Methodologies for Evaluating the Impact of STEM Outreach on Historically Marginalized Groups in Engineering: a Systematic Literature Review (Other, Diversity)

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Introduction and Background

As a form of informal science learning [1], STEM (Science, Technology, Engineering, and Mathematics) outreach activities involve the delivery of "STEM content outside of the traditional student/teacher relationship to STEM stakeholders (students, parents, teachers…) in order to support and increase the understanding, awareness, and interest in STEM disciplines" [2]. In the K-12 out-of-school context, outreach programs include camps, workshops, and after-school or weekend clubs, which occur outside of formal in-classroom learning and hours. STEM outreach programs are initiated with short-term and long-term goals of engaging children and youth in STEM education through inclusive approaches outside of high-stakes testing environments and through offering community connections and role models [3].

In recent years, outreach activities have gained traction as a mechanism for offering informal STEM education opportunities for historically marginalized and underserved youth [3], [4]. The specific young people who are considered underserved in STEM depend on geographical, sociocultural and sociopolitical contexts. Unequal access and structural barriers to STEM education opportunities are produced through intersecting axes of oppression, such as due to gender, race, disability, and socioeconomic status, and can be tied to experiences of discrimination and prejudice [4], [5], [6].

STEM outreach programs specifically designed for identified underserved youth often aim to address *underrepresentation* within STEM, particularly within post-secondary programs or STEM careers. We note that the framing of underrepresentation in STEM may suggest a mere lack of knowledge about or opportunity to engage in STEM as the primary barrier to equity in STEM. This framing does not acknowledge the structural exclusion inherent in STEM; many marginalized individuals may already have opportunities to engage in STEM education or careers but are not welcomed or supported in STEM spaces [5], [6]. As such, outreach programs may aim to disrupt inequities of marginalized youth's access to *and experiences in* STEM through promoting inclusion, culturally relevant programming [7], [8], the development of STEM identity [9], [10], community-building [11], and even challenging hegemonic STEM pedagogies [12], [6].

While the body of research on informal STEM learning has grown dramatically since 1980, the effect of these outreach programs is unclear [3]. There is a wide variety of formats for STEM outreach – from short activities to multi-week intensives, covering a range of topics and sub-topics [2] – and an even wider array of methods evaluating the impact of outreach programs.

Some past work, partly from school-based interventions, suggest particular constructs are important to entering STEM careers. Previous work has shown that some competence beliefs are predictors of persistence in STEM. In one example of a link between a competence belief as a predictor of persistence in STEM, Blotnicky *et al*. [13] found that middle school students with higher STEM career knowledge and students with higher mathematics self-efficacy had increased intention to pursue a career in STEM. For girls, the likelihood that they would pursue a career in STEM increased with participation in a science summer camp [14]. Other in-school studies have found that increasing STEM self-efficacy may be linked to increasing STEM career participation. Falco and Summers [15] found that a STEM career development intervention during in-school math classes improved students' STEM self-efficacy in adolescent girls, and that this improved their career decision self-efficacy. Altogether, studies over longer periods of time would give further evidence regarding the effects of outreach interventions on persistence in STEM careers.

Exposure to STEM topics has been linked to increased interest in those topics, as well as interest in STEM careers. There have been some connections between recalled interest in science and math in middle school, recalled STEM activities (outreach and at home) and STEM career interest in university [16]. And within-school K-12 exposure to engineering has been linked with impacts on student interest and attitudes [17]. Interest in engineering has also been shown to increase with outreach [18]. Additional work has shown that students participating in an engineering camp were more likely than control students to take STEM courses in high school [19].

STEM identity describes the extent to which an individual sees themselves as a "science person", "math person", etc. [20]. STEM identity has also been linked to youth enrolling in post-secondary STEM education [21]. Fit or belonging is also believed to be a factor in gender gaps in STEM enrolment, where explanations based on abilities, interest, and self-efficacy fall short [22].

While we list a number of possible constructs above, it is unclear which one(s) (such as STEM identity and self-efficacy) are important to evaluating immediate, short-term, and long-term STEM engagement, and how best to evaluate them, particularly for youth who have been historically marginalized in STEM. Therefore, we are interested in what methods are being used, what constructs are being measured, and what theoretical and conceptual frameworks are underpinning the methods in studies that attempt to measure the impacts of STEM outreach on marginalized youth participants. We are also interested in understanding the variety of methods that are more meaningful or culturally relevant to the specific identities of the participants.

The purpose of this systematic review is to determine what methodologies and methods are used to evaluate the impact of STEM outreach on marginalized youth in STEM. Our goal is to produce a comprehensive summary of methods that future researchers can refer to when evaluating similar programs.

Methods

Author Positionality

Our research team consists of undergraduate and graduate students, and teaching and research faculty at a large, research-focused university with an extensive STEM outreach program. Six of us have academic backgrounds in engineering and two in social science. We bring a mix of experience with qualitative and quantitative research methodologies in education, which enabled each of us to apply our expertise to subsets of papers for the review. Some of the authors took part in STEM outreach as youth, which influenced their trajectories into engineering, and many of the authors have also contributed to STEM outreach programming and/or evaluation. Such experiences provided motivation for this review as well as potential bias in interpreting trends in the studies. We are all women and have varying intersecting identities such as straight, queer, disabled, able-bodied, white, non-white, and various family backgrounds. Some of these identities may have led us to identify with the participants of the studies due to the historical marginalization of these identities in STEM. On the other hand, some of our identities are more privileged in STEM, potentially creating more distance between us and the participants of certain studies. For example, none of the authors are Black, Indigenous, or Latina, but many of the papers we looked at focused on youth with these identities.

Search strategy
We used a standard systematic review approach following the PRISMA guidelines [23]. We searched three education-related databases: ERIC (EBSCO), Education Source, and Australian Education Index (also known as "International ERIC"). We composed a search string using keywords for concepts related to our objective (Table 1), and completed the search in December 2023. We limited our search to 1993 onward, papers written in English, and peer-reviewed research work.

Table 1: Search terms used. Search strings for each concept were combined with AND to create an overall search string. Note that listing "science" or "engineering" alone in the content concept gave many extraneous results, so content and type were mixed to provide a more consistent set of citations. Recognizing that terminology has evolved over time, we also included a range of identity terms that may have been used in past work, even if no longer commonly used.

Concept	**Search string**
Content of activity	(stem or steam or "science, technology, engineering and mathematics" or "science education" or "engineering education" or mathematics or math or "science outreach" or "engineering outreach" or "science camp" or "engineering camp" or "science club" or "engineering club" or "science workshop" or "engineering workshop")
Type of activity	(outreach or workshop* or camp or camps or club or clubs or "informal education" or "informal learning" or "after school program")
Participants	(children or child or adolescent* or youth or teenager or "young adult" or teen or kids or "K-12" or elementary or secondary or "high school" or "pre-college" or girl or girls or boy or boys or campers or tween* or "middle school")
Measurement	(evaluation or assessment or effectiveness or impact)
Identities *(general marginalized group terms, gender, race, Indigenous, disability, neurodiversity, sexuality, immigrant, socioeconomic)*	("underserved populations" or "under-represented" or marginalized or "equity-seeking" or "equity-deserving" or HPSM or underserved or girls or women or "non-binary" or genderqueer or "gender fluid" or "third gender" or "minority gender" or "gender non-conforming" or transgender or minority or minoritized or racialized or race or ethnicity or Black or "African American" or "African-American" or hispanic or Latina or Latino or Latinx or native or indigenous or tribal or Inuit or Metis or "First Nation" or "American Indian" or "Native Hawaiian" or "Pacific Islander" or aboriginal or BIPOC or IBPOC or POC or "person of color" or "person of colour" or "South East Asian" or disability or disabled or deaf or blind or neurodiver* or autism or autistic or LGBT or LGB or LGBTQ or gay or lesbian or sexuality or "sexual orientation" or "sexual minority" or bisexual or homosexual or queer or "two spirit" or immigration or immigrant* or undocumented or refugee* or asylum or "non-status" or socioeconomic or poverty or impoverished or "low income" or SES or "low SES" or intersectional*)

Citations were imported into Sciwheel (Sage, London, UK), and 88 duplicates were removed automatically. The citations were manually checked for duplicates (removed 3) and ineligible items (removed 5), then the set of 411 citations were exported to a spreadsheet for screening. See Figure 1 for details. Pairs of authors each screened about 100 citations each (title and abstract) based on predetermined inclusion/exclusion criteria (Table 2), with any disagreements being resolved through discussion between the pair. 215 citations were excluded at this point.

Retrieval and assessment for eligibility

After agreement was obtained between author pairs, we retrieved 194 papers to be assessed for eligibility. Authors divided the papers for full-text assessment based on the same criteria listed in Table 2. Each author reviewed about 25 papers, and consulted with a second author if unsure. Papers were also categorized during this step by factors including type of study (quantitative, mixed methods, or qualitative), age group, marginalized group of focus, construct(s) measured, and type of event. After eligibility assessment based on the full text, 104 papers were included.

Table 2: Inclusion/exclusion criteria for papers. Criteria were determined prior to searching.

Inclusion Criterion	Justification
K-12 participants	The study should focus on outreach to pre-college participants, since this population is the most common demographic for STEM outreach and may be the most likely to change career plans toward STEM. This included adults studying K-12 content.
STEM program *	The studied program or activity should be focused on introducing participants to STEM, either overall or in one aspect. If there is no STEM content, STEM attitudes are unlikely to change.
Outreach **	The activity was optional outreach, not part of school (which we defined as either in the classroom with a regular teacher or invited facilitator, or a school trip to a science museum or similar). We chose to exclude mentoring when framed as outreach.
Evaluation of camp participants	The evaluation completed in the study should focus on the participants, rather than teachers, leaders, parents, etc., as they are the individuals who are intended to be influenced toward STEM careers.
Historically marginalized groups	The evaluation completed in the study should either focus on groups historically marginalized in STEM and/or report results divided by identity where some groups are considered marginalized.
Measured outcome beyond “satisfaction” or similar	The evaluation completed in the study should include some measure other than simply satisfaction (e.g. “did you enjoy this camp?”) or similar outcomes. It is not clear that self-reported satisfaction with an activity indicates there is any change in attitudes toward STEM or STEM careers.
Peer-reviewed original research	The studies should be peer-reviewed original research. This excludes review papers, meta-analyses, and governmental reports, among other works.

* STEM is most commonly defined as science, technology, engineering, and mathematics, and sub-fields within those fields. Sometimes adjacent fields are included (e.g. medicine and healthcare). In this paper, we include work which the authors claim is STEM, even if it does not fall within the traditional boundaries (e.g. cancer research, which could be bench-based science (traditionally STEM) or clinic-based human trials (not traditionally STEM)).

** For this review, we narrowed the scope of outreach to only out-of-school contexts in which programs occurred outside of the formal classroom and class hours to highlight programs of ‘free-choice’ informal learning [1].

We divided the papers into quantitative, qualitative, and mixed methods studies, and further divided them based on the construct that was being evaluated, and authors with experience in these sub-groupings led analysis for each construct/study type.

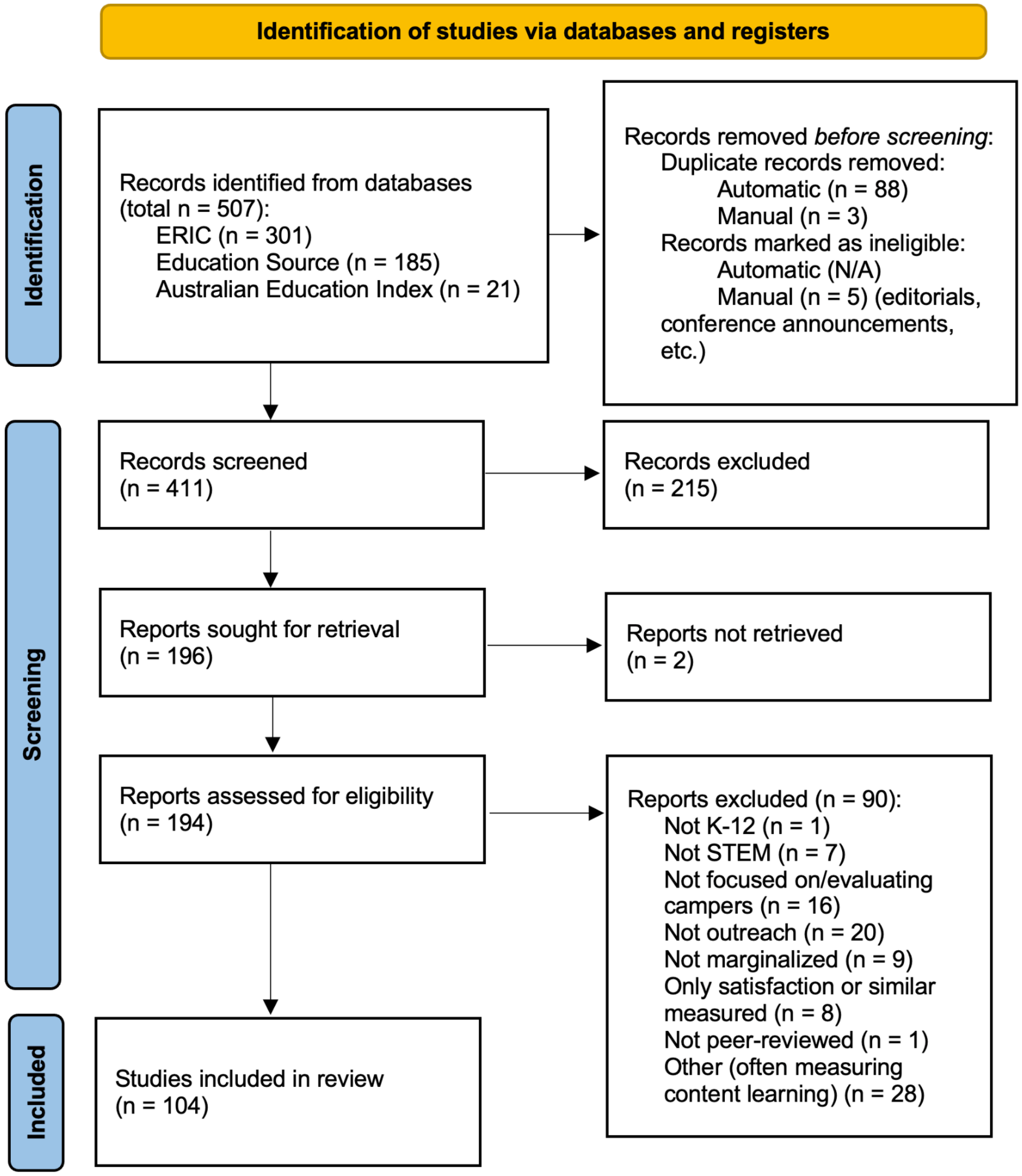

Figure 1: PRISMA 2020 flowchart of papers during identification and screening. [23]

Results

Based on familiarity with some of the literature, we created an initial list of constructs that might describe the focus of research questions (Table 3). The usage of the construct term, the specific underlying theoretical framework, and the definition of the construct in a paper may differ between papers and from our table, and the table is not all-inclusive. We also did not identify all the constructs in advance - constructs that surfaced from the papers are listed under “other”.

Notably, many papers measured satisfaction with the camp or activities (e.g. “I enjoyed STEM camp”). We excluded these because they do not appear to be directly measuring factors that might lead to the pursuit of STEM in the future. Another group of papers measured content learning that occurred during outreach (such as math skills or geophysics concepts). While this may influence self-efficacy measures and/or better prepare students should they choose to enter STEM, it is not directly measuring factors that most authors focus on as proxies for change to educational and career paths. We have not included tests of content knowledge in the descriptions of the outreach evaluation.

Table 3: Examples of commonly referenced constructs in the papers, and our definitions.

Construct	Definitions
Attitude	What an individual believes or values about STEM as a field (e.g. "Math is useful")
Interest	Whether STEM is of interest to that individual, "curiosity and … the enjoyment of learning about a certain topic or field" (e.g. "I like math") [16]
Belonging/fit	Whether the individual feels that they fit (feel authentic) in STEM or STEM spaces (e.g. "I feel at home in math class") [22]
Self-efficacy	Whether an individual believes that they can do STEM (e.g. "I am good at math") [24]
Identity	Whether an individual has a STEM identity (e.g. "I see myself as a math person") [25]
Educational choice plans and/or outcomes	Whether an individual plans to take further STEM education (or has chosen to do so, measured at follow-up) (e.g. "I want to take more math courses")
Career choice plans and/or outcomes	Whether an individual plans to go into a STEM career (or has chosen to do so, measured at follow-up) (e.g. "I want a job that uses math") [26]
Other	Social capital: strength and abundance of the networks/ relationships among members of a community where information is spread. I.e., "what networks of relationships are present, and how do those networks allow for the transmission and interpretation of information" [27] Grit: perseverance and passion; whether an individual believes they are a hard worker [28] [29] Anxiety/Stress: i.e., emotions associated with worry and physical manifestation of body stress (i.e. high blood pressure) [30] Motivation: levels and/or types of motivation that promotes, directs, and sustains STEM choices, behaviour, and goals [31], e.g., based on Self-Determination Theory [32] Self-Determination: having the ability to have choices and some degree of control over what to do and how to do it [33] Support: from family, friends, teachers, etc., in pursuing STEM learning [34] [35] STEM work knowledge: Understanding the roles, components, and utility of STEM work, knowledge of careers in STEM [35] Epistemic frame: participants' familiarity with and application of the culture, practices, and norms of a STEM field tied to deep interconnections between skills, knowledge, identity, values, and epistemology [36] Relevance: whether learning feels relevant to the student's present life or future [37] Home resources for learning: whether students have resources at home that can support science learning, which indicates science-specific socio-economic status [34]

The summaries of all included papers are listed in Table 4 (quantitative methods), Table 5 (qualitative methods), and Table 6 (mixed methods). Note that the approaches between these groups of studies were quite different, so the tables are purposefully different. Also note that the description of the youth group of focus was recorded using the study authors' language.

Table 4: Quantitative study summary. 58 quantitative papers were included. Evaluation was by survey unless otherwise listed.

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Self-efficacy	Inspired by Computer Programming Self Efficacy Scale for Computer Literacy Education [38]; new validated instrument is Mastery Experiences in Programming Questionnaire (MEPQ). Sample item: “I am able to test a program on a robot to verify that it works as planned.” (Self-efficacy)	Pre-post	174 (94 girls)	Girls	10-14 years old	Allaire-Duquette 2022 [39]
Identity	Used the Common Instrument Suite for Students (CIS-S) [40] Sample item: “I think of myself of a science person” (Identity)	Retrospect. self change (post)	110	"Urban school district", "multiple underrep’d backgrounds"	Elementary school	Ayers 2020 [41]
Interest	"Students improved their attitudes about engineering and understanding of what it meant to be an engineer"; "girls changed their attitudes most dramatically, from a negative perception to a positive perception." (Questions/tests are not provided.)	Pre-post	Grades 3-5: 20 Grades 6-8: 20	Deaf children; also, girls among them	Grades 3-8	Bennie 2015 [42]
Interest	Sample statements: "I am more interested in taking STEM classes in school" (Interest) "I am more interested in participating in STEM activities outside of school requirements" (Interest) "I am more confident in my STEM knowledge, skills, and abilities" (Self-efficacy) "I am more interested in pursuing a career in STEM" (Career)	Post	>5000; from 2014 to 2018 (each year >1500)	"U2": two or more of: low-income; racial/ ethnic groups historically underrep’d in STEM; disability; ESL; first gen; rural; girls.	Middle and high school students: three levels: 7th-8th grade, 9th-10th grade, 11th-12th grade	Brown 2020 [43]
Attitudes, Interest, Educational choice, Career choice	Sample statements: "The geosciences are interesting." (Attitudes) "I am interested in science." (Interest) "I will attend the University of Texas at El Paso." (Education) "After participating in Pathways would you like to become a geoscientist?" (Career) College enrollment and program of past participants (Education)	Pre-post, Longitudinal	230 (Pre-post) 86 (Longitudinal)	Hispanic American youth	High school (9th grade)	Carrick 2016 [44]
Self-efficacy, Educational choice, Career choice	Modified from Soto-Johnson 1996 [45]. Statements from the following theme: 5. I am confident in my mathematical ability. (Self-efficacy) Pre-camp short answer: "What are your career plans? Will they require you to study much mathematics?" (Career, Education) Follow-up survey: College enrollment and program requiring calculus for past participants (Education)	Pre-post, Pre, Longitudinal	36 (Pre-post, Pre) 16 (Longitudinal)	Girls/young women	High school (9th to 12th grade)	Chacon 2003 [46]
Career, Education	Knowledge tests, surveys, reflection essays, exit interviews. Details lacking on survey questions. Eventual college enrollment in STEM majors was tracked.	Post-camp, follow up	63 SARE, 47 BRBT	From under-resourced backgrounds	High school	Crews 2020 [47]
Interest, Attitudes, Education, Career	"I like math." (Interest);"I like science." (Interest); "It is important for everyone to have a basic understanding of Science, Technology, Engineering, Math (STEM)." (Attitude); "In high school I will take math or science courses even if they are not required." (Ed;); "I am considering a career in a math or science field." (Career)	Pre-post	28	Girls	High school (entering 9th and 10th grades)	Dave 2010 [48]
Self-efficacy, Int., Career, Other (STEM work know.)	"I think science is" (hard-easy scale) (Self-efficacy) "I think science is" (boring-fun scale) (Interest) "I’d like to become a Science [sic] or Engineer" (no-yes scale) (Career) Also asked about engineering work knowledge, and role models in engineering.	Pre-post	259	Girls	Elementary and middle school (4th to 7th grade)	Dell 2011 [49]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Self-efficacy, Interest	Used existing items [50]. “Confidence”, not explicitly self-efficacy. Sample items: “I am interested in engineering” (Interest); “I feel confident in my ability to succeed in engineering or a related/similar area” (Self-efficacy); “I have hobbies that are engineering related” (Interest)	Pre-post	66 (matched pre and post)	Girls	High school/"girls entering year 9 or 10"	Dennis 2019 [51]
Self-efficacy	Physics self-efficacy, 24 statements. Sample statements: “I can calculate the standard deviation of a set of data” (Self-efficacy) “I can calculate the voltage output from a potential divider current” (Self-efficacy)	Pre-post	79 (matched, for self-efficacy)	Girls and low SES	High school	Durk 2020 [52]
Self-efficacy	Questions include: (1) perceptions about or attitudes towards school, (2) external support system, (3) self-efficacy, (4) prior exposure to camp topics, (5) interest in camp topics, (6) self-reported understanding of camp topics.	Pre-post	19	Girls	Elementary school	Essig 2020 [53]
Interest, Career	"It would be pretty fun to work in an engineering related job." (Interest, Career) "It would be pretty boring to work in an engineering related job." (Interest, Career)	Pre-post	Not reported	Girls	High school	Everage 2014 [54]
Attitudes, Educational choice	“What is your idea about computer science after the camp?” (Attitude) “Do you intend to continue your studies at the university?” (Education) “In which field do you intend to continue your studies?” (Education)	Pre-post	392	Girls	High school	Faenza 2021 [55]
Interest	Partnerships in Education and Resilience (PEAR) Common Instrument Suite Student (CIS-S) [56]. "Interest and engagement in science" (not clear if they only used some subscales); also perseverance and critical thinking.	Pre-post, case-control	1125 (510 case, 615 control)	Historically underrep’ed in science (Black, Latinx, low income)	Middle school	Fancsali 2021 [57]
Self-efficacy	Validated instrument, the 30-item Morgan-Jinks Student Self-Efficacy (MJSES) [58]. Sample item: “I am a good scientist” (Self-efficacy)	Pre-post	12	Students with visual impairments	Grades 3-12	Farrand 2016 [59]
Self-efficacy, Interest, Career, Other (STEM work knowledge)	"I get good marks in (Math)" (Self-efficacy) "I learn (Math) quickly" (Self-efficacy) "I look forward to my (Math) classes" (Interest) "I get very tense doing (Math) problems" (Self-efficacy) "I feel helpless when doing a (Math) problem" (Self-efficacy) Participants asked to rank their favorite subjects - math rank examined. (Interest), likelihood of pursuing a STEM career (Career). Also, which careers need STEM [13] (Other).	Post, case-control (with school attendees who did not attend camp)	292 (75 camp, 158 non-camp (sub-set of school results, girls reporting good marks in math))	Girls	Middle school (ages 12-14)	Franz-Odendaal 2020 [14]
Interest	"Has your experience in this program changed your level of interest in pursuing a research career?" (Career)	Pre-post	152	1) Black or African American, Hispanic or Latino/a, American Indian, Alaska Native, Native Hawaiian, Pacific Islander; 2) disability; or 3) disadvantaged	High school (9th to 12th grade), and undergrads	Fung 2021 [60]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Career, Education, Attitudes, Self-efficacy, Other (barriers and influences)	Plans to attend university and what discipline they were likely to apply to. (Education) Who/what had the greatest impact on school/career decisions. (Career, Influences) If someone important to them had ever made a comment about girls' abilities to perform well in math or science. (Influences) "Are you discouraged from pursuing science or using a computer?" (Barriers) Statements on apprehension around choosing engineering because it is a male-dominated field. (Attitudes) Doubts about conducting experiments or working with machinery. (Self Efficacy)	Post	109 (74 follow-up phone surveys)	Girls	High school (grades 10-12)	Gilbride 1999 [61]
Attitudes, Self-efficacy, Interest, Career	Adapted from the Computer Self-Efficacy Scale (CSE) [62] and Computer Attitudes Questionnaire (CAQ) [63]. Sample statements "I feel confident working with technology." (Self-efficacy) "I enjoy doing things with technology." (Interest) "Technology is difficult to use." (Attitudes) "I am interested in doing a job using technology when I grow up." (Career)	Pre-post	203	Girls	Middle and high school (ages 10-15)	Grant 2023 [64]
Career	Survey with one question asked if the learning experience enhanced their career development skills (5-pt Likert scale). (Career Choice)	Pre-post	20	Girls, first-generation, low-income, rural	High school	Hanley 2022 [65]
Attitudes, Self-efficacy, Interest, Career	Test of Science Related Attitudes (TOSRA) survey [66], 28 of 70 items (not detailed): attitudes and career interest. 31-item Information and Communication Technology Attitude (ICTA) survey developed by the project: self-perceptions for ICT skills. (Survey details not included, no reference provided).	Pre-post	44	Hispanic youth, girls	Middle school (7th and 8th grade)	Hayden 2011 [67]
Attitudes, Self-efficacy, Interest, Other (STEM work know.), Belonging/fit	Middle School Attitudes to Mathematics, Science and Engineering Survey (MATE) [68] (Attitudes, Self-efficacy, Interest, Other (STEM work knowledge)) Draw an Engineer Test (DET) [69] (Belonging/fit)	Pre-post	47	Not specified (Included "students from traditionally underserved and typically underrep'ed populations")	Middle school (5th to 7th grade)	Hirsch 2017 [70]
Career, self-efficacy	Sample questions: "How much do you think this workshop helped show you that you are capable of working with computers or robotics?" (Self-efficacy) "How much has this workshop encouraged you to consider working with computers or robotics when you grow up?" (Career)	Post	9	Visually impaired	Middle school	Howard 2012 [71]
Interest	Effect of Mentoring: "Increased my interest in studying science/engineering in college." (Career) "Made me more confident in my ability to succeed in science/engineering." (Self-efficacy) "Increased my confidence in my ability to participate in science/engineering activities." (Self-efficacy)	Pre-post	17 (pre) and 22 (post)	Under-represented minorities	Grades 9 and 10; grades 6-8	Ilumoka 2017 [72]
Attitudes	Children were shown a series of five faces (sad to smiling): "Point to the face that shows how happy or unhappy math makes you feel."	Post	655 (320 case, 335 control)	Primarily low-income	Kindergarten	Jacob 2020 [73]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Career, Education	Students were asked about their education and career aspirations. One question about their interests in nine potential fields in science or health. (Career, Education)	Pre-post	26	Rural community, low income, first gen, girls	High school	Karara 2021 [74]
Career, Education, Attitudes, interests, Self-efficacy	Sample questions: "I can see how math is important in my life." (Attitudes) "Science is one of my favorite subjects." (Interests) "I am good at problem solving." (Self-Efficacy) Questions about STEM careers and college interest. (Career, Education)	Pre-post	30	African American boys/men	Middle school (grades 6-8)	Ladeji-Osias 2018 [75]
Career, Education, Self-efficacy	Sample items: "I would like to major in some area of Science in College." (Education) "It is clear to me what a career in Engineering would be like. I know what an Engineer does." and "I would like to be a Scientist." (Career) "If I majored in science in College, I believe I would do well in my courses." (Self-eff.) Parent survey (6 items). Example: "I believe this program has increased my child's confidence in their ability to do well in high school classes with similar subject matter."	Pre-post	11 (IEPS), 15 (not on EIPs)	Students on Learning Disability Related Individualized Education Programs (IEPs)	Grades 6-8	Lam 2008 [76]
Self-efficacy	Attitudes towards CS, likelihood to study CS, and computer self-efficacy. Modified scale for computer self-efficacy (MCSE) [77], 10 items. Sample item: "Computers frighten me."	Pre-post	856	Girls	High school (15-16 year olds)	Lawlor 2020 [78]
Attitudes, Career, Other (support)	Subset of Changes in Attitude about the Relevance of Science (CARS) Questionnaire [79] (17 items). Sample statements: "Science will help me to understand the effect I have on the environment." (Attitudes) "I am interested in a career as a scientist or engineer." (Career) "I have support from others to excel at science." (Other, support)	Pre-post	28	Girls	Middle school	Levine 2015 [80]
Att., Ed., Career, Other (support)	Subset of Changes in Attitude about the Relevance of Science (CARS) Questionnaire [79] (26 items). Sample statement: "I plan to take more science classes in high school." (Education)	Pre-post	67	Girls	High school (8th-11th grade)	Levine 2018 [81]
Attitudes, Interest, Self-efficacy, Other (Home resources for science learning, support)	Study uses longitudinal data from the Activated Learning Enables Success 2014/2015 datasets. Sample statements: "I think scientists are the most important people in the world." (Attitudes) "After a really interesting science activity is over, I look for more information about it." (Interest) "I think I am very good at doing experiments" (Self-efficacy) "How often are [technology, books, study locations] available to you" (Other, Home resources for science learning) "Someone in my family takes me to places where I can learn new things" (Other, Family support for learning)	Pre-post summer, Longitudinal (pre- measures at multiple timepoints)	2252 in dataset, 711 high SES and 719 low SES	Lower SES	Middle and high school (6th to 9th grade)	Liu 2020 [34]
interest in STEM career	The questions and the data are not presented.	Pre-post, case-control	60 case, 120 control	English-Spanish bilingual youth	High school	Lucero 2021 [82]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Career, Attitudes	Students rated their interest in pursuing a career as a scientific researcher (Career) and the usefulness of the program in increasing their readiness to engage in demanding research (Attitudes), improving their self-confidence as a researcher (Self-efficacy), and understanding more clearly what it takes to become a researcher (Attitudes).	Pre-post	46	Girls, Black/African American, Spanish/Hispanic /Latinx, Econ. disadv., First-gen, Disability	High school	Mekinda 2021 [83]
Interest	"How interested are you in Science?" (Interest) "How interested are you in Math?" (Interest) "How interested are you in going to college?" (Career)	Pre-post	283	Under-represented minorities	5th grade	Meyers 2012 [84]
Career, Education, Interests, Attitudes, Self-efficacy	Survey asking about career choices, stem interest, self efficacy and annual survey on education path taken. Participants were asked about the likelihood that they would attend college (e.g. "I will attend a community college") and take STEM courses in college. (Career, Education) Sample statements: "I am good at science" (Self-efficacy), "I am interested in science" (Interests), "The geosciences are useful." (Attitudes)	Pre-post and annual follow-up	69	Hispanic-American	High school	Miller 2007 [85]
Att., Ed., Self-efficacy, Interests	Sample statements on perception of engineering: "I like what engineers do"; "By studying engineering I will be able to help people." Sample statement: "I am interested in studying engineering." (Interest)	Pre-post	787	Girls	High school	Molina-Gaudo 2010 [86]
Attitudes	"Youth participants reported more positive attitudes towards these competencies [i.e. STEM areas] following their internships." (Details not included)	Pre-post	22	Low-income youth of color	High school	Morgan 2021 [87]
Career, Self-efficacy, Identity, Interests	Pre- and post-survey sample statements: "I feel confident in my abilities to work in a science laboratory." (Self-efficacy) "I am interested in learning more about STEM" (Interest) "I see myself as a STEM person" (Identity)	Pre-post	291	Low income	High school	Nadelson 2022 [88]
Career, Education, Self-efficacy, Interest	Science Self-Efficacy (SSE), 7-items, partially adapted from the STEM Career Interest Survey (STEM-CIS) [89]. Examples: "I like my science classes," and "I complete my science homework." (Self-Efficacy) Science Motivation (SM), 4-items, adapted from the Relevance of Science Education (ROSE) Questionnaire [90]. Examples: "learning science in a real-life context is stimulating," and "learning science has made me more critical." (Attitudes) STEM Career Interest (SCI), 12-items, using the Career Interest Questionnaire (CIQ) [91]. Examples: "I would enjoy a career in science," and "I will make it into a good college and major in an area needed for a career in science." (Career and Education) Desire for STEM Career (SD), 11-items. Examples: "school science has improved my decision-making," and "I would like to get a job in technology." (Career and Education)	Pre-post	116 (58 participants, 58 control)	Low-income and Native Hawaiian	High school (grades 9-12)	Nariman 2021 [92]
Interest, Career, Education	Pre: "How relevant do you think sustainability is to your future goals?" (Int./Career) Post: "How relevant do you think sustainability is to your future goals?" (Interest/Career) "After this module, how likely are you to pursue engineering as a major?" (Education)	Pre-post	2014: 89 2015: 115 2016: 130	Gender; also asked ethnicity and did ethnic background comparison	High school	Oswald Beiler 2017 [93]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
	"After this module, how likely are you to pursue engineering with a focus on sustainability? (Education)					
Attitudes, Self-efficacy, Education, Career, Other (STEM work knowledge, support)	Adapted from previous work [94]–[97]. Sample statements: "People who work with computers are smart." (Attitudes) "I am interested in a career involving computers." (Career) "Computers are fun." (Interest) "What is your skill level using computers?" (Self-efficacy) Rating interest in and knowledge of specific IT jobs, e.g. mobile apps or animated movies (Career) "I plan on taking (or am taking now) computer courses in middle school." (Education) "I receive encouragement to learn about computers from my friends." (Other (Support))	Pre-post (matching for returning campers for 1-year follow-up), Case-control	16 to 30	Girls	Middle school (entering 6th to 8th grades)	Outlay 2017 [35]
Career, Interest, Attitudes	Sample statements: "Having a career in science would be challenging." (Career) "Scientists make a meaningful difference in the world" (Attitudes) "I want to learn more about STEM for myself" (Interest)	Pre-post	Not reported	Girls, Asian, Black, Hispanic, Mixed	Middle school (6th-8th grades)	Prasad 2022 [98]
Self-efficacy, Attitude, Other (Motivation)	SAM (self-efficacy, attitude, motivation) science survey validation. Sample items: "I am sure of myself when I do science." (Self-efficacy) "Science is dull and boring." (Attitudes) "Doing well in science is important for my future." (Motivation)	Pre- and post- (unmatched)	162 (post survey only)	"Underrepresented minority (primarily African American)"	High school	Puvirajah 2015 [99]
Other (social capital)	Social Network Analysis (SNA): number, direction, strength of "ties" between members in a network. This study considered a unidirectional relationship between participant and instructor(s). Students assigned 1-4 per instructor based on the following scale. 1." I have never met this person (no idea who they are)"; 2."I know who this person is but haven't had a conversation with them"; 3."I have asked this person for help on how to do some of the activities during the sessions"; 4. "I have asked this person for personal advice, which could include my future or my well-being".	Pre-post (completed on day 1, then each week during the 4-week camp)	30 8th grade students; 23 9th grade students	Girls	Ages 12-14 (entering 8th or 9th grade)	Reding 2017 [27]
Self-efficacy	Surveys taken from the "Assessing Women in Engineering (AWE) project" [100], some questions adjusted. Sample questions: 1. "How often do you raise your hand during class?". Sample answer: "I raise my hand for every question...). 2. "How confident are you in your math and science skills?". Sample answer: "I am very confident in my math and science skills".	Pre-post	234 (across 2 years)	Girls	High school	Schilling 2019 [101]
Interest	Interest in learning mathematics and science. (Details not further specified).	Post survey	89	Girls, from a high % African American pop.	Grades K-12	Shores 2010 [102]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Motivation, Self-efficacy, Interest, Identity, Other (Support)	Created scale with 5 sub-scales (28 items - not all available in paper): Motivation, self-efficacy, interest, identity, support: Self-motivation, interest, and confidence in science: e.g. "Science is easy for me." Self-perceptions of science ability relative to peers: e.g. "Compared to others my age, I am good at science." Family, friend, and teacher science support: e.g. "My science teachers encourage me to learn more science." Also measured active and engaged citizenship. Adapted from previous work: [103]–[106]	Pre-post	39	Primarily low-income youth of color	Middle school (6th to 8th grade)	Sprague Martinez 2016 [107]
Interest (per author)	"I feel more comfortable with technology after my experience at Girls Tech Camp."	Post	66 (2016-18)	Girls	Middle school (6th-8th grade)	Stapleton 2019 [108]
Attitudes, Self-efficacy, Interest	Adapted from the Middle School Student Attitudes toward STEM (S-STEM) instrument [109]. Sample statements: "Knowing coding will help me earn a living." (Attitude) "I know I can do well in coding." (Self-efficacy) "I am interested in coding." (Interest)	Pre-post (survey), post (focus group)	132	Girls	Middle school (entering 6th to 8th grades)	Stewart 2020 [110]
Self-efficacy	Information communication technology (ICT) self-efficacy Sample item: “I am confident in completing the homework of the information and communication technology subject.” Surveys modified from the PISA 2012 assessment [111]. 3. information communication technology (ICT) self-efficacy 4. Perceived difficulties in using ICT 5. Interest in studying ICT 6. Perceived value in studying ICT	Pre-post matched	411	Girls	12-14 years old	Tam 2020 [112]
Attitude, Interest, Other (STEM work know.)	Development/validation of 37-item instrument covering 7 factors. Sample statements: Factor 1: Science attitude - "I enjoy doing science." (Interest) Factor 3: Importance of Science and Math - "Knowing math is not important to get a good job." (Other (STEM work knowledge)) Factor 4: Math attitude - "I like to spend more time on math than on other subjects." (Interest) Factor 5: Participation in activities - "I enjoy doing puzzles." (Interest) Factor 6: Future need to know science and math - "I will need to know science my whole life." (Attitude) Factor 7: Importance of science and math classes - "It is important for me to take more science classes." (Attitude).	Pre-post, post	354 (pre-post, instrument development), 129 (post, baseline data)	Girls, "non-white"	Elementary school	Teshome 2001 [113]

Construct(s)	Specific Quantitative Metric/Instrument/Question	Evaluation type	n	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Interest, Self-efficacy, Attitude, Identity	Interest in science was taken from the Colorado Learning about Science Survey [114]. Sample statement: "I enjoy solving science problems." (Interest) Science efficacy was measured using two scales (self-concept of ability and student task value) from [115]. Sample items:"How good at science are you?" (Self-efficacy); "How important is it that you learn science?" (Attitude) Science attitudes were measured using the Attitudes Toward Science in School Assessment (ATSSA) [116]. Sample statement: "Science is fun." (Attitude) Science identity, 4 items adopted from an earlier pilot study [117]. Sample statement: "I think of myself as a scientist." (Identity)	Pre-post, randomized trial case-control	41 (31 case, 10 control)	Girls	Middle school (entering 6th to 8th grades)	Todd 2019 [118]
Career, Education, Attitude	Annual survey to assess long-term college and career outcomes. (Career, Education). College type and majors were categorized (such as science or engineering). Authors state that pre-post camp surveys covered attitudes and beliefs about science and college, but no details on these questions were given in the paper.	Pre-post and annual follow-up	476 (20 year span)	Low income (parsed by ethnicity and gender)	High school	Winkleby 2009 [119]
Career	Sample statement: "As a result of this week's activities, I have increased my understanding of the kinds of careers I could have as an engineer." (Career)	Post	341 (camp)	Girls; low-income region	High school	Winn 2011 [120]
Career, Ed., Self-efficacy	Motivated Strategies for Learning Questionnaire (MSLQ) [121], self-efficacy and other scales.	Pre-post	22	African American	High school	Yan 2019 [122]
Self-efficacy, Interest, Education, Career, Other (STEM work know.)	Upper Elementary School Student Attitudes toward STEM Survey (S-STEM) [109]. Sample statements: "I am good at math." (Self-efficacy) "When I'm older, I might choose a job that uses math." (Career) "I am curious about how electronics work." (Interest) "Do you plan to take advanced math or science classes in future years in school?" (Education) Focus group transcripts, content coded (frequency analysis). Also included items about usefulness of science and math knowledge to future careers (Other).	Pre-post (survey), post (focus group)	25 (survey) 16 (focus groups)	Title 1 schools (at least 40% of students are from low-income families)	Upper elementary school (4th to 6th grade)	Yang 2022 [123]

Table 5: Qualitative methods study summary. 13 qualitative methods papers were included.

Relevant Qualitative Data Collection Methods	Data Analysis Methods and/or Methodological Framework	Goal of Outreach Program	Relevant Theoretical Framework and/or Construct	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Interviews (semi-structured)	Thematic analysis of interview transcripts using multimodal systemic functional linguistic approach (Przymus, 2016 [124])	"Provide the learning experiences, community, and role-models needed to make an impact on Latinas' self-assessment, self-determination, and identity" (Caraballo, 2019 [125])	Imagined identities (Przymus, 2016 [124]) and in-practice identities (Caraballo, 2019 [125]) as a framework for STEM identity	"Secondary school Latinas" in the US	High school	Przymus et al., 2021 [9]
	Deductive coding using categories pertaining to science identity and science capital, and communicative methodology Gómez, Puigvert, & Flecha, 2011 [126])	Contribute to building and inclusive science identity and building science capital in vulnerable children	Science capital (Archer, DeWitt, & Willis, 2014 [127]) Science identity (many citations)	Socially excluded children at from schools with a high % of ethnically Roma students, immigrants, and low SES in Spain	3rd-6th grade	Salvadó et al., 2021 [10]
	Interpretative phenomenological analysis of Draw-an-Engineer Test (Knight and Cunningham, 2004 [69]) followed by semi-structured interview and iterative coding and thematic analysis of data	Increase women's participation in engineering	Possible Selves Theory (Markus and P. Nurius, 1986 [128]) as a framework for engineering identity development	Middle school girls "nearly all white" in the US	4th-8th grade	Clark and Kajfez, 2023 [129]
	Analytic coding based on the 3 stages of their sociopolitical development framework, followed by re-coding and sub-coding tied to gender, race, and intersectional identities	"Foster sociopolitical agency *and* move beyond a single-axis treatment of systemic oppression"	An adapted 3-stage sociopolitical development framework (Watts and C. Flanagan, 2007 [130]; intersectionality (Collins, 2000 [131]; Crenshaw, 1991 [132]) to examine participants' sociopolitical agency and self-efficacy in changing their STEM education conditions	"Girls of color" in the US	Age 13-18	Garcia et al., 2022 [133]

Relevant Qualitative Data Collection Methods	Data Analysis Methods and/or Methodological Framework	Goal of Outreach Program	Relevant Theoretical Framework and/or Construct	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Open-ended surveys	Thematic analysis approach using an open coding style (Braun & Clarke, 2006 [134]; Coffey and Atkinson, 1996 [135])	"Encourage females to develop and maintain interest in STEM"	No theoretical framework; exploring interest in science and science career possibilities	Girls in the US	Age 14-17	Bindis, 2019 [136]
	General inductive approach (Thomas, 2006 [137])	Broadening participation in STEM, particularly of underrepresented groups	No theoretical framework; "explore perspectives and experiences" of the participants; one of the questionnaire questions was "what are your plans after graduation?"	Participants were selected from schools that served "predominantly diverse (American Indian and Hispanic) students from low-income families" in the US	11^{th}-12^{th} grade	Wu et al., 2019 [138]
Studies using two or more methods of data collection						
Observations, longitudinal interviews, and classroom and student artifacts	A priori coding based on the components of an "activity system"	Goal of "disrupting racist limitations on who can do science and what counts as science" and "disrupting STEM or science as a property of whiteness", "the target outcome is for participants to develop a science identity as a result of authentic participation in science activities, consistent with the theory of a community of practice."	Combined framework of Critical Race Theory (Ladson-Billings & Tate, 1995 [139]), communities of practice (Vakil, 2014 [140]), and Activity Theory (Engeström, 1999 [141])] to evaluate science identity development	"African-American middle school girls" in the US	6^{th}-8^{th} grade	Wade-Jaimes et al., 2022 [6]
Observations of campers, science journals (Lofland, Snow, Anderson, & Lofland, 2022 [142]), interviews with campers' mothers ("parents as reporters" on girls' identity shifts)	Interview coding based on "parents' words, phrases, thoughts, feelings, and patterns"; Descriptive coding of field observations	"Establishing a transformative experience for young female students, and broadening their perceptions about scientists (Farland-Smith, 2009 [143])"	Formation and complexity of identities-in-practice (science identity and personal science identity), interest, self-efficacy, confidence	"Female middle school students" "Caucasian and middle class" in the US	Middle school	Farland-Smith, 2016 [144]

Relevant Qualitative Data Collection Methods	Data Analysis Methods and/or Methodological Framework	Goal of Outreach Program	Relevant Theoretical Framework and/or Construct	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Interviews, field notes, videos	None noted: "Because this paper is a project report that aims at introducing the camp, only necessary information regarding the methodology is addressed"	"The very first science camp for students in Taiwan who are blind or visually impaired" ; "students with visual impairments should be provided with... inquiry-based science curriculums and lesson plans that are designed to meet their needs so as to support their learning in science"	Interests toward science; student perceptions toward science and themselves	"Students with visual impairments in central Taiwan"	Middle school and high school	Chiu, 2020 [145]
Longitudinal field notes, Retrospective interviews	Thematic analysis using Taguette software (Braun & Clarke, 2006 [134])	Program "aimed at tribal school children in evolving a positive attitude toward science in general, further encouraging them specifically to take up higher studies in chemistry."	"Interest in science and future studies" ; "enjoying science" ; Service Learning as a conceptual framework (Bringle & Hatcher, 1996 [146])	Remote "tribal communities in South India, [with] low literacy rates and ... a socio-culturally marginalized status"	"school children"	Augusthian et al., 2022 [147]
Focus groups, interviews, photographs	Case study methodology, framework analysis approach (Rabiee, 2004 [148])	"Enhance [deaf and hard of hearing (DHH)] students' abilities to identify with STEM and in turn impact the way they engage with STEM content and learning opportunities" with larger goal to "move DHH adolescents successfully into STEM careers"	Identity development, intersectionality, Deaf identity	"[Deaf and hard of hearing] minority racial/ethnic high school students" (majority of participants were African American) in the US	Age 16-20	Renken et al., 2021 [149]
Focus groups, open-ended survey	Constant comparative method (Strauss, 1998 [150])	"To implement place-based, field experiences in informal settings to broaden learning opportunities and science interest among African American and Latin@ children."	Sociocultural theory (Vygotsky, 2012 [151]), equitable science teaching (Bianchini & Cavazos, 2007 [152]; Hewson, Kahle, Scantlebury, & Davies, 2001 [153]), social justice, place, interest in science	"African American and Latin@ youth" "urban students of color" in the US	3rd-6th grade	Leonard et al., 2016 [154]
Group discussions, group interview, camper journals and other camper artifacts	Recursive coding using a naturalistic, interpretive approach (Denzin & Lincoln, 2011 [155])	"The culturally responsive, project-based interdisciplinary science camp .... purpose was to develop students' interest in their environment and to nurture positive attitudes toward science learning."	Social constructivism (Vygotsky, 1978 [156]), culturally responsive pedagogy (Gay, 2018 [157]), project-based learning, critical literacy (Freire, 1970 [158]), and multimodality, interest in science, grounded in local cultural context	Mixed gender "African American [and] Caucasian" students in a "rural southeastern U.S. town"	4th-7th grade	Stevenson and Casler-Failing, 2023 [159]

Table 6: Mixed methods study summary. 33 mixed methods papers were included.

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Exploratory Sequential Design	Focus group interviews, surveys	Self-efficacy, interests in engineering, and perceptions of engineering	Social Cognitive Theory (SCT) (Bandura, 1988) [160]	ESIPS Instrument (Denson, Austin, & Hailey, 2014)** [161]	Underrepresented student populations, primarily based on race and ethnicity. California, Maryland, Washington, and Utah, USA	High School	Denson, 2017 [162]
	Reflections, surveys, and student-generated work	Confidence, interest, accommodation of activities (ability to participate)	N/A	N/A	Students with diverse disabilities, including learning disabilities and motor impairments. Washington, USA	High School (college-bound)	Melber & Brown, 2008 [163]
Explanatory Sequential Design	Pre- and post-surveys, focus group interviews	Interest in engineering, attitudes about school, educational expectations, students' interest in careers as scientists or engineers	N/A	2007 Trends in International Mathematics and Science Study (TIMSS) (IEA, 2009) [164]	Low-income, predominantly Hispanic students. Texas, USA	Middle School (grades 6-8)	Blanchard et al., 2015 [165]
		Grit, career, attitudes, self-efficacy	N/A	TIMSS - Trends in International Mathematics and Science Study Student 4th Grade Questionnaire (National Center for Education Statistics [NCES], 2011) [166] Engineering is Elementary (EiE) Engineering and Science Attitudes Assessment (Engineering is Elementary, 2010)** [167] Short Grit Scale (GritS) (Duckworth & Quinn, 2009) [168]	Youth from underserved populations, predominantly racialized youth ("80% identified as either African American or Hispanic/Latino") who would otherwise have limited opportunities for science projects at school ("69% indicated they had opportunities at school for doing science projects once per month or less"). California, USA	Ages 8 -13	Adams et al., 2018* [28]
		Attitudes towards STEM, measuring self-efficacy towards science, math, and engineering	N/A	Student Attitudes toward STEM Survey-Upper Elementary School Students (S-STEM) (Friday Institute for Educational Innovation, 2012) [109]	Students from Title 1 schools with high percentages of children from low-income families ("at least 45% of students receive free or reduced lunch"). USA	Grades 4-6	Yang & Chittoori, 2022* [123]

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
	Pre- and post-surveys, artifact-based reflective group interviews, workshop activity logs	Computational thinking skills and attitudes towards computing	Computational thinking framework (Brennan & Resnick, 2012), (Wing, 2006) [169], [170]	Computer Attitude Scale (CAS) (Loyd & Gressard, 1985) [171]	Students from underserved communities, particularly low-income. Philadelphia, USA	Grades 6-10	Çakır et al., 2021 [172]
	Pre- and post-surveys, one-on-one interviews	Identity, motivational factors measured through key socializers and subjective task value (utility value, enjoyment, and attainment), interest in STEM subjects and careers	Expectancy-Value Framework (Eccles, 1994) [173] Social Cognitive Career Theory (Lent et al., 1994; 2000) [26] Epstein's (2001) framework for Six Types of Involvement in School, Family, and Community Partnerships [174]	The STEM Career Interest Survey (STEM-CIS) (Kier et al., 2013) [89]	Students from rural, high poverty schools with a general population of 62.3% African American, 30.3% White, 5.1% Hispanic, and 1.7% two or more races and 1.7% American Indian/Pacific Islander. The percentage of free-and-reduced lunch at all participating schools was greater than 70%. Southeastern USA	Middle School	Blanchard et al., 2017 [175]
	Pre- and post-surveys, observations, one-on-one interviews	Motivation, Perceived usefulness of computer science, confidence with coding	Computational thinking (Wing, 2006) [169] and a K-6 computational thinking curriculum framework (Angeli, 2016) [176]; the correlations of learning mathematics concepts and computer programming abilities (Clements, 2002) [177]	Survey measuring motivations in school generally (Papastergiou, 2009) [178] and computer science (Belanger et al., 2018) [179]	Students from elementary schools with repeatedly reported low standardized assessment scores in math. Predominantly low-income and Black students (90%), 10% of students were classified as learning disabled and/or autistic. Southeastern USA	Grades 3-5	Luo et al., 2022 [180]
	Surveys, observations, pre-, near-post-, and distant-post-interviews, focus group interviews	Interest in computer science, confidence with computing, and intent in pursuing computer science for education or career paths. Identity in context: participants "saving face" while participating and developing an identity as a learner.	Goffman's presentation of self ("face-saving") (1956) [181]; active motivation not to learn factored by cultural values in conflict with classroom values and expectations (Kohl 1994) [182]; disidentification with school and learning (Osborne, 1997) [183]	Face-saving survey developed from similar tools (Bond & Lee, 1981; Juvonen, 2000) [184], [185]	African American teenage boys, many of whom qualified for free or reduced lunch and live within single-parent homes or homes with neither parent present. Georgia, USA	14-18 years old	DiSalvo et al., 2014* [7]

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
Embedded Design	Pre- and post-surveys	Expectations of success, the intrinsic and utility value of science, career choices, perceptions of science	Expectancy-Value Model (Eccles, 1983) [186]	Questionnaire about expectations of success, the utility value of science from Eccles and Wigfield (1995) [187] The Science Technology Engineering and Mathematics (STEM) Semantics Survey (Tyler-Wood, Knezek,& Christensen, 2010) [91]	Girls of varying ethnic groups; 72% White British, others were from a variety of ethnic groups including 15% Southeast Asian, 5% mixed race. Newcastle, United Kingdom	12-14 years old	Skipper & de Carvalho, 2019* [188]
		Self-efficacy, perception of engineering, and interest in engineering	N/A	N/A	Girls, majority Caucasian from suburban communities in the USA	16 or 17 years old	Cloutier et al., 2018* [189]
	Pre- and post-surveys via voice recorders	Relationship with science: broadly, how students engage with and see their role in science, self-efficacy, interest in STEM careers	Mediation model of the effects of science support experiences (Chemers et al., 2011) [190]	N/A	Girls from minoritized communities (low income, and as minoritized race or ethnicity). Colorado, USA	Middle School (ages 12-13)	Broder et al., 2023 [191]
	Surveys, semi-structured interviews, student documents	Educational and career plans/choice/outcomes	Expectancy-Value Framework (Eccles, 1994) [173]	N/A	Academically talented young women from urban, low-income, single-parent families; mostly minorities (89.47%), 83% Black USA	High School (Grades 9 and 10)	Fadigan & Hammrich, 2004* [192]
Convergent or Triangulation Design	Pre- and post-Surveys, pre- and post-interviews, video- recorded observations, and review of students' journals and notebooks, skin temperature biofeedback	Attitudes, Anxiety	Constructivism (Piaget, 2013) [193] Attitudes towards science (Klopfer, 1971) [194]	2007 Trends in International Mathematics and Science Study (TIMSS) *Student Attitudes Toward Science Survey* (Martin et al., 2016) [195]	Participants from school district with 90% low-income families and diverse ethnic populations (African American 26%, Asian 3%, Caucasian 28%, Hispanic 39%). Suburban Northern Illinois, USA	12 year olds	Hsu et al., 2023* [30]

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
	Pre- and post-interviews, pre- and post-surveys, video observations, review of artifacts, physiological data	Attitudes towards science and science confidence and anxiety, interest in STEM careers	Constructivism (Piaget, 2013) [193]	TIMSS (Trends in International Mathematics and Science Study) *Student Attitudes Toward Science Survey* (Martin et al., 2016) [195] Biodots to measure anxiety	"Non-dominant youths" in a suburban school district which serves students from underrepresented populations and diverse ethnic student populations (African American 20%, Asian 3%, Caucasian 20%, Hispanic 52%) Northern Illinois, USA	12 year old youths	Hsu et al., 2022* [196]
	Pre and post surveys, participant observations, focus group interviews, and brief informal conversations during hands-on activities.	Math, science, and engineering attitudes, self-efficacy with nanotechnology, and interest in STEM careers and postsecondary plans	Microaggressions (Pierce, 1970), (Sue et al., 2007) [197], [198] Experiential learning theory (Dewey, 1998) [199]	S-STEM (Unfried, Faber, Stanhope, & Wiebe, 2015) [109] Nanotechnology Content Test (NCT) (Chang, Giordano, Mason, & Krajcik, 2004)** [200]	Compared experience of Black participants with non-black participants. Indiana, USA	High School (grades 9-12)	Mutegi et al., 2019 [201]
	Surveys, video interviews, and written student-narratives	Interest in STEM careers and appreciation of STEM	N/A	N/A	Girls in the USA	High school (Juniors and Seniors)	DiLisi et al., 2011* [202]
	Surveys , reflective journal responses, and semi-structured focus group interviews	Attitudes towards science, science identity, and science career outcomes	Constructivism (Bruning 2004; Moshman 1982; and Phillips 1995) [203]–[205] Vygotsky's sociocultural theory of human learning (Vygotsky 1978) [156] Maslow's Theory of Human Motivation, and Maslow's Hierarchy of Needs (Maslow 1971) [206]	N/A	Girls, with an emphasis on African American girls Large midwestern urban city in the USA	High School including eighth grade	Robinson -Hill, 2022 [207]

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
	Pre- and post-surveys, observations, and video recordings of workshops	Interest and confidence in robotics programming, computer hardware, and computing, and future education and career interests, as well as assessment of workshop activities' accessibility	N/A	N/A	Students with visual impairments Southern California and one in New York, USA	Grades 7–12	Ludi & Reichlmayr, 2011* [208]
	Pre-, post-, and follow-up surveys, focus group interviews, and field notes	Attitudes, interest, self-efficacy, higher education and career aspirations related to computer science	Gendered stereotypes of computer science (Papastergiou, 2008; VanLeuvan, 2004) [178] [209] Self-efficacy (Bandura, 1997) [24]	N/A	Girls, with a focus on girls from low-income families and with special needs, with limited experiences in computer science. Rural area of southeast. USA	Ages 10-16	Won Hur et al., 2017 [210]
	Pre-, post-, and follow- up interviews; participants' camp work; meetings and interactions video/audio recorded.	Engineering identity, engineering values, epistemology, engineering knowledge, and engineering skills	Communities of practice (Wenger, 1998) [211] with an epistemic frame (Shaffer, 2004, 2006) [36], [212]	Epistemic Network Analysis (Shaffer et al., 2009) [213]	Girls from diverse backgrounds. Minnesota, USA	Middle School	Svarovsky et al., 2011* [214]
	Pre- and post-surveys, video observations	Attitudes, STEM identity, and content specific or social-emotional interests	The Framework for Quality K–12 Engineering Education (QEE) (Moore, 2014) [215]; the Socioscientific Issues (SSI) framework (Zeidler, 2016) [216]	N/A	Girls in the USA	High school (grade 9-12) (ages 12-18)	Burks et al., 2019 [217]
	Pre- and post-surveys, interviews	Positive STEM identity	Drawing from Gilmartin et al. (2007) [218] and Eccles (2007) [219], positive STEM identity is defined through a conceptual framework which assesses 1. Interest in STEM and STEM careers 2. Self-concept related to STEM domains 3. Influence of role models on students' perceptions of STEM professionals	Assessing Women in Engineering (AWE) (AWE, 2008) [100]	Girls in the USA	Middle School (oncoming grades 6-10)	Hughes et al., 2013* [220]

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
		Self-confidence	N/A	N/A	Selected gifted and talented students interested in STEM careers from low-income schools. Special focus was on recruiting diverse, English language learners, and girls. Central Florida, USA	Middle School students transitioning to high school	Dieker et al., 2012* [221]
		Self-efficacy, attitudes measured by interest-stereotypic aspects, interest-non-stereotypic aspects, positive opinions, negative opinions, problem solving, and technical skills, motivation, and self-determination	Constructs measured through a conceptual framework analyzing Motivation (Glynn & Koballa, 2006) [31], self efficacy (Bandura, 1997) [24], and Self-Determination (Koballa & Glynn, 2010) [33]	Engineering Motivation Questionnaire (EMQ) adapted from the Science Motivation Questionnaire (Glynn et al., 2011) [222] Middle School Students' Attitude to Mathematics, Science, and Engineering Survey (MSE) (Gibbons et al.,2004) [68]	Students with diverse backgrounds (ie. "56% Latino participants, 27% White participants, 5% African-American participants, and 12% Other.") Texas, USA	Middle School (Grades 6-8)	Martinez Ortiz et al., 2018* [223]
	Surveys, observations	Interest in engineering and computer science	N/A	N/A	Girls in Ontario, Canada	Middle and Secondary school	Veltman et al., 2012* [224]
		Interest in STEM and perceptions of woman scientists and scientific careers	Gendered academic identities (Davison & Frank, 2006)(Delamont, 1990) [225], [226]	N/A	Girls, majority middle-class and British White. All participants were able-bodied with no evidence of special educational needs. United Kingdom	Year 8 (age 12) and Year 9 (age 13)	Watermeyer, 2012* [227]
	Surveys, retrospective surveys, evaluation cards, observations, focus group interviews	Attitudes and aspirations towards math, science, and engineering	N/A	Survey instrument designed to measure "knowledge", "attitude", and "aspiration" items.	Girls who already have an interest in math and science but are not necessarily gifted or interested in engineering. Ohio, USA	Eighth Grade	Weavers et al., 2011* [228]
	Pre and post tests of knowledge and skills, interviews.	Environmental health literacy measured through functional literacy (changes in knowledge), interactive literacy (sharing with family), and critical literacy	Nutbeam's framework for health literacy (Nutbeam, 2008) [229]	Survey adapted from existing validated instruments for environmental literacy more generally (Leeming, O'Dwyer, & Bracken, 1995; Smith, 2009; Zimmerman, 1996) [230], [231] [232]	Youth from the Apsáalooke (Crow) reservation	9–13 years	Simonds et al., 2019* [8]

Mixed Methods Approach	Methods of Evaluation	STEM-Related Constructs Evaluated	Referenced Theoretical or Conceptual Frameworks Used to Evaluate Constructs	Referenced Existing Research Instruments to Evaluate Constructs	Historically Marginalized Youth of Focus	Age/Grade of Outreach Participants	Citation
	Pre- and post-surveys, review of program documents, observations	Science literacy (measured through science knowledge and science importance), Science confidence, Career choice, role of outside support for science	N/A	N/A	Urban and primarily racial minority girls, mostly African American (60 %) and Latina (27 %). Wisconsin, USA	Middle School (sixth to eighth grade) (ages 11–14)	Lackey et al., 2007* [233]
	Surveys, interviews	Intrinsic and extrinsic relevance as measured on three levels: individual, societal, and vocational relevance	Relevance Theory (Stuckey et al., 2013) [37]	N/A	Girls in Helsinki, Finland Girls were not targeted for the program, gender was only explored as a factor in the analysis	Primary School	Halonen & Aksela, 2018 [234]
		Changes in academic and social capital which contribute to STEM persistence, Identity - shared identities and possible selves	Communities of practice (Lave and Wenger, 1991) [235] Social and academic capital (Bourdieu 1986) [236] Possible selves (Markus and Nurius, 1986) [128]	N/A	Women and/or members of historically marginalized racial and ethnic groups. New York, USA	6th grade - 12th grade	Habig et al., 2020 [11]
		Education and career outcomes	N/A	N/A	African American, financially disadvantaged, first generation college and rural Appalachian youth West Virginia, USA	High School (from grade 9 through to grade 2)	Chester et al., 2020* [237]

*papers we have classified as mixed methods ourselves

**instruments that cannot be presently found

Discussion

Due to the large volume of results, we will primarily discuss overall patterns among the papers, both productive trends and challenges. Given the relatively different approaches, we will discuss quantitative, qualitative, and mixed methods papers separately.

Quantitative Methods

We found 58 quantitative papers that fit the inclusion criteria. Many papers with quantitative methods emphasized the logistics, curriculum, and pedagogy of the outreach activities (e.g. what activities were completed by the students, the technical content of the activities, whether peer mentors such as undergraduate students were the instructors of the activities). The vast majority of data collection was through surveys. In a couple of cases, a focus group [123] or interview [47] was used in addition to surveys, but were not analyzed in a qualitative way (e.g., only had quantitative counts of mentions of a topic). Some studies provided insufficient details on the data collection and analysis to be certain of the form of data collection.

One interesting observation was the inclusion of items that spoke directly to the stereotypes that impact girls and women in STEM. Some studies focusing on girls included items that explored participant alignment or belief in gender stereotypes related to STEM, for example, whether a particular gender was better at STEM work [46], [48], [49], [64], [112], [113]. Examples include: "Women are not encouraged as much as men to go into STEM fields." [48]; "Boys are better at using computers than girls." [64]. These types of identity stereotype items were not present in studies focused on marginalization related to, say, racialized status, income status, or disability status. It is not clear why these types of questions were only asked about gender.

Productive Trend 1: Using quantitative instruments from the literature

Many of the papers used existing instruments. An advantage of this approach is an ability to compare across studies. Many of these are well validated (e.g., S-STEM [109]), but others seem to have limited validation.

Cited instruments among the quantitative studies include: the Common Instrument Suite - Students (CIS-S) [40]; the Morgan-Jinks Student Self-Efficacy (MJSES) instrument [58]; the Computer Self-Efficacy Scale (CSE) [62]; the Computer Attitudes Questionnaire (CAQ) [63]; the Test of Science Related Attitudes (TOSRA) survey [66]; the Middle School Attitudes to Mathematics, Science and Engineering Survey (MATE) [68]; the Draw an Engineer Test (DET) [69]; the Computer User Self-Efficacy (CUSE) scale [77]; the Changes in Attitude about the Relevance of Science (CARS) Questionnaire [79]; the STEM Career Interest Survey (STEM-CIS) [89]; the Relevance of Science Education (ROSE) Questionnaire [90]; the Career Interest Questionnaire (CIQ) [91]; a variety of surveys from the Assessing Women and Men in Engineering (AWE) project [100]; the Upper Elementary School and Middle School/High School Student Attitudes toward STEM (S-STEM) instruments [109]; the PISA 2012 assessment [111]; and the Motivated Strategies for Learning Questionnaire (MSLQ) [121]; the Colorado Learning about Science Survey [114]; the Attitudes Toward Science in School Assessment (ATSSA) [116]; and several unnamed approaches from other papers [13], [45], [50], [94]–[97], [103]–[106], [115], [117]. A few of these (such as STEM-CIS [89] and S-STEM [109]) are also used in the mixed methods papers.

Productive Trend 2: Within-person pre-post matching and long-term follow-up
The majority of studies used pre-post evaluation, which reduces variability via repeated measures comparisons within an individual. This may allow for smaller changes to be detected, or even stratifying changes based on other factors, like age or outreach format.

Several studies used a longer term follow-up, such as an annual followup [119] and telephone survey years later about the influence of camp on career direction [61]. Longer term follow up can help identify long-term effects of the outreach program on participants, which is often the stated goal. It can also help to more directly connect immediate post-outreach measures to the long-term outcome of interest, such as STEM education or career retention.

Productive Trend 3: Array of constructs used
Studies covered a wide range of constructs, and most studies asked about several related things. While in some cases such a broad approach might be less ideal, due to the risk of survey fatigue, in this case there is not clearly a single construct that is recognized as ideally predictive of entering STEM fields, and the impact of constructs may vary over different marginalized groups.

We observed the use of some constructs outside of those we identified in advance, which were added under the "other" category. For example, Reding et al. assessed *social capital* by looking at connections between STEM camp participants and instructors using social network analysis [27]. Although the authors note that social capital is not commonly measured to determine outreach effectiveness and that further research is needed to validate the instrument, it is a promising focus for future outreach evaluation as there is an often an "opportunity gap" for marginalized groups in STEM, where networks associated with academic and career success are not established [27].

Challenge 1: No clear winning quantitative instruments
It is not clear from the reviewed quantitative studies that there is a consensus on what are the best specific instruments to use to evaluate the impact of outreach with particular marginalized populations in STEM. Many cited instruments were used just once within the set of quantitative papers. As a result, even for similar outreach interventions in similar groups (e.g. girls), it is not easy to compare the results to determine how specific outreach programs might be more effective in shifting a construct. It may be that different constructs or instruments are better measures in one group than another, but it is not clear that this question is being investigated.

Challenge 2: Short-term measures not well-connected to long-term outreach goals
There are limited longitudinal associations being made between instruments and STEM degree/career outcomes. The stated goals of the outreach programs in the quantitative grouping are almost exclusively about increasing diversity or representation in STEM educational programs and careers, e.g., "advancing students' interest toward STEM fields and careers" [92]; "motivating their interests and career choices in engineering fields" [238]; "intrigu[ing] middle school aged girls with technology focused career opportunities" [110]; "encourag[ing] students from diverse backgrounds to pursue scientific majors and science-related careers" [81]; etc. However, very few studies examined the long-term outcomes of outreach described in the goals, such as post-secondary STEM program enrollment or STEM career paths. Similarly, it is not

clear which short-term measures are associated with continuation in STEM for each marginalized group, such that we could evaluate new outreach interventions on a shorter timescale [19].

Challenge 3: Which marginalized groups?
It is also clear that some marginalized groups are more studied than others. Twenty-two (22) of the 58 quantitative papers focused on girls/young women as their only marginalized group, with another 13 papers looking at either girls with intersectional identities or an analysis by gender within a population with another marginalized identity (totalling 60% of papers). It is not clear if there is more girl-focused outreach happening, or if the girl-focused outreach is simply studied more often.

Qualitative Methods
We classified 13 papers as qualitative. Some contained additional quantitative components documenting concepts that were not of interest to our review (e.g. science content knowledge; camper satisfaction), therefore for our purposes we have classified these papers as qualitative in their approach to our concepts of interest. The majority of qualitative papers focused on young people in high school (6 papers) and middle school (5 papers) rather than elementary school (2 papers). Regional emphasis is within the United States, with 10 papers studying youth in this nation and three additional papers situated in Spain, Taiwan, and India. Race/ethnicity (9 papers) was the most common form of STEM marginalization authors considered. Given the US focus of the papers, African American and Hispanic identities were the most often documented. Authors also analyzed STEM underrepresentation based on gender (6 papers), socioeconomic status (3 papers), rural/urban regions (3 papers) and ability (2 papers). Of all 13 papers, nine considered two or more of these social locations together (e.g. "predominantly diverse (American Indian and Hispanic) students from low-income families" [138]).

Six of the 13 papers used just one method to collect data on the concepts of interest to this review. Of these six papers, four employed interviews and two used open-ended surveys. The remaining seven papers used more than one qualitative method of data collection (e.g. a combination of field observations, interviews, open-ended surveys, text analysis, and focus groups). A variety of approaches were taken to analyze the data.

The qualitative papers we reviewed offer some unique methodological contributions to the study of STEM outreach programs and also present some challenges.

Productive trend 1: Intersectionality as a method of inquiry
As noted earlier, the majority of qualitative papers considered more than one of participants' social locations (e.g. "girls of color" [133]) in assessing the impact of STEM outreach. Some of these papers incorporated these mutually constitutive social locations into their research design and analysis. For example, Renken, Scott, Enderle, and Cohen [149] theorize intersectionality at the micro-level through psychological identity development: "intersectionality refers to the ways in which social identities, such as gender, race, and ethnicity, interact with one another to shape an individual's defined self-structure and experiences" [239]. Their goal is to document "how the intersectionality of deaf and hard of hearing [DHH] minority racial/ethnic high school students' identities relate to their engagement with STEM activities" [149]. The authors discern that DHH

students experience barriers to STEM, including through the lack of STEM concepts available in ASL signed words. However, Black DHH students encounter these barriers in ways interconnected with race and ethnicity: Black ASL differs from the ASL taught in schools, Deaf culture can marginalize Black culture, and Black culture can marginalize deafness. The authors identify these fundamentally intersectional barriers to interpret participant Nikolas' desire for a STEM mentor who is not only DHH but also Black: "being able to share black and deaf. It's not really skin color. It's just more that they're understanding of what my struggles are rather than just deaf or just black, it's a deaf/black thing" [149].

Productive trend 2: Expanding concepts to reflect the lives of marginalized young people
The use of intersectionality as a method of inquiry lent itself, in some papers, to an incorporation of concepts that attempted to more accurately reflect the lived experience of marginalized young people in STEM outreach. For example, Renken et al. [149] seek to theorize identity by building from critiques of traditional identity theories "based in research with predominantly white, college-aged participants from middle- to high-income families" that did not capture "the way individual differences along gender, racial, and ethnic lines may impact identity and identity development" [240]. In some cases, this expanded conceptual focus went hand in hand with a broader approach to metrics of success for outreach programs. Garcia et al. [133] envision program outcomes tied to the "need to support women of color navigating discriminatory STEM environments by fostering feelings of sociopolitical agency, or their perceived ability to engage in everyday acts of transformative resistance against oppressive social structures" [241]. Similarly, Wade-Jaimes et al. acknowledge properties of whiteness embedded within formal science education and seek to understand the extent to which African American girls achieve a sense of ownership over science as one program outcome intertwined with their development of a science identity [6].

Productive trend 3: Drawing on context for analytical purposes
A methodological strength of some of the qualitative papers was the way they retained the social context in which campers' lives were embedded. One notable paper expanded its unit of analysis to incorporate the impact of the outreach program on outreach participants' shared community. Augusthian et al. retained the presence of *Adivasis* (Indigenous) students' remote South Indian Tribal community in their analysis [147]. The authors not only recorded the impacts of the camp on student interest in future science studies, but also captured the way the camp itself and students' attitudinal shifts impacted the community over time, such that a local network of science education support structures and opportunities began to emerge (which in turn, reinforced students' interest in science studies). This study implicitly reported not just whether the camp was effective for the campers, but for the community the campers were embedded in (thus acknowledging the unique barriers to STEM education faced by rural students, as well as the fundamental role of community in Indigenous ways of being). A second paper by Farland-Smith documented Caucasian American mothers' perceptions of their daughters' behavioral and identity shifts post-outreach, positioning "parents as reporters" of girls' ongoing identity work in familial context [144]. The author explains that "in this study, parental engagement is not an outcome or an expectation, but rather a lens through which to view middle school girls as they interact and construct their science identity in an out-of-school experience" [144]. Mothers' comparisons of their daughters' behavior pre- and post-camp were triangulated with field observations of campers and camper's science journals.

Productive trend 4: Taking a qualitative approach to surveys

Bindis employs a seemingly quantitative, deductive method (a post-camp survey) in a qualitative way using six open-ended survey questions [136]. The open-ended questions documented female campers' perceptions – in their own words – of the way the camp informed their opinions about science and science careers. This enabled the researchers to address features like word choice in participant responses – for example, participant Mae reflected on her science abilities by stating, "I like science & *apparently* (test scores show) I'm great at it" [136]. Data analysis was done through open thematic coding [240],[135], which enables researchers to inductively identify trends in participants' responses, rather than coding for a predetermined set of topics from the literature. Two researchers engaged in check-coding to reach a minimum 95% agreement on codes and themes, thus increasing analysis reliability. This use of surveys with open-ended questions is an efficient and affordable data collection method that offers some of the richness of qualitative research, though the researchers noted that "the responses provided by the participants were not as in-depth as they could have been" [136]. While open-ended surveys give participants the opportunity to share their perspective with reduced researcher influence over the narrative, there is no opportunity for the probing and clarifying questions that may occur during an interview or focus group. A mixed-methods approach can address some of these limitations, as will be discussed later in this paper.

Productive trend 5: Clearly identifying and describing guiding frameworks

The majority of the qualitative papers specified theoretical frameworks that guided their studies, in addition to generally having a high level of transparency in the discussions of methodology, researcher positionality, and ethics. These practices aided in clarifying assumptions made in the study design and analysis, as well as acknowledging the foundations upon which the research builds.

Multiple papers developed their own conceptual frameworks based on existing theoretical approaches. For example, Wade-Jaimes et al. developed a framework for their work that combined communities of practice, Activity Theory, and Critical Race Theory as learning, analytical, and theoretical frameworks, respectively [6]. With this combined framework, "Activity Theory is used as a way to understand the components of a community of practice, and Critical Race theory (CRT) as a way to understand the cultural and historical impacts on and by the community of practice" [6]. Similarly, Garcia et al. developed a "three-stage intersectional sociopolitical development framework" [133] informed by theories of sociopolitical development [130] and intersectionality [131],[132]. This framework helped the authors "to view girls' [sociopolitical] development in terms of their intersecting experiences with race and gender" in their analysis [133].

Other papers simply used existing theoretical frameworks, such as Clark and Kajfez's, which utilized Possible Selves Theory [128] as a framework for understanding identity development in their middle school girl participants [129]. This contrasts with many of the quantitative papers that measured "identity" without specifying a framework. Other examples are Leonard et al.'s [154] use of a framework of sociocultural theory [151] and equitable science teaching [152], [153], and Stevenson and Casler-Failing [159] framing their program and study in social constructivism [156], culturally responsive pedagogy [157], project-based learning, critical literacy [158], and multimodality.

Many of the qualitative papers also included discussion of the methodologies informing the research, the biases and positionality of the researchers, and the ethics considered in the studies. For example, see Clark and Kajfez's "Methods" section for a particularly thorough description of research procedures, participants, data collection, analysis, researcher positionality, and methodological limitations [129]. This level of transparency allows other researchers to follow the study better, to make their own assessments about how the conclusions were reached, and can guide future researchers in designing and writing up qualitative assessments of STEM outreach in similar ways, in line with Stenfors et al.'s key criteria in evaluating the trustworthiness of qualitative research [242]. Additionally, although many of the quantitative papers reviewed implicitly assumed a positivist epistemology, as is the norm in engineering, some qualitative papers acknowledged other epistemologies and approaches as valid and effective.

Challenge 1: Making participants' whiteness part of the analysis
Qualitative papers with primarily white participants (usually white girls) often acknowledged this in the participant demographics section, sometimes noting it as a limitation of the sample but not including it as part of the analysis in the way that is often done with racial minority participants. Yet white girlhood is not racially absent or neutral. Ideas about whiteness are just as much a product of social forces as are ideas about blackness or other racial categories. There is an opportunity here to theorize whiteness as a meaningful component of young people's intersectional social locations informing their engagement with STEM outreach. For example, a researcher could ask: what privileges might girls who see themselves as white and/or are perceived to be white experience that shape their outreach outcomes? Studies theorizing whiteness in this way could offer useful methodological and analytical contributions given that the interlocking systems of oppression that produce marginalization are connected to the interlocking systems that produce privilege [131],[132].

Challenge 2: Expanding methods for generating qualitative data with children in outreach
The youngest outreach participants among the qualitative papers we reviewed were eight years old. These papers with young participants utilized a combination of interviews, group discussions, focus groups, journals, outreach artifacts, open-ended surveys, and/or drawing. However, when collecting data with children, it can be challenging to ensure they understand all questions posed and can communicate their ideas fully in a verbal or written format, particularly when asked about more abstract conceptions of self [243]. A 2023 systematic review in the *International Journal of Qualitative Methods* identified several child-centered data generation methods that can be triangulated with other methods, including draw-and-tell, role play sequences, persona doll or puppet scenarios, and child-guided tours [244]. Draw-and-tell was the most common. Non-permanent drawing mediums such as chalk were found to "create a safer environment for communication and encourage deeper dialogue from children" as they are able to erase and revise in a low-stakes meaning-making process [244].

Challenge 3: Addressing power relations in outreach data collection and interpretation
Researcher-participant power relations are important to consider when conducting research with children and youth, as they can shape the outreach data collection and analysis process. For example, in some papers, data collection in the form of interviews or focus groups was

conducted by an outreach program teacher or someone otherwise known to participants. This familiarity can strengthen rapport but may also direct participant responses in unintended ways, with participants potentially withholding concerns, criticisms, or downsides of their outreach experiences. It is worth noting that some papers did describe steps taken to address power relations, such as conducting interviews with children in groups of three to help them feel more at ease sharing their views with an adult [147]. Beyond the data collection itself, there are additional ways to share power with participants, including involving them in "selecting their preferred data-collection methods and assisting in data interpretation" [244]. Participants can also confirm that the researchers' interpretation of the findings truly reflects their experience through a member checking process, which can increase validity [245]. Lastly, power relations can also inform participant well-being, including participants' sense of agency over their role in the research process. Among the 13 qualitative papers, the collection of assent (children's informed agreement to take part in the research process) was only mentioned in three.

Mixed Methods

A total of 33 papers were classified as mixed methods (Table 5). Following Creswell's methods-oriented definition of mixed methods [246], only papers that collected, analyzed, and interpreted both qualitative and quantitative data for the purpose of investigating the same relevant research questions were retained as mixed methods within our review. Papers that simply collected and analyzed qualitative and quantitative data without integrating the qualitative or quantitative results were excluded from this classification and placed within the more appropriate other grouping (qualitative or quantitative). As well, methods or instruments that evaluated content knowledge and program-specific satisfaction were excluded from our analysis.

Of the 33 papers, 11 papers explicitly followed and referenced a mixed-methods approach. The remaining 22 papers were classified as mixed methods if both qualitative and quantitative methods and collected data were used to inform the results. The papers were categorized into four key mixed methods approaches [246], [247]: explanatory sequential design (7 papers), exploratory sequential design (2 papers), embedded design (4 papers), and triangulation or convergent design (20 papers). The most commonly used methods consisted of a combined use of surveys and interviews (23 papers). Additional complementary methods include field notes, observations, or video recordings (13 papers), student work (4 papers), program documents (2 papers), student reflections (3 papers), and physiological data through skin temperature biofeedback (2 papers).

These studies predominantly took place within the United States (29 papers) with four additional papers situated in Canada (1 paper), United Kingdom (2 papers), and Finland (1 paper). The majority of the mixed methods studies focused on youth in middle school and high school (10-18 years old) (30 papers) with limited focus on children in primary school (under 10 years old) (5 papers). Given the geographical contexts of these studies, the outreach programs aimed to address barriers in STEM education based on race and ethnicity, primarily for African American and Hispanic/Latinx youth (17 papers), gender (16 papers), socioeconomic status (14), Indigeneity (1 paper), and disability (4 papers).

Since mixed methods approaches utilize both quantitative and qualitative methods, much of the discussion in this review paper thus far is applicable within the individual quantitative and qualitative methods of a given mixed methods paper. The mixed methods papers reviewed herein, additionally highlight some unique advantages of mixed methods in general, and specifically how mixed methods can benefit the evaluation of STEM outreach.

Productive Trend 1: Adding depth, context, and robustness through mixing
Mixing quantitative and qualitative methods in one study can help to address shortcomings of either method and achieve more than what is possible within a single method. Most notably, mixed methods work can broaden the scope of what one study can achieve and consequently enable greater efficiency in the process. For example, instead of relying on a subsequent study to delve deeper and explain the context behind quantitative data, mixed methods can intentionally include qualitative data in a number of different ways that are either sequential or concurrent to the collection or analysis of quantitative data. Explanatory sequential mixed method designs align particularly well with this noted strength as they involve collecting and closely analyzing quantitative data, followed by qualitative data collection and analysis [246]. Adams et al. studied the impact of an after school club on the attitudes, career understanding, and grit of a group of primarily African American and Latinx youth (8-13 years old) in the US [28]. Using an explanatory sequential design, the authors were able to conduct pre- and post- surveys using a number of validated survey instruments (including the TIMSS [195]) and followed up with a focus group to provide more clarity on the quantitative findings [28].

Convergent mixed method designs involve the collection of quantitative and qualitative data, separate analyses, and a comparison of results that ideally “converge” to describe a phenomenon [246]. Martinez-Ortiz et al. investigated the impact of a summer engineering camp on middle school students in a Latinx community and utilized a convergent design [223]. Quantitatively little difference was seen in the students’ self-efficacy as a result of the camp, however, qualitative findings were able to show that students came into the camp with high senses of self-efficacy, thus the limited changes over the course of the camp could be explained in context [223]. Similarly, triangulation involves simultaneous quantitative and qualitative data collection about a particular phenomenon to enable robust conclusions to be drawn based on comparison of the results from both models [248]. For convergent or triangulation mixed methods studies that are longitudinal, interviews can add important context to outcomes by highlighting recollections and perceptions of the impact that outreach will have in the future [11], [192], [237]. The specific qualitative tools used in conjunction with quantitative surveys also influences the robustness and depth of mixed methods studies. For instance, with ethnographic observations, mixed method studies offer an opportunity to add contextual depth of marginalized students’ experiences that cannot be directly asked through surveys and interviews. To illustrate, Mutegi et al. provide contextual insight into the racial disparities in survey outcomes between African American and non-African American students through highlighting the encounters and impact of microaggressions faced by African American participants [201].

Productive Trend 2: Enabling the creation of context-specific instruments and theories
The integration of qualitative and quantitative approaches offers the opportunity for studies to create their own validated instruments or conceptual frameworks and theories that are specific to the demographic of student participants and the evaluated program. For example, following an exploratory sequential design, Denson used data from focus group interviews, interpreted through a grounded theory approach, to develop a reliable quantitative instrument [162]. The

resulting survey instrument was then used to explore the program-specific impact and influence on students' self-efficacy and engineering interests and perceptions. Similarly, for convergent parallel-mixed methods, as Burks et al. illustrate, code categories used for quantifying video qualitative responses can be derived from surveys and open-ended responses [217]. Such an approach complements the authors' use of grounded theory with a constant comparative analysis in which multiple data sources are systematically collected and analyzed to create a conceptual framework relevant to the outreach program.

Productive Trend 3: Capturing the presentation(s) of self across research methods
A person's identity, confidence, or sense of belonging is not necessarily stable; it can shift depending on the social environment the person is in. Every research method is tied to a social environment. For example, focus groups are shaped by group interaction, interviews are shaped by one-on-one dynamics, and surveys are shaped by the absence of interaction but the presence of a text. Is data produced through one context more "true" than the others? DiSalvo et al. [7] conducted research with African American male adolescents completing covert outreach framed as paid video game testing employment. The covert nature of the outreach was intended to support "African American men from marginalized communities [in] navigat[ing] how to maintain social acceptance of the outreach activity within their various social groups (family, peers, etc.)" [7]. By using different methods of data collection (surveys, observations, interviews, and focus groups), the research team was able to document how participants perform their identity strategically for different audiences through "face-saving tactics that the young men used to negotiate between maintaining cultural values and identifying with learning and computer science" [7]. For example, focus groups highlighted the role of peer-pressure and face-saving tactics based on the expectations of group consensus. Early observations illustrated face-saving tactics of projecting a "cool pose" despite survey and interview responses expressing interests in computer science. Surveys also highlighted the limitation of failing to capture avoidance, a key aspect of self-presentation. Through a mixed-method approach, this study illustrated how the triangulation of different data types can illustrate how participants, in real time, perform their identity in different and possibly contrasting ways.

Challenge 1: Lack of clarity of methods integration and methods reporting
The integration of several qualitative and quantitative components in methodological development or results analysis is a key stage of mixed methods. In studies incorporating both qualitative and quantitative data from multiple sources, particularly convergent design studies or methods with observations, we found limited discussions elaborating upon how each data source informed the results. Additionally, there was a general lack of detail in the presentation of the mixed methods design in the studies we reviewed. According to a recent review of mixed methods research in interventional outreach studies, these reporting flaws "warrant close examination because they may prevent researchers from fully communicating the unique insights afforded by a [mixed methods] approach" [249].

Challenge 2: Addressing threats to validity
As with quantitative and qualitative approaches, mixed methods have their own unique set of threats to validity, differing between types of mixed method designs [246]. A potential threat involves the unequal sample sizes between quantitative and qualitative methods and the subsequent weighing of results such as differences between the number of outreach participants

completing the survey and number of outreach participants interviewed. A key question, primarily for convergent studies, lies in how results from multiple methods are weighed to determine a conclusion. For example, DiSalvo et al. highlight a limitation in the use of surveys and identifying statistically significant differences without establishing norms or a baseline [7]. As such, the researchers highlighted greater emphasis on results from focus group interviews and observations. For explanatory designs, designing for validity involves asking participants the right questions to explain quantitative results [246]. As such, incorporating theoretical or conceptual frameworks is imperative to identifying the right questions to explain students' quantitative results. For exploratory designs, a challenge lies in the validation of an instrument or intervention, designed through translating qualitative results, in which demographics of outreach programs may vary between each cohort [246].

Implications and Future Directions

There are some general limitations applicable across quantitative, qualitative, and mixed methods papers that emerged from this review, warranting further discussion and recommendations.

Firstly, the goals of outreach programs and the motivations for writing outreach papers differed among authors. Many studies were aimed at program evaluation and/or improvement and did not directly aim to investigate mechanisms behind why or how a particular phenomenon or construct (e.g. self-efficacy) impacted historically marginalized individuals' participation in or perception of STEM. There was often an incongruence with the purpose of an outreach program and what was evaluated. In other words, a STEM camp may be motivated and targeted to improve inclusion of girls in STEM careers, but a paper evaluating the camp may focus instead on how girls like the camp or learn the material and omit evaluation of metrics related to inclusion. This made it challenging to find an adequate basis of comparison for papers.

Additionally, there was a wide variety of instruments (e.g. surveys or survey questions) used in the different outreach studies examined, adding to the challenge of cross-paper comparison. Many studies did not use validated instruments or used validated instruments in different contexts without previously testing the applicability/extension of the instrument in the new context. For example, an instrument may have been validated for use in a school context, for a particular marginalized group, and may or may not be able to be extended to an informal outreach program aimed at a different marginalized group. This highlights a need for a more consistent, high quality set of validated instruments for evaluating important constructs and guidance for how outreach evaluators ought to select and validate instruments.

Much like certain instruments cannot be used across all contexts and groups, some of the concepts and theories that are well-established within STEM outreach literature (e.g. "identity development" [149]) may have been defined in ways that reflect more privileged life experiences and may not be relevant for all marginalized youth. To address this gap, a number of papers expanded their conceptual lenses for documenting participant outreach outcomes (e.g. by measuring "sociopolitical agency" [133]) and paid attention to the ways participants navigated cultural values during STEM outreach [7]. These approaches are indicative of the need to continue acknowledging experiences of systemic oppression at a methodological and theoretical level within outreach study design.

In many cases, the methodological limitations found in our sample reflect the lack of funding within outreach programs as well as limited opportunities for staff capacity-building for evaluation training. It may be that limited staff hours and limited social science research expertise on the outreach teams leads to some of the trends, such as: (a) a majority of quantitative studies among all studies (more familiar to STEM-trained individuals), (b) primarily short-term measurements, (c) use of unvalidated items/instruments, (d) missing explicit conceptual frameworks, and (e) evaluation of a particular camp or workshop rather than generalizable research about outreach. There is therefore a need for outreach program funding for high quality assessment and/or to foster relationships between programs and outreach facilitators/researchers (e.g. via universities).

Limitations of our approach

One limitation of our systematic review is that, despite a 30-year search window, the vast majority of papers we located across quantitative, qualitative, and mixed-methods were published within the past 10 years. This may have been shaped by our search terms and exclusion criteria (e.g. some outdated language for historically marginalized groups that we failed to capture). However, it is also conceivable that there has been a more recent push to investigate the impact of outreach on historically marginalized groups, due to enhanced attention, funding, and policy in this area.

Second, due to the variable ways in which authors referred to historically marginalized groups, we used the author's specific terminology so as to not impose a categorization of groups that was not intended by the author. Although this is most accurate, it makes it more difficult to examine trends across or within specific historically marginalized groups.

Finally, we focus only on *informal* outreach programs. Future research could look at the impact of other types of outreach programs that exist during school time, or that might exist through mentorship programs, both of which were considered out of scope for this study.

Conclusion

If we hope to improve the representation of historically marginalized groups in STEM through informal outreach, evaluating the effectiveness of such initiatives is critical. In the included studies of this systematic review that have evaluated such outreach initiatives, researchers have incorporated qualitative, quantitative, and mixed methods to varying degrees of applicability and success. Mixed methods and qualitative studies were generally of higher quality and depth since they enabled authors to explore and explain not only the trends towards inclusion in STEM, but to adequately capture the context. Additionally, there are a wide variety of constructs that can be measured to connect to what would be considered an effective outcome and a variety of instruments that can be used to measure such constructs. Definitions for such constructs, and utility for such instruments is not consistent. Finally, measures tended to be short-term, but outreach goals were long-term, and this mismatch was not addressed in most studies. There is room for improvement in applying high-quality methods to these questions of outreach impact.

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