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Centering marginalized voices in STEM education: undergraduate mentors' perspectives on equity in a summer enrichment program for persistently marginalized youth

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Abstract

Purpose – This study investigates the perspectives of marginalized undergraduate mentors in a summer STEM enrichment program, focusing on how they perceive equity and inclusion within the program's curriculum and instructional practices. The research aims to amplify the voices of these mentors, who bring unique insights as individuals who have themselves been marginalized in STEM education.

Design/methodology/approach – We conducted semi-structured interviews and focus groups with 15 undergraduate STEM mentors from marginalized backgrounds. The mentors were paired with predominantly African American students in an urban US public school district. Data were analyzed using qualitative thematic analysis to explore the mentors' perceptions of the program's curriculum, instructional practices and socio-emotional learning components.

Findings – The study reveals two key themes: (1) the importance of balancing high expectations and socio-emotional development in STEM curriculum; and (2) the role of culturally affirming practices in countering cultural incongruences between teachers and students.

Originality/value – This research highlights the critical role of marginalized undergraduate mentors in shaping STEM programs for historically underrepresented youth. Their perspectives offer valuable insights into how curriculum and instructional practices can be improved to foster greater inclusivity, equity and engagement in STEM education.

Keywords STEM education, Undergraduates, Mentorship, Equity, Inclusion, Culturally relevant teaching, Socio-emotional learning

Paper type Research paper

STEM curriculum and instructional practices have pervasively excluded marginalized student groups in the USA, including Black, Hispanic and Latinx students, LGBTQIA+ students, students with dis/abilities and non-English speaking students (Martin & Fisher-Ari, 2021). This systemic exclusion contributes to persistent disparities in STEM opportunities and representation. As a result, these marginalized groups are often underrepresented in STEM careers, which exacerbates societal inequalities. These disparities are not only a matter of access but reflect deeper systemic barriers that deny marginalized students the opportunity to meaningfully engage with STEM content in ways that affirm their identities and lived experiences.

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University-school partnerships have shown promise in addressing opportunity gaps and inequities for marginalized student groups through informal programming with mentors in STEM fields (Palid *et al.*, 2023). These partnerships create a bridge between formal educational environments and community-based learning experiences, offering additional pathways to engage students who may feel alienated or excluded from traditional STEM instruction (Hunter, 2024). Informal STEM programs, often held in the summer or after-school contexts provide unique opportunities for mentorship, hands-on learning and the development of critical problem-solving skills (Bell *et al.*, 2016). Through these programs, students gain exposure to STEM content in a setting designed to foster inclusivity, cultural relevance and collaboration. These partnerships allow students to interact with mentors, such as undergraduates from similarly marginalized backgrounds, who can serve as role models and help dismantle barriers to STEM engagement (Denson *et al.*, 2015).

We argue that undergraduate mentors who have been marginalized by STEM and educational systems are not just important participants in school-university partnerships but are essential to them. These mentors bring lived experiences that allow them to better understand the unique challenges faced by marginalized youth and they can advocate for instructional practices that prioritize equity (e.g. Borum & Walker, 2012; Charleston *et al.*, 2014; Leyva *et al.*, 2022). By centering the voices and insights of marginalized undergraduate mentors, university-school partnerships can more effectively design programs that address the systemic inequities present in STEM education. These undergraduates, having navigated their own paths through often exclusionary STEM environments, are uniquely positioned to support students in ways that traditional educators may not be able to, making them agents of change in efforts to foster more inclusive and equitable learning environments.

This study positions undergraduate mentors who identify themselves as being marginalized in STEM as both mentors to youth and key partners with educational researchers in exploring how to center equity within a summer STEM enrichment program serving predominately African American youth. The question guiding this research is: How do undergraduate mentors from marginalized groups in STEM perceive the equity and inclusiveness of curriculum and instructional practices within a summer STEM enrichment program? By involving these undergraduates as mentors, the study not only utilizes their unique perspectives to enrich the mentoring experience but also centers their voices, insights and guidance as central to the research process as they served as collaborators in data collection and analysis.

Literature review

The purpose of this literature review is to present an argument for expanding opportunities for marginalized undergraduate students to serve as mentors for predominantly marginalized youth and to have spaces to share how equity and inclusion is centered (or not) in STEM curriculum, instruction and programming. This review will explore existing research on the impact of undergraduate mentors in STEM education, identify gaps in current feedback mechanisms and propose strategies for amplifying the voices of marginalized mentors in shaping STEM learning environments.

The role of undergraduate mentorship in promoting equity and inclusion in STEM

STEM learning environments often fail to provide a welcoming and relevant space for students of color and those with marginalized identities (Bullock, 2017; Curry & Shillingford, 2015; McCoy *et al.*, 2017). These experiences of exclusion and marginalization in K-12 STEM education hinder the pursuit of higher-level STEM opportunities for Black and Brown students (Scott & Martin, 2014). This exclusion stems from a lack of representation and cultural incongruence, as most STEM educators are White and learning opportunities are often misaligned with the experiences of marginalized students (Basile & Lopez, 2015; King &

Pringle, 2019; Keratithamkul *et al.*, 2020). Consequently, students with marginalized identities often feel like outsiders among their White peers, isolated as the sole representative minority and compelled to prove their intellect and value in the field (McClain, 2014).

Some promising evidence comes from STEM enrichment programs, especially those emphasizing mentorship, safe spaces and cultural wealth (Worsley & Roby, 2021); these programs have shown potential for boosting engagement, content expertise and self-identification as a STEM professional among marginalized youth (Taylor *et al.*, 2024). When STEM curricula and programming center the assets of students and their communities, they can foster positive STEM identities as early as elementary school (Rawhiya Jacob *et al.*, 2022). Students who have opportunities to be matched with mentors with whom they relate, such as those from similar socio-cultural backgrounds, may feel a deeper sense of belonging in STEM (Klein & Bell, 2023; Slaughter-Defoe *et al.*, 2006; Hazari *et al.*, 2013; Syed *et al.*, 2012). While the logistics of matching underrepresented STEM mentors to students are challenging, particularly due to the difficulty of finding mentors from non-dominant backgrounds who have the time and capacity to work with youth, these connections remain crucial for fostering equitable access in STEM (Milkman *et al.*, 2015).

Programs like "I AM STEM," led by King and Pringle (2019), serve as a practical example of how an informal mentoring and enrichment program can influence positive STEM identities for Black females. In the case of "I AM STEM," the program promoted STEM to establish a sense of community among mentors and Black female students in grades 4th-8th. This initiative provided a safe environment for the girls to openly discuss the negative narratives they encountered in their formal science classrooms, validate each other's experiences and build relationships with mentors through immersive STEM activities and environmentally focused field trips (King & Pringle, 2019). The study suggests that mentoring relationships in informal settings can instill confidence in students of color, enabling them to express their authentic selves when engaging with STEM. This, in turn, makes it easier for them to envision themselves as future STEM professionals.

It is also essential to recognize the impact that mentoring youth can have on the mentors themselves. Research by Wilkins-Yel *et al.* (2022) highlights how mentoring can provide a valuable counterspace (Solorzano *et al.*, 2000), a safe, supportive and healing environment, where marginalized undergraduate mentors can explore and affirm their own identities within STEM. This counterspace allows mentors to navigate the challenges they may face in these fields while using their skills and knowledge to serve others. By mentoring, these undergraduates contribute to the development of the next generation of STEM leaders, while simultaneously strengthening their own sense of belonging and purpose in STEM (Wilkins-Yel *et al.*, 2022). This dual benefit underscores the importance of creating more opportunities for marginalized undergraduate mentors to engage meaningfully in STEM education, both as learners and as contributors to the advancement of others.

Importance of undergraduate mentors' perspectives on equity and inclusion

Historically, STEM education has been shaped by the needs and perspectives of white males, which continues to marginalize students from diverse racial and ethnic backgrounds (Tandrayen-Ragoobur & Gokulsing, 2022). This exclusionary legacy is perpetuated in curricula and materials that prioritize Eurocentric representations, often alienating students who value collectivism and community-focused contributions (Martin & Fisher-Ari, 2021; McGee *et al.*, 2019). In addition to curriculum content, marginalized students in STEM, both at the K-12 and undergraduate levels, frequently encounter bias and discrimination from teachers and peers, which negatively affects their learning experiences (McGee *et al.*, 2019). For example, Black queer students spoke to the neutrality and silence of non-dominant identities and humanity in STEM spaces as well as their feelings of isolation among their peers (Leyva *et al.*, 2022). These students provide implications emphasizing relationships, human narratives and support networks in STEM higher educational spaces (Leyva *et al.*, 2022). These

experiences of racial bias and microaggressions can create unwelcoming environments that hinder student success.

To move toward more equitable STEM education, it is important to center the voices of marginalized communities in the design and implementation of STEM curricula and instructional practices, particularly in enrichment programs. The National Academies of Science, Engineering and Medicine (NASEM, 2024) has recommended that STEM curricula be built on community resources and collaboratively developed by diverse teams, ensuring that underrepresented voices are included in decision-making processes. Undergraduate mentors, especially those from marginalized backgrounds, are uniquely positioned to provide valuable insights due to their experiences navigating similar systemic barriers as the younger students they mentor (Trujillo *et al.*, 2015). Their lived experiences and proximity to students allow them to serve as critical advocates for inclusive STEM practices.

While this broader call for inclusion is well established, less attention has been given to how marginalized undergraduate mentors perceive and critique K–12 STEM learning environments. We argue that these mentors, drawing from their lived experiences, are especially well equipped to identify exclusionary practices and recommend changes that make curriculum more inclusive and reflective of diverse worldviews. Their feedback is essential for shaping culturally responsive programming that authentically meets the needs of underrepresented students. Engaging undergraduate mentors in the design and evaluation of STEM enrichment efforts not only helps dismantle barriers but also promotes a sense of belonging among younger learners. Additionally, their involvement can guide teachers in adopting more culturally relevant instructional practices, which research shows enhances both engagement and comprehension in STEM subjects (Ladson-Billings, 2014).

Theoretical lens

In this study, we draw on counterstorytelling as developed in Critical Race Theory (CRT) to analyze how undergraduate mentors with marginalized identities in STEM shared their lived experiences and perceptions of equity within a summer STEM enrichment program. Counterstorytelling, a methodological approach within CRT, is "a method of telling the stories of those people whose experiences are not often told" (Solórzano & Yosso, 2002, p. 32). Originating in legal scholarship, counterstories serve to challenge dominant narratives that obscure the realities of racism by foregrounding experiential knowledge (Bell, 1980; Crenshaw, 1989; Delgado & Stefancic, 2017). Counterstorytelling also honors the oral traditions of Indigenous and African American communities and has been used in educational research to center non-dominant perspectives and challenge systems of oppression rooted in whiteness (Solórzano & Yosso, 2002; Martin & Garza, 2020; Miller *et al.*, 2020). In STEM education, counterstories offer a powerful lens for elevating the voices of students and mentors who are too often left out of conversations around curriculum, pedagogy and equity (King & Pringle, 2019; Wright & Riley, 2021).

While the undergraduate mentors in our study did not explicitly identify themselves as "counterstorytellers," we analyze their narratives as counterstories because they disrupt dominant assumptions about who belongs in STEM and how STEM education is experienced by students from historically marginalized communities. These undergraduate mentors shared rich reflections about exclusion, representation and opportunity in STEM spaces. Although they may not have used the formal vocabulary of CRT, their testimonies revealed experiential knowledge of systemic bias, aligning with the goals of counterstorytelling to uncover and challenge racialized structures in education (Yosso, 2002; O'Hara, 2022).

This study addresses a notable gap in the literature. While much research examines marginalized undergraduates' experiences within university settings (Leyva *et al.*, 2022; Morton & Nkrumah, 2021), less is known about how these students perceive and critique K–12 STEM education. Their proximity to youth and shared experiences navigating STEM as marginalized learners allow them to identify exclusionary practices and envision more

inclusive curricula. Their perspectives offer programmatic and policy-level recommendations rooted in lived experience, helping to co-construct more culturally responsive, student-centered learning environments. Engaging undergraduate mentors in this way supports the development of equitable instructional practices and fosters collective action among educational stakeholders (King & Pringle, 2019; Wright & Riley, 2021). Ultimately, these counterstories illuminate how rigorous, humanizing and community-rooted STEM programming can be co-created with those most affected by educational inequities.

Positionality of authors

Educational systems have historically been constructed to reinforce the dominance and privilege of White individuals. In this project, we explicitly confront the power differentials that exist between those who design and those who participate in equity-oriented educational initiatives by interrogating our own positionalities and relationships to the work.

Author 1, a white female science education faculty member, served as the principal investigator on a federal grant focused on how minoritized undergraduates in STEM could support K–12 students and teachers through culturally responsive, community-engaged STEM learning. At the request of district leaders, she developed a plan to prepare undergraduate STEM mentors to assist teachers and students during a two-week STEM summer enrichment program. To co-construct this experience, she invited Author 2 (a white female faculty member in English Education) and Author 3 (a Black female faculty member in School Psychology) based on their respective expertise in digital literacies and the socio-emotional development of marginalized youth.

Together, Authors 1, 2 and 3 co-conceptualized the program, designed curriculum and training experiences and coordinated the logistics of the summer partnership. Authors 1 and 2 collaborated with district leaders to design the STEM curriculum, facilitated professional development for undergraduate mentors and teachers, managed communication among all stakeholders and conducted individual interviews with undergraduate mentors at the end of the camp. Author 3 developed and led the socio-emotional learning components, facilitated daily debriefs with the mentors (including Authors 4 and 5) and conducted post-camp focus groups.

Authors 4 and 5, Black women undergraduates with experiences in STEM courses and camps, initially participated as mentors in the program. After expressing interest in the research component, they were invited to join the project as full collaborators, contributing to peer interviews, data analysis and manuscript writing. Although they began the project in participant roles, their transition to co-authors was guided by principles of ethical research, namely, informed consent, shared decision-making and acknowledgment of their intellectual labor. We recognize that involving undergraduate mentors as co-authors raises important ethical considerations. We were intentional in ensuring that their participation was voluntary, meaningful and critically supported. Throughout the year-long collaboration, Authors 4 and 5 regularly communicated and worked alongside Authors 1, 2 and 3 in an environment grounded in trust and mutual respect. These interactions supported authentic collaboration in data collection and analysis and interpretation of findings. Authorship decisions were made collectively based on equity, time, expertise and contribution.

While our diverse backgrounds and perspectives enrich this project, we do not assume they automatically ensure equitable research practices. We continue to navigate the tensions inherent in our social identities and professional roles, striving to center marginalized voices not only as subjects of research, but as knowledge producers whose insights are essential to disrupting dominant narratives in STEM education.

Context

This study is set within a school-university partnership between a large urban school district and the School of Education at a mid-sized liberal arts university in the mid-Atlantic region of the USA. The partnership is mutually beneficial. The district serves as a site for teacher

preparation and often hires graduates from the university. Over the past decade, the authors have collaborated with district leaders and teachers to support professional development, student events and community outreach. This project originated from a federally funded exploratory grant designed to examine the opportunities and challenges of STEM undergraduates of color serving as curricular consultants for teachers and mentors for students in classrooms. Through this grant, we have collected data from fifty teacher-undergraduate partnerships. The data for this study was collected in 2022, the first-year undergraduates participated in the program, working alongside teachers and mentoring students. Each year, we have continuously refined and revised the program based on collected data.

This summer STEM enrichment program was offered in conjunction with, but distinct from, the district's formal summer school programming. While the district's traditional summer school focused on academic remediation in mathematics and literacy, this enrichment program was designed to foster curiosity, identity and engagement in STEM fields through hands-on, exploratory learning experiences. District leaders intentionally created a space that differed in both structure and purpose from formal classroom instruction. The program was free to families and open to all middle and high school students in the district, which serves a predominantly African American student population with high rates of economic disadvantage. Due to space limitations, the program was housed in a central middle school and enrollment was determined through a lottery system, with a maximum capacity of 250 students.

Authors 1 and 2 collaborated with district STEM leaders to design a two-week enrichment program focused on STEM content, while Author 3 contributed the social-emotional learning components to support students' well-being and sense of community. Together, they conceptualized a summer program intended to engage middle and high school students who have historically been underserved and often enrolled in traditional summer school remediation. Key components of the program included: (1) partnering certified teachers with undergraduate STEM majors who identified as marginalized in the field; (2) preparing undergraduate mentors to facilitate socio-emotional activities designed that help students from different schools foster friendships, collaborate effectively and build confidence; (3) engaging students in an age-appropriate, design-based challenge that emphasized grade-level skills and content, culminating in a community expo where students presented their designs to peers, families and local stakeholders and (4) a field trip to the undergraduates' university to promote college-going aspirations and familiarity with STEM pathways.

Partnering certified teachers with undergraduate STEM majors. Author 1 recruited undergraduates primarily from a university scholarship program for academically distinguished students who have overcome unusual adversity and/or are members of underrepresented groups who would contribute to campus diversity. Author 1 is a faculty mentor within this program and has relationships with the undergraduates who participated. All undergraduates were STEM majors or felt confident in mentoring students who may be working with STEM concepts; all undergraduates had experiences serving as mentors to K-12 students. Each undergraduate received $2000 for mentoring students in the program and formally consented to participate in interviews, daily debrief sessions and focus groups with Authors 1, 2 and 3 to share their experiences working with students and teachers. Each mentor collaborated with a teacher in the district who committed to teaching in the summer STEM enrichment program. Due to teacher shortages, district administrators could not ensure that all teachers had a science or mathematics background and there were no designated special education teachers or teachers certified to serve English learners. Most teachers with whom mentors worked were White (10); five collaborating teachers identified as Black.

Preparing mentors to support socio-emotional learning. Author 3 developed a structured, socio-emotional learning curriculum called D.R.E.A.M for mentors to facilitate that was focused on goal setting and attainment and youth empowerment. The program uses the acronym D.R.E.A.M, which stands for Determined, Reassured, Equipped, Affirmed and

Moved. The D.R.E.A.M curriculum focuses on empowering students to think about their future goals and how their daily actions can help them achieve those aspirations. These concepts were explored through reflective activities and exercises designed to help students build confidence, set both short-term and long-term goals and develop the necessary skills and mindset to pursue their dreams. Mentors integrated socio-emotional activities into the daily camp curriculum. These activities included icebreakers for students to build connections, the creation of short-term and long-term goals, the writing of letters of encouragement to their future selves and collaborative games designed to encourage students to collaborate in problem-solving.

Author 3 also provided training for all mentors. The first phase of the training was designed to promote critical reflection by encouraging the college students to identify their motives and vision for mentoring underserved youth through the summer program (Mitchell & Donahue, 2023). During this phase the mentors completed an icebreaker activity where they shared their strengths as a mentor, concerns about being a mentor, what they hoped to gain from the experience and what they hoped their mentees would gain from the experience. For example, mentors shared their passion for serving underserved youth and providing opportunities for the next generation, considering their own identities as marginalized college students. Most mentors expressed concerns about developing authentic relationships with the middle and high school students, a topic that was later addressed during the training. From there, the mentors discussed the readings they were assigned prior to the training and shared what the readings meant to them. Mentors read three articles related to culturally relevant mentoring of African American youth (i.e. Davis & Allen, 2020; King, 2017) and critical service learning (Mitchell & Donahue, 2023). The mentors noted that the readings reaffirmed their passion for ensuring that marginalized youth would have access to caring adults, while also creating opportunities for students to pursue knowledge and skills in the STEM field.

During the second phase of the training, the mentors learned about the technical aspects of being a mentor for the program (Cannata *et al.*, 2007). This portion of the training began with an overview of how mentorship is defined, how to develop trust and an authentic relationship with the mentees (e.g. getting to know them, respecting their values, being fully present) and how to build upon one's personal experience to strengthen the mentorship relationship (e.g. sharing their experiences navigating middle and high schools). The trainer also emphasized the importance of developing boundaries during the experience to ensure the safety of the middle, high and college students. From there, the mentors learned about specific expectations they would be required to adhere to during the camp (e.g. attendance, co-leading activities) and the support they would receive to help them during the experience.

Finally, the third phase of training was designed to prepare the mentors to implement the D.R.E.AM. curriculum. Author 3 provided an overview of the D.R.E.AM. program and highlighted how it could be used as a tool to encourage the mentees to think about their future goals and aspirations. After learning about the curriculum, the mentors practiced delivering the core content and received feedback focused on their personal strengths and areas for growth. All mentors were encouraged to continue to practice delivering the content and be prepared to provide personal examples to the "bring the content to life" and connect with their mentees.

Curriculum and community expo. School-district STEM administrators, Authors 1 and 2 and graduate student employees worked together to craft four distinct challenges for students. These included a/an:

(1) Alternative energy challenge-*students explored alternative forms of energy and designed a model car that reduced society's carbon footprint.*

(2) Sea-level rise challenge -*students explored the impact of global climate change on sea-level rise globally and in their communities; students were asked to design a model of their community that mitigated some of the impacts of sea-level rise*.

(3) Biomimicry challenge-*students explored principles of biomimicry and drones to design a bird-like drone to deter the destruction of orchards, without harming the bird population.*

(4) Genius hour challenge-*students explored an interest and creatively presented their new learnings to an audience in a community expo at the end of the program.*

The school district's STEM administrators provided teachers and undergraduate mentors with the curriculum and daily activities before the enrichment program began. They also organized a one-day planning session where teachers and undergraduates collaborated to discuss how they would jointly facilitate these activities. Each day of the program, students created projects to showcase at the community expo, where families and community members were invited to view their final work at the program's conclusion.

Field trip. Authors 1 and 2 collaborated with faculty, staff and graduate students at their university to host all students from the camp. Key experiences of the field trip included middle and high school students visiting with Biology majors in a genetics lab, touring the university library and media center, participating in a campus scavenger hunt and eating in the common student dining hall. Undergraduate mentors led students and teachers around the university and transportation was provided by the school district.

Participants

The participants of this study are 15 undergraduates who participated as mentors to students and collaborators with teachers. Table 1 provides pseudonyms, and the identities put forth by the undergraduates.

Data collection and analysis

Authors 1, 2, 4 and 5 conducted individual, semi-structured interviews with all undergraduate mentors via Zoom at the end of the camp. To ensure consistency and minimize bias, Author 1

Table 1. Undergraduate mentors and their identities

Undergraduate pseudonym	Identities
Luna	Asian Bangladeshi American female, neuroscience major, minor in computer science, pre-medicine track
Arielle	Black, female, kinesiology major with a minor in entrepreneurship
Amira	Black, female, mathematics major with a minor in art, had intentions of pursuing a graduate degree in mathematics teaching
Author 5	Black, female, English and education major
Kiana	Black, female, public policy major
Max	Black, male, neuroscience major and a business analytics minor
Olivia	Black, female, neuroscience major with the intention to pursue a graduate degree in science teaching
Elena	White Hispanic female, Biology major
Author 4	Black female, Kinesiology major, health Science minor
Farah	Black female, Psychology major
Riley	Black female, kinesiology and health science major
Gia	Latina computer science major
Dax	Black male Biology major
Jada	Black female, Business major, Biology minor with a specialty in interactive approaches to conservation
Scarlett	Black female, Ethiopian, psychology major

Source(s): Authors' own creation/work

conducted the interviews with Authors 4 and 5. Zoom's automatic transcription feature was used to generate initial transcripts, which were equally divided among the interviewers for cleaning and accuracy prior to analysis. The interview protocol invited mentors to reflect on key components of the program, including students' engagement in the STEM and socio-emotional curriculum, the university field trip, instructional practices observed in their collaborating licensed teacher, their evolving role as a mentor and their recommendations for future iterations of the program.

In addition to the interviews, focus group discussions were conducted via Zoom by Author 3 approximately two months after the program concluded. These sessions were designed to explore mentors' perceptions of the training and support they received, as well as their roles in supporting students. Zoom transcripts were auto generated and cleaned to ensure accuracy. While the focus groups primarily addressed mentorship experiences, some discussions organically surfaced topics related to equity and inclusion in the camp's curriculum and instruction. For this study, only those portions of the focus group transcripts that explicitly addressed the equity and inclusion of curriculum and instructional design were coded and analyzed. These excerpts were used to enrich the interpretation of themes that primarily emerged from the interview data.

Author 3 also facilitated daily debriefing sessions with the undergraduate mentors during the two-week program. Each session lasted 30–45 minutes and was intentionally not recorded to foster a safe and trusting environment. However, detailed notes were taken to provide contextual understanding and support triangulation with the interview and focus group data. These debriefs offered mentors space to process their interactions with students, reflect on STEM teaching and learning and share suggestions for programmatic improvement.

Authors 1 and 2 met biweekly with Authors 4 and 5 over the course of an academic year to engage in a collaborative and iterative coding process. The team employed descriptive coding (Saldaña, 2021) to assign concise labels to excerpts from interviews and relevant focus group content, capturing salient ideas shared by participants. Sample codes included "perception of mentoring role by self and students," "student engagement," "curriculum critique," "student growth," "collaboration with teachers," and "perception of field trip." Each interview transcript was independently coded by either Author 1 or 2 and by either Author 4 or 5, enabling comparison, discussion and refinement across multiple perspectives to enhance intercoder reliability.

In addition to descriptive codes, in vivo coding was used to capture participants' own words, especially in early rounds of coding, to preserve the authenticity of their voices. The team generated analytical memos for each mentor to develop holistic characterizations of their program experiences. These memos and codes were then examined using a constant comparative method, through which the research team refined and organized the data into emergent themes grounded in the lived experiences of the undergraduate mentors.

Findings

In our analysis of undergraduates' interviews, focus groups and debriefing notes, we identified two themes that describe how mentors perceived the role of equity and inclusion in the summer STEM enrichment program. These themes included (1) the importance of balancing high expectations and socio-emotional development in STEM curriculum; (2) the role of culturally affirming practices in countering cultural incongruences between teachers and students.

Balancing high expectations and socio-emotional development in STEM curriculum

Overall, mentors perceived the curriculum to be inclusive, with opportunities to engage students in STEM topics through hands-on activities while encouraging exploration of personal interests and socio-emotional development. Author 4, who led high school students through coding and drone-flying exercises, praised the curriculum for supporting collaboration and allowing all students to find their own way to contribute. She felt that the curriculum was inclusive of

students' diverse interests stating, "The biomimicry had something for each person...there was a piece that every student could enjoy." Arielle, who facilitated the sea-level rise challenge, specifically noted higher engagement when students were doing activities like "building cities, making s'mores, and walking around outside" compared to when students were asked to research background information "just sitting down and writing in their notebooks." Mentors found the program's focus on active, experiential learning to be a dynamic environment where students could thrive both academically and personally.

Undergraduate mentors also provided critical feedback about the STEM curriculum to make it more rigorous, structured and engaging. For example, Luna, a neuroscience major critiqued the sea-level rise challenge for lacking scientific depth and mixing middle school grade levels. She believed this hindered engagement, stating, "We didn't really learn why climate change or sea level rise happens, like the scientific reasoning. . .because of climate change, global warming. . . they were just told to like build a product." Author 5, who was not a STEM major, also facilitated this challenge and found the curriculum to be appropriately challenging, noting that one student said, "this is the best thing that I have ever done, and I'm taking it home to show my mom". Gia and Dax who facilitated passion projects, noted that while students were highly engaged, many projects were not STEM-related. Dax appreciated the interest-driven approach but felt that more structure and goal-setting opportunities were needed for students to complete their self-guided projects. Gia shared, "While the Genius Hour challenge followed the engineering design process, not all the students focused on STEM-related projects. It was a bit of a stretch to call it strictly STEM, though the process of thinking critically and designing something still aligns with those skills."

Mentors also agreed that socio-emotional curriculum was an essential aspect of the program and were personally inspired during moments of facilitating the D.R.E.A.M curriculum. Luna was profoundly impacted by students' letters to themselves recalling, "they're telling themselves to not give up to always follow their dreams". Max specifically appreciated the focus on goal setting, noting, "The curriculum did a good job of breaking down how to set goals and think critically about short-term and long-term goals, like weighing the pros and cons. It helped the kids realize that achieving a goal isn't always a straight line and how to navigate those bumps in the road." Dax echoed a similar sentiment when remarking, "I don't think that [the students] were ever sat down and someone just told them to think about things that they may be interested in accomplishing."

While the mentors praised the inclusion of the D.R.E.A.M curriculum, they critiqued the way that it was situated in a notebook through a series of worksheets and its alignment with the STEM focus of camp. Max captured this sentiment well when saying,

> Especially during the summer, students don't want to feel like they're just sitting and writing in a notebook. It was up to us mentors to make the D.R.E.A.M curriculum engaging. Also, there was a disconnect between the D.R.E.A.M curriculum and the renewable energy activities. It felt like we were switching from one to the other without much connection between the two.

Arielle also notes that "trying to mesh the D.R.E.A.M curriculum with the STEM curriculum is very hard" and Jada reported that "the students didn't understand how [the curriculum] fit together; they were like, 'we just want to make stuff'". The mentors' reflections emphasize the importance of attending to socio-emotional learning, while also making the experience feel more "interactive" and less "like school" by not having a booklet that required written answers. We found that mentors often modified the socio-emotional activities to feel less structured and more relaxed, deviating from the typical schoolwork format.

Countering cultural incongruences with culturally affirming practices

The theme of using culturally affirming practices to counter cultural incongruencies is central to the mentors' experiences in the summer STEM enrichment program. Culturally affirming practices, such as adapting instruction to the students' backgrounds and learning preferences,

played a key role in addressing moments of cultural disconnect and enhancing student engagement. These practices were critical in fostering an inclusive and supportive environment, particularly when the prescribed curriculum or instructional methods did not align with the students' needs or experiences.

Kiana identified key differences in the ways in which she and her collaborating teacher approached the curriculum; her teacher wanted to teach the curriculum "by the book" whereas Kiana worked in small groups with students and "preferred adapting to how the kids were reacting and responding." Kiana focused on making passive activities more active with discussions and modeling. By shifting away from traditional schoolwork formats and focusing on interactive, hands-on activities, Kiana recognized the need to make learning feel relevant and fun for students in this informal learning environment. Gia praised her collaborating teacher for allowing her to take ownership of some of the lessons, deviating from the scripted curriculum and encouraging "brain breaks", varied instructional strategies. Gia even felt empowered to develop short activities on coding to share her expertise as a computer science major. Scarlett "constantly asked for students' feedback" because she "wanted them to feel that their opinion mattered".

Some mentors observed that students approached them more frequently and openly than the classroom teacher, as they felt a stronger sense of connection and relatability with the mentors. The mentors also identified instances where teachers made comments that silenced and marginalized students. For example, Scarlett shared, "I'm Black, and my teacher was White, and we had predominantly Black students. Sometimes, the teacher would make cultural comments that were a bit insensitive in her attempt to connect with the students." Similarly, Author 4 recounted how a white male teacher referred to the students "in terms of broken English and uneducated-ness." Max highlighted the frustration of working with a teacher who enforced disciplinary measures without warning, creating a sense of unfairness. Luna also noted that students gravitated toward her because they perceived the teacher to be "a little bit biased toward Black male students," often singling them out for disciplinary actions. These cultural disconnects highlight the important role mentors played in the classroom, as their understanding of the students' backgrounds allowed them to navigate these situations with greater sensitivity and care.

The undergraduate mentors provided a culturally affirming presence that fostered trust and openness among the students. Their shared backgrounds and ability to navigate cultural dynamics enabled them to build meaningful relationships, allowing students to express themselves more freely and seek guidance. Scarlett emphasized her role as a trusted figure in the classroom, saying, "I think I made an effort to really get to know the students, which helped them trust me more. They opened up about personal things, like having ADHD or being autistic, which allowed me to tailor my teaching style to their needs. I don't think the teacher had that same connection." Max also reflected on his ability to relate to students' experiences growing up in strict households, often viewing teachers as disciplinarians. As a result, he made himself approachable and available for students to ask questions. All mentors discussed how they affirmed students, celebrating "Black brilliance" (Author 4) and witnessing individual growth, such as shy students becoming more engaged and others stepping into leadership roles. These experiences highlight the complexities of navigating cultural incongruences in the classroom and underscore the importance of using culturally affirming practices to address these challenges. By adapting the curriculum, engaging students in ways that resonated with their lived experiences, and serving as cultural bridges, the mentors created more equitable and inclusive learning environments that empowered students to thrive both academically and personally.

In addition to cultural incongruencies between teachers and students, the undergraduate mentors highlighted significant cultural incongruences during the field trip to their university, which reflected broader challenges in connecting students with the college experience. Initially excited to introduce students to college life, many mentors expressed concerns afterward about the relevance of certain planned activities. For instance, Max noted that

students showed little interest in the genetics lab visit, finding the concepts too advanced and disengaging. Several mentors echoed this sentiment, pointing out that the students were far more enthusiastic about having lunch in the dining hall, where they enjoyed the wide variety of food options. Given the limited time for the field trip, the mentors recommended having more autonomy in planning activities that would resonate better with the students. They suggested focusing on aspects of college life that felt more accessible, such as touring dormitories, exploring common social areas and visiting the Center for Student Diversity. These activities, they believed, would provide a more relatable and engaging introduction to college life.

Cultural representation and historical context also played a pivotal role in shaping the students' experiences. A particularly poignant moment occurred when the students passed by a memorial acknowledging the university's history of enslaved people. This had a noticeable impact on the students' energy and engagement, with one mentor, Author 5, recalling how her students reacted: "The whole energy of my kids shifted until lunch. . .they were like, 'this school had slaves and slaves worked here, I don't like that.'" This moment underscored the importance of representation, with Author 5 and others suggesting that future field trips should include visits to Historically Black Colleges and Universities (HBCUs) where students could see people who looked like them, fostering greater relatability and comfort. HBCUs hold deep historical and cultural significance, having been founded to serve Black students during a time of exclusion and segregation and continue to be sites of academic excellence, empowerment and community for many students of color.

Mentors also pointed out missed opportunities to make the trip more empowering. For instance, Scarlett noted that when the cost of attending the university was brought up, the tour guide only mentioned the full sticker price without discussing scholarships, grants or other financial aid options. This left some students feeling discouraged, rather than motivated. Additionally, the tour's emphasis on meeting a football coach felt stereotypical, with mentors wishing for more emphasis on success stories in medicine or STEM to show a broader range of opportunities (Author 5). These reflections highlight the need for culturally responsive field trips that consider the students' backgrounds and lived experiences. By advocating for more control over planning field trips and tailoring activities to students' interests, the mentors emphasized the importance of creating educational experiences that not only introduce students to college life but also help them envision themselves thriving in those spaces.

Discussion

The purpose of this paper is to amplify the voices of undergraduate mentors who have faced marginalization in STEM and participated in a university school partnership, highlighting what they believe is most important in STEM education for youth. The findings of this study, grounded in undergraduate mentors' perceptions of equity and inclusion within a summer STEM Enrichment Program, underscore both the potential and challenges of such programs in fostering culturally responsive and inclusive learning environments.

The first theme that emerged from mentors participating in this program was the importance of balancing high expectations and socio-emotional development in STEM curriculum. As noted by Ladson-Billings (1995), culturally relevant teaching includes holding students to high expectations, supporting them to understand themselves and each other and fostering learning environments for students to critically think about the social and political factors that shape society. The mentors found aspects of both the STEM and the D.R.E.A.M curriculum to be culturally relevant to students while also identifying that the curriculum needed to be more thoughtfully intertwined to sustain student engagement. This aligns with critiques in the literature that STEM curricula often fail to consider the full scope of students' experiences, thereby alienating those who might otherwise thrive if given culturally relevant, hands-on opportunities (Leyva *et al.*, 2022; Martin & Fisher-Ari, 2021).

The mentors built relationships with the students and despite not being teachers themselves, found ways to adapt the curriculum to better fit the needs of students. They paid close attention

to moments when students seemed disengaged and took proactive steps to connect with each student on a personal level, building meaningful relationships. When the curriculum or instructional practices fell short or were culturally incongruent, these mentors adapted their approaches, demonstrating their commitment to creating an inclusive and responsive learning environment. Scholars argue that culturally relevant teachers, like these mentors, must actively seek to understand their students and adapt the content accordingly (Emdin, 2011; Morrison *et al.*, 2022). The mentors' awareness and adaptability underscore their commitment to understanding and addressing the unique needs of students. Additionally, the relationships described highlight the significance of near-peer mentoring in informal settings, aligning with findings that emphasize the importance of informal programs that emphasize mentorship in STEM (e.g. King & Pringle, 2019; Klein & Bell, 2023).

Most notably, undergraduates demonstrated their concern and frustration in instances where cultural incongruencies occurred between teachers and students and when adults used deficit language when describing students' background and ascribed deficit notions to students' abilities. The mentors' ability to navigate cultural dynamics, as seen in their critiques of deficit comments from teachers and inequitable disciplinary practices, further underscores their role as advocates for equity in STEM education. The undergraduates were acutely aware of students' experiences in STEM and school and were attuned to students' feelings of distrust toward instructors. This mirrored the experiences of other marginalized undergraduates who shared similar feelings of exclusion from STEM (e.g. McGee, 2016, 2021). Mentors positioned themselves as a counterspace for students (Solorzano *et al.*, 2000), a safe space for youth to ask questions, share their frustrations and trust. This is particularly important in STEM, where traditional classroom environments often feel alienating to students from marginalized groups.

The mentors understood the profound impact of their representation for students, shaped in part by their own experiences of lacking mentorship during their secondary years and in higher education at a predominantly White university. In addition to the cultural disparities between teachers and students, the undergraduate mentors emphasized notable cultural mismatches during the university field trip, highlighting broader challenges in helping students connect with the college experience at a predominately White institution. Swanson *et al.* (2021) put forth that middle school students who visit colleges are more likely to reach out to college personnel and are more likely to enroll in advanced science courses in high school. While there are clear advantages for youth in visiting colleges, there is little to no research that examines how to make these college visits culturally relevant for underrepresented students. Undergraduates made important and necessary insights and recommendations about the field trip for future iterations of the program.

Conclusion and implications

To create more equitable and inclusive STEM programs, it is essential to center the voices of those who have experienced systemic barriers firsthand. Undergraduate mentors from marginalized backgrounds offer valuable insights into how STEM curricula and instructional practices can better serve underrepresented students. Actively involving these mentors in the critique and development of STEM education allows institutions to address deep-rooted inequities that continue to limit participation and success for these students. For example, it may be helpful to have mentors preview materials such as socio-emotional learning activities, lesson plans and agendas for field trips prior to implementation. It may also be helpful to provide a variety of feedback mechanisms for mentors to share their thoughts including focus groups, surveys and informal conversations.

Challenges are inevitable when implementing community-based, collaborative work. University-school partnerships often face tensions, as school stakeholders grapple with translating academic theories into sustainable practice (Martin *et al.*, 2011). These partnerships must be grounded in trust (Lewison & Holliday, 1997), where university

researchers foreground the assets and listen to the needs and challenges experienced by marginalized students. It is crucial that researchers be willing to renegotiate their goals to ensure they are equitable and inclusive. School stakeholders, undergraduates and university partners must also establish norms and practices that promote empathy and respect, creating safe and equitable spaces for all participants to engage in discussions about equity. For example, teachers and undergraduates can be prepared together to implement culturally relevant practices such as noticing students' engagement and adapting curriculum and instruction accordingly.

Power dynamics are inherent in collaborations among diverse stakeholders. The impact of undergraduate mentors on student learning often depends on teachers' willingness to collaborate and value diverse representation in STEM classrooms (Kier & Johnson, 2024). Some undergraduate mentors may feel uncomfortable sharing ideas or suggestions for creating more equitable learning spaces. To alleviate this discomfort, providing safe spaces for mentors to process their experiences is essential. Lac *et al.* (2022) emphasize that justice-oriented work with youth requires adult allies to provide care beyond the research project, building genuine relationships and considering students' well-being (p. 161). As we move from counterstories to collective action between schools and university stakeholders, it is important for partners to intentionally commit to raising awareness of marginalized students' experiences and fostering a culture of empathy and adaptiveness. This shift includes co-designing curriculum and enrichment activities with teachers and mentors, creating sustained dialogue between university faculty and school leaders and using shared reflections from the field to inform systemic changes. For some teachers, navigating the deep-seated oppressive structures and philosophies about STEM education will be challenging. Therefore, it is critical for school stakeholders to form alliances that amplify the need for equitable reform.

This study carries significant implications for the design, teaching and implementation of both formal and informal STEM educational opportunities. The findings underscore the need to include diverse stakeholders early in the planning phases of program development. Because this study was the first year that undergraduate mentors were invited into the summer STEAM program, this study has focused on their voices, perceptions and experiences. While we do not have space here to address the myriad ways that undergraduate voices shaped future iterations of the program, subsequent research may want to examine how undergraduate mentors' voices inform the planning and implementation of curriculum and instruction with teachers. Fostering collaboration between program facilitators and administrators, alongside educators and undergraduates with marginalized identities, is imperative. Recognizing and addressing the power dynamics between those inside and outside the school system, along with the complexities of discussing race in STEM education, is challenging but necessary. We encourage school district administrators to reach out to their local universities, many of whom have offices of community engagement who can work with school districts to partner on these kinds of initiatives.

The narratives shared by undergraduates about their own and their mentees' experiences serve as powerful tools for advancing equity in STEM. These counter-stories challenge biases about the capabilities of youth who are persistently marginalized in STEM education. Through intentional facilitation, these stories have the potential to disrupt entrenched prejudices and foster a more inclusive and equitable landscape in STEM education. By amplifying the voices of those with lived experiences of marginalization, we can work toward creating STEM programs that affirm the identities and potential of all students, ultimately transforming the educational landscape for future generations.

Institutional review board statement

The study was conducted in accordance with the William & Mary Institutional Review Board and determined to be exempt from formal review in accor- Educ. Sci. 2022, 12, 48 23 of 25 dance with the Department of Health and Human Services Federal Regulations: 45CFR46.104.d.1, 45CFR46.104.d.2.

This states that studies are exempt from formal review when: (1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies and research on the effectiveness of or the comparison among instructional techniques, curricula or classroom management methods and (2) Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude and achievement), survey procedures, interview procedures or observation of public behavior (including visual or auditory recording) if any disclosure of the subjects' responses outside of the research would not reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, educational advancement or reputation.

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