ethic (McGee and Bentley, 2017). We posited that engagement in such purposefully designed activities, which allowed for the application of their skills to equity-focused efforts (McGee, 2021a), might create opportunities that supported scholars' STEM identity development (Carlone and Johnson, 2007), which in turn has the potential to influence their STEM persistence. Thus, in this study, we sought to answer the following

question: In what ways did participation in designing and implementing equity-based STEM outreach activities support women of colour's STEM identity development?

## Programme context: the I CAN PERSIST STEM Initiative

The Initiative is an evidence-based, multigenerational mentorship community designed to advance academic and career persistence among women and girls from racially and ethnically minoritised communities who are interested in or actively pursuing STEM careers (Wilkins-Yel et al., 2022). As part of the Initiative's multigenerational focus, it supports women and girls of colour at five educational levels: secondary school, community college, undergraduate, graduate and post-degree professionals (master's and PhD). The Initiative is located in three states in the US: two predominantly White institutions in the Midwest and Southeast regions, and a minority-serving institution in the Northeast region. The Initiative aims to provide scholars with a culturally sustaining counterspace where they not only learn about the academic and real-life application of STEM-related ideas, but also receive experiential opportunities to enact those skills.

The Initiative is a response to the systemic under-representation of women of colour, a phenomenon often noticed in STEM disciplines. Experiencing pervasive isolation and marginalised experiences tends to diminish feelings of belonging, particularly among women of colour in STEM (Wilkins-Yel et al., 2022). Hence, counterspaces, such as the ones we strive to facilitate in the Initiative, are viewed as 'safe-spaces' (Ong et al., 2018: 206) where women of colour are able to exist fully and authentically, and can also reject the prevailing cultural and societal norms of STEM spaces being solely for White men (Ong et al., 2018). Such counterspaces not only support the diverse needs of women of colour, but also advance their persistence in STEM spaces. For example, during recruitment interviews with women of colour for this Initiative, they indicated an interest in engaging with other women of colour and with the community. Their collective interest was well-aligned with a pre-established, core activity within the Initiative, where scholars designed and implemented equity-based STEM outreach activities with secondary school girls of colour. This work with secondary school girls of colour was organised as an activity within a seminar-style one-credit course to develop scholars' critical lens within the context of environmental and health inequities plaguing minoritised communities.

Through this course, scholars have the opportunity to go beyond traditional STEM education – not only by teaching STEM concepts through an equity lens, but also by engaging in art-based activities. Scholars could leverage the emancipatory role of creativity and self-expression through the creation of STEM storyboards – audiovisual projects that showcased the scholars' STEM journeys and afforded opportunities to practise STEM communication through multiple media (Mejias et al., 2021). In this way, the Initiative also facilitated STEAM education. The Initiative uses a STEAM approach to outreach activities, as opposed to the more traditional STEM approach, as a means to support students' creativity and the unique funds of knowledge they bring into the seminar space. Broadening the scope of what counts as STEM participation and engagement affords participating scholars the opportunity to bring their authentic selves into the classroom without the burden of considering what is traditionally defined as STEM.

In addition to the aforementioned activities, scholars received robust wraparound support, such as: (1) mentorship opportunities from STEM professionals who identified as women from racially and/or ethnically minoritised backgrounds; (2) socio-emotional support from advanced graduate students in psychology, referred to as Well-being Consultants, and who also identify as women of colour; and (3) other near-peer social activities that fostered feelings of inclusion and belonging (for example, bowling). This article focuses on the Initiative's equity-based STEM outreach activities where scholars engaged with secondary school girls of colour.

## Conceptual framing

Our examination of scholars' STEM identity development throughout their engagement with secondary school girls of colour in STEM-based equity activities is situated within two theoretical frameworks: Carlone and Johnson's (2007) STEM identity framework and McGee and Bentley's (2017) equity ethic. Both Carlone and Johnson's (2007) and McGee and Bentley's (2017) frameworks support the exploration of the nuance within women of colour's intersectional experiences within STEM. At its core,

intersectionality provides a perspective to analyse power dynamics and the tension that occurs when power interlocks and intersects, exposing who is left at those intersections (Crenshaw, 2017). Without regard for the multiplicity of identity, women of colour are positioned at the intersection of both their gender and race/ethnicity. Due to their affinity identity (Gee, 2000) – or disciplinary interest – within STEM, these women of colour are placed at yet another intersection where they face oppression, not just as women or individuals of colour, but also being both and holding both of those identities simultaneously within a space that privileges hyper-masculine, and often middle-class, White male ways of being (Ong et al., 2018). This tripartite intersection of power, or 'triple oppression' as popularised by Black socialist Claudia Jones (McDuffie, 2011: 4, as cited in Taş, 2021), where women of colour are disadvantaged due to the intersection of their race, class and gender, can be seen throughout STEM spaces. Carlone and Johnson's (2007) STEM identity framework supports us in disentangling how women of colour develop STEM identities while in the midst of STEM spaces which can at times be hostile to women of colour's personhood, while McGee and Bentley's (2017) framework of equity ethic provides insight into why women of colour choose to persist in spite of challenges.

## STEM identity development

Identity has been used as a lens in research to address marginalised groups' persistence in STEM disciplines. In simple terms, identity denotes an individual's conceptualisation of self, that is, how one views oneself, as well as how one changes as one interacts and communicates with the environment and others within each environment (Mead, 1934). Identity is how an individual identifies themself to be in the present and what they hope to become in the near future. Studies have found that students' persistence in STEM disciplines, higher education and science professions is related to their successful and stable STEM identity development (Hill et al., 2018; Matthews et al., 2014). Identity is the holistic sense of self that individuals develop through social interactions (Hill et al., 2018). To understand STEM identity development, we draw on the science identity framework introduced by Carlone and Johnson (2007). This identity framework extends the conceptualisation of identity as an abstract psychological process to actions and skills that are observable. Recognising that STEM identity is not a fixed state of being underscores the importance of creating environments that foster positive STEM identity. Identity is not a singular, fixed or decontextualised attribute, and it is continuously being shaped by exposure to the external environment. Carlone and Johnson (2007) introduced three interrelated components of STEM identity: performance, competence and recognition. How one views oneself holistically by integrating multiple intersecting identities (gender, racial or ethnic identities) influences one's motivation to act, current actions and even future trajectory. When it comes to STEM students, the process of identity development is particularly important, because their persistence in STEM, both academically and professionally, is often influenced by how stable their STEM identity is or what type of identity they develop as they evolve in STEM spaces.

According to Carlone and Johnson's (2007) identity framework, motivation and the knowledge needed to engage in STEM practice would be considered competence in STEM. Competence captures the extent to which an individual feels they have the necessary skills required to undertake the responsibility of a designated position. The ability to demonstrate proficiency in STEM practice is the performance component. In other words, one may be able to perform relevant STEM activities by understanding the norms of the specific discipline and undertaking the assigned roles and responsibilities. Recognition involves the positive recognition as a STEM person by outsiders (family, peers) and insiders (teachers, scientists, professors, mentors) to STEM (Avraamidou, 2020). This may include the recognition of students' potential as STEM persons (Hazari et al., 2010), or the recognition of their STEM skills and proficiency by people around them (Carlone and Johnson, 2007). However, depending on whether individuals are engaging in a routine social interaction, or working at a laboratory, how people recognise them as a STEM person would be different. Recognition by self is related to how individuals perceive STEM disciplines, and whether that aligns with their values and preferences (Carlone and Johnson, 2007). Among these three components of STEM identity, recognition has the most direct relation to marginalised identities in terms of gender, race and ethnicity (Carlone and Johnson, 2007). Thus, students with multiple marginalised identities face unique challenges in developing their STEM identity (Avraamidou, 2020; Salehjee and Watts, 2022). Often such students are recognised by STEM insiders based on their outward-facing, marginalised identities (for example, Latinx female), and not by their scholarly identities as STEM people, which can disrupt the development of strong STEM identities.

Disrupted STEM identities occur when an individual's bid for recognition is interfered with by ethnic, racial and gendered interactions. It is important to note, however, that individuals can still find success within STEM if they hold a disrupted STEM identity. But such an identity can make their STEM pathway more challenging.

Increased participation in STEM practices has been found to increase marginalised students' sense of belonging in STEM and to increase their self-recognition as part of the STEM community of practice, thus strengthening their STEM identity (Carlone and Johnson, 2007; Rainey et al., 2018). Carlone and Johnson (2007) found altruistic tendencies to be another strong factor related to the strong identity development of STEM individuals from marginalised groups. Individuals with strong STEM-centred altruistic tendencies may develop alternative meanings of science around their STEM experience. Additionally, they might seek recognition from others in non-traditional STEM spaces, such as their communities, which are meaningful to them. In other words, they see themselves as a STEM person when they engage in altruistic pursuits. These altruistic tendencies of people of colour align with McGee and Bentley's (2017: 6) concept of *equity ethic*, defined as the 'principled concern for social justice and for the well-being of people who are suffering from various inequities'.

## Equity ethic

An equity ethic as defined by McGee and Bentley (2017) is a set of moral values held by individuals of colour (Black, Latinx and Indigenous), including a principled concern for justice – specifically, racial justice – that addresses both racial and systemic inequities, and serves to address the individual's suffering due to such inequities. For persons participating in STEM, enacting their equity ethic would manifest as using their STEM-specific skills positions to address systemic inequity. Research has found that equity ethic motivates STEM persistence among under-represented and marginalised students in STEM (Espinosa, 2011; Felton et al., 2008, as cited in McGee and Bentley, 2017).

There are two focal components of this framework – a principled concern for social justice and collectivism/altruism – and the disconnect that those values have within STEM disciplines (McGee and Bentley, 2017). This principled concern for social justice appears as a deep commitment to pursuing equity in eliminating systemic injustices faced by communities of colour. As individuals with an equity ethic have a deeper sense of purpose or motivation guiding their STEM pursuits (McGee, 2021a), they tend to perform duties external to their assigned research load or educational pathway, leading to a 'service burden'. Such burdens are often not experienced by their counterparts who do not identify as people of colour (McGee, 2021b). For instance, when learning about a topic such as water quality and its subsequent impacts on various population groups, a student with a principled concern for social justice might go beyond learning this concept for their course and delve deeper into the topic to investigate how this impacts marginalised communities. Such explorations might be motivated by the fact that they themselves come from those communities.

Black and Latinx cultures are historically rooted in collectivist ideals, which place a higher emphasis on the goals and needs of the group, as opposed to those of the individual (McGee and Bentley, 2017). Research has shown that Black college students approach work as a means of expressing connectedness with, and showing care for, the larger Black community (Beasley, 2011, as cited in McGee and Bentley, 2017), and Latinx students tend to be more interdependent and make sacrifices based on group benefit (Stone et al., 2006). This sense of collectivism felt by Black and Latinx students has meaningful implications for how they undertake STEM endeavours – and for what reasons.

More than caring about members only within their own group, research highlights that marginalised students care about achieving equity overall (Thoman et al., 2014, as cited in McGee and Bentley, 2017). This sense of altruism, or selfless concern for the well-being of others, also shows up in students' equity ethic and how they approach STEM. McGee (2021a) found that marginalised student participants held a sense of responsibility to help humanity, including those of backgrounds other than their own, through making societal contributions that improve quality of life. This 'ethic of care' has roots within the shared suffering of many marginalised communities – as shared misery and societal exclusion can result in those communities developing helping behaviours towards others (McGee, 2021a).

Current discourse surrounding STEM, in both academic and professional spaces, highlights the 'leaky' STEM pipeline, which refers to high attrition rates of students who initially plan to go into STEM fields, but who pursue alternative paths for a variety of reasons (Van den Hurk et al., 2019). It is important to note that high attrition rates within STEM, especially among those who identify as women

and marginalised students, are highly misleading, as STEM pathways function more as a filter sifting out those who are not deemed 'qualified' to enter the field (Clark Blickenstaff, 2005). Regardless, the narrative has shifted from examining what is wrong with the STEM pipeline because of the low number of individuals persisting within STEM career pathways (ITEA/ITEEA, 2009, as cited in Brown et al., 2011) to economic and educational competitiveness – both relatively individualistic goals (Brophy et al., 2008; Congressional Research Service, 2006; Ehrlich, 2007; National Science Board, 2007; all as cited in Brown et al., 2011). This prevailing narrative surrounding STEM and its general disconnect for the improvement of marginalised communities is a point of contention for under-represented and marginalised students with interests in both STEM and social justice (Campbell et al., 2014). In the face of value conflicts between STEM interest for societal betterment versus economic gain, combined with the somewhat chilly climate for marginalised individuals – particularly women – marginalised students with an interest in pursuing STEM pathways have to display extreme persistence in the face of adversity. Given the salience of engaging in STEM activities that align with marginalised students' equity ethic, the current study sought to understand how participation in equity-based STEM outreach activities influenced women of colour's STEM identity development.

# Methods

In the following sections, we describe the study participants, the positionality of the researchers, the qualitative study design, the data collection procedure, and the data analysis process.

## Research team positionality

The authors of this study hold multiple unique identities. We all identify as women from marginalised racial, ethnic and religious backgrounds from South Asian, African American and Caribbean descent. We are also at various stages in our academic and professional journeys (for example, doctoral students, postdoctoral researchers and tenured faculty). The lead author identifies as a Black woman committed to creating science curricula steeped in a social justice ethos that validates the narratives of Black and Brown communities. Together, we are committed to creating empowering and inclusive spaces that advance women of colour's STEM identity, belonging and persistence. Four of the seven co-authors were also instructors of the Equity Seminar in the Initiative. To reduce bias, the data used in this study were analysed after the seminar ended, and they were de-identified by team members who had no prior established relationship with scholars.

## Participants

The current study consisted of 12 scholars who consented to participate in the research. These participants ranged in age from 19 to 30 years and self-identified as Asian/Asian American ($n = 4$), Black/African American ($n = 5$), Hispanic/Latinx/Latina ($n = 1$), and bi/multiracial ($n = 2$). Participants all identified as women and included both graduate ($n = 4$) and undergraduate ($n = 8$) women of colour in a range of STEM academic majors (see Table 1). Pseudonyms were assigned to maintain participants' anonymity.

## Equity-based STEM outreach activities

Scholars in the Initiative engaged in a one-credit STEM Equity Seminar each semester. Activities encompassed in this seminar are designed to support scholars' STEM identity development, as well as to deepen their understanding of how STEM can be used to advance equitable solutions to sociocultural issues plaguing minoritised communities (Wilkins-Yel et al., 2022). One of the activities involved bi-monthly secondary school visits during the spring semester of their enrolment. Scholars designed and implemented two justice-centred, community-based STEM outreach activities throughout their year-long participation in the programme (see Figure 1). Designing and implementing such a unit with high-school girls of colour positioned scholars as STEM experts, requiring them to communicate their STEM knowledge pertaining to issues related to water pollution and food deserts within minoritised communities.

**Table 1. Participant demographic information**

| Participant pseudonym | Academic standing | Year in programme | Age | Race/ethnicity | STEM major |
|---|---|---|---|---|---|
| Tisha | Graduate | 3rd | 27 | Native American/Alaska Native, Black/African American | Marine Science |
| Maya | Graduate | 3rd | 30 | Asian/Asian American, Black/African American, Bi/multiracial | Geology |
| Alexis | Graduate | 1st | 28 | Asian/Asian American | Marine Science |
| Anna | Undergraduate | 1st | 19 | Black/African American | Public Health |
| Simone | Undergraduate | 2nd | 20 | Black/African American | Chemistry |
| Alyssa | Graduate | 1st | 24 | Black/African American | Master's in Physiology |
| Monica | Undergraduate | 3rd | 23 | Hispanic/Latinx/Latina | Biology |
| Danielle | Undergraduate | 3rd | 21 | Black/African American | Biology |
| Kelly | Undergraduate | 3rd | 21 | Asian/Asian American | Biology |
| Isabelle | Undergraduate | 2nd | 20 | Asian/Asian American | Neuroscience |
| Courtney | Undergraduate | 1st | 20 | Black/African American | Biology |
| Shelly | Undergraduate | 2nd | 20 | Asian/Asian American | Undecided, leaning towards Information Science |

## Data collection

As part of the Equity Seminar, we collected scholars' written End of Year (EOY) Reflections as a reflexive activity to capture their experiences in the Initiative. While scholars completed two reflections during their year-long participation, here we focus on the reflections completed at the end of this year-long participation in the Initiative, because these reflections captured the scholars' thoughts after they had led equity-based STEM outreach activities with secondary school girls of colour.

## Analysis protocol

We used a qualitative approach to analyse the data. Line-by-line analysis was conducted on EOY Reflections to create codes that foregrounded scholars' experiences (Strauss and Corbin, 1998). An initial codebook was created using two randomly selected EOY Reflections, followed by the coding of two more reflections using the first round of codes. As a coding team, we discussed and edited this codebook to capture nuances as expressed in scholars' EOY Reflections. Once our team had developed a common

understanding of the meaning of codes, we used this revised codebook for independent coding of remaining EOY Reflections. Afterwards, we met as a team, and used Braun and Clarke's (2006, 2019) process of thematic analysis to compile these codes into emerging themes. The discussions among our coding team helped to ensure that the codes and themes were grounded in the data, which increased the confirmability and trustworthiness of the findings. Four themes that emerged from scholars' EOY Reflection data are discussed below.

**Figure 1. STEM-based equity outreach activities the Initiative employs in engaging scholars in STEM equity topics**



# Findings

## Increased STEM recognition

Findings indicated that leading equity-focused STEM outreach activities with secondary school girls of colour led to scholars' increased recognition. One of the scholars, Monica, shared:

> This experience has positively impacted my ability to see myself as a 'STEM person' by increasing my confidence in my skills and my knowledge in STEM.

Monica's experience revealed that positioning scholars as experts in STEM not only reinforced their disciplinary STEM knowledge, but also encouraged them to view themselves as STEM professionals. This opportunity also created a space that contributed to a rising feeling of confidence among the scholars, which led to an increased sense of recognition surrounding their accomplishments.

Another scholar, Anna, who switched her major from biology to public health, underscored how engagement in the Initiative broadened her understanding of what it meant to be a 'STEM person'. She revealed that engagement in this STEM outreach programme helped her realise that there are multiple entry points and opportunities for engagement in STEM fields. She stated:

> It's been difficult to fully call myself a 'STEM person' … I felt like it didn't apply to me because I wasn't taking a chemistry or biology class … or anything else that we typically attribute to being a 'STEM person'.

When concluding her EOY Reflection, she shared that by teaching secondary school girls of colour equity outreach STEM activities, she now 'clearly' sees herself as having a future within STEM broadly. Similar to Anna, Kelly pointed out that she had also struggled with identifying herself as a STEM person. She followed this sentiment by voicing that the opportunity to serve as a mentor to secondary school girls of colour was a large contributing factor to her emergent recognition of herself as a STEM person, stating, 'although I do have a long way to go before I can fully consider myself as part of the STEM field, I can declare that I have at least entered the field in some way'. Both Anna and Kelly displayed what Carlone and Johnson (2007) label as a 'disrupted' STEM identity. Having a disrupted STEM identity negatively impacts how an individual views themself as a 'STEM person', which in turn confounds their relationship with STEM disciplines (Carlone and Johnson, 2007).

Engaging in equity-based outreach activities made both scholars rethink their sense of belonging in STEM and served to increase their recognition of themselves as STEM persons. Thus, their experiences foregrounded how being involved in efforts related to justice and equity within community-engaged spaces both rekindled their connection to STEM and served to mend their disrupted STEM identities. In summary, these reflections suggest that providing opportunities for individuals to authentically engage with STEM not only offers them hands-on experience, but also contributes substantially to their STEM identity development.

## Display of disciplinary confidence (performance)

A common experience shared by Initiative scholars in their EOY Reflections was increased understanding surrounding STEM and its connections to equity-based socio-scientific issues. Monica stated:

> This experience has influenced my development as a future STEM professional by increasing my confidence presenting and being in a mentor role … being able to teach has allowed me to strengthen my communication and mentoring skills as I engage with students.

This scholar's experience reveals how such efforts are mutually beneficial – not only for secondary school girls of colour, who are recipients of mentorship and increased STEM learning opportunities, but also for scholars who are able to deepen their knowledge and communication of STEM through their positioning as teachers and/or mentors.

In addition to improving their understanding of STEM content, scholars shared how this experience improved their ability to apply STEM content to solving real-life social justice and equity issues. Regarding the integration of social justice and equity into STEM, Simone shared:

> As the year went by, I was constantly put in situations where I would eventually have to learn how to apply them [concepts being taught in the equity outreach activities] to real-life situations such as food deserts, and environmental justice, and presenting these ideas to secondary school students.

Simone's experience foregrounds how the practical experience of engaging secondary school girls of colour is instrumental in translating knowledge into action and promoting positive change within STEM. Gaining such experiences is beneficial for nurturing one's positive STEM identity.

Danielle's EOY Reflection indicates another important aspect of the 'performance' component of STEM identity development. She mentions the work she and her classmates dedicated to planning experiments for the secondary school girls participating in the Initiative, stating:

> When Shelly [another scholar in the Initiative] and I were thinking about safety protocols and certain items we would need, we both felt confident in our proposals, and I think this was us stepping into the role of being a STEM person.

Through carefully planning experiments, scholars positioned themselves as experts, and they became deeply acquainted with the use of various STEM tools and language relevant to their experiment.

Danielle, like other scholars, explained the connections they formed between experiments carried out through the equity-based outreach activity and their real-life implications. It is important that both the scholars and the secondary school girls alike were able to recognise the real-life connections between the equity-based STEM and socio-scientific issues to solve equity-based, STEM-rooted societal issues.

## Deepened understanding of inequities

Scholars' EOY Reflections indicated increased understanding of societal inequities through learning about and the execution of equity-based STEM activities with the Initiative's secondary school girls. The Initiative's framing of teaching socio-scientific issues through an equity lens was important, as Isabelle underscored, 'low income and people of colour are disproportionately affected by environmental injustice'. Tisha stated, 'I feel that most stories we learned in the [traditional STEM] courses mainly highlighted white neighbourhoods.' This is unsurprising, as the traditional STEM curriculum fails to acknowledge the intersections of STEM and social justice, and issues that impact communities of colour. Alexis found a similar experience throughout her education, sharing:

> The [Initiative] journey enhanced my understanding of social justice and equity, the learning in college and school is beyond textbooks. If we are not advocating for issues that speak for us, we are not profiting from every penny spent on our education.

Both scholars' thoughts regarding traditional STEM education, and the lack of attention toward issues that impact marginalised communities, foregrounded the importance of curricular content that connects STEM and social justice.

Simone revealed at the start of the Equity Seminar that she was unaware of how STEM was connected to equity and social justice. With sustained participation in the Initiative, she shared:

> Throughout each step of this, my vocabulary grew … Not only had I become more aware of how the government was integrated into inequality into racial and class lines but I had learned how these barriers … had related to my own story.

Simone was not alone in her initial lack of awareness surrounding STEM and social justice. Monica stated, 'The concepts of social justice and equity were not new to me; however, I learned more about all the different aspects and ways that social injustice is impacting communities.' She credits activities within the equity-based STEM outreach for helping her understand how STEM can be used to solve socio-scientific issues.

## Commitment to social change

As a result of participation in equity outreach activities with secondary school girls of colour, scholars began to build a strong commitment to social change. These commitments varied from large-scale systemic improvement to more localised mentoring efforts. One scholar, Anna, highlighted the impact of first learning about 'equity ethic', and then teaching secondary school girls of colour about the concept, and how they can enact it. Anna shared, 'It was such a powerful feeling to put a name to the motivation growing inside of me to use my education to fight for my communities.' Anna felt this connection as a stepping stone to immersing herself in her community and educating them on public health issues as they connected to STEM work. Anna expressed through learning about equity ethic that there is a responsibility or duty to be able to aid communities and to mentor other students.

Courtney also vocalised a connection to social change through participation in both the equity seminar and equity-based outreach activities. Discourse surrounding environmental factors within the local community and around the country sparked connections for scholars on how close to home the problem was. Courtney reflected on how this realisation thrust her into wanting to be a part of the solution and change, sharing:

> The environmental injustices we discussed in the fall semester and the podcast we made, such as water resources and how most treatment facilities for water are placed in these marginalised areas, made me think more on how I can change these problems now so that the future populations will not have to go through the same thing.

Like Courtney, Tisha reflected on the impact of the equity seminar and equity-based outreach activities on her commitment to social change, stating:

> It makes me want to strive even more for science communication to the public and to make sure that the generation can find ways to beat the system and learn to get around the roadblocks in order to break them down.

Scholars' EOY Reflections signified their appreciation for equity-based course content and outreach activities that allowed them to connect their education to the betterment of society. This form of STEM education is especially important for scholars with disrupted STEM identities. Shelly underscores this, as she shared:

> I felt like the [secondary school students] were really engaged by the content and enjoyed the lessons we created. It felt extremely fulfilling knowing that we were creating something that meant something to them because I've been struggling to find something in STEM that leaves me feeling fulfilled. I want to have a career where it feels like I'm actually impacting other people's lives positively rather than being a cog in a capitalist machine.

Approaching STEM education in this manner provided relevance and meaning that helped scholars find belonging within disciplines that can be quite inhospitable to marginalised groups.

## Discussion and conclusions

The Initiative is a holistic and inclusive programme intended not only to broaden participation in STEM, but also to actively engage women of colour in STEM activities that develop their STEM identities and increase their persistence in STEM fields. Through qualitative analysis of the undergraduate women of colour's EOY Reflections, we were able to show the influence of engagement within authentic, equity-based STEM outreach activities on participating scholars' identity development. In this section, we discuss our findings, contextualising them within the broader discourse surrounding STEM education and equity initiatives for women of colour in STEM.

### Empowerment through increased STEM recognition

Reflections shared by scholars such as Monica, Anna and Kelly foreground the transformative impact of engaging in equity-based STEM outreach activities on scholars' perception of themselves as STEM professionals. Through intentional positioning of scholars as mentors and experts within STEM, the Initiative not only strengthened their disciplinary knowledge, but also supported a sense of belonging and recognition within a STEM community. Carlone and Johnson (2007) describe the significance of recognition within STEM (both by the individual themselves and by meaningful others) in the development of a strong STEM identity. For example, Monica's experience, in particular, highlights how participation in equity-based activities can serve as a catalyst in increasing scholars' confidence within STEM practices and knowledge, hence contributing to the repairing of disrupted STEM identities.

### Enhanced disciplinary competence and performance

The reflections shared by scholars show a significant enhancement in their understanding of STEM content and its application to real-life socio-scientific issues through engagement in equity-based outreach activities. Scholars such as Monica, Simone and Danielle displayed enhanced ability to communicate STEM concepts effectively, and to apply them to address societal challenges, showing increased disciplinary competence. This foregrounds the mutually beneficial nature of facilitating equity-focused STEM outreach activities, in that scholars deepened their own knowledge and skills, while also empowering secondary school girls of colour through mentorship and increased participation in STEM learning opportunities. Traditional STEM spaces tend to have a narrow conception of what performing STEM looks like, and they tend to restrict who can legitimately participate (Wilkins-Yel et al., 2019). The Initiative disrupts these norms by expanding performance and competence to include teaching and engaging others in disciplinary discourse within STEM and STEM practices as a whole. This expansion of norms surrounding participation in STEM connects to scholars' equity ethic (that is, a set

of moral values, including a principled concern for justice – specifically, racial justice), motivating STEM persistence and formation of strong STEM identity development.

### Deepened understanding of societal inequities and commitment to social change

By framing STEM education through a hands-on, equity-based lens and integrating social justice themes into outreach activities, scholars gained insight into power dynamics and structural barriers that disproportionately impact marginalised communities. These experiences not only enhanced scholars' understanding of STEM, but also helped to develop their critical consciousness, making them feel empowered and motivated to seek out opportunities to meaningfully contribute to the development of a better society through STEM. These results align with existing literature (Riney and Ku, 2021) that advocates participation in inquiry-oriented, equity-based STEM activities for all students, in particular students of colour, because of the academic, psychological and socio-emotional benefits. Combining hands-on engagement with equity-based STEM outreach activities provided scholars with the opportunity to develop deep understandings of the societal implications of their work in STEM. This holistic approach could potentially serve to create a more socially conscious and responsible STEM workforce.

Providing scholars with equity-based STEM outreach activities that aligned with their equity ethic played a salient role in the development of their STEM identity. By introducing scholars to principles of social justice and providing crucial opportunities to put these principles into action, the Initiative not only nurtured emergent STEM professionals, but also instilled within them a sense of responsibility to address equity issues within STEM. Although the task of addressing equity in STEM is not the responsibility of marginalised individuals alone, strengthening the ways in which STEM can be used to combat these inequities is key to aligning STEM with the altruistic values of students of colour, and, in turn, with their intentions to persist in STEM. For instance, one dimension of deepening scholars' understanding of societal inequities necessitates the importance of integrating equity-focused content and activities into STEM programmes to foster a sense of belonging among marginalised groups in STEM. The Initiative's approach to promoting diversity in STEM goes beyond surface-level representation. It actively encourages scholars both to form and to further develop their equity ethic. Additionally, the Initiative provided scholars with experiences such as the equity-based STEM outreach activities where they could enact their equity ethic towards positive societal change. This connection between scholars' equity ethic and STEM content was shown to foster heightened enjoyment of STEM content, deeper connections to STEM, and an overall heightened sense of belonging within STEM overall.

In conclusion, the findings of this study highlight the profound impact of equity-focused STEM outreach activities on scholars' recognition within the STEM community, development of disciplinary competence and performance, understanding of societal inequities including their own intersectional positioning as women of colour in STEM, and commitment to social change. Moving forward, it is imperative for educators, policymakers and stakeholders to prioritise the integration of equity and justice principles into STEM education initiatives, thereby fostering a more inclusive, equitable and socially responsible STEM workforce capable of addressing the complex challenges facing our global society.

# Declarations and conflicts of interest

## Research ethics statement

The authors declare that research ethics approval for this article was provided by the University of North Carolina at Chapel Hill's ethics board.

## Consent for publication statement

The authors declare that research participants' informed consent to publication of findings – including photos, videos and any personal or identifiable information – was secured prior to publication.

## Conflicts of interest statement

The authors declare no conflicts of interest with this work.  All efforts to sufficiently anonymise the authors during peer review of this article have been made.  The authors declare no further conflicts with this article.

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