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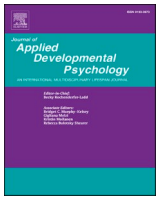

fsQCA for discovering social emotional pathways to adult STEM engagement

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ABSTRACT

The Roads Taken Project utilized fuzzy set qualitative comparative analysis (fsQCA) to examine necessary and sufficient conditions for achieving STEM involvement of alumnae(i) of six intensive STEM-based youth programs 15 to 25 years after participation. Outcomes included overall STEM involvement (including STEM academics and careers, personal STEM involvement, community STEM involvement, and long-term STEM identity), and post-program and program contribution to social-emotional learning and development. We identified conditions contributing to pathways to these outcomes. Results revealed that, although differing for the varied participant groups, social-emotional learning and development played a role in all the pathways but was particularly prominent in pathways to community STEM involvement. High program dose accompanied by a sense of competence, relatedness, and autonomy in programs with highly varied strategies led to social-emotional learning and varied by participant groups. Along with presenting findings, this study highlights fsQCA as a method for revealing the complex relationship of social-emotional development to STEM outcomes and the multiple pathways for achieving them.

Introduction

From a wide range of intensive long-term STEM youth programs that have occurred over the past 50 years, the Roads Taken research project (NSF #1906396) learned about the role of social-emotional learning and development in pathways from program participation to involvement with STEM (Science, Technology, Engineering, and Math)15 to 25 years later. Specific to this paper, we asked to what STEM outcomes did social-emotional learning and development contribute, in what ways did they contribute, and how do those ways may have been unique to populations historically underrepresented in STEM professions (specifically female, low SES, and/or from racial/ethnic minorities). Moreover, we recognized the complexity of our question and the need for a methodology that would accommodate it. That is, rather than establishing an effect size of social-emotional learning and development in a most probable causal pathway to adult STEM involvement, we were interested in the varied ways social-emotional learning and development specifically interact with other conditions such as STEM identity and the programming itself to contribute to adult STEM involvement. Recognizing the limitations of inferential statistics to reveal a satisfyingly complex response to this question, we explored fuzzy-set qualitative comparative analysis (fsQCA) as a method for doing so. More specifically, we sought to find evidence to support or refute two overarching hypotheses. First, we expected that social-emotional learning would play varied important roles in adult STEM involvement. Second, we expected that fsQCA would provide a practical tool for revealing these varied contributions. By understanding these varied relationships, practitioners would be able recognize how to differently affect them and researchers would understand how to differently investigate them.

Since the 1970s, out-of-school time (OST) youth programs have engaged underserved youth with STEM learning and career exploration and have become a major feature in the educational landscape of the

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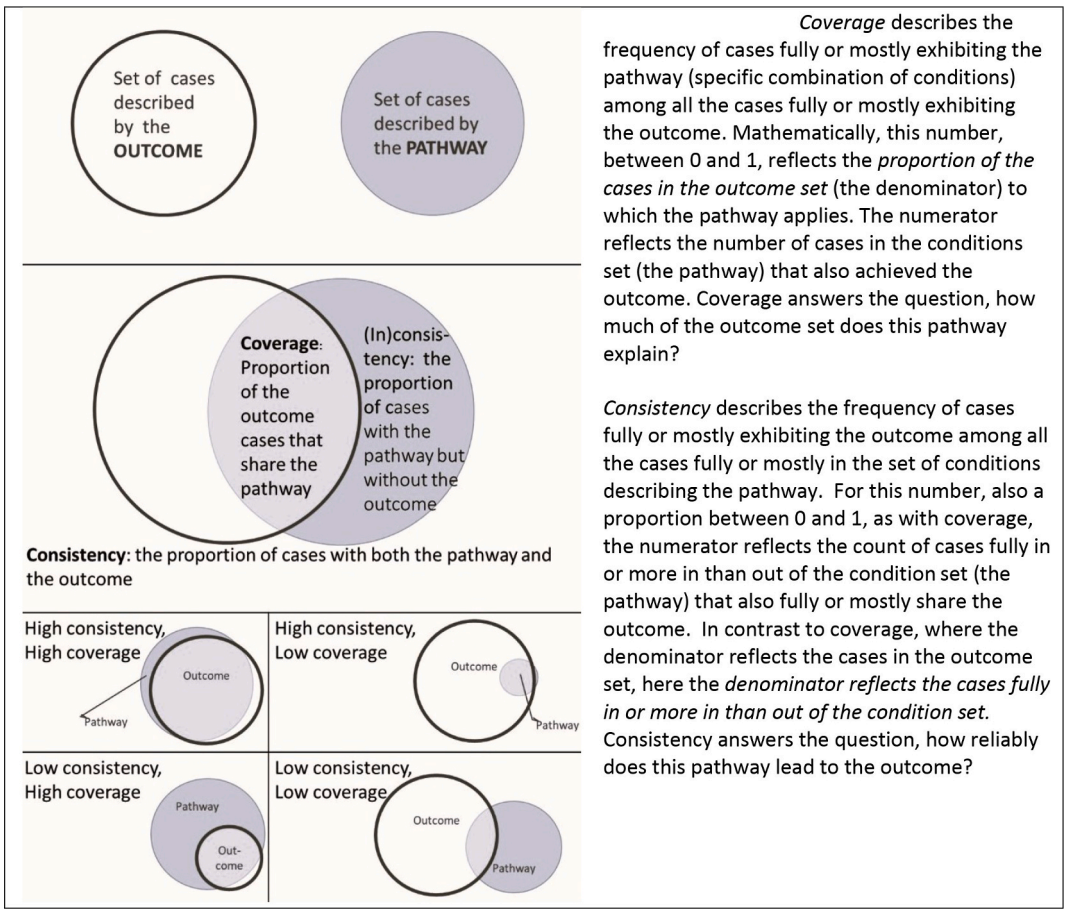

Fig. 1. An Explanation of fsQCA consistency & coverage.
Coverage describes the frequency of cases fully or mostly exhibiting the pathway (specific combination of conditions) among all the cases fully or mostly exhibiting the outcome. Mathematically, this number, between 0 and 1, reflects the *proportion of the cases in the outcome set* (the denominator) to which the pathway applies. The numerator reflects the number of cases in the conditions set (the pathway) that also achieved the outcome. Coverage answers the question, how much of the outcome set does this pathway explain?
Consistency describes the frequency of cases fully or mostly exhibiting the outcome among all the cases fully or mostly in the set of conditions describing the pathway. For this number, also a proportion between 0 and 1, as with coverage, the numerator reflects the count of cases fully in or more in than out of the condition set (the pathway) that also fully or mostly share the outcome. In contrast to coverage, where the denominator reflects the cases in the outcome set, here the *denominator reflects the cases fully in or more in than out of the condition set.* Consistency answers the question, how reliably does this pathway lead to the outcome?

United States (Schweingruber & Fenichel, 2010). Many of these programs additionally offer youth development activities, work-skills training, exposure to STEM careers, and encouragement to persist in math and science coursework to prepare for university programs. However, these STEM-focused programs often function on untested assumptions that participation influences education, career, and life choices related to STEM with lasting effects. In 2015, the National Research Council cited two major limitations in approaches used in youth program studies: 1) focus on short-term outcomes while ignoring long-term outcomes and impact, and 2) not recognizing the differences among programs in assessing impact. To date, multiple studies have examined short-term outcomes of these programs. However, few have had the resources to conduct and confront the multiple challenges of long-term follow-up studies. (See Weiss et al., 2025).

This paper addresses the challenge of documenting the contribution of youth programming to adult outcomes, especially given the complexity of any number of life influences (Befani & Mayne, 2014; Staus et al., 2021), social-emotional learning and development among them. The relatively few published long-term studies have sought to meet this attribution challenge with mixed methodology (e.g., quantitative questionnaires and qualitative interviews), including quasi-experimental comparison group designs (Burack et al., 2019; Meschede et al., 2022; Schumacher et al., 2009). Others have been primarily qualitative; some identify themes for motivations for participating in and pursuing STEM (McCreedy & Dierking, 2013) or for program strategies that contributed to STEM outcomes (Habig et al., 2020). Quantitative analysis has ranged from simple descriptive statistics (Linzer & Munley, 2015; VanMeter-Adams et al., 2014; Wasserman et al., 2020) to hierarchical modeling (Garibay, 2018), path analysis, and causal modeling using structural equations (Soldner et al., 2012; Wasserman et al., 2022). In addition to structural causal modeling, the Roads Taken project identified causal pathways by using fsQCA.

Herein, we describe the fsQCA aspect of the Roads Taken study, offering the methodology not only as a viable addition to meeting the attribution challenge but particularly to elucidate the complex role of social-emotional learning and development as a mediator between STEM youth programming and adult STEM outcomes. In this analysis, fsQCA modeling included participant perception of post-program social-emotional development as a condition that could contribute to adult STEM identity and involvement 15 to 25 years after the program. Modeling also included various program strategies that may have functioned independently or in conjunction to contribute to the perception of the program's contribution to social-emotional development.

Our objectives for this paper have important implications for both research and practice. First, by demonstrating the important and varied

roles of social-emotional learning to adult STEM involvement, we contribute to the evidence from which future practitioners and funders can draw to support this kind of learning in STEM programming. Second, by demonstrating fsQCA as an effective methodology, we help researchers understand the complexity of conditions under which social-emotional learning contributes to STEM and other learning outcomes.

Method

Fuzzy set qualitative comparative analysis

Fuzzy Set Qualitative Comparative Analysis (fsQCA) is a set-theoretic approach that identifies combinations of conditions that may be necessary or sufficient for an outcome to manifest. Pioneered by sociologist Charles Ragin to use case-based data to establish the complexity of multiple co-occurring causal pathways to an outcome, the method supports the investigation of both quantitative and qualitative data (Fiss, 2011; Rihoux & Ragin, 2012). By allowing for comparison across observed cases, while still recognizing the complexity of each case (Rihoux & Ragin, 2009), it reveals multiple pathways to a given outcome. For our analysis, we defined a *case* as an alumna(us) from one of six partnering programs who completed an online questionnaire. By selecting cases that demonstrated an outcome of interest (see section below titled The Roads Taken Conceptual Model) and comparing across them, the method revealed multiple and varied combinations of conditions that lead to those outcomes.

Functionally, fsQCA identifies in a dataset, sets of cases that share combinations of conditions (referred to as a "condition set", Khairati et al., 2021) consistently associated with an outcome—consistently, because, with rare exception, in addition to demonstrating the conditions, each of those cases also demonstrated the outcome's presence and rarely its absence. We use the term "pathways" to refer to these groups of conditions that consistently lead to an outcome.

As illustrated in Fig. 1, the proportion of the cases in the condition set that share the outcome is considered *consistency,* one of two important indicators of the integrity of an fsQCA solution. Consistency is most closely related to reliability in more traditional analytical methods, meaning a pathway or solution with low consistency does not reliably lead to the outcome.

The second important indicator of solution integrity is *coverage*, also illustrated in Fig. 1. The proportion of the cases in the outcome set in *common* with the cases displaying the combination of conditions (the condition set), is considered *coverage*. Each combination identified as consistent with an outcome independently may or may not demonstrate high coverage (A decided advantage of the method is its ability to reveal pathways less frequently followed but equally as effective). Together, however, the combination of pathways in an acceptable solution should demonstrate enough coverage to be able to explain most all of the pathways that lead to the outcome. Coverage in fsQCA is most closely related to model fit and coefficients in a regression analysis, describing how much of the variance in an outcome the conditions jointly explain.

Two additional terms, "necessary" and "sufficient", are central to fsQCA analysis and meaning making. When every case (or almost all cases) in the outcome set also demonstrates a particular condition, the condition is considered *necessary* to the outcome (e.g., completing a minimum number of credits is necessary but not sufficient for college graduation). *Sufficient* for leading to an outcome are sets of conditions mostly shared (that's the fuzzy part) by at least a small but perhaps even by a large number of cases that all share the outcome. These conditions are considered sufficient because they occur repeatedly across cases that share the outcome but are not *always* present. For some students, having easily accessed financial resources and a strong peer support network in addition to the necessary minimum credits may be sufficient for the graduation outcome. Others may need intrinsic motivation and perseverance along with the *absence* of easily accessed financial resources.

In this college graduation example, a combination of conditions of taking specific courses within a particular degree program, class attendance, and financial resources may have high coverage because, in the set of all college graduates, many cases also fit into the set that combines the three conditions—sufficient for college graduation, but not necessary. A necessary condition would likely be attaining a requisite number of credit hours at a passing rate. The consistency measure would be the rate of college students with the three conditions who did graduate, removing from the numerator those who did not.

Note that in fsQCA, set theory guides the understanding of sets made up of cases with certain conditions such that each case can be considered in or out, and in fuzzy set analysis, also more in than out or more out than in. (In what is known as *crisp set QCA,* cases can only be in or out.) Independent variables are used to define a condition to which a case has full, partial, or absence of membership. As an example, for this study we used variables from responses to STEM-identity questionnaire items to determine membership in the set of people with the condition of being *highly* STEM-identified. Thus, the method refers to "conditions" rather than "variables." Similarly, because it describes a set with a threshold for membership, the term "outcome" is used rather than "dependent variable."

The process of determining status of set membership is called *calibration*. Calibration allows for the incorporation of extensive case knowledge to numerically capture the variation across conditions (Ragin & Fiss, 2008). During this process, experts with extensive knowledge of the variables as applied to cases make judgments for calibrating, i.e., determining membership as in, out, or some degree of in or out of each condition and each outcome. Calibration involves placing the cases into sets for each condition and outcome using thresholds for full membership, a crossover point at which a case becomes *more in than out* of versus *more out than in* the set, as well as a threshold for full non-membership. The calibrated values used in the fsQCA analysis range from 0 (fully out of the set) to 1 (fully in the set).

Boolean algebra provides the foundation in fsQCA for assessing set relationships, particularly how conditions—defined in each case by a range of set membership (1) to non-membership (0)—overlap to form causal pathways (as illustrated in Fig. 1). When conditions exhibit overlap with each other (i.e., when the combination of their presence appears across multiple cases in the dataset), they may indicate a potential causal configuration. Boolean algebra enables the logical operations—intersection (and), union (or), and complementation (not)—that define these set relationships while the measures of consistency and coverage are quantitative assessments of proportions based on set membership scores.

Three associations form the basis of how fsQCA reveals the causal complexity (Ragin & Fiss, 2008), which is critical to explaining long-term STEM outcomes:

(1) E*quifinality* involves multiple differing pathways that can lead to the same outcome.
(2) In *conjuncturality*, specifically interdependent conditions comprise these pathways; and
(3) With *asymmetry,* some of these pathways may include the presence of a specific condition, while others include its absence *or,* whereas the presence of a set of conditions may consistently lead to an outcome, the absence of those conditions don't necessarily lead to the absence of the outcome (Masue et al., 2013).

This complexity is difficult to model for confirmatory and even exploratory inferential statistical analysis. Moreover, even if modeled, it is often missed because these traditional methods are designed to estimate the effect of an isolated condition on an outcome or test the fit of a single modeled explanation of the outcome (Thiem & Baumgartner, 2016). In a regression analysis of data where multiple contrasting conditions lead to an outcome in some contexts and not in others, unless specifically identified with interaction terms, the covariates would likely average to insignificance (Fainshmidt et al., 2020; Thiem &

Baumgartner, 2016; Vis, 2012). For example, consider data where, in some cases, the absence of STEM identity combined with high STEM support leads to social-emotional development, and in other cases, the presence of STEM identity combined with leadership programming also leads to social-emotional development. Unless specifically hypothesized and modeled, these contrasting roles of STEM identity would be lost in a regression analysis. Moreover, too many interaction terms in a regression equation make results difficult to interpret. With fsQCA, they would simply emerge as two pathways to social-emotional development, each with their own coverage and consistency.

Thus, fsQCA presents STEM development researchers with an analytical option that more closely captures the messy and varied contributions of human experience to an outcome. For practitioners, it produces less prescriptive results, more aligned with making sense of the varied conditions they face. These kinds of results set them up for expecting and programming for multiple pathways and program theories.

Proponents of fsQCA argue that the approach effectively bridges the gap between the results of quantitative research and the depth of information that is often known about individual cases (Fiss et al., 2013) and aids the evaluation of programs with outcomes affected by complex variables both within and outside of the programming (Hill et al., 2019) due to its inherent emphasis on causal complexity (Mello, 2021; Schneider & Wagemann, 2012). This is because fsQCA leverages set theory and Boolean algebra to produce a solution that honors the complexity inherent in the configurations of conditions necessary or sufficient for an outcome (Rihoux & Ragin, 2012).

On the other hand, we note here that the tradeoff for documenting this complexity is the absence of information about the relative amounts of contribution of conditions to an outcome. For example, in a pathway to graduation that consists of intrinsic motivation, perseverance, and financial resources, fsQCA will not be able to provide estimates of how much of each is necessary.

Relative to this study's hypothesis that social-emotional learning would play varied important roles in adult STEM involvement), we selected fsQCA as the method of choice because fsQCA analysis would reveal multiple and varied pathways to STEM involvement without the need for a priori models. Included among the pathways revealed may be some with high consistency but low coverage, likely testing as insignificant with inferential statistics, even using an a priori model. Moreover, within each of the condition sets sufficient for achieving each outcome, fsQCA analysis would reveal how social-emotional learning would need to specifically combine with other conditions rather than assuming each given condition would contribute independently. In addition, it might be possible that social-emotional learning might not be a necessary component in any of the pathways in our dataset, thus providing no evidence to support the hypothesis. With these varied combinations of sufficient conditions revealed, practitioners would be able recognize how to differently affect them or, in the words of one Roads Taken practitioner, "[the fsQCA approach] captures what goes on in a program and brings to life a strategy for program reflection)."

FsQCA has a long history of use in analyses in the fields of comparative sociology and comparative politics (Fiss et al., 2013) and has expanded to additional disciplines (Ragin & Fiss, 2008; Rihoux et al., 2013), becoming more accessible due to improving technical sophistication and the development of analysis software and R software packages (Duşa, 2019; Oana & Schneider, 2024). In social service and educational program evaluation, fsQCA has been introduced as a method that supports realistic evaluation (Befani, 2013) and, following the same logic, accounts for varied combinations of context and program variables, supporting contribution analysis (Mayne, 2012) as well.

More recently, fsQCA has been applied to educational and psychological studies as varied as the study of the intentions of pre-service teachers (Zhang et al., 2023), enablers of entrepreneurship (Huang et al., 2021; Sisu et al., 2024), construction worker safety behaviors (Yuan et al., 2022), and organizational psychology (Cangialosi, 2023). Across all these studies, fsQCA has been utilized to reveal necessary contextual factors, always or often present when the outcome is present, and multiple sufficient pathways to an outcome, present some of the time, and any of which can involve multiple conditions and interactions between them.

Application of fsQCA in the study of youth attitudes and emotional development is also not new. In 2008, Charles Ragin teamed with Fiss to use fsQCA to investigate the relative importance of student test scores and socioeconomic background to the outcome of "life chances," in their parlance. In Sweden, a group of scholars investigated the youth-friendliness of youth clinics to identify the best combination of conditions needed to implement desired practices in the service of young people (Goicolea et al., 2016). Another team of authors (de la Barrera et al., 2019) investigated the associations between social and emotional factors such as emotional competence and self-esteem on adolescent mental health and well-being. Another investigated student characteristics like perceived relevance, perceived confidence, media affinity, and perceived self-efficacy and their influence on students' attitudes toward the use of video games for educational purposes (Martí-Parreño et al., 2018).

The roads taken research project

Funded by the National Science Foundation (#1906396: Roads Taken: A Retrospective Study of Program Strategies and Long-term Impacts of Intensive, Multi-year, STEM Youth Programs), the research project was designed initially with a mixed method approach using an online quantitative questionnaire analyzed with structural causal modeling (Elwert, 2013) augmented with qualitative analysis of structured interviews, journey maps, photo journals, and resumés from a purposive sample of questionnaire respondents. Lower than expected response rate (due largely to challenges described in Weiss et author., this issue) directed our attention to QCA in general (and fsQCA specifically) as a means of triangulating our structural equation modeling results and our concerns for lack of power to detect significant relationships.

To locate alumnae(i) for this follow-up study, the Roads Taken research project turned to six programs initially established as part of the YouthALIVE! (**Youth A**chievement through **L**earning, **I**nvolvement, **V**olunteering, and **E**mployment) Initiative led by the Association of Science and Technology Centers and funded by the DeWitt Wallace-Reader's Digest Fund (now the Wallace Foundation). The initiative, funded from 1991 to 1999, was one of the more comprehensive efforts to provide intensive, multi-year, STEM-focused, youth programs. Leaders provided extensive technical assistance to its member institutions in developing, implementing, and sustaining meaningful and dynamic programs for youth aged ten to seventeen. YouthALIVE! strategies varied across program sites but generally targeted youth from populations traditionally underrepresented in STEM education and careers, providing them with combined strategies for youth development, academic STEM enrichment, pre-employment training, and mentoring. Across multiple years of participation, teens may have become guides for exhibits on complex scientific concepts, engaged visitors through scientific demonstrations, taught STEM activities for younger children, and explored career options in STEM with adult role models, all while learning about and practicing workplace skills. YouthALIVE! funding ended in 1999. The overall evaluation (Sneider & Burke, 2010) and many individual program evaluations identified successful short-term outcomes.

This Roads Taken study drew from six YouthALIVE! Programs, each designed and initiated more than 25 years ago as youth development programs based in museums, zoos, aquariums, science centers, and botanical gardens. We selected the six partnering programs because they continue today, and their administrators had access to program participant records from 1991 through 2005. Each hired a program alumna (us) or staff member to function as a liaison to fellow alumnae(i).

Liaisons met regularly and received training in contacting alumnae(i), explaining the Roads Taken project and questionnaire, and keeping careful records that included a complete alumnae(i) list from the years of interest, location attempts (e.g., through parent phone numbers, social media, snowball contacts, etc.), invitations, follow-up asks, consent, and data completion. Their work consisted of search (free address lookup services, Internet searches, social media, news releases, and word of mouth), contact, invitation, and follow-up.

Using a protocol, determined exempt from Human Subjects Review by I&E Review, liaisons located, contacted, and invited alumnae(i) to participate, sent them the link to the questionnaire, and gained their consent to participate. No monetary incentives were provided to alumnae(i) to complete the questionnaire, though some programs used the contact to invite alumnae(i) to reunions. Many alumnae(i) reported that they were eager to provide feedback to help their program. Data from the 196 alumnae(i) who completed at least 75 % of the questionnaire were considered for inclusion in the fsQCA phase of the project.

Roads taken participants

Across the six programs, administrators identified 1812 individuals who participated in the six programs over the ten-year period (1995 to 2005). Of that total, liaisons found at least some (not always up to date) contact information for 434 (23 %), nine of whom were deceased. They reached 378 (89 %). Of the contacted group, 361 (96 %) accepted the invitation to participate, and 221 (58 %) initiated the questionnaire with their program name. Of those who initiated the questionnaire, 194 (88 %) completed it. We include these details for practitioners considering meeting the challenge of contacting Alumnae(i).

For purposes of the fsQCA analysis we excluded from this dataset 15 cases, each from a population historically well-represented in the STEM professions, i.e., with the combined privileges of being male, Caucasian, and higher social-economic status (SES) or male, Asian *and* higher economic status (since some programs served recent, lower SES Asian immigrants, we included them in the study even though Asians are well represented in STEM careers). Because of our complex model and relatively small sample size in relation to it, we could afford only a single condition representing these race/ethnicity & SES variables. As such, we created a condition representing presence of privilege. Once calibrated, analysis including the variable as present (or absent) in a pathway would confound the "fully in" with the "more in than out" cases, i.e., the groups of participants who had all privileges but one, e.g., white, higher SES, Caucasian females, groups we wanted to understand more distinctly. Our remedy was to remove the 15 most privileged. Sacrificing learning more specifically about their pathways was acceptable to us because Youth Alive programs' missions involved bringing new populations into STEM careers.

Of the remaining 180 alumnae(i), 118 (67 %) were not male (i.e., without male privilege). The race and ethnicity of the responding alumnae(i) varied among the six programs. When asked to select all that applied from US Census categories, they were allowed to select multiple affiliations, so totals don't add to 180. We included in the fsQCA study, in order of largest group to smallest, 61 (31 %) White/Caucasian alumnae(i), 57 (32 %) Hispanic or LatinX, 41 (23 %) Black or African American, and 39 (22 %) Asian. We received five or less completed questionnaires from Native Hawaiians or Pacific Islanders ($n = 5$, 3 %), Middle Eastern or North Africans ($n = 2$, 1 %), and Native Americans or Alaska Natives (n = 2, 1 %), all of whom are included in this study. Five individuals (3 %) preferred not to answer and were included as "not self-identified as Caucasian."

Using PELL grant and free or reduced lunch eligibility as indicators of low family income during the program, 108 (60 %) of responding alumnae(i) came from low-income households. When we include those who were the first generation in their family to attend college ($n = 103$, 57 %), the result is 150 (83 %) cases that we considered low socioeconomic status.

Just more than half of the respondents had academic degrees beyond high school. Of the remainder, one did not graduate from high school, and 53 graduated from high school without attending a college or trade school (29 %). Thirty-one (17 %) started college and didn't receive a degree. Of those with degrees, we included in the study 46 with a bachelor's degree (26 %), 39 with a Master's degree (22 %), and 8 with doctorates (4 %) as their highest degrees.

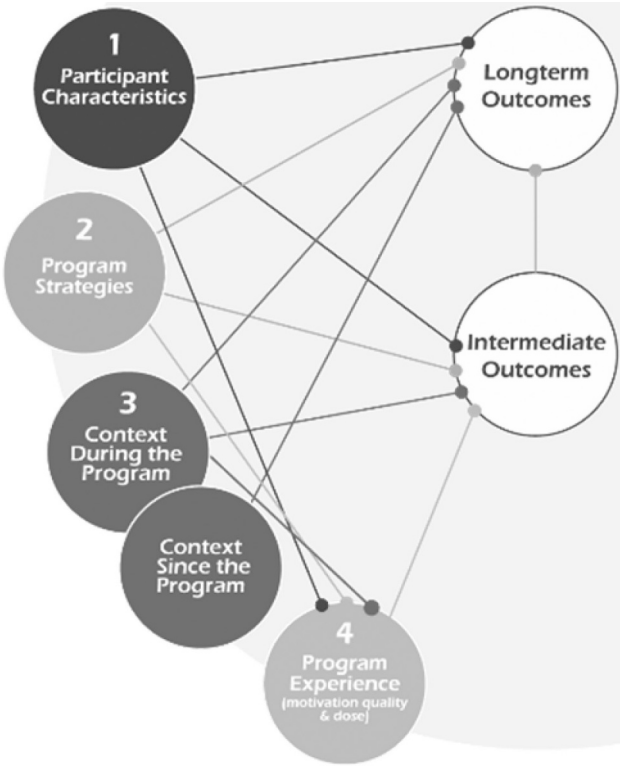

Fig. 2. The Roads Taken conceptual model.

We asked respondents when they started and ended the program and how often they attended (rarely through always). We then calculated the duration in months, considered the level of attendance, and arrived at a *dose* for each case. We note that all six programs encouraged participants to stay throughout their high school years; however, some started earlier and some allowed participants to stay through college.

The Roads Taken conceptual model

Our content-specific hypotheses for this study derived from our conceptual model shown in Fig. 2. With this model, we hypothesized that personal characteristics (i.e., alumnae(i) *from populations historically excluded from STEM* and *pre-program STEM identity* and *academic standing*), program experience quality (*program dose* and *self-determined experience*, *perceived program contribution to social-emotional development*, *perceived program contribution to STEM Identity*, and *extra-program STEM support*) would contribute to *post-program STEM identity* and *social-emotional development* in the short term and to *STEM identity*, *STEM Academic & Career Paths, Community STEM Involvement*, *and Personal STEM Involvement* as adults. Note that in this paper, we refer to perceived program contribution to social-emotional development as a contribution to "social-emotional learning," and to post-program social-emotional development as "social-emotional development."

This model derived from both human ecological theory and self-determination theory (Bronfenbrenner, 1989; Deci & Ryan, 2000). Bronfenbrenner's human ecological theory (Rosa & Tudge, 2013) structured how we modeled the varied direct and indirect program influences on the pathways alumnae(i) take. At the microsystem level, the model includes participant characteristics and participant perceptions of their interactions with and the influence of the program's strategic

activities (labeled in Fig. 2 as *Program Strategies*). **Extra-program aspects of participants' microsystems** (e.g., strategic interactions with families, friends, and schools), **exosystem factors** (e.g., administrative support for the program, program-school system relationships), and **macrosystem effects** (e.g., structural racism, sexism, or counteracting opportunities) collectively constitute *context during the program*. The same mesosystem and macrosystem factors, but describing events after program participation ended, constitute *context since the program*. Finally, a self-determination theoretical understanding of motivational quality informed the conceptual understanding *of self-determined program experience*.

From a Self-Determination Theory perspective, three elements distinguish a community that fosters engagement and the potential for continued participation or longer-term overall benefit (Ryan & Deci, 2017). Such a community fosters its members' satisfaction (and not frustration) of the basic psychological needs for a sense of competence, relatedness, and autonomy (defined as choice-making that is free from tension, pressure, or ambiguity). According to self-determination theory, internalized motivation associated with satisfied basic psychological needs leads to more durable positive long-term outcomes (e.g., career and well-being) than does external motivation, characterized by unsatisfied or frustrated basic psychological needs and associated with external rewards or punishment, e.g., guilt for not fulfilling a parental expectation (Ryan & Deci, 2000). Motivation quality (ranging from external to internalized or intrinsic) has also been linked to identity formation (La Guardia, 2009; Luyckx et al., 2009); and more specifically, STEM identity has been linked to positive longer-term outcomes (Merolla & Serpe, 2013; Stets et al., 2017). Thus, we sought to identify program strategies that worked to satisfy and counter frustrations of these basic psychological needs experienced throughout the ecological systems. We also identify potentially reciprocal pathways between basic psychological needs satisfaction and science identity (CAISE Informal Science, 2018) and how either or both affect longer-term outcomes. Later in the narrative, we detail how each of these dimensions was operationalized both for the questionnaire and for the fsQCA analyses.

This conceptual model and associated hypotheses, therefore, served both as the foundation for creating our online questionnaire and for using the data it produced to create the QCA conditions used to define pathways to adult STEM involvement. To our knowledge, no other long-term follow-up study has so comprehensively included each of these covariates (to use statistical language) or conditions (to use fsQCA language). In our mixed-method study we conducted surveys and interviews, analyzing the survey data with both structural equation modeling (SEM) and fsQCA. Note again that for this paper, we present only the social-emotional learning and development aspects of the fsQCA segment of the study.

Questionnaire measures and QCA calibration

In the narrative below, we explain how data collected from our sample using the questionnaire resulted in raw scores that could, in turn, be calibrated during the fsQCA process. We also explain limited details about that calibration. Further details can be requested in even more detail from the authors, or downloaded at [URL].

To calibrate the outcomes and conditions present in the program's conceptual model, we utilized the judgment of youth programming experts, including those with high familiarity with the exact programs studied, as well as our own understanding of the nuances present in fsQCA. As a team, we built consensus for each calibration on the points at which a case would become a full member and a full non-member of the set. We also set the crossover point between where we would consider a case to be "more in than out" of a set or "more out than in." Our calibration included two groups of cases on each side of this crossover point, or four total, including full non-membership (assigned the value of 0 for analysis) in the condition, more out than in (assigned 0.3), more in than out (0.7), and full membership (1) in each set. We describe each below. A summary table can be found in Appendix A.

fsQCA conditions constructed to reflect long-term and intermediate outcomes

Overall STEM involvement. This outcome is an aggregation of the values collected on the questionnaire for each of four outcomes (STEM education & career, personal STEM involvement, community STEM Involvement, and long-term STEM identity). Calibration decisions centered on the number of these outcome sets for which a case was determined to be at least more in than out. For example, fully in this set were cases who were more in than out of at least three of the four outcomes. The distribution of cases for this outcome: 15 fully out, 38 more out than in, 70 more in than out, and 57 fully in.

STEM education and career. For education, participants selected from a list of degrees, licenses, and certificates completed. Where relevant, they provided their related field or education major. For career, participants indicated if employment was in a STEM or non-STEM field and then selected from a look-up list to identify their work more specifically. Calibration decisions were made from a two-by-two table of response values in this area. Those calibrated as fully out neither pursued STEM academically nor worked in a STEM career. Those calibrated as fully in pursued STEM academics beyond high school ultimately leading to a STEM career. The crossover point included those who worked in a STEM career despite pursuing a non-STEM post-secondary education. The distribution of cases for this outcome: 69 fully out, 28 more out than in, 40 more in than out, 43 fully in.

Personal STEM involvement. The questionnaire included a personal STEM Involvement Inventory of decision-making for self and family (e.g., home maintenance, purchasing goods, recycling and environmental safety, or participating in activities such as talking about STEM topics, visiting museums, STEM hobbies, learning, conservation & environment, civics). Those calibrated as fully out were more likely to respond "seldom" or "never." Those calibrated as fully in were more likely to respond "frequent" or "often." The distribution of cases for this outcome: 11 fully out, 16 more out than in, 75 more in than out, 78 fully in.

Community STEM involvement. The questionnaire included a Community STEM Involvement Inventory querying use of STEM knowledge, attitudes, or skills in activities such as local government, volunteering, tutoring/mentoring, and advocating. Those calibrated as fully out engaged "never" or "seldom." Those calibrated as fully in engaged in at least one community activity "frequently." The crossover point included those who engaged in at least one community activity "often" but not "frequently." The distribution of cases for this outcome: 24 fully out, 44 more out than in, 46 more in than out, 66 fully in.

Long-term STEM identity. The questionnaire used two measures to quantify this outcome. The first was a selection from Venn diagrams representing "STEM" and "me" (similar to McDonald et al., 2019) with the explanation, "by STEM we mean any science (including social science) OR engineering OR math OR technology or any combination of these." It is important to note that this overlap view depends on other interests. In other words, a person could be highly STEM-identified (STEM-interested, STEM successful, STEM acknowledged, and confident in their ability to learn STEM) and, for example, highly involved in the arts. In this case, while STEM identity is high, they may perceive their overlap with STEM as only 50 %. For that reason, we tempered perceived overlap with averaged STEM identity factors. For this purpose, we used a second STEM identity measure derived from the Physics Identity Survey (Potvin & Hazari, 2013), which includes domains for recognition, competence/performance, interest, future value, and utility value (Nine items, $\alpha = 0.90$). Venn diagram selection most strongly reflected identity ($r = 0.602$), and interest ($r = 0.591$). Calibration was

based first on responses to the identity items and second on the Venn diagram selection. The distribution of cases for this outcome: 9 fully out, 47 more out than in, 38 more in than out, 86 fully in.

Perception of post-program social-emotional development (intermediate outcome). Questionnaire items were derived from five CASEL subdomains on the WCSD Social and Emotional Competency Short Form (self-awareness, social awareness, self-management, relationship skills, and responsible decision-making (Crowder et al., 2019)) and four subdomains on the 21st Century Skills Survey Instrument (relationship skills, creativity, critical thinking, and communication; Kelley et al., 2019). Responses were on a 1–5 scale across poor, fair, good, very good, and excellent respectively (14 items, $\alpha = 0.93$). Those calibrated as fully out scored less than a 3 on average, "fair." Those calibrated as fully in scored at least a 4.5 on average, "excellent." The crossover point included those that averaged at least a 4.0 ("very good"). The distribution of cases for this outcome (also a condition in some analyses): *6 fully out, 82 more out than in, 54 more in than out, 38 fully in.*

Perception of post-program STEM identity (intermediate outcome). The calculation of raw scores here involved the same items as the long-term STEM identity outcome described above, though asked for a retrospective answer connected to the time point at which they ended their program participation (9 items, $\alpha = 0.90$). Venn diagram selection most strongly reflected identity ($r = 0.619$), attainment ($r = 0.602$), and interest $r = 0.570$). Those calibrated as fully out reported an overlap between self and STEM of 0 % or met other conditions. Those calibrated as fully in reported an overlap between self and STEM of 100 % or met other conditions. The crossover point was conditional, based on relative amounts of Venn overlap and post-program STEM identity scores. The distribution of cases for this condition: 9 fully out, 23 more out than in, 65 more in than out, 83 fully in.

fsQCA conditions constructed from independent variables

Historically excluded from STEM. The questionnaire collected race/ethnicity and gender identities and information about childhood socio-economic status. Those calibrated as fully out reported all of what we considered "privilege" factors such as high socio-economic status as a child, male gender, and a race/ethnicity identity of white. Those calibrated as fully in reported no such factors. The crossover point was the presence of one factor. The distribution of cases for this condition: 0 fully out, 28 more out than in, 82 more in than out, 70 fully in.

Strong academics & STEM identity. The questionnaire collected Pre-program STEM Identity as portrayed by a Venn diagram overlap between "me" and "STEM." Academic standing was queried using an item that asked for recollection ranging from very low to very high previous academic achievement compared to classmates. Those calibrated as fully out reported low pre-program STEM identity and academic standing. Those calibrated as fully in reported high pre-program STEM identity and academic standing. The crossover point was conditional and based on relative amounts of change scores and identity scores. The distribution of cases for this condition: 19 fully out, 66 more out than in, 63 more in than out, 32 fully in.

Perceived support during the program. The questionnaire collected a measure of perceived support during the program at the mesosystem level (5 areas: school, extra-curricular activities, community, family, and other youth programming) and macrosystem level (10 areas: Social messages, role models, political messages, justice, economic messages, health care, gender discrimination, racial discrimination, LGBTQ discrimination, and geophysical events). We recognized that, at both levels, events can have both positive and negative effects that either support or hinder the program experience and that positive effects can balance negative ones (Noble & McGrath, 2011). Meso and macro response items followed the format, "How much did … affect your program experience?" (Positive meso effect item reliability, 5 items ($\alpha = 0.84$; macro effect, 10 items, $\alpha = 0.91$). Those calibrated as fully out experienced equally negative or positive effects more negative effects than positive. Those calibrated as fully in experienced large positive effects. The crossover point was an experience that was moderately more positive than negative. The distribution of cases for this condition: 39 fully out, 47 more out than in, 39 more in than out, 55 fully in.

Perceived support since the program. Questionnaire items for context since the program ended were the same as those used for context during the program (sans "other youth programming"), but followed the prompt, "Please tell us the degree to which each of the following influences affected the nature of your current STEM involvement–negatively, positively, or not at all." (Positive meso effect item reliability, 4 items, $\alpha = 0.84$; macro effect, 10 items, 8 items, $\alpha = 0.94$.) This condition was calibrated the same as the condition titled "Supported During." The distribution of cases for this condition: 28 fully out, 28 more out than in, 53 more in than out, 71 fully in.

High dose & experience of self-determination. The questionnaire produced a program dose score through merging an attendance response (self-reported as percent of time in attendance) multiplied by the count of months attended to yield an adjusted months score which we then divided into year groups: Low = duration less than 9 adjusted months; Medium = 1 to 2 school years; High = 3 to 4 school years; and Extra high = more than 4 school years. To measure program-related basic psychological need satisfaction and frustration, we adapted Chen et al.'s (2014) scales which consider need satisfaction and frustration as two separate domains. Within each, four items serve as indicators for each of the three needs (24 items). In the interest of questionnaire length, we removed two per group resulting in 12 items. (Need satisfaction, 6 items, $\alpha = 0.80$; need frustration, 6 items, $\alpha = 0.72$). Those calibrated as fully out either participated for less years or had low basic psychological need satisfaction during the program, or both. Those calibrated as fully in participated for more years and had more basic psychological need satisfaction during the program. The crossover point was either participation for more years or more basic psychological need satisfaction, but not both. The distribution of cases for this condition: 16 fully out, 51 more out than in, 72 more in than out, 41 fully in.

Large contribution to STEM identity. The questionnaire used the following prompt after the items assessing post-program STEM identity: "Now that you've told us about how you related to STEM topics and ideas before and at the end your program participation, please answer the following: Look back over your responses above. Overall, how much did [the program] contribute to the increases you identified?" "Overall, how much did [the program] contribute to the decreases you identified?" (only 13 responses); and "Overall, how much did [the program] contribute to how much you maintained a high level of how you related to STEM topics and ideas?" Response choices were on a five-point scale: not much at all, a bit, moderately, a lot, a huge amount. From these responses, we assigned a contribution score using the respondent's rating of contribution to increased STEM identity. Cases with decreased STEM identity were labeled as fully out. Those calibrated as fully in reported a contribution score of 4 or more. The crossover point was a contribution score of 3. The distribution of cases for this condition: 9 fully out, 23 more out than in, 65 more in than out, 83 fully in.

Large contribution to social-emotional development. The questionnaire used the following prompt after the items assessing pre- and post-program Social-Emotional Development (described as an intermediate outcome): Now that you've told us about your social-emotional development before and after your program participation, please answer the

following. Respondents used a five-point (1 to 5) scale across "not much at all, a bit, moderately, a lot, a huge amount" to rate the program's contribution to their gain scores, decreased scores and those that were maintained at a high level. From these responses we assigned a contribution score based on their average pre-post difference, using the gain score when the difference was greater than 0.5 and the maintained score when the difference was less than 0.5. Where the difference was greater than 0.5 or a response was missing, we assigned a 1, indicating a contribution of "not much at all."

Cases calibrated as fully out reported a contribution score of 1, "not much at all." Those calibrated as fully in reported a contribution score of 5, "a huge amount." The crossover point was a contribution score of 3.5. The distribution of cases for this condition (also a short-term outcome in one model): 34 fully out, 34 more out than in, 79 more in than out, 33 fully in.

Program strategies. We created several condition sets related to long-term participant recall of program strategies that they remembered from their own experience as a youth. Programs at different locations used varying strategies and these conditions are an indicator of the relative "stickiness" of those experiences. Later analyses of the intermediate outcome, post-program social-emotional development, includes the following program strategies (defined further on the project's website: [https://nam11.safelinks.protection.outlook.com/?url=https%3A%2F%2Fcosi.org%2FMOBILEAPP%2Fcre%2Fprojects%2Froads-taken.php&data=05%7C02%7Cr.ponnusamy%40elsevier.com%7Ca7dab47928684d1a714308dd573e0da0%7C9274ee3f94254109a27f9fb15c10675d%7C0%7C0%7C638762646235147019%7CUnknown%7CTWFpbGZsb3d8eyJFbXB0eU1hcGkiOnRydWUsIlYiOiIwLjAuMDAwMCIsIlAiOiJXaW4zMiIsIkFOIjoiTWFpbCIsIldUIjoyfQ%3D%3D%7C0%7C%7C%7C%7C&sdata=hqUcR3emAlQUeCV%2FmQbfV3f6%2FgYoN9mzly997OulhaM%3D&reserved=0]): Communication Skills Building, Planning for Future (Financial Planning, Career Development, Educational Awareness and Planning, Group Visits or Field Trips); STEM Literacy & Learning (Digital and Technological Literacy, STEM Knowledge or Skills, Field and Lab Research); Work-based Skills (Paid Positions, Career Ladder); Authentic STEM Work in Museum Settings (Explainer, Interpreter, or Demonstrator, or Exhibition Development); Learn to Teach – Teach to Learn (Teaching Younger Children, Family Involvement, School Involvement); Leadership (Youth Leadership Development, Youth Advisory Council, Community Leadership); Relationship Building with Adults (Staff Role Models, Mentoring by Adults); Relationship Building with Other Youth (Participant-to-Participant Mentoring, Relationships with Teens at Other Institutions). Those calibrated as fully out for each of these eight sets reported a contribution score of less than 4 (on the 7-point scale). Those calibrated as fully in reported a contribution score of 7 or "a great deal." The crossover point was a contribution score of more than 5.

Analysis

We uploaded calibrated conditions and outcomes into Ragin's fs/QCA 4.1 software (available at https://sites.socsci.uci.edu/~cragin/fsQCA/software.shtml). Traditional procedure (Schneider & Wagemann, 2012) calls for two steps of analysis: first, a test of whether any conditions are necessary for the outcome, and second, an investigation of combinations of conditions that, while not necessary, are sufficient for achieving the outcomes. As described in our methods section, both procedures rely on combinational logic, Boolean minimization, and fuzzy membership scores (fuzzy set theory) to allow the software to identify arrays of conditions associated with an outcome either as a superset (necessity) of the case-based outcome set or as a subset (sufficiency). For either one, the fs/QCA software requires input of a model in the form of an outcome and the individual conditions that may contribute to it. Ragin & Fiss, 2008 and others (Mello, 2021; Schneider & Wagemann, 2012) have suggested that values of more than 0.9 for consistency along with high coverage values indicate necessity in the relationship between a condition and an outcome.

To create sufficiency models, we divided our overall model into two categories of sub-models. Life-event models involved program-related and extra-program-related conditions (program experience, context, and participant characteristic conditions) that led to long-term and intermediate outcomes. Program-strategy models involved specific program strategies that contributed to achieving intermediate conditions included in the life-event models. Models in both categories included demographic and entrance narrative conditions.

For brevity and because we are focusing on social-emotional development, we have selected four models for description in this paper–three life event models and one program-strategy model. Among the three life-event models, we present the long-term overall STEM involvement model because it functions as a summary; the community STEM involvement model because of the prominence of the social-emotional learning and development conditions as contributing factors; and the model of social-emotional learning and development as an intermediate post-program outcome. The fourth model presents program-strategy pathways to perceiving that the program contributed highly to social-emotional development.

Results

In this section, we present fsQCA results that explain how, in this population, social-emotional learning and development contributed to STEM outcomes and how those contributions differed by subpopulation. Note that the tables presented in this section and in Appendix A follow fsQCA protocol, i.e. they meet expectations of fsQCA reporting, just as coefficients tables meet expectations for reporting regression analysis. We have worked to make these tables as transparent as possible to the reader. For further explanation, see Schneider and Wagemann (2012). We begin with a presentation of necessary conditions for each of our four outcome models. They appear first because conditions identified as necessary are removed from the second analysis, that of sufficient but unnecessary conditions. Next, following fsQCA reporting protocol, we present *truth tables* that provide a list of and descriptive information about all possible combinations of the conditions in the model: the frequency of their appearance in the data and how consistently each combination of conditions leads to the outcome. Often, only the most frequent combinations are shown with the others described. Finally, we present sufficiency tables for each model, one for each outcome for which we are seeking to understand causal pathways. Sufficiency tables provide evidence that supports or challenges the hypothesized relationships between the variables in a conceptual model. For readers less familiar with reading fsQCA results, for each expected reporting component, we explain its contents and purpose before presenting specific results.

Necessary conditions

For this study, we did not identify any necessary conditions in any of our outcome models. This finding was quite plausible considering the expected nuance among conditions that would vary in their impact on varied groups of youth. However, as an example, in Table 1 we present the necessary results analysis for *high overall STEM involvement* (remaining analyses can be found in Appendix A). For each of the conditions that may contribute to this outcome, the table lists the consistency and coverage associated with the outcome's presence. In a necessity table, the array includes only the single condition in the table row and consistency measure of the rate of cases fully or mostly in that the condition set who also became adults with high overall STEM involvement. C*overage* for this necessity calculation is the rate of participants fully or mostly in the *high overall STEM involvement* outcome set who also are fully or mostly in the set with that condition. Only

Table 1
Table of necessary condition analyses related to overall STEM involvement.

Conditions		Presence	
		Consistency	Coverage
Participant entrance characteristics	Historically excluded from STEM	0.82	0.71
	Strong Academics & STEM Identity	0.69	0.84
Intermediate outcomes	High Post-Program STEM Identity	0.90	0.78
	High Post-Program Social-Emotional Development	0.69	0.79
Context	High Support During	0.64	0.77
	High Support Since	0.72	0.72
Program	High Dose & Experience of Self-Determination	0.72	0.79
	Large STEM identity contribution	0.85	0.69
	Large Social-Emotional Development Contribution	0.70	0.84

conditions with both consistency and coverage values above 0.90 are considered *necessary* to an outcome. (Ragin & Fiss, 2008). For High Overall STEM involvement, no conditions met this threshold.

Truth tables underlying sufficient conditions

Following fsQCA methodology, for each outcome of interest, we created a "truth table" that provides descriptive understanding of the distribution of cases across all possible combinations of conditions. Truth table rows list all potential combinations of the conditions included in each model. For example, given that a model has 2^k possible combinations of conditions (where *k* denotes the number of conditions), a model with 3 conditions has 8 possible combinations and the truth table has 8 rows, one for each combination. In this study, our outcome models had 9 conditions and, therefore, 2^9 possible conditions or 512 rows in the truth table.

Only cases *more in than out* or *fully in* a given condition set qualify for inclusion in a row marked with a "1" for that condition. Thus, each case has only one sequence of 1s and 0s across all conditions and, therefore, belongs to only one row in the truth table. A truth table's frequency column, by which the table is typically sorted from largest to smallest, shows the count of cases defined by that row's presence (1) or absence (0) of each condition. The final column shows the consistencies of each combination with the outcome, (i.e., the average calibrated outcome value among those cases; Fiss, 2011). As with any table of descriptives, seeing truth table distributions helps the reader better understand the frequencies and distributions of the data underlying the final analysis.

Table 3
Sufficiency table for high level of overall STEM involvement.

Conceptual Model	Conditions	Pathways			
		1	2	3	4
Participant entrance characteristics	Historically excluded from STEM				
	Strong Academics & STEM Identity		−		+
Intermediate outcomes	Post-Program STEM Identity	+			+
	Post-Program social-emotional development			−	−
Context	STEM Support During				−
	STEM Support Since				
Program	High Dose & Experience of Self-Determination		+	+	
	Large STEM identity contribution	+	+	+	
	Large social-emotional development contribution	+			
Consistency		0.86	0.85	0.84	0.92
Raw coverage		0.61	0.42	0.34	0.29
Number of cases with > 0.5 pathway membership		79 42 %	36 19 %	28 15 %	17 9 %

Solution Consistency (0.83), Solution Coverage (0.76).

Where outcome models share the same conditions, they also share the same truth table (except for the consistency column). The truth table for two long-term outcomes is shown in Table 2 (additional tables can be found in Appendix A). The table shows nine columns of conditions on the left and eight (of the 512) specific combinations of calibrated values as rows. For presentation, we reduce the table to show only combinations representing sets with a membership of 4 or more cases. To the right of those columns, we show the frequency, or count of cases demonstrating that row's combination. Finally, columns for each outcome list the consistency of those cases with the outcome. For example, consider the first row. Of the set of 15 cases that were fully in or more in than out of all conditions except strong academics and STEM identity, 91 % intersected with the outcome set of cases with high overall STEM involvement and 87 % with the outcome set of cases with high community STEM involvement. That is, for both outcomes, this combination of conditions had high consistency. Note that these percentages don't represent specific proportions of 15 because the total set of cases also include partial or "fuzzy" members - see "logical remainders" below.

We also note that in our analysis, as is common, only a portion of the combinations had even one case assigned to them. In fact, about 80 % of our truth table rows had zero case membership. However, even in these

Table 2
Truth table associated with high overall STEM involvement and high community STEM involvement.

A	B	C	D	E	F	G	H	I	Frequency	Overall STEM[1] involvement Consistency	Community STEM[2] involvement Consistency
1	0	1	1	1	1	1	1	1	15 (8 %)	**0.91**	**0.87**
1	1	1	1	1	1	1	1	1	12 (7 %)	**0.96**	**0.92**
1	1	1	1	1	1	0	1	1	8 (4 %)	**0.96**	**0.93**
1	1	1	0	1	0	1	1	1	4 (2 %)	**0.98**	**0.82**
0	1	1	1	1	1	1	1	1	4 (2 %)	**0.96**	**0.85**
1	1	1	0	0	0	1	1	1	4 (2 %)	**0.95**	**0.83**
1	0	1	1	0	1	1	1	1	4 (2 %)	**0.92**	**0.86**
1	1	1	1	0	1	1	1	1	4 (2 %)	**0.91**	**0.95**

Note: A = Historically excluded from STEM, B = Strong Academics & STEM Identity, C = Post-Program STEM Identity, D = Post-Program social-emotional development, E = High Support During, F = High Support Since, G = High Dose & Experience of Self-Determination, H = Large STEM identity contribution, I = Large social-emotional development contribution.

[1] There were 8 combinations present for 3 cases, and 17 combinations for 2 cases that are also included in the analysis. The consistency cutoff for this outcome was 0.903.

[2] There were 8 combinations present for 3 cases, 17 combinations for 2 cases, and 67 combinations for 1 case that are also included in the analysis. The consistency cutoff for this outcome was 0.802.

Table 4
Sufficiency table for high level of community STEM involvement (long-term outcome).

Conceptual Model	Conditions	Pathways									
		1	2	3	4	5	6	7	8	9	10
Participant entrance characteristics	Historically excluded from STEM				+		+	−			−
	Strong Academics & STEM Identity	−					+			+	
Intermediate outcomes	High post-program stem identity			+		+			+	+	−
	High post-program social-emotional development	+	+			+	+	+		−	
Context	High support during	−			+						
	High support since		−	+		+	−	+	+		
Program	High dose & experience of self-determination	+	+				−		+	+	+
	Large STEM identity contribution										
	Large social-emotional development contribution	+	+	+	+			−			
Consistency		0.89	0.85	0.86	0.92	0.80	0.85	0.84	0.82	0.82	0.84
Raw coverage		0.22	0.23	0.46	0.44	0.49	0.18	0.18	0.43	0.16	0.17
Number of cases with > 0.5 pathway membership		6	9	54	30	46	2	1	45	21	1

Solution Consistency (0.81), Solution Coverage (0.75).

unassigned rows, as well as in the rows with case membership, "logical remainders," or data associated with cases that are neither full non-members nor full members in condition sets, still influence the analysis. Specifically, during the process of minimizing cases into pathways, many cases have *more out than in* membership in these rows (Mello, 2021). In other words, though the *more in than out (0.7)* membership values they were assigned determine their row placement in the truth table, their slight membership in other rows (0.3), albeit with reduced influence, are still considered in the mathematical analysis that *minimizes* the truth table to create the sufficiency solution.

Sufficient conditions

Minimization creates *prime implicants* as an output of Boolean algebra calculations (Befani, 2013). Prime implicants are the condition combinations that consistently contribute to outcomes (i.e., pathways) and because of their high consistency with the outcome are considered "sufficient" for producing the outcome. Minimization reduces the truth table to include only those combinations of conditions consistently associated with the outcome. This process removes noise caused by condition combinations that only sometimes lead to the outcome. This step begins in the fsQCA software with the user selecting minimum thresholds for outcome consistency among rows and a minimum case frequency. Only cases in rows meeting these two criteria continue forward into the Boolean analysis (except for consideration of *logical remainders* explained above). Our selection for minimum case frequency was two in all but one of our analyses and our selections for minimum outcome consistency varied by the outcome investigated.

Note that fsQCA scholars advocate for experimentation with consistency thresholds and alternative calibration schemes during analysis (Schneider & Wagemann, 2012). As recommended, once analysis of each outcome was completed, we revisited the choices we made for consistency cutoffs and even adjusted calibration to ensure robust, useful, and valid solutions.

The final step for determining sufficient conditions is investigating the solution terms displayed with complex, intermediate, and parsimonious results, the latter selected for the analysis presented here. The parsimonious result is simpler in structure than the others, involving fewer pathways and pathways with a smaller number of conditions in combination, making it more useful in an evaluation intended for practical application by youth program leaders.

We share each of our solutions from this step of the analysis process below.

High levels of overall STEM involvement

We present the solution for prime implicants of overall STEM involvement in Table 3. This, and the remaining tables in this section, show conditions arranged by the categories in our conceptual model, as rows on the left. On the right are the solution pathways with prime implicants (conditions that constitute the pathway) identified as either consistently present (+) or consistently absent (−) within the pathway. A plus sign indicates that all cases associated with the pathway were either *fully in* or *more in than out* of the associated condition set; a minus sign indicates that all cases were more out than in or fully out of the associated condition set. Empty cells, without a plus or minus sign, indicate that the condition has no influence on the pathway and was present in some cases with membership in that condition set and absent in others.

In the final rows we present the values for the consistency and coverage of each pathway along with the number of cases that met the criteria for the condition set (pathway): either fully in or more in than out of the outcome set *and* being fully in or more in than out of the set of conditions that comprise the pathway. Note that all pathways have a greater than 0.70 consistency with the outcome (i.e., approximately 70 % of the cases in the condition set were fully in or more in than out of the outcome set).

Specific to Table 3, four types of participants achieved well-rounded STEM involvement. As a way of capturing the nature of their pathways,

Table 5
Sufficiency table for high post-program social-emotional development (intermediate outcome).

Conceptual Model	Conditions	Pathways					
		1	2	3	4	5	6
Participant entrance characteristics	Historically excluded from STEM						
	Strong Academics & STEM Identity		−	+	+	+	−
Context	High Support During	+					+
	High Dose & Experience of Self-Determination		+	−	−		
Program	Large STEM identity contribution				+	+	
	Large Social-Emotional Development contribution	+	+	+		−	
Consistency		0.90	0.93	0.95	0.93	0.89	0.90
Raw coverage		0.62	0.48	0.36	0.39	0.38	0.47
Number of cases with > 0.5 pathway membership		54	32	12	12	9	26

Solution Consistency (0.83), Solution Coverage (0.86).

we've identified these pathway participants as the benefiters, the converted, the program-enhanced STEM enthusiasts, and the program-free STEM enthusiasts.

- The *benefiters*, the most common group (pathway #1, 61 % coverage), attained high levels of adult STEM involvement through the interaction between the program's contribution to both post-program STEM identity and post-program social-emotional development along with a strong post-program STEM identity (indicated by the plus sign in the table).
- The *converted* (pathway #2, 42 % coverage) began the program as academic low-achievers with a low STEM identity (indicated in the table with a minus sign). To achieve high STEM involvement as adults, they benefited from the program's contribution to their STEM identity but did not necessarily need social-emotional development contribution (blank in the table).
- *The program-enhanced STEM enthusiasts* perceived themselves as leaving the program with low social-emotional development. They experienced lengthy program dose and high need-satisfaction (experience of self-determination) with high program contribution to their STEM identity (pathway #3, 34 % coverage).
- The *program-free* STEM *enthusiasts* (Pathway #4, 29 % coverage) started the program as academic high achievers with strong STEM identities and probably would have become STEM-involved adults no matter what. They perceived themselves as leaving the program with low social-emotional development (post-program social-emotional development and saw themselves as having little extra-program STEM support during the program.

Note that, in order to become highly STEM-involved adults, participants who perceived themselves as having poor social-emotional development during the program (as measured by their perception of post-program social emotion development) needed *either* to have had strong STEM identity and academics prior to the program (pathway #4) *or* program contribution to both their STEM identity and social-emotional development (pathway #3).

High level of community STEM involvement

For purposes of understanding the relationship of social-emotional learning and development to adult STEM-related community involvement, we have identified four types of participants across the ten identified pathways shown in Table 4. To do so, we took the liberty of referring to participants completing the program with high social-emotional development as "empaths." Thus, our groupings include: (a) *program-enhanced empaths*; (b) *program-enhanced social-emotional learners*; (c) *program-free empaths*; and (d) *program-enhanced STEM enthusiasts*.

- *Program-enhanced empaths* arrived at adult high STEM-related community involvement through high need-satisfying program experiences and large program dose that contributed highly to their post-program social-emotional development (pathways 1 & 2, 22 % & 23 % coverage). In both cases, social-emotional development compensated for either lack of support during the program, or lack of support since.
- *Program-enhanced social-emotional learners* did not necessarily consider themselves as having high social-emotional development at the end of the program but credited the program with highly contributing to the amount they did have. For some of these learners, the STEM enthusiasts (pathway 3, 46 % coverage), high program contribution to social-emotional development interacted with post-program STEM identity and STEM support after the program ended. For another group, the *STEM-excluded externally supported* (pathway #4, 44 % coverage), social-emotional learning interacted with being from a population historically excluded from STEM (with one or none of three privileges) and high program-concurrent extra-program STEM support.
- *Program-free empaths* involved participants who left the program with high social-emotional development but did not attribute it to the program. Three different types of pathways led these social-emotionally high-functioning youth to high adult community STEM involvement. To distinguish them from each other, we call them the *lifetime* STEM *enthusiasts*, the *accommodators*, and the *replicators*. For the lifetime STEM enthusiasts, the interaction between high post-program STEM identity, high post-program SED, and STEM support after the program led to high community STEM involvement (pathway #5, 49 % coverage). For accommodators, from various populations historically excluded from STEM, high pre-program STEM identity and strong academics interacted with no STEM support since the program (pathway #6, 18 % coverage) to lead them to community STEM involvement. For this group, high social-emotional development appears to have helped them accommodate adversity and want to give back to their communities. The third group, the replicators (pathway #7, 18 % coverage), with only mildly limited STEM access (i.e., from only one of the three populations historically excluded from STEM—with two of the three "privileges") and STEM support since leaving the program, appears to use their high social-emotional development to replicate the support they have received.

Some pathways did not involve social-emotional development.

- Not unexpectedly, adult community STEM involvement among program-enhanced STEM enthusiasts (i.e., participants with high program dose and experience of self-determination along with a

Table 6
Sufficiency Table for perceiving high program contribution to social-emotional development (Intermediate Outcome).

Conditions		Pathways								
		1	2	3	4	5	6	7	8	9
Participant entrance characteristics	Historically excluded from STEM									
	Strong Academics & STEM Identity					+			+	
Strategies	Communication Experiences		+							
	Planning for the Future			+						
	STEM Learning Experiences				+					
	Work Skills Experiences	−	−	−	−	−	−			−
	Museum Work Experiences	−						+	+	
	Teach to Learn; Learn to Teach experiences							+	+	
	Leadership							+		+
	Relationships Experiences	+	+	+	+	+	+			
Program	High Dose & Experience of Self-Determination						+	+	+	
Consistency		0.75	0.83	0.82	0.76	0.81	0.80	0.80	0.95	0.89
Raw coverage		0.18	0.23	0.24	0.20	0.22	0.23	0.23	0.37	0.35
Number of cases with > 0.5 pathway membership		8	13	15	10	9	12	12	34	22

Solution Consistency (0.80), Solution Coverage (0.62).

strong post-program STEM identity) did not seem to require social-emotional development at all in their pathway. For them, the pathways to community STEM involvement additionally required either high post-program STEM support (pathway #8, 43 % coverage) or strong pre-program academics and STEM identity and low social-emotional development (pathway #9, 16 % coverage).

- In the final pathway, participants came through the program with high dose and self-determination and no other sufficient conditions if they were from populations with only mildly limited access to STEM (i.e., from populations historically excluded from STEM) and who left the program without much of a STEM identity (pathway #10, 17 % coverage).

High post-program social-emotional development

We found six pathways to high post-program social-emotional development among the participants who perceived themselves as having high social-emotional development when they left the program (Table 5). The *STEM-supported social-emotional learners* arrived at large post-program social-emotional development through an interaction between program contribution to social-emotional development and STEM support from outside the program (the most common pathway, #1, 62 % coverage). *STEM- adjacent* (so-called because they were in a STEM program but with low STEM identity) *Social-emotional learners'* path to post-program social-emotional development involved interaction between entering the program without strong academics and STEM identity and high program dose and experience of self-determination, and large social-emotional development contribution from the program (pathway #2, 48 % coverage). The *short-term STEM enthusiast learners* achieved post-program social-emotional development through pre-program strong academics and STEM identity, with low program dose and self-determined experience, but large program contribution to social-emotional development (pathway #3, 36 % coverage).

Two of the three remaining groups, whom we call the *compensators*, completed the program with high social-emotional development, compensating for low-dose and a low-experience of self-determination (pathway #4, 39 % coverage) or in spite of low social-emotional learning contribution from the program (pathway #5, 38 % coverage). The final group, the *"how did I get here?" compensators* (pathway #6, 47 % coverage) appear to have used or formed their social-emotional development and STEM support during the program to compensate for entering an intensive STEM program with a lack of strong academics and lack of a STEM identity.

Perceiving program contribution to social-emotional development

Not surprisingly, relationship experiences (e.g., peer or adult mentoring) were prominent for pathways leading to this intermediate outcome, figuring in six of the nine pathways to perceiving that the program contributed highly to social-emotional development (#s 1 through 6 in Table 6).

In two of these pathways, relationships alone were sufficient for contributing to this perception, especially in the absence of work skill or museum work experience program strategies. In other cases, relationships needed to be augmented with the program strategies of communication skill development, planning for the future, or STEM learning. Curiously, each of these relationship-defined pathways included the absence of work skill development strategies. Where relationship experiences may or may not have played a role (blank spaces in pathway #'s 7 through 9), high program dose and program experience of self-determination along with the teach-to-learn and museum work strategies (pathway #8), and in some cases augmented with leadership experiences (#7) or leadership alone (#9), took the place of relationships. Participants entering the program with strong academics and STEM identity (pathway #'s 5 & 8) needed either relationship experiences or the teach-to-learn/learn-to-teach experiences interacting with museum work experiences.

Discussion

In this study, we used six YouthALIVE! Programs, a detailed conceptual model, and fsQCA methodology to learn about pathways from program participation between 1995 and 2005 to STEM involvement and the role of social-emotional learning and development. For each of our four outcomes, we identified multiple pathways (equifinal solutions), many of which included the youth programming as vital. In addition, solutions to our STEM outcome models revealed examples of how social-emotional learning and development contributes differently by population and under varied circumstances to long-term STEM involvement and particularly to community STEM involvement. Beyond these content-specific results, we have also provided an exemplar for how fsQCA can function as a methodology for revealing multiple pathways to common outcomes. These solutions have important implications for providing evidence to support the important role of intensive STEM-based youth programming and for future program planning and development.

A limitation of this study was that it likely involved significant non-response bias, particularly related to a sense of connection to and recall of the program. Without this bias, we may have seen more non-program-related pathways to outcomes. On the other hand, across each of our conditions and outcomes and the variables that defined them, respondents demonstrated a full range of response, providing some evidence that that the bias did not correlate with response types. Whatever the effects of the bias, this study revealed extant pathways within the group of responders. Additional pathways could and probably do exist among program participants who did not contribute to our data. On the other hand, the study has revealed some important patterns for future research and practice. Ultimately programming, funding, and policy decisions will benefit from a deeper understanding of the complexity involved in these multiple pathways.

In a more generalizable way, we have shown that one pathway does not fit all. Pathways to adult STEM involvement exist but can involve interaction between differing combinations of conditions, one of which is social-emotional learning and development. More specifically, these results show that, among a population with varied amounts of privilege or absence of it, social-emotional learning and development varies in its role for different populations and under different circumstances.

The fsQCA calibration process opens possibilities for meta-analysis that could assemble a larger dataset across a wider range of programming. For example, across other studies that have gathered data on the same conditions with different variables, the condition sets calibrated with variables from this study's questionnaire variables could be, with the proper content expertise, similarly calibrated across those studies as fully or partially in or out of the same conditions. The larger dataset may reveal more pathways and/or reinforce those that emerged in this study. fsQCA has been recommended for this purpose (El Sherif et al., 2024; Srinivasan et al., 2012) and successfully used for a review of behavioral interventions (Kahwati et al., 2016) addressing medication compliance.

The role of social-emotional learning and development in pathways to four outcomes

These analyses have provided insight into ways that social-emotional learning leads to high adult STEM involvement, high adult community STEM involvement, post-program social-emotional development, and participant's perception of the program's contribution to social-emotional development. More specifically, out of the many conditions these participants experienced before and during the program (and since the program, in the case of the adult outcomes), this study revealed condition combinations that were enough, or in fsQCA language, "sufficient," for leading a participant to achieve the outcome.

Of the pathways identified as sufficient for achieving high overall adult STEM involvement, the most common (the one with greatest coverage) included social-emotional learning as it interacted with

program contribution to STEM identity and post-program STEM identity. Alternate sufficient pathways showed that in the absence of this program-inspired social-emotional development, pre-existing STEM identity and/or strong program contribution to that identity could substitute.

This finding implies that, for less naturally STEM-focused youth, STEM programming that attends to social-emotional development particularly supports adult overall STEM involvement. Thus, attending to social-emotional learning and development may be particularly helpful when young people are ambivalent about their science interests or commitments. Social-emotional learning in a STEM context can be the key ingredient to becoming a STEM-involved adult. Further research could investigate how or why this process occurs.

Of the pathways identified as sufficient for achieving high community STEM involvement, high social-emotional learning and development were necessary to six of the nine identified pathways. Thus, we have produced evidence that attention to social-emotional learning will enhance the success of STEM programming seeking to instill community-responsible STEM attitudes and behaviors (e.g., climate change responsibility and community STEM capital development). This evidence for integrating social-emotional learning with STEM education is supported by Garibay (2018) research on long-term social responsibility. From an extensive literature review, the author establishes such factors as service-learning programs and courses connecting science and societal issues as instrumental to longer-term social responsibility. The science itself may generate critical thinking skills that encourage social-emotional development (Khairati et al., 2021; Setia Permana et al., 2021), e.g., proposing solutions, thinking independently, and setting goals.

Our results also showed multiple ways STEM-based programming contributes to achieving post-program social-emotional development. Three of the six solution pathways attributed post-program social-emotional development directly to the program, as the program's main contribution (with STEM identity contribution being incidental). For practitioners, this finding encourages the recognition of STEM-based youth programs as youth development programs and, similarly to our findings about overall STEM involvement, supports efforts to build into programming strategies that provide social-emotional care and learning. This direction is especially important given the role the program's contribution to social-emotional development played in achieving overall STEM involvement and community STEM involvement outcomes (discussed above and illustrated in Tables 1 and 2).

Further supporting this conclusion is that one of the three pathways with program contribution to social-emotional development required the *absence* of high program dose and self-determined experience. This pathway would indicate that whatever the circumstances that abbreviated the program and/or made the respondents feel not related, less competent, and/or pressured (i.e., not self-determined), something about this adversity generated social-emotional learning. In other words, for these participants social-emotional development emerged as they confronted challenges to their STEM program participation. This bi-directional function of social-emotional learning and development, where the learning and development that stems from adversity helps to weather later adversity, has been documented in the relationship of enhanced friendships with adolescent resilience (van Harmelen et al., 2021); fewer problem behaviors and greater resilience with enhanced social-emotional learning during the Covid-19 pandemic (Martinsone et al., 2022) and reviewed more generally by Noltemeyer and Bush (2013).

We have also established that various combinations of strategies worked together to produce at least the perception of a program's contribution to social-emotional learning and development. Interactive strategies in pathways taken by these responding alumni toward social-emotional learning reflect principles in the literature, e.g., creating contexts that focus on the real world, developing social emotions through disciplinary practices, and establishing interpersonal relationships of equality and mutual support (Su & Guo, 2023). Applied to these pathways, museum work experiences and the teach to learn/learn to teach experiences incorporate both real-world focus and disciplinary practices. These two practices, prominent in the pathways with greatest coverage, speak to the strength of *YouthALIVE!* programming which took place in informal learning institutions and emphasized the importance of giving young people the opportunity to engage with STEM for a meaningful purpose, in this case, to develop expertise to share with visitors to their institution. Practitioners seeking to enhance social-emotional learning could use these findings to support the inclusion of similar practices and capitalize on their inclusion to enhance learning.

fsQCA as an effective methodology

The fsQCA solutions identified in this study meaningfully supported the complex relationships between social-emotional development and STEM outcomes, reflecting that multiple and varied conditions are unlikely to act on individuals in isolation, but instead in combination with other important contextual factors. Further, the approach recognized that not all combinations of conditions will support all individuals affected in the same way, identifying multiple pathways to each solution.

Many of these findings, particularly those with high consistency but low coverage, or in solutions with asymmetry, may have been missed in traditional statistical analyses. These pathways, significant only for a small group of people, would have contributed to the "error" term(s). In fact, with inferential statistics, though we may have been able to test for each model, we would have been confronted with two problems. First, for many of the pathways, our power would have been too small to detect significance with our relatively small dataset. Moreover, with so many variables to test, selecting models for testing would have been unwieldy. One advantage of fsQCA as an approach is that now we have created models for future testing.

The fsQCA methodology made it possible to identify which conditions, including program dose, were necessary when positive outcomes were present. In this study, no such conditions were identified. However, it also identified pathways through which program dose, in combination with other programming and contextual conditions, was identified as sufficient to produce positive outcomes, an important addition to the scholarship in this area. The relationship of social-emotional learning and development to adult STEM engagement is multi-faceted and complex. No single model could explain the multiple roles social-emotional learning and development take in these varied pathways to those outcomes. This methodology has successfully revealed the complexities inherent in the relationships between these roles and other conditions. We encourage future researchers to consider its use for understanding the role of social-emotional learning not only for adult STEM outcomes but for other educational outcomes as well.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the author(s) used Chat.openai.com in order to clarify wording for describing fsQCA methodology and to assure proper APA style. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

CRediT authorship contribution statement

Deborah L. Wasserman: Writing – review & editing, Writing – original draft, Project administration, Investigation, Formal analysis, Data curation, Conceptualization. **Jason Torres Altman:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Christine Klein:** Writing – review & editing, Writing

– original draft, Project administration, Funding acquisition, Conceptualization. **Priya Mohabir:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Carey Tisdal:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

None.

Appendix A. Tables not included in the text

Calibration table

Condition		Code	Fully Out	Cross-over	Fully In
Intermediate Outcomes	High Post-Program Social Emotional Development		Post-program score less than 3 (average of "Fair" or "Good")	Post-program score of at least 4.0	Post-program score of at least 4.5 (average of "Excellent")
Long-Term Outcomes	Total STEM involvement		More out than in or fully out of all four STEM outcome sets (STEM identity, STEM academics & career, Community STEM, Personal STEM)	More in than out of three categories or fully in one and fully or mostly in a second	More in than out of all four outcome categories
	High level of community STEM involvement		Engaged never of seldom across all 5 activities	Engaged in at least one community activity often but none frequently	Engaged in at least one community activity frequently
Participant entrance characteristics	Historically excluded from STEM	A	All "privilege" indicators present	One of "privilege" indicators present	None of "privilege" indicators present
	Strong Academics & STEM Identity	B	Low pre-program STEM identity **and** academic standing	Medium level of pre-program STEM identity and academic standing in aggregate (potentially medium in both, or high in one and low in the other)	High pre-program STEM identity **and** academic standing
Intermediate outcomes	Post-Program STEM Identity	C	Perceived overlap between self and STEM ID is 0 % OR perceived overlap between self and STEM identity meets other criteria	Perceived overlap between self and STEM was 100 % but interest is less than moderate (1 or 2 out of 5) OR perceived overlap with lower association with other STEM identity factors meets other criteria.	Perceived overlap between self and STEM was 100 % OR 90 % with higher association with other STEM identity factors meets other criteria.
	Post-Program social-emotional development	D	See intermediate outcome above		
Context	Supportive During	E	Experienced equally negative and positive effects or worse (0 or negative score on scale)	Aggregate experience was moderately more positive than negative (0.5 or more)	Experienced large positive effect (1.0 or more)
	Supportive Since	F	Same as above for "Supportive During"		
Program	High Dose & Experience of Self-Determination	G	Either participated for less years or had less motivation, or both	Either participated for more years or had more motivation	Both participated for more years and had more motivation
	Large STEM identity contribution	H	Contribution score of 0 or less	Contribution score of 3	Contribution score of 4 or more
	Large social-emotional development contribution	I	Contribution score of 1 or less	Contribution score of 4	Contribution score of 5 or more

Truth tables

Table 2
Truth table associated with high post-program social-emotional development.

A	B	E	G	H	I	Frequency	Outcome
1	0	1	1	1	1	23 (13 %)	**0.96**
1	1	1	1	1	1	22 (12 %)	**0.94**
1	1	1	1	1	1	12 (7 %)	**0.92**
1	1	1	0	1	0	12 (7 %)	0.91
0	1	1	1	1	1	11 (6 %)	**0.99**
1	1	1	0	0	0	9 (5 %)	0.88
1	0	1	1	0	1	7 (4 %)	0.89
1	1	1	1	0	1	6 (3 %)	0.74

Note: A = Historically excluded from STEM, B = Strong Academics & STEM Identity, E = Supportive During, G = High Dose & Experience of Self-Determination, H = Large STEM identity contribution, I = Large SED contribution and Outcome = Intermediate Outcome: High Post-Program Social Emotional Development; There were 5 combinations present for 5 cases, 1 combination present for 4 cases, 4 combinations present for 3 cases and 10 cases present for 2 cases also included in the analysis and the consistency cutoff was 0.915. Conditions not included in analysis were not appropriate for consideration for intermediate outcomes.

Table 3
Truth table associated with program contribution to high social-emotional development.

A	B	C	D	E	F	G	H	I	J	K	Frequency	Outcome
1	0	1	1	1	1	1	1	1	1	1	12 (8 %)	**0.94**
1	1	1	1	1	1	1	1	1	1	1	11 (8 %)	**0.94**
1	1	0	0	0	0	0	0	0	0	0	5 (4 %)	0.47
1	0	1	1	1	1	1	1	0	0	1	3 (2 %)	0.90
1	1	1	1	1	1	0	1	1	1	1	3 (2 %)	0.86
1	1	1	1	1	1	1	1	1	1	0	3 (2 %)	0.91

Note: A = Historically excluded from STEM, B = Strong Academics & STEM Identity, C = Communication Experiences, D = Planning for the Future, E = STEM Learning Experiences, F = Work Skills Experiences, G = Museum Work Experiences, H = Teach to Learn; Learn to Teach experiences, I = Leadership, J = Relationships Experiences, K = High Dose & Experience of Self-Determination and Outcome = Short-term Outcome: Program contribution to social emotional development; There were 16 combinations present for 2 cases also included in the analysis and the consistency cutoff was 0.935.

Necessary analysis

Table 4
Table of necessary condition analyses related to high community STEM involvement.

Conditions		Presence	
		Consistency	Coverage
Participant entrance characteristics	Historically excluded from STEM	0.83	0.68
	Strong Academics & STEM Identity	0.65	0.75
Intermediate outcomes	Post-Program STEM Identity	0.87	0.71
	Post-Program social-emotional development	0.69	0.77
Context	Supportive During	0.64	0.74
	Supportive Since	0.72	0.69
Program	High Dose & Experience of Self-Determination	0.70	0.74
	Large STEM identity contribution	0.84	0.66
	Large social-emotional development contribution	0.72	0.82

Table 5
Table of necessary condition analyses related to high post-program social-emotional development.

Conditions		Presence	
		Consistency	Coverage
Participant entrance characteristics	Historically excluded from STEM	0.89	0.67
	Strong Academics & STEM Identity	0.70	0.73
Context	Supportive During	0.72	0.76
Program	High Dose & Experience of Self-Determination	0.77	0.74
	Large STEM identity contribution	0.87	0.62
	Large social-emotional development contribution	0.78	0.81

Table 6
Table of necessary condition analyses related to high program contribution to social-emotional development.

Conditions		Presence	
		Consistency	Coverage
Participant entrance characteristics	Historically excluded from STEM	0.88	0.64
	Strong Academics & STEM Identity	0.68	0.69
Strategies	Communication Experiences	0.88	0.72
	Planning for the Future	0.83	0.68
	STEM Learning Experiences	0.74	0.67
	Work Skills Experiences	0.75	0.65
	Museum Work Experiences	0.72	0.67
	Teach to Learn; Learn to Teach experiences	0.79	0.68
	Leadership	0.60	0.75
	Relationships Experiences	0.75	0.71
Program	High Dose & Experience of Self-Determination	0.81	0.74

Data availability

Data will be made available on request.

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