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Reimagining informal STEM learning opportunities to foster STEM identity development in underserved learners

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Informal science, technology, engineering, and mathematics (STEM) learning opportunities offer great potential to position learners as insiders to STEM and to foster their positive STEM identity development. Despite their goal to create equal insights and access to STEM learning for all, however, these informal STEM learning opportunities often fail to reach underserved students, hindering their STEM identity development and perpetuating inequity. To address this issue, out-of-school programs need to be designed with underserved students in mind, and concepts, as well as practical approaches that foster STEM identity development, need to be identified. In this article, we review 13 peer-reviewed publications that investigate informal STEM learning opportunities for underserved learners at a young age. We synthesize concepts such as competence, performance, recognition, supportive relationships, sense of belonging, agency, interest, and attitudes that influence underserved learners' STEM identity development, and corresponding practical approaches such as personal relationships, role models, authentic settings, hands-on-activities, and non-stereotypical structures fostering agency. We also discuss theoretical frameworks for underserved learners' STEM identity development. We suggest that recognition, a sense of belonging, supportive relationships, and agency play important roles in fostering STEM identity development in underserved students. The paper concludes with recommendations to change traditional patterns in informal and formal STEM education to empower underserved students to construct their own STEM identity as agentic individuals.

KEYWORDS

STEM identity, underserved students, out-of-school, informal STEM education, intersectionality

1. Introduction

A wide range of diverse perspectives and skills in science, technology, engineering, and mathematics (STEM) are important prerequisites for solving complex global challenges such as climate change or the COVID-19 pandemic. STEM activities in out-of-school contexts can contribute to the development of these diverse competences as they stimulate learners' STEM-related attitudes and interests (Vennix et al., 2018; Baran et al., 2019) whilst fostering STEM career aspirations (Dabney et al., 2012; Sahin et al., 2015; Kitchen et al., 2018). They help young learners to explore their own identities when navigating STEM fields and to understand their positioning within those fields. This development of a positive STEM identity (in other words:

to see oneself as a 'STEM person') is an essential part of accessing STEM fields and becoming a scientifically literate person (Brown et al., 2005). However, historically, STEM learning activities were oriented to exclusively facilitate white male learners from higher or middle socioeconomic classes. In doing so, many of them reproduced an image of STEM which contributes to the marginalization of a substantial group of STEM learners, including women and non-binary persons, as well as those from lower socioeconomic classes, or diverse ethnic backgrounds (Taconis and Kessels, 2009). This contradicts the United Nations' Sustainable Development Goal 4 ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all. By underserving specific groups of learners, we fail to support the development of these learners' STEM identities, their STEM literacy and linked STEM career aspirations, which are so desperately needed to create an equitable and sustainable society.

Although to date, there are STEM interventions and programs specifically designed to support underserved learners, evidence for effective methods and specific concepts that foster STEM identity development in underserved learners is still limited. Thus, this review is a meta-synthesis [following the framework of (Gessler and Siemer, 2020)] which aims at identifying central methods, theories, and concepts to foster STEM identity development in underserved learners in out-of-school STEM interventions.

2. Underserved learners and STEM identity development

2.1. Who is underserved in STEM fields?

The definition of who is underserved always depends on the context, the environment, and the specific societal structures. Concerning STEM fields, there is unequal access to STEM learning opportunities, STEM education, and STEM-related careers for people based on gender, ethnicity, and socio-economic class. In other words, people can experience structural or cultural barriers to STEM fields as well as discrimination and prejudice based on their gender, ethnicity, or class. For example, Steegh et al. (2019) found evident gender differences in participation and achievements in mathematics and science Olympiads. In a broader sense, a literature review by Blackburn (2017) revealed that despite increased efforts to promote women in STEM education in the U.S., exclusive environments characterized by stereotypes, biases, and a lack of sense of belonging remain significant barriers for women. This suggests a need for continued efforts to address these issues in the field. STEM topics and practices often are associated with stereotypically masculine traits such as "hard" or "brainy," which make them more accessible for middle-class men (Archer et al., 2010). As Haynes and Jacobson (2015) have shown, stereotypes against certain ethnicities influenced an interest in STEM-related careers. Similarly, Dabney et al. (2012) reported that female students were less interested in STEM careers than male students, which might be due to less inclusive designs of STEM learning opportunities for this group of learners as posited by the authors. In a study by Archer et al. (2015), students with low science capital tended to be female and from lower socio-economic backgrounds, showing "that science capital is strongly socially patterned, being concentrated in more privileged social groups" (Archer et al., 2015, p. 940). Moreover, people can be confronted with multiple stereotypes when they are marginalized in more than one dimension based on the context, thus experiencing discrimination along intersecting axes of oppression (Crenshaw, 1989; Avraamidou, 2020a,b). An example of this in the context of STEM can be found in Bodnar et al. (2020) who showed that while girls, in general, had lower science aspiration scores than boys, especially Black girls scored lowest in that category.

Hence, people who identify as female or non-binary, have a lower socio-economic background, and represent ethnic minorities are underserved groups in STEM contexts. However, we are aware that the term *underserved* carries the potential threat of labeling and othering certain groups of people. Especially in the context of educational research, which focuses on people, we as researchers need to be aware of our own racial and cultural influences that can be potential biases for how we conduct research (Milner, 2007). Thus, we want to be transparent about our own background as researchers, as often made explicit in ethnographic studies but still rather unusual in science education publications: We are three people with academic degrees in STEM contexts who identify as female and have a high socio-economic background. We stem from middle-class as well as working-class families without academic backgrounds. Our cultural identities are influenced by German, Turkish, and Dutch cultures. We see ourselves as privileged and not underserved in STEM contexts. It is important for us to emphasize our aim is not to amplify negative stereotypes surrounding underserved groups. On the contrary, we aim to center underserved groups in STEM learning and reflect on their missing representation so far. However, to do so, it is important to talk about who is being underserved and why, so that everyone, regardless of their gender, ethnicity, or socio-economic class can gain a rightful presence in STEM. We are aware of our responsibility when applying labels to individuals based on their group identity as this can potentially stigmatize people and neglect the unique needs of diverse learners. We have carefully debated the terminology used in this paper and selected the term "underserved learners" to highlight the barriers that these learners encounter in accessing informal STEM environments, particularly in the case of young learners. By doing so, we aim to underscore the systemic issues at play and the responsibility of those in positions of power within the field.

2.2. STEM identity as a prerequisite for being an insider in STEM

If we want people to become insiders to STEM fields, the development of a *STEM identity* needs to be an available option for them (Johnson et al., 2011). The concept of STEM identity is what we define as the ways in which people navigate the meaning of STEM aspects for their everyday lives and how they position themselves in STEM fields. Since "the concept is slippery and difficult to operationalize in a way that provides solid methodological and analytic direction" (Carlone and Johnson, 2007, p. 1,189). Carlone and Johnson (2007) developed a model of *science identity*, as they call it, to clarify the construct. According to their model, the science or STEM identity of a person can be explained by the three dimensions *competence*, *performance*, and *recognition*. While *competence* refers to the knowledge a person has in STEM, the term *performance* relates to the STEM-specific skills of a person. The dimension *recognition* underlines the importance that for identifying as a STEM person, people have to be recognized as such by meaningful others as well as by themselves (Carlone and Johnson, 2007).

Identities are discursive and dynamic concepts which develop over time and are influenced by (educational) contexts, societal structures, cultural factors, and interactions with others (Holland et al., 1998; Brickhouse, 2001; Brown, 2004). Moreover, people can negotiate different identities at the same time, which can overlap with their STEM identity or conflict with its development (Brickhouse, 2001; Carlone and Johnson, 2007). Hence, identity development can be understood as a constantly changing process. In educational contexts, a person's identity work might be influenced by other personal identities (Avraamidou, 2020a) as well as by teachers or educators (Wade-Jaimes et al., 2022), peers (Leath et al., 2022), and home environment (Dou and Cian, 2022). A positive STEM identity has been linked to developing scientific literacy (Brown et al., 2005) as well as STEM career aspirations and the likelihood of entering a STEM career (Carlone and Johnson, 2007; Stets et al., 2017; Bodnar et al., 2020), whereas learners with a negative or low STEM identity tended to drop STEM and were less interested in STEM careers (Archer et al., 2015). Hence, the development of a positive STEM identity is needed for people to become insiders to STEM.

2.3. STEM identity development of underserved learners

Although STEM education intends to equally position all learners as insiders to STEM, barriers for STEM identity development in underserved learners have been found in both formal and informal STEM learning settings. Informal STEM education institutions such as museums, science centers, and other science communication formats often do not reach people from low socio-economic backgrounds, ethnic minorities, and people from non-academic backgrounds due to their non-inclusive designs (Dawson, 2014a,b; Schrögel et al., 2018). Furthermore, various studies have found challenges for underserved learners in STEM fields in formal education. For example, teachers tended to adapt less to the needs of African American female students, expected less academic achievement from them, and recognized them less as science learners (Pringle et al., 2012). Concerning university STEM education, Black undergraduate women (Dortch and Patel, 2017) as well as Hispanic/Latinx PhD students and post-doctorates (Chakraverty, 2022) in predominantly white institutions have reported experiencing microaggressions, racism, and sexism, which negatively influenced their sense of belonging in STEM (Dortch and Patel, 2017; Chakraverty, 2022). Hence, formal and informal institutions create barriers to STEM learning opportunities as well as challenges for positive STEM identity development in underserved learners. When STEM learning opportunities implicitly exclude certain people, they narrow the image of who counts as a STEM person. As Brickhouse (2001) states, "we know that individuals are not free to be anyone they wish. When formal education is required for membership in scientific communities, and women do not have access to these institutions, they are not free to be these kinds of scientists." (p. 286). This issue does not only concern women but all kinds of marginalized people in STEM contexts. As a consequence, underserved learners have fewer opportunities to gain scientific literacy and to aspire to STEM careers as their images of who can become a scientist do not include themselves (DeWitt and Archer, 2015).

2.4. Out-of-school contexts can foster STEM identity development

In general, out-of-school contexts can provide excellent opportunities to foster STEM identity development in underserved learners since they offer the possibility to work in small groups and concentrate on specific topics. Moreover, out-of-school programs do not need to follow specific curricula and therefore are easy to adapt to the learners' individual interests and needs, which is especially important to support underserved groups. As studies have already shown, out-of-school programs helped students to connect STEM fields, schoolwork, and everyday life (Baran et al., 2019), hence fostering scientific literacy. Furthermore, out-of-school programs promoted students' interest in STEM, their positive attitudes toward STEM (e.g., Vennix et al., 2018; Baran et al., 2019) as well as an interest in pursuing a career in STEM fields (Dabney et al., 2012; Sahin et al., 2015; Kitchen et al., 2018). As career aspirations seem to start forming during elementary school (Auger et al., 2005), STEM identities might be forming at a young age as well. Thus, there is evidence that points toward out-of-school programs as good opportunities for fostering STEM identity development from a young age. However, these programs need to be reimagined "as vehicle for social justice" (Archer et al., 2022). To achieve this, out-of-school programs need to explicitly make STEM identities available to underserved learners whilst preventing identity conflicts or negative ascriptions (Johnson et al., 2011). This way, out-of-school programs, which are explicitly designed to fit the needs of young, underserved learners can be reimagined to foster the STEM identity development of underserved groups.

3. Research questions

Although a wide range of STEM intervention projects has been specifically designed for under-served learners, most internationally published examples focus on college-level students. However, as a study by Carlone et al. (2014) showed, STEM identification became less in middle school students, declining between fourth and sixth grade. Hence, it is important to design programs that specifically fit young learners to enhance STEM identity development. As already stated, out-of-school programs for young, underserved learners carry a high potential to promote positive STEM identity development. Consequently, this paper aims to identify and analyze concepts and methods to foster STEM identity development in out-of-school contexts for young underserved learners. We want to find out how we can use STEM identity as a lens for re-imagining out-of-school STEM learning opportunities and its connection to STEM education in general. Therefore, we analyzed research papers on out-of-school STEM interventions for young underserved learners and how these interventions contributed to students' STEM identity work. We sought to examine the mechanisms by which these interventions impacted students' STEM identity development. We aimed to identify the underlying theories, concepts, and practical approaches employed by such interventions that were effective in fostering positive STEM identity development. Ultimately, our goal was to make these findings widely accessible for use in designing future out-of-school STEM learning opportunities. The following research questions are addressed in this study:

1. What are superordinate key theories and concepts that contribute to underserved students' STEM identity development?
2. What are related practical approaches that contribute to underserved students' STEM identity development?
3. Which experiences of underserved students highlight aspects for further investigation on STEM identity development?

4. Methods

For answering our research questions, we looked for relevant literature based on specific criteria. We searched for peer-reviewed articles which investigated informal STEM programs in an out-of-school or after-school setting. Common examples of such programs are science or STEM clubs as well as summer programs. Moreover, we looked for articles which focused on programs for underserved, underrepresented, or marginalized students defined by class and/or ethnicity. We did not define gender on its own as an indicator of underrepresentation and only included studies that focused on gender combined with, for example, ethnicity. We decided to do so since we wanted to look at the issue of underrepresentation from an intersectional perspective. Further, articles had to investigate aspects of students' STEM identity or STEM capital. Regarding age, we included interventions that focused on school students, e.g., middle or high school students.

We excluded papers (1) studying visitors of informal learning spaces such as museums without specifically designed intervention programs, (2) where the majority of participants were older than high school age (e.g., programs for college or university students), and (3) describing detailed project guidelines with no investigation of participants' STEM identity. Moreover, we excluded dissertations and not peer-reviewed literature such as project evaluation reports from our analysis. In some cases, we found publications that belonged to a series of papers all investigating the same out-of-school STEM program. In those cases, we chose the most recent and most fitting paper of that series. One article by Rahm and Ash (2008) combined the findings of two programs: one program that focused on participants who visited informal learning spaces and one program that focused on a specifically designed intervention. We decided to focus on the results of the specifically designed program only, since the results were reported separately in the article and were important for answering our research questions.

As this is a relatively new research field, we decided to follow a rapid review approach (see Gessler and Siemer, 2020) and focused on literature from the past almost 20 years (2004–2022). Since we also had a very specific research purpose, we reviewed relevant literature as a starting point for future development instead of giving an in-depth overview of the existing literature. A search on Web of Science and ERIC gained less than 10 papers relevant to our research question. Hence, we started reading relevant papers and used cross-references as well as looking through articles and their reference lists to identify further relevant papers. In the end, we identified 13 peer-reviewed articles, which investigated out-of-school STEM programs for underserved school children aged 10–17 from low-income families, ethnic minorities, or both. We then examined these articles through a STEM identity lens, inspired by Carlone and Johnson's (2007) framework, to extract overarching key theories and concepts that contribute to the development of students' STEM identities. Throughout this process, we identified concepts that aligned with Carlone and Johnson's framework, as well as additional theories and concepts that added to their framework. We then also looked at methods used in the programs that were described in the articles as well as quotes given by participants in those programs for further research on STEM identity development.

5. Results

First, we will start by describing the identified underlying superordinate key theories and concepts that foster positive STEM identity development for underserved students. Second, we will synthesize the methods used for fostering STEM identity development. Last, we will conclude our findings by looking at selected quotes from underserved students, which indicate interesting aspects for future investigation on STEM identity development.

An overview of the analyzed studies can be found in Table 1. Overall, the studies were published between 2004 and 2022. Most of the studies were from the U.S., except for two from Canada, one from the UK, and one from Spain. All studies are peer-reviewed and investigated out-of-school programs of varying contexts and durations. The research was mostly conducted through qualitative research, such as semi-structured interviews or ethnography. Three studies used a mixed-methods-approach, while one study used quantitative methods only.

5.1. Multiple factors can foster or hinder a positive STEM identity development in underserved students

In general, it is noteworthy that most of the analyzed studies did not refer to a framework for STEM identity development or any other theoretical framework for that matter. However, the frameworks which were mentioned in the studies are: Yosso's (2005) community culture wealth framework (Lane and Id-Deen, 2020), Eccles (1994) model of achievement-related choices (Fadigan and Hammrich, 2004), an equitable outcomes model based on the study's findings (Archer et al., 2022), an own model for STEM identity development in STEM contexts (Burke and Navas Iannini, 2021), and a culturally responsive computing approach (Scott and White, 2013). Some of the studies did mention the science identity model by Carlone and Johnson (2007), although they did not state to use it as a definite framework. Since there was no overarching STEM identity framework, we were not able to examine specific constructs of STEM identity development in the articles but had to look for other concepts indicating STEM identity development. Hence, we identified implicit indicators for STEM identity development, which were investigated in each of the articles (see Table 1). Most of the time, STEM identity development was measured by looking at interest in STEM, STEM

TABLE 1 Reviewed publications.

Publication	Name of project	Duration and informal learning context	Country	Sample	Variables used to measure STEM identity development	Study design
Archer et al. (2022)	Youth Equity + STEM (YESTEM)	Weekly sessions and summer program at Digital Arts Center, weeklong project at Community Zoo, weekly school-based Girls STEM club, bi-weekly school-based club with trips to Science Center	UK	33 young people from ethnically diverse backgrounds, and from working as well as middle-class backgrounds, aged 11 to 14 years	Equitable youth outcomes (own model)	Ethnography
Blanchard et al. (2015)	Beyond Blackboards	Year-long after-school program led by teachers and mentors as well as participation in competition 4 month after start of the program	US	74 participants from low-income, Hispanic community in Texas took part in survey, 58 of those at two points of time (fall and spring) + 19 focus group interviews, middle school age	Interest in engineering, understanding of engineering, career aspirations	Mixed-methods
Burke and Navas Iannini (2021)	STEM Academy science club program	Weekly sessions on Saturday during an academic year in community spaces	Canada	202 children from low-income neighborhoods answered a survey, 45 children for focus group sessions and 9 club staffers, children aged 6 to 14 years	Interest in science, attitudes towards science, and emotional engagement as indicator for self-concept as science person	Mixed-methods
Calabrese Barton et al. (2021)	Six different programs: STEM club, Coders Hangout, STEM Mash-Up, YAC, Forensics, and summer camps	After school clubs, summer camps, once-a-month weekend clubs, and weeklong all-day club	US	170 youth in total from 6 programs (mix of programs targeting Black youth only and programs with equally White youth and Youth of Color) and 8 STEM educators of programs involved, students aged 10 to 16 years	Students' meaningful engagement, moments of collaborative critique and disrupted practice that centered participants' lives and needs	Ethnography
Calabrese Barton and Tan (2010)	GET city	Weekly after-school program for a year at a local community club	US	20 students from low-income families of ethnic or racial minority, aged 10 to 14 years	Expressions of agency in science	Ethnography
Fadigan and Hammrich (2004)	Women in Natural Sciences (WINS)	7-Week summer program + weekly meetings as well as monthly trips during academic year, yearlong program	US	78 girls from single-parent families, low-income homes, and ethnic minorities; 12 of those gave semi structured interviews, 9th or 10th grade	Students' career choices and career aspirations	Mixed-methods
Kuchynka et al. (2022)	-	4-Week summer program	US	97 students from ethnically underrepresented groups, mean age of 15 years	Changes in implicit and explicit science identity, attitudes towards science as well as social belonging	Longitudinal quantitative survey
Lane and Id-Deen (2020)	-	Two summer programs (6 weeks for first-year college students and 4 weeks for high school students)	US	14 Black women and girls from low-income or middle-income families, aged 15–23 years	STEM capital and STEM career aspirations	Semi-structured interviews
Pinkard et al. (2017)	Digital Youth Divas	Weekly 2-h out-of-school program over several months	US	17 girls from schools with a majority of non-dominant students (Latino and African American) in underserved neighborhoods, middle school age	Interest in STEM activities, agency, and identification with narrative characters	Ethnography
Rahm and Ash (2008)	Scientifines	Every day after-school science program	Canada	Two girls from schools in poor and ethnically-diverse communities with many first-generation immigrants, aged 9 to 10 years	Attitudes towards science, skills, and students' self-identification as competent science insiders	Ethnography
Rahm and Moore (2016)	COSMOS	6-Week summer program with mentoring, counseling and tutoring sessions and field trips	US	Four first-generation college-bound and/or low-income students, 13–15 years	Moments of figured worlds, positionality, and authoring of self as well as educational and identity pathways	Ethnography

(Continued)

TABLE 1 (Continued)

Publication	Name of project	Duration and informal learning context	Country	Sample	Variables used to measure STEM identity development	Study design
Salvadó et al. (2021)	---	7 Scientific out-of-school workshops + visit to institute	Spain	20 girls and boys from 6th grade from schools in communities with high numbers of low-income families and ethnically as well as culturally diverse backgrounds, aged 11 to 12 years	Students' science capital and science identity dimensions, perceptions of science	Semi-structured interviews
Scott and White (2013)	COMPUGIRLS	Weekly 2-year multimedia after-school program including a 4-day summer program for 5 weeks	US	41 African-American and Latino girls from economically disadvantaged backgrounds, aged 13 to 18 years	Girls' self-perception as future technologists	Ethnography

capital, or STEM career aspirations. We then looked at the findings related to these indicators and synthesized seven overarching concepts (competence, performance, recognition, sense of belonging, supportive relationships, agency, and interest and attitudes) to categorize the findings related to STEM identity development.

5.1.1. Competence: knowledge in or about STEM topics, STEM fields, and STEM career options

We identified Carlone and Johnson's (2007) concept of *competence* to emerge in cases where new STEM knowledge (e.g., knowledge in or about different STEM topics and fields), knowledge about college courses, knowledge about life and work at college or university, or knowledge about different STEM career options was gained by participants throughout the investigated programs in the articles. This competence gain was reported to open up new future options for them which indicates that STEM fields became more accessible (see Fadigan and Hammrich, 2004; Rahm and Ash, 2008; Blanchard et al., 2015; Rahm and Moore, 2016; Burke and Navas Iannini, 2021; Salvadó et al., 2021; Archer et al., 2022). After participating in the programs, students reported having a wider content knowledge (Rahm and Ash, 2008; Archer et al., 2022), having more information about possible jobs in STEM fields (Salvadó et al., 2021; Archer et al., 2022) and being positively influenced by this knowledge in their future options or career aspirations (Fadigan and Hammrich, 2004; Blanchard et al., 2015; Rahm and Moore, 2016). Even students who already considered a STEM profession indicated new knowledge about the skills and tasks scientists have to perform in their job which Rahm and Moore (2016) argue made these students reposition themselves within STEM. Nevertheless, we saw that this gain in competence needs to be balanced with gains in terms of performance. As some of the studies showed, some students had a missing understanding of scientific concepts when programs only focused on performing scientific activities without the knowledge of the concepts behind those (Rahm and Ash, 2008; Burke and Navas Iannini, 2021), which hints at a hindrance of STEM identity development. Through participation in out-of-school programs for underserved learners, students stated to gain competence and therefore started feeling like insiders in STEM fields according to (Rahm and Ash, 2008), which shows a strong connection between participation and identity development. Also, participation in STEM programs made students gain knowledge about the complexity of STEM, the connections between various scientific fields, and its usefulness for society (Salvadó et al., 2021). Hence, the knowledge gained in the programs seems to have positively influenced the scientific literacy of the students.

5.1.2. Performance: executing skills that position students as competent STEM persons

Narratives of Carlone and Johnson's (2007) concept of *performance* occurred in the studies when students gained and applied STEM-specific skills such as creating hypotheses, collecting data, doing interviews, applying lab techniques etc. Performing such skills positioned them as people who can do STEM and fostered their STEM identity development. However, we saw that the complexity of such skills should be carefully balanced with students' abilities. Findings showed that when participants had to perform too challenging skills, it made them question their own identities as competent STEM persons, indicating possible challenges for positive STEM identity development (Rahm and Moore, 2016). A gain in performance and its positive effects were identified in multiple papers (Fadigan and Hammrich, 2004; Rahm and Ash, 2008; Scott and White, 2013; Blanchard et al., 2015; Rahm and Moore, 2016; Burke and Navas Iannini, 2021; Archer et al., 2022), for instance when students executed their STEM skills in form of experiments, which was reported to boost their confidence and their positive attitudes towards STEM (Burke and Navas Iannini, 2021). However, the fun associated with performing scientific activities needed to be "grounded in the identities, values and needs of youth from under-served communities" (Archer et al., 2022) to promote STEM identity development (Archer et al., 2022). This means that conducting STEM-specific activities might come with fun, but should also focus on an explicit experience of performance or a gain in competence.

5.1.3. Recognition: seeing oneself as a STEM person and being seen as a STEM person by others

Matters of Carlone and Johnson's (2007) concept of *recognition* were found in the majority of all analyzed papers in cases where participants were recognized and valued as competent STEM persons by significant others (Fadigan and Hammrich, 2004; Scott and White, 2013; Rahm and Moore, 2016; Pinkard et al., 2017; Lane and Id-Deen, 2020; Burke and Navas Iannini, 2021; Calabrese Barton et al., 2021; Archer et al., 2022). Examples of such incidents were cases where staff offered participants to work as volunteers in informal STEM learning settings (Fadigan and Hammrich, 2004). Also, scientists and undergraduate students treated participants as competent and valuable contributors to mutual research projects (Rahm and Moore, 2016). Furthermore, students were seen as competent STEM persons by their family, friends, and teachers after participating in out-of-school interventions (Archer et al., 2022). As Calabrese Barton et al. (2021) argue, when educators take the time and space to acknowledge participants' knowledge, their experiences, and listen to possible criticism, they become important supportive allies who recognize students and position their way of being as deserving in the STEM context. Findings in some studies showed that this recognition by others helped students to see themselves as STEM person (Rahm and Moore, 2016; Archer et al., 2022) and thus fostered their STEM identity development. Participants reported that being recognized by other people in the program motivated them to keep on working and therefore enhanced their STEM aspirations (Lane and Id-Deen, 2020). Fadigan and Hammrich (2004) showed that 64% of participants were influenced in their educational and career aspirations because they were able to talk to staff all the time and felt like they were treated as individuals. This show that these students felt recognized by their educators. Findings indicated that this recognition needs to be repetitive and constant over a long period of time to influence participants' STEM identity development (Archer et al., 2022).

Another important form of recognition is a recognition of oneself as a competent STEM person. An example of this can be found in Archer et al. (2022), where a participant reported that by being good at performing STEM skills during a project, they recognized themselves as competent STEM person. Archer et al. (2022) argue that in such cases, STEM programs for underserved students can function as spaces to act out already existing STEM identities. This can give students a place to be assured of their identity, which they might be missing in everyday school contexts. Also, by working on solutions for socio-scientific issues, students experienced a confidence boost which made them recognize their own performance-skills and enhanced their STEM-specific knowledge (Blanchard et al., 2015).

5.1.4. Sense of belonging: countering traditional STEM identities to feel valued, accepted, and represented in STEM fields

In addition to the framework of Carlone and Johnson (2007), we saw the concept of a *sense of belonging* occur in the articles as a further concept for STEM identity development. We saw that students in the interventions experienced a sense of belonging when they felt valued, accepted, and represented in the professional STEM fields when spaces were created with them in mind, and when they implemented their own ways of being in the STEM field. The impact of the investigated programs on students' sense of belonging can be found in a majority of the papers (Fadigan and Hammrich, 2004; Scott and White, 2013; Blanchard et al., 2015; Rahm and Moore, 2016; Pinkard et al., 2017; Lane and Id-Deen, 2020; Burke and Navas Iannini, 2021; Calabrese Barton et al., 2021; Salvadó et al., 2021; Archer et al., 2022; Kuchynka et al., 2022). For instance, locating the out-of-school program in the students' community created a sense of belonging as children were offered "something that they could see as their own" (Burke and Navas Iannini, 2021). Educators and staff valuing the experiences and opinions of underserved youth as rightful and valuable furthermore contributed to students feeling a sense of belonging. As Calabrese Barton et al. (2021) reported, moments where individual students' lives and experiences in the STEM context were seen and heard by educators resulted in a generally enhanced engagement of participants as these moments opened alternative ways of engaging in the STEM program.

Furthermore, in two cases, a missing representation of women from ethnic minorities and people from low-income families in STEM was seen as motivation for participating girls to aim for a STEM career in the future (Lane and Id-Deen, 2020; Archer et al., 2022). In these cases, students interacted with educators and scientists from diverse backgrounds, which, according to Archer et al. (2022), underlines how these mentors can influence students' sense of a rightful belonging in STEM. Contrary, when participants in the intervention described by Salvadó et al. (2021) were confronted with spaces that reinforced traditional ways of being and working in STEM fields, they mentioned that they did not feel like a STEM career would match their realities. We consider this as an indication that traditional STEM spaces and missing mentors of non-traditional, diverse backgrounds might hinder STEM identity development. The importance of being aware of stereotypes that underserved students might experience in their lives and countering those for a positive development of STEM identity was also reported by Pinkard et al. (2017).

5.1.5. Supportive relationships: parents, teachers, educators, and peers enable STEM access and encourage further engagement

A further concept that emerged from the articles was the importance of *supportive relationships*. Supportive relationships for underserved students can be those with parents, teachers, other participants, staff, or educators in interventions. Overall, the importance of supportive relationships occurred in 10 of the selected papers (Fadigan and Hammrich, 2004; Rahm and Ash, 2008; Calabrese Barton and Tan, 2010; Scott and White, 2013; Blanchard et al., 2015; Lane and Id-Deen, 2020; Burke and Navas Iannini, 2021; Calabrese Barton et al., 2021; Salvadó et al., 2021; Kuchynka et al., 2022). Since family members and friends played a central role as enablers who encouraged students to engage in out-of-school programs (Rahm and Ash, 2008; Lane and Id-Deen, 2020; Burke and Navas Iannini, 2021), they seem essential for enabling students' STEM identity development. In the program reported by Lane and Id-Deen (2020), parental support played a positive role as it influenced students' competence as well as their career aspirations. For instance, on a cognitive level, parents in this program supported their children with different resources, such as toys, for promoting STEM knowledge. A connection to aspirations was found when those families supported on an emotional level and acted as motivators for further engagement in STEM. A strong positive relationship with their families was reported to promote students' STEM career aspirations as the participants viewed a STEM career as a way to financially support their families in the future. In this program, mothers seemed to play a central role in engaging their daughters to continue in STEM as they explicitly enabled their daughters' access to out-of-school programs. However, students' engagement can only be promoted by parental encouragement when parents themselves hold positive attitudes towards STEM (Burke and Navas Iannini, 2021).

During the out-of-school programs investigated in the articles, we saw that peers became important supportive allies. As some students reported in the studies, meeting friends and people who are interested in the same things positively affected their career aspirations

[55% of students report that friends made in the program influenced their STEM career aspirations; (Fadigan and Hammrich, 2004)]. As Lane and Id-Deen (2020) showed, these supportive networks can also help improve participants' STEM skills, thus fostering their performance.

As a further supportive mechanism, Lane and Id-Deen (2020) report that educators and staff built up participants' cultural capital by telling them about the missing representation of Black students in STEM. While doing so, they also encouraged students not to be discouraged by this underrepresentation and simultaneously informed them about the necessary steps to enter a STEM career (Lane and Id-Deen, 2020). Hence, educators and staff supported students on a psychological level and helped them become more resilient and persistent. This persistence and resilience were further promoted through supportive relationships with other participants in the program, which also fostered students' sense of belonging (Lane and Id-Deen, 2020). Moreover, findings from some studies showed that mentors also encouraged students' career aspirations and STEM identity development (Blanchard et al., 2015; Lane and Id-Deen, 2020). Supportive allies such as coaches and mentors enhanced students' competence by being an important source of information concerning future STEM opportunities (Blanchard et al., 2015). Kuchynka et al. (2022) compared different types of supportive relationships in STEM programs to investigate their differing influential power. Their results showed that near-peer mentors had a greater influence on students' STEM identity development and their social belonging than teachers did. They argue that near-peer mentors are closer to participants' lifestyles and hence offer a better opportunity to identify with them. Moreover, Pinkard et al. (2017) argue that mentors who come from similar backgrounds as participants can help students in finding ways to overcome barriers to STEM by sharing their own strategies.

5.1.6. Agency: constructing a self-narrated STEM identity

We identified the concept of *agency* as an additional factor contributing to STEM identity development in several of the reviewed publications. In these articles, agency was observed when participants were given the opportunity to construct their own understanding of STEM identity during the program (see Rahm and Ash, 2008; Calabrese Barton and Tan, 2010; Scott and White, 2013; Blanchard et al., 2015; Rahm and Moore, 2016; Pinkard et al., 2017; Burke and Navas Iannini, 2021; Calabrese Barton et al., 2021; Archer et al., 2022). For instance, when participants experienced themselves as the owners of their projects or were positioned as people with their self-created STEM identity (e.g., Rahm and Ash, 2008). For being agent, participants needed to realize their own strengths and worth (Blanchard et al., 2015). Burke and Navas Iannini (2021) point out that the link between activities and students' agency in STEM needs to be made explicit to be influential in STEM identity development. By contextualizing STEM programs in students' own communities and criticizing traditional STEM practices, participants were able to connect personal or cultural experiences with STEM. Hence, they were able to connect their other identities within their STEM identities, which prevented identity conflicts (Calabrese Barton and Tan, 2010). Apart from this individual focus on agency, Archer et al. (2022) emphasize the importance of a collective agency among underserved learners, which they argue can be promoted through recognition and explicit representation of a rightful presence of underserved people in STEM.

5.1.7. Interest and attitudes: a strong interest and positive attitudes towards STEM foster further engagement

Further adding to the concepts that influence STEM identity development, we recognized that some articles showed that engaging in STEM interventions maintained an *interest* in STEM in underserved students (Burke and Navas Iannini, 2021) or even led to a higher interest (Archer et al., 2022) and more positive *attitudes* towards STEM (Burke and Navas Iannini, 2021; Archer et al., 2022; Kuchynka et al., 2022). However, we also saw that programs for underserved students can lead to negative attitudes about STEM and therefore hinder STEM identity development when traditional ways of engaging in STEM are being transported, as can be seen in Salvadó et al. (2021). When students' views of STEM were changed to more favorable ones, they opened up to the possibility of further engagement in STEM, which indicates a positive STEM identity development. As mentioned by Pinkard et al. (2017), a stronger interest can lead to a stronger engagement with the program itself. Students' attitudes towards STEM were positively influenced when significant others, such as teachers, students, parents, or community leaders, recognized students' successes (Blanchard et al., 2015).

5.2. Methods to nurture STEM identity development in underserved students

Although all of the analyzed programs in the articles aimed to nurture STEM identity development in underserved students, they used different practical approaches to do so. We conducted a synthesis of the practical approaches employed in the programs as detailed in the articles and will provide a summary of the most commonly used methods. These methods included establishing personal relationships and providing role models, utilizing authentic settings, engaging in hands-on activities, and implementing non-stereotypical structures that promote agency. In the following sections, we will present those methods in more detail.

5.2.1. Foster relationships between participants

It is reported that fostering relationships between participants positively impacted a group identity and the feeling of wanting everyone to succeed, which can further motivate participants to engage in the program (Lane and Id-Deen, 2020). Most of the programs that have been investigated in the articles explicitly used methods to foster a social network and personal relationships between participants. For example, many articles reported that programs intentionally initiated group work between participants on either whole programs or on specific occasions during the programs (Rahm and Ash, 2008; Burke and Navas Iannini, 2021; Salvadó et al., 2021; Archer et al., 2022; Kuchynka et al., 2022). Further methods to foster a social network between participants were: (i) making room for discussions and personal conversations (Fadigan and Hammrich, 2004; Scott and White, 2013), (ii) ensuring that there are no competitions between participants in one program (Lane and Id-Deen, 2020) by (iii) fostering a group identity through competitions against teams from other programs (Blanchard et al., 2015), as well as

(iv) implementing group games (Burke and Navas Iannini, 2021), and (v) team-building activities (Burke and Navas Iannini, 2021). Moreover, some of the programs made sure to accept participants from similar family backgrounds only, similar ethnic backgrounds, and/or the same gender to create a sense of belonging (Fadigan and Hammrich, 2004; Calabrese Barton and Tan, 2010; Scott and White, 2013; Rahm and Moore, 2016; Pinkard et al., 2017; Lane and Id-Deen, 2020).

5.2.2. Foster relationships between participants and staff

In addition to social networks between participants, many programs aimed to enhance supportive relationships for students by creating personal relationships between participants and program staff such as educators, teachers, mentors, or scientists. In order to do so, the articles reported that programs made room for discussions as well as personal conversations (Fadigan and Hammrich, 2004), and implemented group games as well as team-building activities for participants and staff (Burke and Navas Iannini, 2021). Furthermore, some articles mentioned nurturing a deeper relationship between participants and staff by questioning the hierarchical relationships between staff and participants by (i) making jokes (Archer et al., 2022), (ii) playing music during program sessions and providing sweets (Archer et al., 2022) as well as (iii) calling teachers by their first name (Calabrese Barton and Tan, 2010).

5.2.3. Provide students with role models

The implementation of mentors in the forms of near-peer mentors (Blanchard et al., 2015; Rahm and Moore, 2016; Burke and Navas Iannini, 2021; Kuchynka et al., 2022), industry mentors (Blanchard et al., 2015), or mentor-teachers (Scott and White, 2013) was another method most of the programs used to foster a social network and to give students role models as possibilities for identification. Further tactics to strengthen a network and opportunities for identification were hiring ethnically diverse staff (Pinkard et al., 2017; Lane and Id-Deen, 2020) and meeting real scientists from ethnically diverse backgrounds (Archer et al., 2022; Kuchynka et al., 2022).

5.2.4. Use student-centered hands-on activities, experiments, and authentic scientific contexts

In most of the programs, student-centered hands-on activities such as interviewing the public, lab activities, or creating some kind of artwork as well as experiments (Fadigan and Hammrich, 2004; Rahm and Ash, 2008; Calabrese Barton and Tan, 2010; Rahm and Moore, 2016; Pinkard et al., 2017; Burke and Navas Iannini, 2021; Salvadó et al., 2021; Kuchynka et al., 2022) were used to bring in fun elements for further engagement and to enhance participants' STEM-specific skills. Furthermore, many of the programs let students experience authentic scientific contexts. Examples of such methods were meeting scientists (Fadigan and Hammrich, 2004; Rahm and Moore, 2016; Salvadó et al., 2021), making field trips to different informal STEM learning sites and colleges or universities (Fadigan and Hammrich, 2004; Calabrese Barton and Tan, 2010; Scott and White, 2013; Rahm and Moore, 2016; Kuchynka et al., 2022), conducting hands-on experiments with own hypotheses and authentic data collection processes (Calabrese Barton and Tan, 2010), and working on projects with practical scientific value (Scott and White, 2013; Rahm and Moore, 2016).

5.2.5. Foster participants' autonomy and agency

A central practice in the analyzed programs was to foster participants' autonomy and agency. For instance, participants were asked to work on project topics of their own choice (Rahm and Ash, 2008; Calabrese Barton and Tan, 2010; Scott and White, 2013; Rahm and Moore, 2016). Staff asked the students to bring their own ideas into the programs by co-designing project elements (Pinkard et al., 2017) or co-planning activities with teachers (Calabrese Barton and Tan, 2010). Participants were positioned as responsible and agentic creators of their projects when they were enabled to interview members of the public (Calabrese Barton and Tan, 2010) and to present their projects to the public as well as political representatives (Calabrese Barton and Tan, 2010; Scott and White, 2013), for example in forms of self-created announcements for local TV channels (Calabrese Barton and Tan, 2010). Pinkard et al. (2017) also mention an additional online-tool, which enabled participants to engage with the program on an individual level and to add their own views and experiences to the program.

5.2.6. Explicitly foster non-stereotypical ways of doing or being in STEM

In some cases, programs used specific methods to explicitly foster non-stereotypical ways of doing or being in STEM to make it more accessible for students. For instance, in the program investigated by Pinkard et al. (2017) program coordinators used a narrative storyline with non-stereotypical characters (Black girls doing STEM activities) to structure club activities. In another program, students were allowed to use informal language and abbreviations in power point presentations and videos which would be called informal elsewhere (Calabrese Barton and Tan, 2010). Moreover, in some cases, students were encouraged to criticize staff's practices allowing them to question traditional STEM stereotypes and hierarchies in programs to make room for non-traditional ways of doing or being in STEM, hence making it more relatable for students (Scott and White, 2013; Calabrese Barton et al., 2021; Archer et al., 2022).

5.3. Experiences of underserved students for further investigation

Although the analysis of the articles resulted in a detailed list of superordinate key theories and concepts with factors that can affect STEM identity development, we also identified little moments and experiences mentioned by underserved students themselves, which indicated there might be further influential categories and factors. In the following, we will give some examples of those moments by presenting original quotes given by participants of different programs and analyzing indications for further investigation.

5.3.1. Role of emotions: having a safe space

Some participants mentioned the personal and emotional value of the programs in terms of feeling safe and valued. For example, the importance of informal STEM learning settings as safe spaces for participants was mentioned by some participants in Fadigan and Hammrich's (2004) research as they talked about their peers in the program:

> A lot of them came from similar socio-economic backgrounds that I did, similar parts of the city that I did where the crime rate tends to be up, violence tends to be a big factor there, single-parent homes. To be able to have people that understand you in that way and to connect with you in that way tends to be very helpful, tends to kind of provide a safety net for you to lean back on. To have somebody there encouraging you when you kind of get discouraged by what you see around you. (p. 851)

Moreover, some students mentioned the setting as their safe space in terms of giving them hope and an actual place for safety from harm:

> Maureen stated, "it was definitely really helpful in helping me to put myself in an ambitious mind set, to know that there's a lot more for me out there than just living in North Philly dodging bullets." Similarly, Arlene commented, "I don't have to worry about a drive-by. That's always good." (Fadigan and Hammrich, 2004, p. 852)

Other students mentioned the feeling of being valued as an important factor when interacting in the program. For example, a student in the study of Calabrese Barton et al. (2021) said:

> When I'm here [at science club] I feel like I can be me. Like, it's not judgmental here. We get to learn and do things and experiments and make things that are real, and they help people… When people see [my light-up dog leash] and they use it, they'll say I did a good job, and I stood up for myself. They'll say I worked hard, and I'm really good at science, and like caring for dogs and people. It's weird because I didn't even like science, but it felt different here to make something for dogs. (p. 1,230)

Or, as another participant stated:

> I'm going to explain what STEM Club is to me, and I've heard comments like this. STEM Club is a place where I can be me, where I can build things, sometimes to help with anger issues. It's just a place where I call home, besides my actual house. A place where I can go to hang out with my friends, talk a little, enjoy life, be young, even though I'm about to be a teenager soon. (Calabrese Barton et al., 2021, pp. 1,245–1,246)

These instances give us hints that a focus on emotional factors could be key for reaching those underserved students who are affected by extreme factors such as missing family support or living in extremely dangerous neighborhoods.

5.3.2. "Underserved students need to work harder"

Some participants mentioned pressure to do better and work harder than not-underserved peers in order to achieve a career in STEM fields. For example, one Black girl in a program said that „they [teacher and program director] tell us it's not a lot of Black people that are engineers and doctors, so that means we need to make sure we work hard to be one of those. "(Lane and Id-Deen, 2020, p. 13). This pressure becomes even more evident in another incident, where one participant "signed the reflection statement with the note, 'Failure is NOT an option!'" (Rahm and Moore, 2016), after being asked to reflect on the program and its impact on his future. Clearly, this pressure could influence the STEM identity development in those students as it might create negative attitudes towards STEM careers.

5.3.3. School STEM vs. club STEM

In their article, Burke and Navas Iannini (2021) discuss the fact that many of the students in the program viewed 'club STEM', as they refer to the activities in the program, as something completely different and unrelated to school STEM. In those cases, the students saw school STEM as rather uninteresting, whereas club activities were viewed as 'real STEM'. For example, one participant answered when being asked about his interest in science:

> Moderator: Okay, what about you John, were you interested in science before the club?
>
> John: Yeah
>
> Moderator: You were?
>
> John: The thing that I didn't want to do when I come is the long stuff like what school does! (Burke and Navas Iannini, 2021, p. 1,444)

This dialog indicates the structure of school STEM activities might hinder STEM identity development for those students. Further, the missing connection between club STEM and school STEM might hinder future STEM identity development in general. The gap participants felt between those two STEM contexts might lead to an identity conflict and needs to be overcome to develop a strong, positive STEM identity in the future (Burke and Navas Iannini, 2021). On the contrary, when intertwined with each other, school STEM and out-of-school programs might be able to foster STEM identity development for underserved students even better. This idea is mentioned by another participant in the same study:

> STREAM: Say like during a Monday to a Friday you were, like, going to school and stuff, say you could like have a project … you should be able to, like, come here and they should be able to, like, help you with that
>
> Moderator: That's an interesting point STREAM. You think that being able to bring your projects from school would make the [science club] a little bit better?
>
> STREAM: And they'll be able to like help you …
>
> Moderator: Okay, so kind of like homework that's related to the club?
>
> STREAM: Yeah! (p. 1,446)

6. Discussion and implications

This study investigated articles that examined out-of-school programs for underserved learners and synthesized key concepts that influence students' STEM identity development as well as practical approaches used to enhance those concepts. Moreover, we shed light on the voices of some underserved students themselves, which hint at additional concepts for further investigation. In the following, we will discuss these findings and give recommendations for practice, research, and policy makers.

6.1. A theoretical framework for STEM identity development in underserved learners

As we have argued before, there was no consensus on one universal framework and definition of STEM identity in the analyzed papers. We drew from Carlone and Johnson's (2007) definition of science identity for our analysis and found instances of competence ('knowing science'), performance ('doing science'), and recognition ('being science') as the dimensions of STEM identity development across the analyzed publications. However, we believe that since the marginalization of underserved children in STEM is based on multiple factors, fostering a positive STEM identity development in those children needs to focus on several overlapping and interconnecting factors, especially on systematic issues leading to such marginalization. Accordingly, we identified further concepts that occurred across the analyzed publications that contributed to students' STEM identity development, namely a sense of belonging, support, agency as well as interest and attitudes. In the following, we will compare our findings with common frameworks for STEM identity development and discuss concepts, which are especially important for fostering underserved learners' STEM identity development.

There are various frameworks for STEM identity. For example, there are frameworks for physics identity (Hazari et al., 2020), math identity (Steele, 1997), or computing identity (Mahadeo et al., 2020). According to our analysis, we find some overlaps with these identity frameworks, as, for example, the dimensions of interest and sense of belonging can also be found in the frameworks of Hazari et al. (2020) and Steele (1997), whilst interest can be found in Mahadeo et al.'s (2020) framework as well. The concepts of supportive relationships and agency, which we also identified, are no dimensions in any of those frameworks. According to Carlone and Johnson (2007), however, meaningful others play an important supportive role in recognition processes. In addition to that, Avraamidou (2020b) argues that the concept of recognition is strongly intertwined with emotions, particularly when looking at STEM identity from an intersectional lens, which indicates further connections between recognition, relationships to supportive others, and underlying emotional processes. Griffith et al. (2019) have shown that students who faced discrimination along intersecting axes of oppression in educational settings felt less recognized and had a low sense of belonging. This lower sense of belonging was also found in women as underserved group in math by Good et al. (2012). Moreover, McGee (2016) reported identity conflicts in underserved students due to racial stereotypes. Those students reported the need for special support structures to find coping strategies and overcome identity conflicts (McGee, 2016; Griffith et al., 2019). Although it is crucial to establish support structures to assist individuals in developing strategies to combat racism, sexism, classism, and other types of oppression in our current systems, we argue that the real solution is systematic change. Our analysis and common STEM identity frameworks suggest that recognition, a sense of belonging, and supportive relationships are critical concepts in altering current mechanisms and facilitating STEM identity development for underserved learners. Due to the lack of representation of underserved groups in STEM, these students have fewer opportunities for identification and therefore have not been encouraged to feel a sense of belonging. Consequently, they have been excluded from recognition in STEM fields as those who do not fit the standard are not encouraged to become insiders. Furthermore, we emphasize the need to prioritize the concept of agency to enable students to engage in STEM identity work consistent with their current forms of capital and identities.

Our second research question aimed at finding relating practical approaches that contribute to underserved students' STEM identity development. An overview of the concepts, the practical approaches linked to these, and evidence where they can be found are given in Table 2. As Danielsson et al. (2023) claim, "it is noticeable that even when research-based instructional strategies have proven to be very successful in improving students' conceptual understanding and their reasoning, the adoption of such strategies more broadly is still low" (Danielsson et al., 2023, p. 20). Hence, in Table 2 we synthesized concepts as well as relating practical approaches that can foster underserved students' STEM identity development for educators in out-of-school STEM learning contexts to use in designing new programs.

6.2. On the role of recognition, sense of belonging, supportive relationships, and agency to position underserved students as insiders in STEM

In the following, we will elaborate on the significance of recognition, a sense of belonging, supportive relationships, and agency in the development of underserved students' STEM identities. We will criticize systemic exclusions present in STEM fields that disregard or impede these concepts. Our third research objective was to identify the experiences of underserved learners in the analyzed STEM learning interventions that shed light on aspects for further investigations. We will demonstrate how these experiences are connected to the criticized systematic exclusions in STEM fields. Furthermore, looking forward, we will discuss how our findings on practical approaches can be used to serve underserved students in terms of recognition, sense of belonging, supportive relationships, and agency.

In general, following Harper and Kayumova's (2022) argumentation, we claim that deficit-based perspectives on underserved learners as well as issues of belonging and representation play a problematic role in hindering STEM identity development in underserved learners rather than students' academic skills or interests. As argued before, with regard to underserved learners, special attention should be given to the role of recognition, sense of belonging, supportive relationships as well as agency as a countermeasure. In the following, we will discuss the importance of these concepts for underserved learners' STEM identity development. According to Kayumova and Dou (2022), science education is influenced by deficit-oriented approaches which base on, for example, hierarchical structures and neglect the value of non-western ways of being and knowing in science. As a consequence, STEM learning opportunities create barriers and mindsets which exclude and other underserved students (Kayumova and Dou, 2022). Combined with the conscious experience of racism and stereotypes (McGee, 2016; Griffith et al., 2019; Burnett et al., 2022), these traditional views lead to a missing recognition of underserved students as STEM persons by others e.g., teachers, (Pringle et al., 2012) as well as themselves (Kim et al., 2018). Thus, underserved learners often feel like they do not belong and experience less recognition in STEM fields, as those who deviate from established norms are often overlooked. To foster inclusivity and recognition, STEM settings must acknowledge and embrace a diverse range of identities as legitimate within the field. It is necessary that all students, not only those who conform to the norm, are reflected and validated as belonging in STEM. As our analysis shows, possible practical approaches to do so are to foster social networks between participants as well as between participants and staff, to provide students with role models, and to foster non-traditional ways of doing or being in STEM (Table 2). As Robnett and Leaper (2013) have shown, friendship group support led to higher interest in STEM careers in ethnically diverse high school students. Moreover, Leath et al. (2022) reported in their study on Black undergraduate women that friendships between Black female students were seen as "homeplaces" (Leath et al., 2022, p. 837) and important factors in their identity development. We also found this emotional value of supportive friendships as 'homeplaces' or 'safe spaces' in the quotes by underserved learners. Our analysis shows that apart from parents and friends, near-peer mentors and educators of diverse backgrounds were frequently used in projects to support students. Following this, other studies have shown that such educators or mentors with similar backgrounds as participants were important influences for student participation (Kricorian et al., 2020), for finding coping strategies when being confronted with oppression along intersecting axes of power (Griffith et al., 2019), and for enhancing persistence in STEM fields (Estrada et al., 2022). Thus, supportive relationships, a sense of belonging, and recognition seem to be closely intertwined with each other as well as with emotions when it comes to STEM identity development in underserved learners.

The traditional power relations in STEM limit learners' views of who can be an insider to STEM and what these insiders have to act like (Kayumova and Dou, 2022). This is especially problematic for students with identities (such as cultural, ethnic, or religious) that might not fit with this narrowed image of who can be an insider to STEM (McGee, 2016; Avraamidou, 2020a). Because of this, underserved students may feel like they have to work harder than their not-underserved peers (Griffith et al., 2019; Burnett et al., 2022) and modify their other identities (McGee, 2016) to achieve the goals in STEM contexts. This pressure to work harder was also mentioned by some of the students in our analyzed study (Rahm and Moore, 2016; Lane and Id-Deen, 2020). In our view, these identity conflicts might lead to either no STEM identity development or to adapting an imposed STEM identity leading to a neglecting of racial or cultural identities as was the case in the study of McGee (2016). This might lead to less stable STEM identities and alienation from families and communities (El-Mafaalani, 2017). Hence, we find it crucial to enable underserved students to become agent individuals in building their own STEM identities by findings ways in which they can connect their STEM identity to their own social and cultural capital (Brickhouse, 2001; Shanahan, 2009; Morton and Parsons, 2018). To do so, STEM fields need to be more open and implement practical approaches in out-of-school contexts that foster this agency, such as including role models, student-centered hands-on activities, and methods that explicitly foster participants' autonomy and agency (Table 2). Furthermore, it takes a will to change and reflect on the part of out-of-school STEM educators. We agree with Avraamidou (2021) that educators need to reflect on their recognition policies, meaning who they recognize as STEM persons and why, for example in accompanying training for educators.

6.3. Recommendations for practice

In general, the findings of this study suggest that STEM learning settings such as out-of-school contexts need to focus on more than just raising participation rates to enhance STEM identity development in underserved learners. Instead, educators and educational systems should work "toward a pluriverse of multiple identities" (Kayumova and Dou, 2022, p. 1) that are possible and have a rightful place in STEM fields. As we have shown, fostering concepts such as recognition, supportive relationships, a sense of belonging, and agency are needed to position these students as insiders to STEM. One possible implication of this is that we need more long-term interventions for underserved learners on a regular basis. Moreover, we suggest that the educational perspectives on underserved learners should focus on their strengths and needs. To achieve this, educational staff could avoid creating predetermined STEM settings that define what STEM is, what a STEM person should be like, and what is considered right or wrong in STEM contexts. Rather, educational settings should be more flexible and less rigid, acknowledging individuals as they are and recognizing their strengths. The focus should be on supporting individuals to achieve their full potential. This way, STEM learning settings might be able to truly serve those learners and support them in ways they need to find their own ways of being in STEM. In order to do so, STEM education settings need to change to enhance STEM identity development for all and to ensure truly equitable access to STEM for all groups of people. As Kayumova and Dou (2022) put it:

> If science spaces continue to operate through dominant cultural norms and values, merely providing access to materials or opportunities to participate in science will not make the kind of changes we seek. […] From this perspective, the design of learning ecologies must create condi-tions of possibility that center on identities, community histories, relations, and experiences of racialized youth from nondominant communities rather than erase them." (p. 17)

To implement such changes, educators in informal STEM education settings can work with students in community-based spaces (Dawson, 2017) and choose projects on socio-scientific issues as a way to bridge students' lives and STEM learning. As Gonsalves et al. (2021) have shown, students need peer groups or communities in STEM contexts that support each other and give them a sense of belonging to persist. Hence, informal STEM programs should not only be physically based in the students' community but also connect with its people to build strong relationships. On a practical level, this takes regular activities, such as icebreaker activities or games that

TABLE 2 Key concepts and corresponding practical approaches for STEM identity development in underserved learners.

Key concepts of STEM identity development	Practical approaches	Publications
Competence	- Student-centered hands-on activities, experiments, and authentic scientific contexts	Archer et al. (2022), Blanchard et al. (2015), Burke and Navas Iannini (2021), Fadigan and Hammrich (2004), Rahm and Ash (2008), Rahm and Moore (2016), Salvadó et al. (2021)
Performance	- Student-centered hands-on activities, experiments, and authentic scientific contexts	Archer et al. (2022), Blanchard et al. (2015), Burke and Navas Iannini (2021), Fadigan and Hammrich (2004), Rahm and Ash (2008), Rahm and Moore (2016), Scott and White (2013)
Recognition	- Foster relationships between participants - Foster relationships between participants and staff - Explicitly foster non-stereotypical ways of doing or being in STEM	Archer et al. (2022), Burke and Navas Iannini (2021), Calabrese Barton et al. (2021), Fadigan and Hammrich (2004), Lane and Id-Deen (2020), Pinkard et al. (2017), Rahm and Moore (2016), Scott and White (2013)
Sense of belonging	- Foster relationships between participants - Foster relationships between participants and staff - Provide students with role models	Archer et al. (2022), Blanchard et al. (2015), Burke and Navas Iannini (2021), Calabrese Barton et al. (2021), Fadigan and Hammrich (2004), Kuchynka et al. (2022), Lane and Id-Deen (2020), Pinkard et al. (2017), Rahm and Moore (2016), Salvadó et al. (2021), Scott and White (2013)
Supportive relationships	- Foster relationships between participants - Foster relationships between participants and staff	Blanchard et al. (2015), Burke and Navas Iannini (2021), Calabrese Barton et al. (2021), Calabrese Barton and Tan (2010), Fadigan and Hammrich (2004), Kuchynka et al. (2022), Lane and Id-Deen (2020), Rahm and Ash (2008), Salvadó et al. (2021), Scott and White (2013)
Agency	- Provide students with role models - Student-centered hands-on activities, experiments, and authentic scientific contexts - Foster participants' autonomy and agency	Archer et al. (2022), Blanchard et al. (2015), Burke and Navas Iannini (2021), Calabrese Barton et al. (2021), Calabrese Barton and Tan (2010), Pinkard et al. (2017), Rahm and Ash (2008), Rahm and Moore (2016), Scott and White (2013)
Interest and attitudes	- Student-centered hands-on activities, experiments, and authentic scientific contexts	Archer et al. (2022), Blanchard et al. (2015), Burke and Navas Iannini (2021), Kuchynka et al. (2022), Pinkard et al. (2017)

allow students to get to know each other as well as educators and community members on a personal level. Moreover, educators can implement arts-based practices to offer alternative ways for students to create their own STEM identity. An example can be found in Chappell and Varelas (2020) who used ethnodance as an arts-based practice to study STEM identity. The implementation of mentors from similar backgrounds as participants can further focus participants' cultural capital in STEM programs. Avraamidou (2021) argues that programs on how underserved groups of learners are being recognized are needed on a systemic level. Following this advice, mentors who are regularly trained on recognition issues seem crucial to allow multiple possible student identities to become STEM insiders.

Informal spaces such as museums should hire diverse staff and ask them to implement their valuable socio-historical experiences and cultural values into the design of museum spaces. Further, museums could seek collaborations with schools in underserved communities and engage in mutual projects. For example, students could work on STEM-related arts projects in their schools, which could be displayed in local museums. Strong partnerships between practitioners in informal settings and researchers can help to enhance equitable STEM education. For example, practitioners and researchers can work together in defining key equity research foci and designing corresponding activities to foster equitable STEM learning. For more details and best-practice examples of such research-practice partnerships see (Penuel, 2017). A strong collaboration between practitioners and researchers might also help bridge the gap between 'school STEM' and 'club STEM' mentioned by some underserved students.

In formal education contexts, little "pockets of equitable practice" (Dawson, 2017, p. 544) need to be inserted as often as possible. Such practices can include, for example, involving students in planning activities or decision processes, hence positioning them as valuable insiders (Dawson, 2017). Moreover, teachers in schools should reflect on their own STEM practices and be trained to observe their own values and lessons from an equity-perspective. These reflection practices can be taught in pre-service teacher education as well. Further valuable impulses for inserting equitable practices in science classrooms can be found in Godec et al. (2017), who offer very detailed guidelines for student engagement through a social justice lens in their "Science Capital Teaching Approach." In addition to that, teachers and educators in school as well as in tertiary education should become aware of their stereotypes and their bias concerning underserved students. General guiding principles for re-framing anti-Blackness in STEM education can be found in Morton et al. (2022).

6.4. Recommendations for research and limitations of the current study

Our analysis offers insights into the STEM identity development of underserved learners in out-of-school contexts at the middle and high school levels. Still, we cannot fully explain the concepts behind the STEM identity development of underserved learners due to various limitations. First of all, there might be further concepts and factors which stem from school, home, and other social contexts that can foster or hinder such a development. Since some of the students in our analyzed study mentioned a distinction between STEM in school and out-of-school contexts, it might be interesting to investigate underserved learners' STEM identity in school contexts as well. Also, this could help to further develop a universal framework for STEM identity in general. Since such a framework was missing in most of our analyzed studies, we had to define indicators for STEM identity development ourselves, which also limits the findings of our study. Further investigation of the concepts found in this study in out-of-school contexts can help to validate our findings and add to a framework. Moreover, most of the studies stem from U.S. contexts. Hence, following Danielsson et al. (2023), it might be interesting for further research to focus on underserved learners in a European context since they might be influenced by different cultural, social, historical, and/or religious identities. In this regard, it seems advisable to aim at anti-deficit frameworks for research. Harper (2010) gives some helpful suggestions for re-framing deficit-oriented questions such as "Why do so few Black male students enroll in college?" to an anti-deficit question like "How were college aspirations cultivated among Black male undergraduates who are currently enrolled?" (Harper, 2010, p. 68).

Concerning the concepts influencing STEM identity development that were found in this study, it seems especially interesting to examine the role of emotions as well as agency in STEM identity development. According to Avraamidou (2020b), STEM identity development is intersectional and strongly influenced by positive and negative emotions. Hence, emotions might influence many of the concepts analyzed, such as recognition, supportive relationships, or a sense of belonging. From an equity perspective, it could be very useful to have more findings on when students adapt to imposed STEM identities (hence neglecting their other identities) and how they can create their own authentic identities.

6.5. Recommendations for policies

Policy makers such as politicians and stakeholders from NGOs, academics, or others can play a crucial role in supporting underserved students through re-imagining STEM education. A reasonable approach to tackle this issue might be to implement referring to students' social, historical, and cultural capital into school science curricula. A possible way might be to focus less on field-specific topics, but rather make the UN Sustainable Development Goals a central focus of those curricula. This enables educators to implement more socio-scientific issues into science classes and to build on students' personal lives. Moreover, the policy could focus their funding for STEM education programs on non-deficit research as well as community-driven projects. In this regard, underserved students could be served by funding additional out-of-school programs and scholarships for them. An implemented training on inclusive STEM education and traditional power relations in the training of educators and teachers can help to create general awareness and create welcoming structures where all students feel like they belong. Furthermore, strategies to enhance equitable STEM education settings might involve recruiting more diverse teaching staff.

Author contributions

JÇ, AS, and IP contributed to the conception and design of the study. The methods and main results were discussed with all authors at various stages. JÇ and AS collectively worked on the main outline of the article and discussed all sections at various stages. JÇ drafted all the sections of the paper. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Archer, L., Calabrese Barton, A. M., Dawson, E., Godec, S., Mau, A., and Patel, U. (2022). Fun moments or consequential experiences? A model for conceptualising and researching equitable youth outcomes from informal STEM learning. *Cult. Stud. Sci. Educ.* 17, 405–438. doi: 10.1007/s11422-021-10065-5

Archer, L., Dawson, E., DeWitt, J., Seakins, A., and Wong, B. (2015). "Science capital": a conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *J. Res. Sci. Teach.* 52, 922–948. doi: 10.1002/tea.21227

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., and Wong, B. (2010). "Doing" science versus "being" a scientist: examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Sci. Educ.* 94, 617–639. doi: 10.1002/sce.20399

Auger, R. W., Blackhurst, A. E., and Wahl, K. H. (2005). The development of elementary-aged Children's career aspirations and expectations. *Prof. Sch. Couns.* 8, 322–329.

Avraamidou, L. (2020a). "I am a young immigrant woman doing physics and on top of that I am Muslim": identities, intersections, and negotiations. *J. Res. Sci. Teach.* 57, 311–341. doi: 10.1002/tea.21593

Avraamidou, L. (2020b). Science identity as a landscape of becoming: rethinking recognition and emotions through an intersectionality lens. *Cult. Stud. Sci. Educ.* 15, 323–345. doi: 10.1007/s11422-019-09954-7

Avraamidou, L. (2021). Identities in/out of physics and the politics of recognition. *J. Res. Sci. Teach.* 59, 58–94. doi: 10.1002/tea.21721

Baran, E., Canbazoglu Bilici, S., Mesutoglu, C., and Ocak, C. (2019). The impact of an out-of-school STEM education program on students' attitudes toward STEM and STEM careers. *Sch. Sci. Math.* 119, 223–235. doi: 10.1111/ssm.12330

Blackburn, H. (2017). The status of women in STEM in higher education: a review of the literature 2007–2017. *Sci. Technol. Libr.* 36, 235–273. doi: 10.1080/0194262X.2017.1371658

Blanchard, S., Judy, J., Muller, C., Crawford, R. H., Petrosino, A. J., White, C. K., et al. (2015). Beyond blackboards: engaging underserved middle school students in engineering. *J. Pre-Coll. Eng. Educ. Res.* 5, 1–13. doi: 10.7771/2157-9288.1084

Bodnar, K., Hofkens, T. L., Wang, M.-T., and Schunn, C. D. (2020). Science identity predicts science career aspiration across gender and race, but especially for White boys. *Int. J. Gend. Sci. Technol.* 12, 32–45.

Brickhouse, N. W. (2001). Embodying science: a feminist perspective on learning. *J. Res. Sci. Teach.* 38, 282–295. doi: 10.1002/1098-2736(200103)38:3<282::AID-TEA1006>3.0.CO;2-0

Brown, B. A. (2004). Discursive identity: assimilation into the culture of science and its implications for minority students. *J. Res. Sci. Teach.* 41, 810–834. doi: 10.1002/tea.20228

Brown, B. A., Reveles, J. M., and Kelly, G. J. (2005). Scientific literacy and discursive identity: a theoretical framework for understanding science learning. *Sci. Educ.* 89, 779–802. doi: 10.1002/sce.20069

Burke, L. E. C.-A., and Navas Iannini, A. M. (2021). Science engagement as insight into the science identity work nurtured in community-based science clubs. *J. Res. Sci. Teach.* 58, 1425–1454. doi: 10.1002/tea.21714

Burnett, M., McBride, M., Green, M. N., and Cooper, S. M. (2022). When I think of black girls, I think of opportunities: black Girls' identity development and the protective role of parental socialization in educational settings. *Front. Psychol.* 13:933476. doi: 10.3389/fpsyg.2022.933476

Calabrese Barton, A., Greenberg, D., Kim, W. J., Brien, S., Roby, R., Balzer, M., et al. (2021). Disruptive moments as opportunities towards justice-oriented pedagogical practice in informal science learning. *Sci. Educ.* 105, 1229–1251. doi: 10.1002/sce.21682

Calabrese Barton, A., and Tan, E. (2010). We be Burnin'! Agency, identity, and science learning. *J. Learn. Sci.* 19, 187–229. doi: 10.1080/10508400903530044

Carlone, H. B., and Johnson, A. (2007). Understanding the science experiences of successful women of color: science identity as an analytic lens. *J. Res. Sci. Teach.* 44, 1187–1218. doi: 10.1002/tea.20237

Carlone, H. B., Scott, C. M., and Lowder, C. (2014). Becoming (less) scientific: a longitudinal study of students' identity work from elementary to middle school science. *J. Res. Sci. Teach.* 51, 836–869. doi: 10.1002/tea.21150

Chakraverty, D. (2022). Impostor phenomenon and identity-based microaggression among Hispanic/Latinx individuals in science, technology, engineering, and mathematics: a qualitative exploration. *Violence Gend.* 9, 135–141. doi: 10.1089/vio.2021.0061

Chappell, M. J., and Varelas, M. (2020). Ethnodance and identity: black students representing science identities in the making. *Sci. Educ.* 104, 193–221. doi: 10.1002/sce.21558

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: a black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *Univ. Chic. Leg. Forum* 1989, 139–167.

Dabney, K. P., Tai, R. H., Almarode, J. T., Miller-Friedmann, J. L., Sonnert, G., Sadler, P. M., et al. (2012). Out-of-school time science activities and their association with career interest in STEM. *Int. J. Sci. Educ., Part B* 2, 63–79. doi: 10.1080/21548455.2011.629455

Danielsson, A. T., King, H., Godec, S., and Nyström, A.-S. (2023). The identity turn in science education research: a critical review of methodologies in a consolidating field. *Cult. Stud. Sci. Educ.*, 1–60. doi: 10.1007/s11422-022-10130-7

Dawson, E. (2014a). Not designed for us: how science museums and science centers socially exclude low-income. *Minority Ethnic Groups. Sci. Educ.* 98, 981–1008. doi: 10.1002/sce.21133

Dawson, E. (2014b). Equity in informal science education: developing an access and equity framework for science museums and science centres. *Stud. Sci. Educ.* 50, 209–247. doi: 10.1080/03057267.2014.957558

Dawson, E. (2017). Social justice and out-of-school science learning: exploring equity in science television, science clubs and maker spaces. *Sci. Educ.* 101, 539–547. doi: 10.1002/sce.21288

DeWitt, J., and Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *Int. J. Sci. Educ.* 37, 2170–2192. doi: 10.1080/09500693.2015.1071899

Dortch, D., and Patel, C. (2017). Black undergraduate women and their sense of belonging in STEM at predominantly White institutions. *NASPA J. About Women High. Educ.* 10, 202–215. doi: 10.1080/19407882.2017.1331854

Dou, R., and Cian, H. (2022). Constructing STEM identity: an expanded structural model for STEM identity research. *J. Res. Sci. Teach.* 59, 458–490. doi: 10.1002/tea.21734

Eccles, J. S. (1994). Understanding women's educational and occupational choices: applying the Eccles et al. Model of achievement-related choices. *Psychol. Women Q.* 18, 585–609. doi: 10.1111/j.1471-6402.1994.tb01049.x

El-Mafaalani, A. (2017). "Transformationen des Habitus" in *Pierre Bourdieu: Pädagogische Lektüren*. eds. M. Rieger-Ladich and C. Grabau (Wiesbaden: Springer Fachmedien Wiesbaden), 103–127.

Estrada, M., Young, G., Flores, L., Hernandez, P. R., Hosoda, K. K., and DeerInWater, K. (2022). Culture and quality matter in building effective mentorship relationships with native STEM scholars. *Bioscience* 72, 999–1006. doi: 10.1093/biosci/biac064

Fadigan, K. A., and Hammrich, P. L. (2004). A longitudinal study of the educational and career trajectories of female participants of an urban informal science education program. *J. Res. Sci. Teach.* 41, 835–860. doi: 10.1002/tea.20026

Gessler, M., and Siemer, C. (2020). Umbrella review: methodological review of reviews published in peer-reviewed journals with a substantial focus on vocational education and training research. *Int. J. Res. Vocat. Educ. Train.* 7, 91–125. doi: 10.13152/IJRVET.7.1.5

Godec, S., King, H., and Archer, L. (2017). *The Science capital Teaching Approach: Engaging Students with Science, Promoting Social Justice*. London. University College London.

Gonsalves, A. J., Cavalcante, A. S., Sprowls, E. D., and Iacono, H. (2021). Anybody can do science if they're brave enough: understanding the role of science capital in science majors' identity trajectories into and through postsecondary science. *J. Res. Sci. Teach.* 58, 1117–1151. doi: 10.1002/tea.21695

Good, C., Rattan, A., and Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *J. Pers. Soc. Psychol.* 102, 700–717. doi: 10.1037/a0026659

Griffith, A. N., Hurd, N. M., and Hussain, S. B. (2019). I Didn't come to School for this: a qualitative examination of experiences with race-related stressors and coping responses among black students attending a predominantly White institution. *J. Adolesc. Res.* 34, 115–139. doi: 10.1177/0743558417742983

Harper, S. R. (2010). An anti-deficit achievement framework for research on students of color in STEM. *New Dir. Inst. Res.* 2010, 63–74. doi: 10.1002/ir.362

Harper, A., and Kayumova, S. (2022). Invisible multilingual black and Brown girls: Raciolinguistic narratives of identity in science education. *J. Res. Sci. Teach.* 60, 1092–1124. doi: 10.1002/tea.21826

Haynes, N. A., and Jacobson, S. (2015). Barriers and perceptions of natural resource careers by minority students. *J. Environ. Educ.* 46, 166–182. doi: 10.1080/00958964.2015.1011595

Hazari, Z., Chari, D., Potvin, G., and Brewe, E. (2020). The context dependence of physics identity: examining the role of performance/competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates. *J. Res. Sci. Teach.* 57, 1583–1607. doi: 10.1002/tea.21644

Holland, D., Lachicotte, W. Jr., Skinner, D., and Cain, C. (1998). *Identity and Agency in Cultural Worlds*. Cambridge, Massachusetts. London, England: Harvard University Press.

Johnson, A., Brown, J., Carlone, H., and Cuevas, A. K. (2011). Authoring identity amidst the treacherous terrain of science: a multiracial feminist examination of the journeys of three women of color in science. *J. Res. Sci. Teach.* 48, 339–366. doi: 10.1002/tea.20411

Kayumova, S., and Dou, R. (2022). Equity and justice in science education: toward a pluriverse of multiple identities and onto-epistemologies. *Sci. Educ.* 106, 1097–1117. doi: 10.1002/sce.21750

Kim, A. Y., Sinatra, G. M., and Seyranian, V. (2018). Developing a STEM identity among Young women: a social identity perspective. *Rev. Educ. Res.* 88, 589–625. doi: 10.3102/0034654318779957

Kitchen, J. A., Sadler, P., and Sonnert, G. (2018). The impact of summer bridge programs on college Students' STEM career aspirations. *J. Coll. Stud. Dev.* 59, 698–715. doi: 10.1353/csd.2018.0066

Kricorian, K., Seu, M., Lopez, D., Ureta, E., and Equils, O. (2020). Factors influencing participation of underrepresented students in STEM fields: matched mentors and mindsets. International journal of STEM. *Education* 7, 1–9. doi: 10.1186/s40594-020-00219-2

Kuchynka, S. L., Reifsteck, T. V., Gates, A. E., and Rivera, L. M. (2022). Which STEM relationships promote science identities, attitudes, and social belonging? A longitudinal investigation with high school students from underrepresented groups. *Soc. Psychol. Educ.* 25, 819–843. doi: 10.1007/s11218-022-09705-7

Lane, T. B., and Id-Deen, L. (2020). Nurturing the capital within: A qualitative investigation of black women and girls in STEM summer programs. *Urban Educ.* 1–29. doi: 10.1177/0042085920926225

Leath, S., Mims, L., Evans, K. A., Parker, T., and Billingsley, J. T. (2022). I can be unapologetically who I am: a study of friendship among black undergraduate women at PWIs. *Emerg. Adulthood* 10, 837–851. doi: 10.1177/21676968211066156

Mahadeo, J., Hazari, Z., and Potvin, G. (2020). Developing a computing identity framework. *ACM Trans. Comput. Educ.* 20, 1–14. doi: 10.1145/3365571

McGee, E. O. (2016). Devalued black and Latino racial identities. *Am. Educ. Res. J.* 53, 1626–1662. doi: 10.3102/0002831216676572

Milner, H. R. (2007). Race, culture, and researcher Positionality: working through dangers seen, unseen, and unforeseen. *Educ. Res.* 36, 388–400. doi: 10.3102/0013189X07309471

Morton, T. R., Miles, M. L., Roby, R. S., and Ortiz, N. A. (2022). "All we Wanna do is be free": advocating for black liberation in and through K-12 science education. *J. Sci. Teach. Educ.* 33, 131–153. doi: 10.1080/1046560X.2021.2008096

Morton, T. R., and Parsons, E. C. (2018). #BlackGirlMagic: the identity conceptualization of black women in undergraduate STEM education. *Sci. Educ.* 102, 1363–1393. doi: 10.1002/sce.21477

Penuel, W. R. (2017). Research–practice partnerships as a strategy for promoting equitable science teaching and learning through leveraging everyday science. *Sci. Educ.* 101, 520–525. doi: 10.1002/sce.21285

Pinkard, N., Erete, S., Martin, C. K., and McKinney de Royston, M. (2017). Digital youth divas: exploring narrative-driven curriculum to spark middle school girls' interest in computational activities. *J. Learn. Sci.* 26, 477–516. doi: 10.1080/10508406.2017.1307199

Pringle, R. M., Brkich, K. M., Adams, T. L., West-Olatunii, C., and Archer-Banks, D. A. (2012). Factors influencing elementary Teachers' positioning of African American girls as science and mathematics learners. *Sch. Sci. Math.* 112, 217–229. doi: 10.1111/j.1949-8594.2012.00137.x

Rahm, J., and Ash, D. (2008). Learning environments at the margin: case studies of disenfranchised youth doing science in an aquarium and an after-school program. *Learn. Environ. Res.* 11, 49–62. doi: 10.1007/s10984-007-9037-9

Rahm, J., and Moore, J. C. (2016). A case study of long-term engagement and identity-in-practice: insights into the STEM pathways of four underrepresented youths. *J. Res. Sci. Teach.* 53, 768–801. doi: 10.1002/tea.21268

Robnett, R. D., and Leaper, C. (2013). Friendship groups, personal motivation, and gender in relation to high school Students' STEM career interest. *J. Res. Adolesc.* 23, 652–664. doi: 10.1111/jora.12013

Sahin, A., Gulacar, O., and Stuessy, C. (2015). High school students' perceptions of the effects of international science Olympiad on their STEM career aspirations and twenty-first century skill development. *Res. Sci. Educ.* 45, 785–805. doi: 10.1007/s11165-014-9439-5

Salvadó, Z., Garcia-Yeste, C., Gairal-Casado, R., and Novo, M. (2021). Scientific workshop program to improve science identity, science capital and educational aspirations of children at risk of social exclusion. *Child Youth Serv. Rev.* 129:106189. doi: 10.1016/j.childyouth.2021.106189

Schrögel, P., Humm, C., Leßmöllmann, A., Kremer, B., Adler, J., and Weißkopf, M. (2018). *Nicht Erreichte Zielgruppen in der Wissenschaftskommunikation: Literatur-Review zu Exklusionsfaktoren und Analyse von Fallbeispielen*. Berlin. Wissenschaft im Dialog gGmbH.

Scott, K. A., and White, M. A. (2013). COMPUGIRLS' standpoint. *Urban Educ.* 48, 657–681. doi: 10.1177/0042085913491219

Shanahan, M.-C. (2009). Identity in science learning: exploring the attention given to agency and structure in studies of identity. *Stud. Sci. Educ.* 45, 43–64. doi: 10.1080/03057260802681847

Steegh, A. M., Höffler, T. N., Keller, M. M., and Parchmann, I. (2019). Gender differences in mathematics and science competitions: a systematic review. *J. Res. Sci. Teach.* 56, 1431–1460. doi: 10.1002/tea.21580

Steele, C. M. (1997). A threat in the air: How stereotypes shape intellectual identity and performance. *Am. Psychol.* 52, 613–629. doi: 10.1037/0003-066X.52.6.613

Stets, J. E., Brenner, P. S., Burke, P. J., and Serpe, R. T. (2017). The science identity and entering a science occupation. *Soc. Sci. Res.* 64, 1–14. doi: 10.1016/j.ssresearch.2016.10.016

Taconis, R., and Kessels, U. (2009). How choosing science depends on Students' individual fit to 'science culture'. *Int. J. Sci. Educ.* 31, 1115–1132. doi: 10.1080/09500690802050876

Vennix, J., Brok, P.Den, and Taconis, R. (2018). Do outreach activities in secondary STEM education motivate students and improve their attitudes towards STEM? *Int. J. Sci. Educ.*, 40, 1263–1283. doi: 10.1080/09500693.2018.1473659

Wade-Jaimes, K., Ayers, K., and Pennella, R. A. (2022). Identity across the STEM ecosystem: perspectives of youth, informal educators, and classroom teachers. *J. Res. Sci. Teach.* 60, 885–914. doi: 10.1002/tea.21820

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethn. Educ.* 8, 69–91. doi: 10.1080/1361332052000341006