frontiers | Frontiers in Education

TYPE Original Research
PUBLISHED 30 April 2025
DOI 10.3389/feduc.2025.1527846

Developing a use-inspired school and community-based 6th through 12th-grade research and invention ecosystem leading to STEM careers: an ethnographic study of the Science Coach Program

Melinda Z. Kalainoff[1]*, Fatiha Bazouche[2], Stephanie R. Couch[3] and Jill M. Ott[4]

[1]Kalainoff Consulting and Research, LLC, Colorado Springs, CO, United States, [2]Department of Educational Studies, Patton School of Education, Ohio University, Athens, OH, United States, [3]Lemelson-MIT Program, School of Engineering, Massachusetts Institute of Technology, Cambridge, MA, United States, [4]Science Coach, St. Louis, MO, United States

OPEN ACCESS

EDITED BY
Joanna K. Garner,
Old Dominion University, United States

REVIEWED BY
Eduardo Hernández-Padilla,
Autonomous University of the State of Morelos, Mexico
Peter Wardrip,
University of Wisconsin-Madison, United States

*CORRESPONDENCE
Melinda Z. Kalainoff
✉ mzkalainoff@gmail.com

RECEIVED 13 November 2024
ACCEPTED 28 March 2025
PUBLISHED 30 April 2025

CITATION
Kalainoff MZ, Bazouche F, Couch SR and Ott JM (2025) Developing a use-inspired school and community-based 6th through 12th-grade research and invention ecosystem leading to STEM careers: an ethnographic study of the Science Coach Program.
Front. Educ. 10:1527846.
doi: 10.3389/feduc.2025.1527846

This study responds to the need for educational offerings for middle and high school students that develop students' awareness of STEM degrees and careers and foster positive attitudes, confidence, and students' ability to see themselves in STEM fields. Theories and methodologies from interactional ethnography guide our examination of ways Science Coach (SC) addresses these needs by educating and supporting 6th–12th-grade science teachers and their students as students identify and solve real problems through authentic research and invention. In this system-level study conducted alongside the program's Chief Executive Officer (CEO), we document and analyze the actors, roles, and relationships to (re)present the SC use-inspired research and invention ecosystem. We also analyze student outcome data collected by the program to examine what is socially accomplished by the actors within the ecosystem. Six design principles guiding SC emerge from our analysis. The student outcomes we document emerge from data elements that SC has chosen to collect as indicators of their success. Analysis of student surveys showed that of the 12th-grade students matriculating from the program since 2019 (N = 612), a subset (n = 234) shared their college degree choice in the final questionnaire. Of these respondents, 91.5% (n = 214) reported that they were pursuing a STEM degree or career after participating in one or more years in SC. Among respondents who identified as underrepresented minorities (URM), 90.3% (n = 149) reported the same. With the growing need for STEM and STEM-related opportunities for all, learning and career readiness programs like SC serve as a potentially scalable model for bridging this gap.

KEYWORDS

use-inspired research, authentic STEM research program, invention education, Science Coach, research and invention ecosystem, STEM career pathway

1 Introduction

In recent years, there has been growing recognition of the importance of engaging students in authentic (i.e., real world) problem-solving and hands-on STEM experiences that prepare them for future careers in science, technology, engineering, and mathematics (Wang et al., 2023; National Science Foundation, 2020). Structured research and invention methodologies provide students with critical opportunities to develop problem-solving skills, scientific inquiry, and innovative thinking (Stokes, 1997) desired by the 21st Century workforce. Additionally, pursuing research and invention to solve problems in their communities or greater society inspires and motivates students to persist through uncertainty, cultivating STEM/inventor identity (Couch et al., 2019), self-efficacy, and long-term career persistence in technical fields (Johnson, 2012; Hughes et al., 2013). However, it's rare that K12 public schools have the laboratory facilities for advanced research and teacher disciplinary and research knowledge to guide students in authentic STEM research and invention. In response to this need, research and invention education programs external to formal school environments have been developing local *use-inspired* research and invention ecosystems that provide teachers and students with community-based resources, professional development, and a network of support for identifying local problems and developing technical solutions. In a recent visit by representatives from a federal agency to one such research and invention program, Science Coach (SC), the representatives identified SC as 'having the most complete model for use-inspired research' and workforce development that they had seen. [Interview transcripts, SC CEO, October 7, 2024]. This study makes visible key elements of the SC research and invention ecosystem model that address the need for STEM and STEM-related opportunities for all. It also offers evidence of SC's learning outcomes, including but not limited to career readiness.

2 Study purpose and questions

The purpose of this community research study is to (re)present SC's use-inspired research and invention ecosystem, identify SC's design principles that are visible in the current iteration of the work, and examine significant program outcomes. The principles and practices of interactional ethnography (Skukauskaitė and Green, 2023) guide our efforts to document the actors within the SC ecosystem, the actions and types of support afforded to students, and the design principles that guide the SC Chief Executive Officer's (CEO's) work. Through interviews with the program leadership and examination of internal program documentation and student questionnaire data, this systems-level case study, undertaken alongside the program's CEO, (re)presents the actors within SC's developing institutional ecosystem that supports both students and teachers. We make visible design principles that emerge from an analysis of the decisions and actions of SC participants and present evidence regarding students' persistence and accomplishments resulting from participation in the SC program. To this end, the study research and evaluation questions are:

Q1. (Research) Who are the actors within Science Coach's ecosystem, and what support do they provide to teachers and students engaging in authentic research and invention? (i.e., What constitutes the Science Coach Research and Invention Ecosystem?)

Q2. (Research) What principles of design emerge from the ways the actors work independently and collectively? How do these principles align with the STEM persistence and self-efficacy literature?

Q3. (Evaluation) What is the evidence that Science Coach supports students' preparation and persistence in STEM undergraduate degrees and career pathways?

3 Literature review

3.1 Research on authentic research and invention opportunities

In the STEM education and research community, "authentic research" refers to engaging in genuine research experiences where the outcome of the research is unknown. In a 2020 synthesis of lessons learned from the STEM Education for the Future subcommittee of the National Science Foundation (NSF), members found that learning environments that supported deeper learning are project-based, personalized, and learner-centered (National Science Foundation, 2020). With respect to authentic research, the committee noted that project-based learning often focuses on "real-world problems that can have significant social impact across society" (National Science Foundation, 2020, p.22) and that the work is personalized where "students start with a project of personal interest and decide how to acquire the knowledge needed to solve the problem" (National Science Foundation, 2020, p. 22). Additionally, learner-centered environments appeal across student demographics because "all groups… enter learning environments that are culturally and linguistically relevant to them, and that are engaging and welcoming" (National Science Foundation, 2020, p. 22). This feeling of belonging (Johnson, 2012) is even more important for recruiting, engaging, and retaining underrepresented minorities (URM), including female students who face additional cultural barriers to entry into STEM-related disciplines (Hughes et al., 2013; Rainey et al., 2018) and, thus, careers.

The tangible outcome of STEM-related research could be an "invention," which is a solution to a problem that is new, novel, useful, and unique. Inventions that are commercialized through entrepreneurial processes are innovations. Students may also seek opportunities to have their research and invention efforts recognized in innovation competitions and science and engineering fairs.

3.2 Two theories for career choice

Our understanding of how authentic research opportunities support students' achievement of a STEM degree is informed by two theories. First, to generate understandings from the perspective of SC's CEO, we considered the Impact Genome Project's theory of change (Impact Genome Project, 2019) that has guided her work as orienting theory since 2018. This theory proposes that STEM students must move from an *interest*, to then acquiring *proficiency* before *persisting* into a STEM career. Where other research and invention programs provide support for one or two of the three phases (i.e., interest, proficiency, and persistence), few focus on the end-to-end developmental process.

This study also draws on a second widely accepted explanatory theory for career choice widely used in STEM career-related research is Social Cognitive Career Theory (SCCT) (Lent et al., 1994). SCCT posits that career choice is a dynamic process that operates through self-efficacy in concert with outcome expectations and personal goals. Other factors include cultural influences such as social and economic factors and contextual influences (e.g., interests and performance domains). According to SCCT and Wang et al. (2023), external environmental factors can influence career choices by affecting individuals' self-efficacy and outcome expectations. In addition, self-efficacy could also affect outcome expectations (Lent et al., 1994). For example, when an individual believes that he/she has the ability to complete an activity, he/she will have positive expectations for the outcome of the activity, which will make him/her interested in the activity. As outcome expectation refers to an individual's perceptions of what would happen if he or she engaged in a certain career, it is often replaced by career perceptions (Mohtar et al., 2019; Wang and Duan, 2021). As such, self-efficacy and career perceptions play key mediating roles in forming career interest and are the basis for its development (Wang and Duan, 2021).

3.3 Use-inspired research and invention in secondary school contexts

The term 'use-inspired' in a research context is attributed to Stokes (1997) who recognized the limitations of a basic and applied research dichotomy because many researchers intend to make new discoveries (i.e., basic research) *and* apply the discoveries (i.e., applied research) simultaneously. Use-inspired science is initiated by identifying community or societal problems such that the rationale, conceptualization, and research directions are driven by the potential and practical use of what is produced through the research (Stokes, 1997). For example, a recent and well-known 'use-inspired' effort was the national coordination across science, government, and industry in May 2020 to produce an effective vaccine against COVID-19. In research and invention contexts, the term 'use-inspired' emphasizes the intention to address specific challenges, solve practical problems, or contribute to the improvement of societal conditions. Local or societal problems are the starting point for use-inspired research, and these problems must be uncovered during a community-based component of the work.

Literature about use-inspired community-based research (i.e., community-based participatory research) is plentiful, particularly as it relates to healthcare disparities, environmental justice, urban planning, and other facets of societal or community problems that require developing solutions for the local context. Prevalent in secondary school STEM contexts, 'use-inspired' could be loosely interpreted as 'localized learning,' connecting STEM learning to students' personal lives and the local community (i.e., STEM careers) as a pedagogical approach (Holmes et al., 2021). Similar approaches more common today that aim to expose students to STEM practices and ways of thinking are project-based learning and inquiry-based learning. However, outside of internships and summer programs, research on secondary students engaging in authentic 'use-inspired research and invention' is very limited. Furthermore, within this scant literature, the object of inquiry is overwhelmingly focused on student outcomes, not on the program's infrastructure and design principles that support students and/or teachers.

4 Background on the Science Coach Program

4.1 Program context

The site of this study is SC, a nationally recognized nonprofit research and invention program that educates 6th–12th grade science teachers in research methodology to coach their students in identifying and solving real problems through authentic research and invention. Serving both teachers and students, teacher-coaches are mentored in teams of five by an experienced Head Coach while teacher-coaches are guiding their students throughout the academic year. Since 2007, the program has guided 162 teachers as they coached over 1,600 students in completing their research and invention projects and participating in regional, state, national, and international science fair competitions.

4.2 Program history

SC began in 2007 when a regional science fair director in St. Louis, Missouri, USA, worked to ensure that science teachers could be supported financially for coaching their students to the science fair just like a school 'coach' is paid to coach their sport. Each year, between 2007 and 2018, SC supported five to six science teachers with professional development and a $2 K stipend to coach 30 to 60 students in research and invention projects. In 2018, a prominent funder encouraged the science fair director to assume full-time leadership of SC as its executive director, now CEO, and take the program to a national level. In 2022, SC established a partnership with a biotech company in St. Louis, which had a need to attract and support local students' pathways toward employment as Medical Laboratory Scientists (MLS) within their company. This partnership bolstered SC's strategic and developmental trajectory to include combining career-connected learning that is scalable for both teacher-coaches and students by expanding research and invention education professional development and learning opportunities in specific careers. Each year since 2019, SC has partnered with 16 to 23 teacher-coaches at 12 to 17 school districts, serving between 200 and 325 student researchers and inventors. In 2024, with increasing opportunities for students to participate in program offerings, such as an online community college dual enrollment course in research, SC served 259 students in eight states across the US. [Interview transcript, SC CEO, July 2, 2024].

4.3 Program timeline

SC is designed as a one-year developmental program of teacher-coaches who guide their students through an authentic research and/or invention experience in which the students participate in innovation or science fair competitions. Prospective teachers apply in the Spring of the year prior to implementation. Head coaches and teacher-coaches are selected in May. In June and July, SC teams are created, and a Head Coach begins to develop mentoring relationships with assigned teacher-coaches. The SC teams of one Head Coach and three to five teacher-coaches participate in a week-long intensive summer professional and developmental 'train-up', Science Coach Academy (SCA), prior to the start of the school year. From August through May, teacher-coaches guide students using the program's Advanced Innovation Methodology (AIM) Teacher and AIM Student curriculum and methodology to identify a problem, refine questions, design and conduct an experiment or project, and obtain Scientific Review Committee/Institutional Review Board approval, if needed. During this time, teacher-coaches continue to meet with their Head Coaches and attend monthly team and SC professional development opportunities. Students create posters or oral presentations for entry into juried competitions from February through May with support from teacher coaches and Head Coaches (Science Coach, 2024).

5 Conceptual framework, methodology and methods

This study, guided by sociocultural theories derived from an anthropologically informed and discursive approach to ethnography (Green et al., 2020; Skukauskaitė and Green, 2023), uses multiple methods to identify, research, and (re)present Science Coach's processes and practices that support middle and high school students' engagement in use-inspired community-based research. The study includes an examination of the actors within SC's invention ecosystem and the ways the actors engage with one another. The ethnographic perspective guiding our study draws on principles of conduct proposed by anthropologists Heath and Street (Heath and Street, 2008) to guide researchers' actions in the field. These principles of conduct are:

- Stepping back from the known (or ethnocentrism) to position oneself to take an emic (insider) perspective.
- Learning *from* and *with* participants.
- Making connections to construct new (emic) ways of knowing.
- (Re)presenting what is known by local actors and what the ethnographer-researchers learn from the analysis at different levels of analytic scale.

Guided by these principles of conduct and an orienting question of "What is the Science Coach Program and what are its program outcomes?," the researcher-ethnographer outsiders (first and third authors) to SC's program came alongside the insider CEO (fourth author) to trace the program's historical and developmental trajectories from the emic perspective of the insider. Our first interview with the CEO served as a starting point for our anthropologically guided ethnographic process of collecting artifacts that could yield insights into the growth and development of the program over time. Seven transcripts from video records of interviews with the CEO and ten other existing program artifacts were analyzed to co-construct data for this part of the study (Ellen, 1984).

An ethnographic logic-of-inquiry (Green et al., 2003) guided the construction of the study archive which expanded as needed across multiple phases of inquiry that were not pre-determined. Initial research questions were modified as needed to be responsive to new understandings emerging from each phase of inquiry. Similarly, the records collected to answer each question emerged abductively (Agar, 2006) as the researchers worked to develop understandings from the perspectives of the insider informant, thereby maximizing the analytic potential (Kalainoff and Chian, 2023) of the CEO interviews and existing program and student records. In (re)presenting our logic-of-inquiry in this study, we unfold findings regarding the actors in the program's research and invention ecosystem (Question 1) and practices (Question 2) visible within cultural artifacts collected from the site (e.g., program documentation and online presence) and from our analysis of semi-structured interviews (Patton, 2002) and conversations of process (Skukauskaitė, 2017) with the SC's CEO. We conclude by showing the results from our analysis of the program's accomplishments (Question 3) that drew on an existing archive of student profile and questionnaire data from SC's records.

This study's methodology, including records/data in the research archive, methods of analysis, and supporting literature for each study question, are shown in Table 1. Records were collected in accordance with Institutional Review Board approval which include interviews with site informants, artifacts of program history and activities, and existing historical files of unidentifiable student profiles and surveys obtained as secondary data.

Studies conducted from this ethnographic perspective are initiated by identifying a 'rich point' (Agar, 2006) during a review of the records in the archive initially constructed by the researcher-ethnographer. The initial archive for this study consisted of cultural artifacts of the site including inscriptions from the site's website (Science Coach, 2024) and program documentation that the informant, the SC CEO, provided to the researchers as evidence of the site's history and development. Ethnographers identify rich points when they come upon something in these records that they do not understand, which leads to a question that guides subsequent phases of inquiry. The rich point for this study emerged during the first interview with the informant as she guided researchers through the program's records. During this interview, the CEO shared the significance of the SC research and invention ecosystem as the defining component of the overall program but the most difficult to conceptualize and explain [Interview Transcript, SC CEO, July 2, 2024]. This rich point signaled that we, researchers, needed to examine this ecosystem further. The initial question (i.e., the first iteration of Question 1) to initiate the abductive logic-of-inquiry for this case study, was 'How can we (re)present SC's ecosystem to show how SC supports the teachers and students with whom it works?'. Through our ethnographically informed analytic process taking place across all seven interviews with the informant, we iterated from this initial question to what is now Study Question 1.

6 Analysis and results by question

This section unfolds each study question as a logic of inquiry. According to the SC CEO, the ability of teachers to guide students through scientific research methodology is a central focus of the SC program. The intended outcome is to increase the number of high school students pursuing STEM careers from high school into higher education. The SC CEO attributed the success of the program in getting students to enter STEM disciplines or careers post-high school to the *research and invention ecosystem* that serves both students and their coaches. [Interview transcript, SC CEO, August 17, 2024]. Therefore, the first research question examines SC's ecosystem.

6.1 Question 1: Who are the actors within the Science Coach's Research and Invention Ecosystem, and what supports do they provide to teacher-coaches and students engaging in authentic research and invention?

To understand who the actors are within the research and invention ecosystem and their roles within the ecosystem, we traced

TABLE 1 Methodology.

Study question	Record types and amount collected	Methods of analysis	Literature
1. (Research) What constitutes the Science Coach research and invention ecosystem that supports teachers to guide students to engage in authentic research and invention? How did it come to be?	• SC Documentation: CEO logbooks (2007–2024) • Video records and transcripts of seven interviews and conversations of process with SC CEO (8.5 h) • Artifacts of the site: o SC Website[1] o SC summary reports and data (10 files)	Textual Analysis Discourse Analysis Conversations of Process	Bloome et al. (2010), Skukauskaitė (2017)
2. (Research) What principles of design emerge from the ways the actors work independently and collectively? How do these principles align with the literature?	• Video records and transcripts of seven interviews and conversations of process with SC CEO (8.5 h) • Artifacts of the site: • SC Website[1] • SC Core Values (provided by SC CEO)	Discourse Analysis Conversations of Process	Bloome et al. (2010), Skukauskaitė (2017)
3. (Evaluation) What is the evidence that Science Coach supports students' preparation and persistence in STEM undergraduate degrees and career pathways?	SC Demographics Records (2007–2018) SC Student Questionnaires (2018–2024): • surveys (n = 2,749) for students (n = 1,419) • student competition outcome records	Quantitative/descriptor analyses	

[1]Website: www.sciencecoach.org.

the CEO's decisions and actions in the program that she inscribed in her logbooks since the program's inception in 2007. After producing a yearly list of actions and program initiatives from these logbooks, the initiatives were grouped into larger categories and traced over time to inform an initial (re)presentation of SC's current research and invention ecosystem.

6.1.1 Science Coach as a developing research and invention program

Table 2 is a summary of the overtime initiatives by academic year(s) (Column 1) over each of the five general categories of effort (Columns 2–6) identified by researchers. For the first decade, from 2007 to 2018, SC focused on providing support directly to teachers, initially with a $2 K stipend and guidance from a Head Coach. Recognizing that science teachers did not necessarily have a strong research background, SC initiated professional development in 2009 with a four-hour summer professional development session. The professional development grew to 7 hours in 2014, addressed International Science and Engineering Fair (ISEF) safety forms, and was held at a local community college. Additionally, teachers could sign out laboratory instrumentation on an annual basis and coordinate for research supplies for students through SC.

In 2018, a local biotech nonprofit recognized the potential for SC to guide local students toward Medical Laboratory Science careers. The company agreed to incubate SC as a nonprofit entity. This strategic pivot is signaled by an abrupt change of scale in Table 2 from one decade (2007–2018) to subsequent years, starting with the 2018–2019 academic year. Table 2 documents the year-over-year expansion of resources for teachers and new offerings initiated to support students directly. SC also initiated efforts toward internal monitoring and tracking of outcomes during this time.

Table 2 shows that SC has consistently expanded its resources and developmental opportunities for both teachers and students each year since 2018. These efforts occurred in parallel with tracking program outcomes and obtaining meaningful feedback to inform decision-making and manage SC's growth.

6.1.2 A (re)presentation of the Science Coach Research and Invention Ecosystem

As another layer of analysis and an extension of Table 2, we engaged in multiple interviews and email correspondence with the SC CEO to identify the current actors in the ecosystem, who supports whom, how, and in what ways. Stepping back from our own assumptions about this cultural context and looking again from the emic perspective of the SC CEO as an insider, we iteratively co-constructed a graphic representation of the actors and their roles and relationships with insider feedback. The end result is shown in Figure 1.

Sixth through twelfth-grade students are shown at the center of Figure 1. The students are shown as being supported by seven types or categories of actors, each represented by an overlapping circle *into* the student circle. The seven categories of actors supporting students are:

1 SC research methodology curriculum resources for students
2 Innovation competitions and science fairs
3 Student incentives or developmental opportunities
4 Innovation to Entrepreneurship Pathway (Intellectual Property (IP)/Patent Protection)
5 Online resource support subscriptions
6 STEM teacher as Research Methodology Coach
7 Community Partners/Valueholders

The last two of the seven categories of actors (i.e., STEM teacher as Research Methodology Coach and Community Partners/

TABLE 2 Timeline of significant Science Coach initiatives and resources (2007-present)[1].

	Science Coach (SC) initiative and resources added to the program (unless otherwise specified)				
Academic year(s)	Administrative and logistical support	Teacher incentives, resources and developmental opportunities	Student disciplinary and project resources	SC monitoring and outcomes tracking	Student incentives and opportunities
2007 to 2018	• Head coach & mtgs • Equipment purchase per teacher and transition to equipment loaning • Supply purchasing	• $2 K stipend • Supply stipend • 1-day in-person summer PD			
2018 to 2019	Liability insurance for students and teachers	• Wrote AIM teacher curriculum • Initiated PD by outside experts: "Statistics for Science Research"	Virtual Student coaching by college students	Formal pre-post surveys instituted for students	
2019 to 2020		• Implemented AIM teacher curriculum • 1-week Summer PD[2]	• Wrote AIM Student Curriculum • SC research lab book with carbonless copies for feedback	• Outcomes tracking with Salesforce portal • Teacher surveys	
2020 to 2021	• Supply requests through portal • Robust research equipment loan program	• 2 h of Graduate Credit for SC Complete (SCC) • Bioinformatics courses offered through PineBio	• Initiated SC direct-to-student opportunities for learning: Bioinformatics course • Implemented AIM Student Curriculum and Innovation to Entrepreneurs pathway • College student coaching stopped from low attendance	• Teacher portal for tracking milestones	Senior stipend: 3 students receive $1 K for continuing research
2021 to 2022	Portal supply request process created	• Drop-in mentoring available • Access to 1 commercial lab bench • Use of teacher success report to inform their annual evaluation • First "Teacher-Coach of the Year" award	• Drop-in coaching available • Access to 1 commercial lab bench • Electronic lab notebook access • Students have access to donor or community-based problems to select as the topic of their research • Formal Request Mentor process through database interface	• Student entry for project, competitions and awards • Expanded outcomes tracking to multi-year • Create an evidenced-based teacher success report	6-wk summer paid cancer internships for 3 students
2022 to 2023	Expand insurance[3]	• $450 for student recruit/retain funding so teachers can build a research program/community • Monthly PD meetings[4] added to Team meetings • Coach Cash for feedback • 1-week summer PD modified to 3-day Science Coach Academy (SCA)	• Instituted Science Coach Pro-MLS program • Field coach support for students	• Rebuilt Salesforce database • Formal tracking of scholarships earned by students	Add 3 paid internships: 2 cancer and 1 neuroscience

(Continued)

TABLE 2 (Continued)

	Science Coach (SC) initiative and resources added to the program (unless otherwise specified)				
Academic year(s)	Administrative and logistical support	Teacher incentives, resources and developmental opportunities	Student disciplinary and project resources	SC monitoring and outcomes tracking	Student incentives and opportunities
2023 to 2024	Consolidate list of donors for free supplies	• Expanded commercial lab access • Stipend for attending monthly PD and Bioscience webinars • 2 graduate credit hours for SCA; 3 h for SCC	• Expanded commercial lab access • Maintain list of disciplinary mentors • ISEF app integrated into Portal • Donor list for free supplies	• Additional Salesforce dashboards created to see outcome trends and performance	• Add paid internships: 3 cancer and 1 neuroscience • First AIM online research class • NSTEM- National STEM Honor Society
2024 to 2025		• Coach and Training Supervisor • Specialized career training for SC Pro-MLS and Engineering	• Implement SC tutors • Access to three research support subscriptions: Journal of Visualized Experiments (JoVE), Data Classroom and Projectboard	• Created Admin portal in Salesforce • Moved to QuickBooks online: connecting to Salesforce allowing for process/milestone automation	Community College Dual enrollment AIM online research course

[1]The initial dataset informing this table was obtained from SC CEO historical documentation and interview transcripts with the SC CEO on July 2, 2024. The table was further refined in subsequent interviews.
[2]PD includes intellectual property coaching for products with commercialization potential and skills training.
[3]Insurance covers teacher personal and professional liability, travel, and accident liability for students in commercial labs.
[4]Consists of research methodology skill building with outside presenters (30 min), SC info (10 min), and team meeting breakouts (20 min).

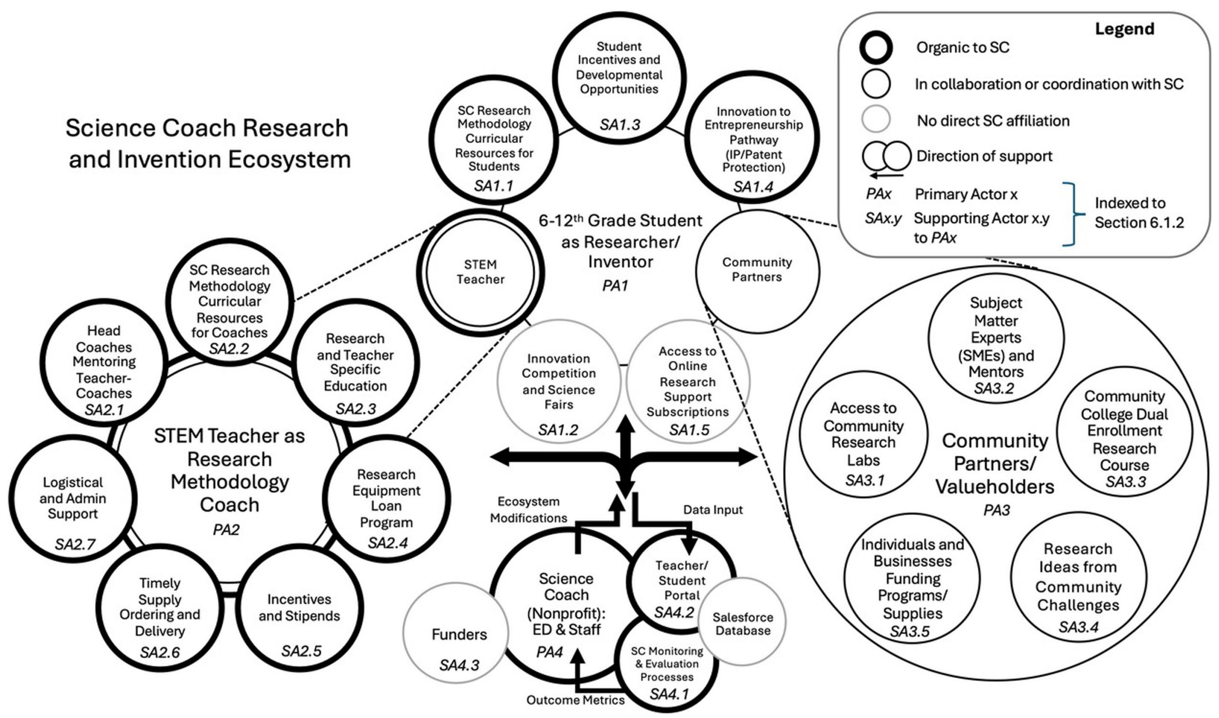

FIGURE 1
Science Coach Research and Invention Ecosystem: actors and relationships [2007–2024 (current)]. Annotations for Primary Actors (PAx) and Supporting Actors (SAx.y) are indexed to Section 6.1.2 in the text.

Valueholders) are pulled forward in Figure 1 to show additional details for the layers of support within each category. The STEM teacher as Research Methodology Coach, the left pullout in Figure 1, is the primary human actor supporting the students' work. The teacher-coach is supported through many SC resources. The seven types or categories of support for the SC teacher-coach are: (1) Head Coaches who mentor the teacher-coaches to guide students through research and invention methodologies, (2) SC research methodology resources for coaches, (3) research and teacher specific education, (4) research equipment loan program, (5) teacher-coach incentives and stipends, (6) timely supply ordering and delivery and (7) logistical and administrative support. The right pullout of Figure 1 shows a cover term 'Community Partners/Valueholders' to represent the various types of community-based resources that support students.

After identifying the diverse array of actors and/or types of resources that support students' work, we revisited the initial interview. We then conducted additional interviews with the SC CEO to determine the relationship of the different types of actors to SC. The relationships are depicted through the type of outline of each circle in Figure 1: those with bold outline are organic to SC; those with a thin outline act in coordination or collaboration with SC, and the shaded outline (i.e., science fair competitions and online research subscriptions) have no formal organizational affiliation with SC. All actors show one type of relationship with SC, except for teacher-coaches where a bold and a thin outline signal that teacher-coaches may be organic to SC and/or engage with students in coordination with SC support. Where the circle outline represents an actor's relationship to SC, a circle *overlapping into another* represents the primary direction of support (see Legend in Figure 1).

We also revisited the interview transcripts to understand *who* SC aims to support (e.g., primary actors from its perspective) and *what counts* as "support" from the perspective of the SC CEO. The SC CEO indicated that teacher-coaches and students are 'who is directly served' by SC and, therefore, are a primary focus for the program (e.g., *who* counts or *primary actors*). [Interview transcript, SC CEO, on December 27, 2024]. The third primary actor(s) are community partners, essential to the use-inspired program model, that support students and teacher-coaches. SC, the orchestrator of the experiences within SC's use-inspired construct, is the fourth primary actor. Additional details about these four primary actors and the SC CEO's description of supporting actors and how these support each of these primary actors within SC's research and invention ecosystem are summarized in the next sections.

6.1.2.1 Primary Actor 1 (PA1): 6th–12th grade students as researchers/inventors

The primary actor-resources for students are their teacher-coach and their community resources (see Figure 1). Through their public, private, and homeschool teacher-coaches, SC encourages students to pursue individual or small 2–3 student-team research projects to solve a local problem that is meaningful to them. Community partners bring disciplinary knowledge, technological expertise, and access to equipment for advanced research and invention. These two resources will be discussed in detail in subsequent sections as Primary Actors 2 and 3. The other five resources that support student researcher-inventors are summarized in Figure 1 and interviews with the SC CEO as follows:

6.1.2.1.1 Supporting Actor 1.1 (SA1.1): SC research methodology curricular resources for students

SC curricular resources for students, known as AIM Student, were developed the year after establishing a teacher version in 2019 to support remote students during the COVID pandemic. Like the teacher version, an advanced research methodology curriculum did not exist for high school students, so SC developed these resources [Interview transcript, SC CEO, July 2, 2024]. Provided in the Canvas learning management system, including the mobile app, AIM Student curriculum resources guide students through the work of identifying a problem, refining research questions, conducting a literature review, designing and conducting the experiment or project, conducting statistical analyses, writing a scientific paper, and presenting results [Interview transcript, SC CEO, on December 27, 2024]. Gaining access to AIM Student may occur in one of four ways (Science Coach, 2024):

1. any teacher in the SC program receives free access,
2. the school or district purchases licenses for classroom use,
3. for students with no research opportunity at their school, students may apply to take a year-long course, the AIM Online Research Class, taught by an SC teacher-coach starting at $2K with optional community college dual enrollment credit for a $60 per credit hour fee, or
4. learners may engage with the curriculum at their own pace by purchasing an AIM Student license at a cost of $300.

6.1.2.1.2 SA1.2: Innovation competitions and science fairs

Competing in an innovation competition or science fair is a stated SC requirement. A list of competitions and science fairs is maintained in the student portal by SC [Interview transcript, SC CEO, December 27, 2024]. The SC CEO explained that competitions are required because it is through these experiences that students begin to see themselves as scientists, engineers, and inventors. Recognizing that they can engage with expert judges as peers in meaningful disciplinary discussions fosters self-efficacy toward STEM degrees and careers. The SC CEO explains as follows:

> "we said, 'all of our students will be building a project to enter a competition'\ And that is different [than other programs]\ some people do research for the sake of doing research\ and maybe have [a presentation] at the end of the semester\ we require the kids to do a competition\… it is this process by which the students experience presenting their research that becomes a transformative engine for the student in their own self-identity [Interview Transcripts, SC CEO, July 11, 2024].

6.1.2.1.3 SA1.3: Student incentives and developmental opportunities

Science Coach maintains a list of STEM-related developmental opportunities offered both externally and internally to Science Coach students. As shown in Table 2, deliberate efforts to incentivize more students to pursue research and invention and other developmental opportunities through SC began in 2020. These efforts have led to national-level STEM recognition for students, opportunities for students to continue working on their research or invention projects, and/or opportunities for broadening their STEM proficiency. For example, SC initiated a STEM internship program in 2021. Currently, SC co-sponsors four internships for 9th–12th grade students, three in cancer research and one in neuroscience. The number of students served through internships is expected to increase in the next year [Interview transcripts, SC CEO, October 22, 2024].

In an interview, the SC CEO shared the significance of these internships, which she described as a 'win-win' for both the SC student and research labs:

> I also grow internships because of the quality of the students that we have… our students have a foundational knowledge of work ethic and self-discipline that has already been taught. They often are ideal candidates for internships, and with such a high percentage of underrepresented minorities, it makes us a gold mine for [businesses and research labs] who are trying to give internships… because the reality of it is, no matter how big your heart is, you cannot take a student who's never had experience in a lab and put them in a lab and expect them to be successful. It just does not work. They end up doing menial things. They know they are doing menial things. … So…SC makes it easier to find those underrepresented students who can do the learning that's needed in order to effectively assist in a lab in a meaningful way. [Interview transcript, SC CEO, December 27, 2024].

The application process for these internships is rigorous. The SC CEO explained this process:

> [Prospective interns] have to demonstrate their knowledge, their ability to articulate science and their ability to work as a team in a six-week virtual training process… [in that] virtual training, they learn the basics of, for example, in the cancer research [internship, they have to demonstrate basic knowledge] basic of cancer research terminology. …they have to read the [research] articles… if they do not actively participate [in the training], meaning they have the camera off, if their answers are incomplete, or they come late or do not show up, … they do not get selected. So, then we narrow it down… out of the 30 kids that submitted applications and took the six-week training course, we narrow it down to three or four [candidates] for each lab, and then they get interviewed and selected by that lab... in-person. [Interview transcript, SC CEO, December 27, 2024].

6.1.2.1.4 SA1.4: Innovation to entrepreneurship pathway (IP/patent protection)

Students with projects that have intellectual property (IP) and patent potential may receive IP coaching toward protecting and commercializing their inventions. Once the invention is fully vetted, this pathway is designed to steward the student through the process of patenting their invention while initiating the entrepreneurial business infrastructure to bring the product to market. The main feature of this pathway, specifically for students entering an undergraduate program, is that students work with a *scientific guardian ad litem*, that is, a SME/business coach in that area of invention who will protect the student's interest in the business until the student is out of college. SC provides $5 K of proof-of-concept funding and formalizes the business relationship for the scientific guardian ad litem to steward the business development as the student completes college. In the meantime, the student inventor works for the company. The program incentivizes students to complete their undergraduate degree as they will receive a larger portion of the company upon college graduation. [Interview transcript, SC CEO, October 28, 2024].

6.1.2.1.5 SA1.5: Access to online research support subscriptions

In addition to the AIM curriculum, students have access to an online student portal. In 2024, three different software subscriptions were added to the student portal. The Journal of Visualized Experiments (JoVE) provides research protocols at a level accessible to a high school student. Data Classroom assists high school students with statistics. ProjectBoard allows for the projects and the digital version of student research papers to be put in a format that can be shared. Furthermore, through ProjectBoard, a student may archive their work so that another student can use that knowledge to inform their own. Thus, SC has a means of collecting and sharing what students have learned as a living archive and resource for other student researcher-inventors. [Interview transcript, SC CEO, October 22, 2024].

6.1.2.2 Primary Actor 2 (PA2): STEM teacher as research/invention coach

SC is designed with a STEM teacher-coach as the primary guide for research methodology for students. Most of the teachers who have engaged with SC first learned about SC while attending an innovation or science fair competition where SC students are recognized for their performance. Some teachers became interested in SC through engaging with an SC staff member at industry booths at professional science teacher events. Others have been recruited by one of their students who wanted to do advanced research. Over 80% of teacher-coaches enter the SC ecosystem through their school purchasing a Science Coach Complete (SCC) membership at $6 K per teacher at the teacher's request [Interview transcript, SC CEO, December 27, 2024]. Therefore, most students participate in SC as part of another 6th–12th grade science course or as an extracurricular activity. However, SC teacher-coaches also guide students directly through SC, outside of a formal learning environment (e.g., homeschooled students) or through a community college online course called the AIM Online Research Course. Minimal teacher-coach qualifications are: (1) being a 6th–12th grade public, private or homeschool teacher with a STEM disciplinary background, and (2) 3 + years of instructing research or Project Based Learning (PBL) (Science Coach, 2024). Additional information about initiatives and resources made available to support teacher-coaches that were identified in Table 2 and shown in Figure 1 are provided in the remainder of this section.

6.1.2.2.1 SA2.1: Head coaches mentoring teacher-coaches

According to the SC CEO, teacher-coach survey responses consistently reflect that the most valuable SC benefit is being part of an SC team and 'having someone to call' for expertise in guiding students [Interview transcript, SC CEO, October 28, 2024]. A SC team consists of an experienced Head Coach who advises three to five teacher-coaches from any combination of public/private or homeschools who work together all year. Head Coaches, who may be teaching their own SC students, do not have this position through their school affiliation. In fact, most Head Coaches are not at the same school as their teacher-coach team members. Rather, SC teams are constructed regionally, which allows an SC team to build relationships with their local community partners (i.e., research labs) and meet in person if needed. In this way, the use-inspired facets of the SC research and invention ecosystem shown in Figure 1, applied in a local context, forms a regional 'hub' consisting of one SC team with a Head Coach and their local community partners. Currently, there are six SC 'hubs' each with one Head Coach: three in Missouri, two in Illinois, and one virtual team with teacher-coaches in Kansas, Missouri, and South Dakota [Interview transcript, SC CEO, December 27, 2024]. The SC CEO shared how head coaches are selected:

> "a head coach is an experienced teacher who has had students go to the International Science and Engineering Fair (ISEF) and has won, or a similar national competition like the Junior Science and Humanities Symposium or Science Talent Search …a well-known, prestigious competition because that tells me that that teacher knows how to coach students to do advanced research." [Interview transcript, SC CEO, August 17, 2024].

Head Coaches have been part of the SC ecosystem since program inception (see Table 2). Because of the critical support and mentoring Head Coaches provide to teacher-coaches, we considered whether Head Coaches were 'primary actors' in this ecosystem. However, with 90% of SC's effort going to support teacher-coaches according to the SC CEO, Head Coaches are not 'who are served'. Rather, their institutional knowledge, experience, and willingness to be that 'someone to call' is an invaluable resource to teacher-coaches [Interview transcript, SC CEO, December 27, 2024].

6.1.2.2.2 SA2.2: SC research methodology curricular resources for teacher-coaches

In the absence of existing research methodology resources for 6th–12th-grade teachers, the SC CEO wrote a research methodology curricular resource for teacher-coaches in 2018 (see Table 2) called AIM (Advanced Innovation Methodology) Teacher [Interview transcript, SC CEO, July 2, 2024]. AIM Teacher supports authentic research instruction as well as teaching problem-based learning (PBL) as the companion to AIM Student. AIM Student curriculum includes disciplinary content mapped to Next Generation Science Standards, Science and Engineering Practices, and Cross Cutting Practices. It uses a PBL instructional design and 5E Model of Instruction (i.e., engage, explore, explain, elaborate and evaluate) as a framework for teaching (Bybee and Landes, 1990). AIM Teacher includes downloadable and modifiable lesson plans, rubrics, classroom activities and instructional materials [Interview transcript, SC CEO, October 28, 2024].

6.1.2.2.3 SA2.3: Research teacher-specific educational opportunities

SC provides teacher-coaches with opportunities for developing professionally by gaining research methodology knowledge and broadening the teachers' comfort level with less familiar disciplinary content. According to the SC CEO, developing teacher-coach proficiency is "a big deal" as "teachers will not do research in an area in which they do not feel like they can be helpful" [Interview transcript, SC CEO, December 27, 2024]. As shown in Table 2, since 2009, these opportunities have grown from professional development in statistics and bioinformatics to obtaining graduate credit for SCA and SCC to specialized training in new disciplines. According to the SC CEO, the key areas of teacher-coach proficiency that SC readily supports are statistical analyses, using zebrafish and c-elegans as model organisms, and hands-on analytical equipment training. Additionally, SC conducts webinars on topics that the teacher-coaches request. Currently, SC is recording their virtual training to make these available in a video library accessible on the SC Canvas system. [Interview transcript, SC CEO, December 27, 2024].

6.1.2.2.4 SA2.4: Research equipment loan program

Because advanced research often requires analytical instrumentation that is not available at the secondary grade levels, SC began building a robust collection of donated instrumentation and equipment for free loans needed for specific student projects and maintained by the teacher-coach [Interview transcript, SC CEO, August 17, 2024]. Some instrumentation available for loan are hydroponic systems, incubators, specialty microscopes, and various types of sensors. Analytical equipment available for long-term loaning includes a spectrometer and gas chromatograph [Interview transcript, SC CEO, October 28, 2024].

6.1.2.2.5 SA2.5: Incentives and stipends

SC incentives for teachers are provided in the form of opportunities for developing professionally and receiving graduate-level credit as well as stipends. These reflect SC organizational values that recognize the teacher-as-professional (i.e., $2 K stipend for after-school work) and the need for fostering camaraderie through student research community-building (i.e., $450 to recruit and retain students) [Interview transcript, SC CEO, July 11, 2024].

6.1.2.2.6 SA2.6: Timely supply ordering and delivery

Obtaining the specialized supplies needed to conduct advanced research is difficult through a school's supply system, vendor approval processes, and 3-week or more purchase order processes. Moreover, receiving supplies that are biological often requires pre-certification of the ordering entity and delivery to a laboratory designated to safely store them at the appropriate temperature or biosafety level. Partnering community laboratories assist in this process. According to the SC CEO, teacher-coaches say that this is the second most important benefit they receive through SC and vital for obtaining supplies quickly [Interview transcript, SC CEO, October 28, 2024].

6.1.2.2.7 SA2.7: Logistical and administrative support

SC has initiated efforts to minimize the logistical and administrative overhead for teachers who organize opportunities for students. For example, SC integrated portal access to SC's Salesforce database for teacher-coaches to quickly complete competition registration and maintain records of awards and scholarships. SC teacher-coaches and their students are also insured for personal and professional liability in commercial research laboratories as well as travel [Interview transcript, SC CEO, July 2, 2024]. According to the SC CEO, teacher-coaches say that insurance is the third most important benefit they receive through SC [Interview transcript, SC CEO, October 28, 2024].

6.1.2.3 Primary Actor 3 (PA3): Community partners-valueholders

Community partners are equally as important as teacher-coaches in supporting student researcher-inventors in this use-inspired research and invention ecosystem. Community partners bring STEM knowledge and research resources beyond what is available in most secondary schools. They bring community-based knowledge of problems embedded in their local contexts that students may choose to investigate and solve through innovative research. The ways and means by which SC partners with STEM-related businesses and research labs in the community are discussed in this section.

6.1.2.3.1 SA3.1: Access to community/commercial research labs

University and commercial research labs provide access to space and use of analytical equipment and instrumentation by teachers and students. As discussed previously, these labs receive and store student chemical and biological supplies and serve as a source for disciplinary mentors and subject matter experts (SMEs). According to the SC CEO, student access to these labs with advanced instrumentation increases teacher-coach comfort level with guiding students pursuing advanced research [Interview transcript, SC CEO, July 2, 2024].

Currently, 4 of the 32 teacher-coaches entered the SC ecosystem through the SC Pro Program [Interview transcript, SC CEO, December 27, 2024]. The SC Pro Program is a business's point of entry into SC to grow its local workforce. The SC CEO explains the details of how businesses partner with SC to bring teachers into the SC Program:

> …most of the companies that we have been dealing with have already been trying to reach out to schools on their own, and they often find it very difficult [to recruit students], and they cannot seem to make an impact… [with outreach] that actually ends up with kids going into [the business'] degree field. They may have one or two students choosing their industry's specific career, here and there, but they are not getting a large number. Those are the companies that are perfect for us, because they know how hard it is to get these kids. [And career fields] like Medical Laboratory Science [require] a longer onboarding… So those kinds of careers lend themselves to a Science Coach Pro [partnership]. They've already been trying to work with the community [and schools], and they know the teachers who respond [to having] them come [into the classroom] and talk to students, or allow them to do hands on activities, or [will] bring their students [into the business' research laboratory]. [Transcript of Interview with SC CEO, December 27, 2024].

Through Science Coach Pro, the business partner makes the connection between SC and the prospective teacher-coach by recommending teachers or school districts with whom they would like to work. Furthermore, when the STEM researcher recognizes and acknowledges the potential of the teacher to guide students in advanced research with SC support, teachers readily want to learn more. In this model, the businesses commit to funding the cost of the teacher to be part of SC Pro (i.e., $6 K per teacher), the cost to support one or more Science Sponsor projects (i.e., $2,500 per project for extra teacher/student compensation and $1 K in dedicated supplies), and the administrative costs such as teacher-coaches working with a Head Coach and any other additional outreach events such as a symposium at the business location. Additionally, in coordination with partnering businesses, the SC Pro Program offers career information, hands-on experiences, tours of the partner business, educational next-level pathways toward the specific career of that partnering business, and teacher skills training. SC also guides SC Pro partners to commit to an initial 3 years of support for SC teacher-coaches [Interview transcript, SC CEO, December 27, 2024]. In an interview, the SC CEO explained why she asks for a three-year commitment:

> I really try to get 3 years of commitment [from the businesses] because I tell them, "the first year [teachers are] figuring out how to do good research. The second year, [the program is] starting to get really grounded, and they are getting 'good science' [from students]. [In the] third year, they have got 'advanced research' being conducted. But it is that support [through SC's research and invention ecosystem] that you need to get them up to where you start getting numbers [of students] that are impactful [(i.e., as a career pathway into the SC Pro partner-business]. [Interview transcript, SC CEO, December 27, 2024].

The potential for growing a local workforce from this business-initiated point of entry into SC is worth noting. For example, the SC CEO explained that in pre-post surveys of two SC hubs, each with a business needing to recruit Medical Laboratory Science expertise, one larger hub had 42 SC high school students interested in pursuing this career pathway and the other smaller hub had nine SC students interested. Before partnering with SC, these two businesses had garnered only one interested student each after one year of outreach [Interview transcript, SC CEO, December 27, 2024].

However, not all STEM-related businesses lead to an effective partnership with SC. The SC CEO explains in the following:

> The best Science Coach Pro program [candidate] is a company whose industry employees require a long educational process that takes multiple years of accumulative knowledge and sequential learning to be a good, valuable employee. It also has to be something that students can do. So Medical Laboratory Science has so many things that [students] can do that do not conflict with the [innovation and science fair] competition rules... and that's really important. And the third component is they have to have a workforce crisis... where they are open to trying something totally new to build their own workforce. [Transcript of Interview with SC CEO, December 27, 2024].

In the 24–25 school year, SC Pro implementations included Medical Laboratory Science (MLS) and Engineering. In the 25–26 school year, the existing MLS/Engineering programs will continue as well as two additional MLS implementations and nursing research [Interview transcript, SC CEO, December 27, 2024].

6.1.2.3.2 SA3.2: Disciplinary-specific subject matter experts (SMEs) and mentors

SC encourages all students to engage someone outside of their school for disciplinary-specific guidance. There are three levels of disciplinary-specific assistance that range from virtual to in-person and minimal to extensive time investment: (1) SMEs short term, (2) SMEs – multi-month, and (3) Mentors. While working with any of the SC students, SMEs may agree to serve in short or long-term coaching and/or mentor roles for students, whereas teacher-coaches guide students in research methodology processes and program milestones [Interview transcript, SC CEO, July 2, 2024]. Mentors commit significantly more time than SMEs. According to the SC CEO, mentors are largely brought into the SC ecosystem through SMEs interacting with an SC student on a project where their relationship grows authentically into mentor and mentee roles [Interview transcript, SC CEO, October 28, 2024]. After project completion, mentors may agree to make themselves available as mentors to other SC students in subsequent years. In this case, the student may request a particular mentor by name or subject area through the SC portal, and SC formalizes the relationship, including background checks, if the mentor agrees. SC currently has approximately 100 vetted disciplinary-specific SMEs and mentors [Interview transcript, SC CEO, December 27, 2024].

6.1.2.3.3 SA3.3: Community college dual enrollment online research course

Like many other SC offerings, this SC offering came about because of a recognized need in the field. In 2023, six remote students requested SC help but did not have a teacher nearby. While one coach was already teaching an AIM research class with AIM Student online, the challenge was that these students were very high achieving and doing independent research in addition to schoolwork. Petitioning for this course to be accepted in their high school as a class for credit was difficult as there was no established outside credibility for the class content. Community college dual enrollment established this credibility. This course is currently a 3-credit, 200-level biology research course with 13 students [Interview transcript, SC CEO, October 28, 2024].

6.1.2.3.4 SA3.4: Research ideas from challenges identified in the community

SC collects problems from local businesses and civic organizations and makes these available through the student portal. This connection not only provides a use-inspired research topic, but many of these organizations also fund supplies in support of students researching their problem. To initiate this process, SC staff talk directly with businesses. As businesses get to know the SC program, SC staff members communicate that they are always looking for real problems in industry and what kind of research would be appropriate for students. Inevitably, businesses start mentioning ideas that are captured by SC. There is often a follow-up where SC staff give businesses access to a Google spreadsheet of “problems” that is used by the students and teachers. Students may also add project ideas as they think of them. Business partners often update this spreadsheet throughout the year as project idea inspiration occurs. SC continues discussions with the business to present the project idea in a way that engages a student’s inventive spirit to solve a real problem that exists today in that industry [Interview transcript, SC CEO, December 27, 2024].

Part of the data collected with the “problem” is the email address of the person who submitted the idea. When students use the ideas, they often reach out directly to the person who submitted the problem. Additionally, SC shares the resulting project research paper with the originating business where possible. Often, the business contact becomes a mentor or SME for the student [Interview transcript, SC CEO, December 27, 2024].

6.1.2.3.5 SA3.5: Individuals and businesses donating or funding supplies

SC maintains a list of donors who provide free research supplies (e.g., biological organisms) to students. Students request these free supplies through a link on the SC portal [Interview transcript, SC CEO, October 22, 2024].

6.1.2.4 Primary Actor 4 (PA4): Science Coach (nonprofit)

Science Coach, the nonprofit, is made up of a CEO and three full-time and two part-time staff members. The CEO designs program enhancements, manages funding streams and staff, recruits ecosystem participants, facilitates their interactions, and ensures that each actor in the network is doing their part. The Supervisor of Coaches and Training provides professional development opportunities for teachers, maintains the research methodology curriculum, and ensures that teachers have administrative and logistical support. The Executive Assistant/Salesforce Administrator operates the monitoring and evaluation system to track program outcomes. The Director of Strategy and Outreach implements the strategic plan, manages all marketing/communication needs, and develops relationships to further the nonprofit [Interview transcript, SC CEO, October 28, 2024]. Other key resources designed by Science Coach or outside entities that support it are described below.

6.1.2.4.1 SA4.1: Monitoring and evaluation processes (supported by a salesforce database)

Since 2018, SC has used Salesforce technology to build the SC systems infrastructure to connect and monitor most parts of the ecosystem. Automating processes where possible where teachers and students can enter data through the SC portal has enabled SC to collect key outcome metrics and monitor another 1,000 data points across the SC ecosystem [Interview transcript, SC CEO, October 22 and 28, 2024].

6.1.2.4.2 SA4.2: Teacher and student portal

The teacher and student portal is a user-friendly custom web interface built by SC using FormTitan that lays over the Salesforce database. Because Salesforce requires a purchased login for every user, SC used FormTitan to construct and customize its own portal interface [Interview transcript, SC CEO, December 27, 2024]. Constructing this SC portal, organic to SC, allows for automating routine processes initiated by teachers and students, such as ordering supplies, requesting a mentor, and sending thank-you notes for donor funding [Interview transcript, SC CEO, October 28, 2024]. The portal includes a built-in message system, allowing for consistent messaging to all students and teachers. Teachers instantly know their milestone earnings, the amount of supply money/recruiting money that remains, and the status of all student research through a custom dashboard. Additionally, with tiered permissions, Head Coaches can monitor the status of their teachers and their students to help anticipate when teachers might need support [Interview transcript, SC CEO, December 27, 2024].

6.1.2.4.3 SA4.3: Funders

Currently, beyond the major benefactor, the primary funders of SC are foundation and local grants. Another significant funding source is schools and districts that purchase Science Coach Complete (SCC) for one teacher to be trained and supported as a science coach with annual benefits (i.e., \$800 in supplies, a \$2 K stipend, \$450 recruitment funding) and student developmental opportunities. However, because of limited school budgets, many schools need help to participate. In these cases, SC finds other ways to bridge this gap. Other private funders in the community provide resources for additional supplies and student incentives. When available funding does not meet demand, SC has organized community fundraisers [Interview transcript, SC CEO, October 28, 2024].

6.1.3 Question 1 summary

Table 2 and Figure 1 show the significance of the actors and roles within the SC research and invention ecosystem in its current state of evolution. According to the SC CEO, what makes SC effective is “how the elements of the ecosystem work together within a common framework” [Interview transcript, SC CEO, August 17, 2024]. We explore and co-construct this framework, conceptualized as principles of design in the next phase of inquiry.

6.2 Question 2: What principles of design emerge from the ways the actors work collectively and independently? How do these principles align with the literature pertaining to STEM career interest?

To understand how the elements of the ecosystem work together as principles of design, researchers revisited the SC website and interviews with the SC CEO to identify textual and video/audio records or transcript segments that signal the rationale(s) that informed decision-making in the program's strategic or developmental trajectory. Additionally, another document provided by the CEO was added to the records archive for this phase of inquiry, one that inscribed SC's core values used internally when onboarding new teacher-coaches. These segments from texts and interview transcripts were collected to construct a dataset for discourse analysis to make visible a proposed list of SC's principles of design. Table 3 traces each principle of design (Column 1) from evidence (Columns 2 and 3) and supporting literature (Column 4) for each principle.

The outcome of this phase of inquiry produced six principles of design, some reflecting interdependencies to various extents. Principle of Design 1 is based on the orienting theory that informed the CEO's actions as she developed SC over time. Specifically, the CEO was guided (i.e., as orienting theory) by the notion that career choice happens through fostering *interest*, then gaining *proficiency*, and then *persisting* in a disciplinary area over time (Impact Genome Project, 2019). The SC CEO deliberately built initiatives of sufficient duration (See Table 2) to support each component of this theory of change. Design Principles 2 through 6 can also be traced back to supporting one or more of the three phases within this theory of change.

Although not informing SC's development, SCCT (Lent et al., 1994) serves as an explanatory theory in this research study for developing insights into how the facets of the ecosystem may work together to produce successful program outcomes. SCCT assumes that students are more likely to become interested and choose to pursue activities where they perform well as long as they have the knowledge, skills, and environmental support(s) to persist along that career trajectory. Students develop self-efficacy in their STEM ability as they gain disciplinary knowledge and practices engaging with SC research methodology resources and their project while supported by their teacher-coaches and mentors. Additionally, students present their research and inventions at competitions that may grow or further reinforce a STEM identity. Related to self-efficacy, outcome expectation (e.g., 'What will happen if I do this?) is another focus area of SCCT. Through SC, students are afforded the opportunity to engage in the processes and practices of solving real-world problems that can make a difference in their community. Students develop outcome expectations based on this first-hand experience. As explained by the SC CEO, in engaging in an SC authentic research or invention project, students have '…already tried on that career\ felt success\ and felt like they could contribute\ and that it was fun' [Interview transcripts, SC CEO, July 11, 2024]. The third variable, also closely related to both self-efficacy and outcome expectations, is personal goals. Guided by their teacher-coach and other SC resources, such as project tracking through the SC student portal, students learn how to organize and guide their behavior toward accomplishing long-term goals through deliberate short-term tasks and milestones. In this way, SC presents students with the next challenging goal, thus scaffolding their research and invention developmental experiences and opportunities accumulating in, according to the SC CEO, strong preparation and persistence to pursue STEM degrees and careers.

6.3 What is the evidence that Science Coach supports students' preparation and persistence in STEM undergraduate degrees and careers?

6.3.1 Overview

To understand how the SC CEO conceptualizes 'persistence,' we collected and analyzed data to determine who SC had served and the outcomes documented by the CEO and SC's monitoring and evaluation processes. We collected available data from program inception through the end of the 2024 academic year. However, our analysis focuses on the last 5 years, given that the current version of the program was in development from 2018 to 2019 and implemented the following year.

6.3.2 Descriptors and demographics

Key program descriptors from SC historical files and student demographics from student registration profiles are shown in Table 4. Data shown in Table 4 is aggregated in Phase I to represent the first decade of the program from Fall 2007 to Spring 2018. As the transition year of SC moving toward a non-profit with national scope, the 2018–2019 academic year represents the last year of the initial SC program model where many new initiatives were planned and some were implemented (see Table 2). Phase II implementation represents the current version of the program with respect to the strategic vision that guides the program culture and developing offerings.

Contrasting Phase I years with Phase II Implementation shows a five-to-six-fold growth in the number of teacher teams, teacher-coaches, and student participants. Under Phase II Implementation, which is still ongoing, an SC team consists of one Head Coach who guides 4–5 teacher-coaches in coaching an average of 12 to 13 students. However, historical data shows that the actual student-to-teacher ratio is widely distributed from 8 to 20 students per coach, given that some teachers teach one or more classes of a research course within a school, and other teachers mentor individual students remotely outside of the traditional school environment. According to the SC CEO, the number of students was artificially inflated during two COVID-19-impacted years (2020–2022) because teachers mistakenly identified all their students as participating research students at the beginning of the school year.

Where the % of female and % URM students has remained relatively consistent (e.g., given that females are included in URM) since program inception, the % of BIPOC students dramatically increased from an average of 1% in Phase I to between 17 to 35% in Phase II implementation. The SC CEO attributes this sustained increase in BIPOC participants as follows:

> In 2018, one of my goals was to increase the number of both URM and BIPOC in Science Coach. I wrote a grant and obtained it to specifically identify the support that is unique for black students to be successful in doing scientific research. The data we discovered was very interesting. While all students respond to having extra encouragement and support, it was vital for underrepresented and especially black students. The imposter syndrome was a very big issue. [But] when students were

TABLE 3 Science Coach principles of design.

Principles of design	Evidence		Supporting literature
	Evidence/rationale	Programmatic initiatives	
1. Building initiatives and connecting all three phases of a theory of change model toward careers: interest, then proficiency and then persistence.	"Way back when we started, STEM programs were… 'Okay, here's marshmallows and toothpicks, make a bridge. It's so much fun'. [then it's] done\ … that may garner an interest, but it does nothing for proficiency or persistence. And even if you go to that next level where you are [helping students with] proficiency… you have to get to the persistence. And [other] STEM programs were doing [one piece of this process with a] little piece here and doing this little piece there. [But] I'm a connector. It became apparent to me that I needed to connect these pieces in the Science Coach Program." [Interview transcripts, SC CEO, July 11, 2024]	• Interest: students receive virtual presentations, hands-on MLS career exploration opportunities, and tour professional laboratories. • Proficiency: (See Table 2, Student Disciplinary and Project Resources) • Persistence: students may participate in SC multiple years and are afforded many developmental opportunities (See Table 2, Student Incentives and Opportunities)	Interest, proficiency and persistence theory of change model (Impact Genome Project, 2019)
2. Fostering an environment where the students self-select the problem or area of research with teacher-coach support.	"It's not so much that every teacher needs to be an expert… but the real goal that I learned a long time ago was that teachers will only encourage students in areas in which they feel comfortable enough to coach\ and if you think about it, whether you are talking about an invention or research, it's still kind of the same thing: If a [student] wants to invent a new telescope and the teacher has absolutely no framework of knowledge, they'll often try to redirect students into something in which the teacher has more confidence\ we learned early on, the wider the comfort level, the more freedom allowed to students [to select their own project]\ now\ that is not necessarily competence, but it's comfort level [of the teacher]\ the more confident the teachers, they more they will allow the students to choose from a wider variety of topics." [Interview transcripts, SC CEO, July 2, 2024] SC Core Value #1: "Forever curious - We encourage students and teachers to continually ask why and develop a thirst for solving real-world problems of personal interest." [SC Core Values document]	• Students are incentivized to choose MLS project ideas from real-world issues facing the industry • Offering teacher-coaches wider opportunities for professional development (See Table 2, Teacher Incentives, Resources and Developmental Opportunities)	Students persist in their project through being personally connected to the problem (Couch and Kalainoff, 2024)
3. Building a broader ecosystem of actors with varied disciplinary knowledge to support student research	"…we also spent a lot of time trying to get the teachers to understand their job was to manage the methodology and the timing of the projects and a subject matter expert or a mentor was handling the specifics of the procedures or experimental design or those things that were outside of the scope of the teacher, and once the teachers found out. It was like, 'Oh, I thought I had to know everything'. And they realized that they did not. Then they became even more willing to collaborate with a [disciplinary specific] mentor. So the teacher manages the timing and the deliverables and the mentor manages the scientific accuracy and [procedures]" [Interview transcripts, SC CEO, July 2, 2024] "In our research ecosystem, as we grow from state to state, we are trying to have a lab component be a part of every ecosystem that gets established\ schools will have a certain amount of equipment, but at some point, there needs to be more to get to that higher level science\ so having those partnerships already pre-assigned is vital…" [Interview transcripts, SC CEO, July 2, 2024] SC Core Value #3: "Live interdisciplinary - We use multiple fields of knowledge in solving real-world problems because that's how real-life works." [SC Core Values document]	• Professional development opportunities in research methodology: statistics, bioinformatics • Establishing role of the teacher as a guide to research methodology. • Addition of disciplinary mentors to shoulder the research-specific disciplinary content knowledge • Growing a new regional SC ecosystem must include a commercial research lab partnership.	Resources to support developing STEM proficiency (Impact Genome Project, 2019) Mentors as part of an invention ecosystem (Kalainoff et al., 2022; Zhang et al., 2023) Professional development for teachers (Skukauskaitė and Couch, 2024)

(Continued)

TABLE 3 (Continued)

Principles of design	Evidence		Supporting literature
	Evidence/rationale	Programmatic initiatives	
4. Honoring the teacher as a professional	"Honoring the teacher and treating them as a professional is one of our core values\ and that's why we have compensations because in real life\ professionals get paid" [Interview transcripts, SC CEO, July 11, 2024] "Sports coaches get paid for their after-school time and expertise. Being a research coach takes more time than sports because it is a year-long endeavor- not just a season. We require that teachers get compensation for their after-school work and do so through a stipend that is based on milestones." (Email correspondence, SC CEO, December 30, 2024) "I want to make sure our PD is impactful training that teachers are asking for and that it is a good use of their time\ and I have no problems if we try something and it's an epic fail\ I switch right there midstream\ …when it's effective, you are going to know it and when it's not effective, you are also going to know\ … I choose to pay attention and switch midstream to have an effective program\ and that honors the teacher's time" [Interview transcripts, SC CEO, July 11, 2024] SC Core Value #4: "Invest in others exponentially - We ensure our people and coaches are effective by investing in them through high-quality professional development, ongoing support, and compensation." [SC Core Values document]	• Head Coaches and Teacher-Coaches receive stipends for afterschool work with students. • PD is an identified need and repetitive administrative processes are streamlined in Salesforce to honor teacher's time	
5. Building student opportunities for belonging with respect to a STEM identity	"We said, 'all of our students will be building a project to enter a competition'\ And that is different [than other programs]\ some people do research for the sake of doing research\ and maybe have [a presentation] at the end of the semester\ we require the kids to do a competition\… it is this process by which the students experience presenting their research that becomes a transformative engine for the student in their own self-identity\ because when you when you are telling somebody about your research\ and they are into it\ and they are Doctor Who[m]ever\ and they are asking you questions\ and you are having a conversation\ …and they are saying things like, 'that's a really interesting way to do that. That's a really interesting question' or 'have you thought about this?' and all of a sudden [students] are seeing themselves\ and this other Doctor Who[m]ever\ as a colleague or as an equal\ and that is it, that's the magic\ and that starts the 'I belong'\ And it is that that experience of seeing yourself\… and succeeding in that environment\ that is the transformative secret component\ where the kids start saying\ 'I could do this'\ and that's how they start choosing this as a career\ and that's why our numbers\ for the percentage of kids who go into STEM\ are so high \ because they have already tried on that career\ felt success\ and felt like they could contribute\ and that it was fun\" [Interview transcripts, SC CEO, July 11, 2024] SC Core Value #2: "It's OK to fail - Sometimes experiments or procedures fail. We celebrate failure as a way to learn and intentionally use those learnings to help develop resilience and persistence." [SC Core Values document]	• Student requirement to participate in a science fair or innovation competition • Student opportunities to become more proficient in STEM and persist contribute to building self-efficacy toward STEM identity (See Principle of Design #1)	Feeling of belonging as important in student persisting to earn a STEM degree (Johnson, 2012), especially for URM to include female students (Hughes et al., 2013; Rainey et al., 2018) Inventor identity (Couch et al., 2019)

(Continued)

TABLE 3 (Continued)

Principles of design	Evidence		Supporting literature
	Evidence/rationale	Programmatic initiatives	
6. Building a community of belonging for students and teachers.	[For teacher-coaches]: "so you start building camaraderie\ and whether that's virtually or in person\ that camaraderie is really important\ because then they have\ they have that person to call\ they have that, you know\ that somebody just to bounce ideas off\ they have that community\ and many\ especially in rural schools\ a lot of times there is only one science teacher\ and they are alone…a focus group of one\ as part of Science Coach they have found their people\ [and] support\ and they are not alone\" [Interview transcripts, SC CEO, July 11, 2024] [For student researchers/inventors]: "the kids who are asking those 'why' questions\ often are the ones that end up gravitating\ or the ones that are inventors\ or the ones that do not necessarily like the structure of\ you know, straight up chemistry\ straight up biology\ and they want to do interdisciplinary things\ and they want to… really make an make a difference\ those are the kids that often gravitate to Science Coach\ and find their people\ and find that it's okay to try\ it's okay to fail\ it's okay… that there are other kids just like them\ that think that research and invention is cool\... and they are not so ostracized or feel isolated\ [Interview transcripts, SC CEO, July 11, 2024]	• Head coaches meeting with their team of coaches collectively (cohorting) • Monthly 1-h SC PD for all teams • 'Recruit and retain' stipend for teachers to bring students together in student events within their school • Connecting students in-person and virtually across schools/states	

TABLE 4 Science Coach Program descriptors and student demographics from academic years[1] 2008–2024.

Descriptives/ Demographics	Phase I		Phase II Implementation				
	AY08-AY18 (average)	AY19	AY20[2]	AY21[2]	AY22[2]	AY23	AY24
# Teams (and Head Coaches)	1	2	4	6	6	5	4
# Teacher-Coaches	5	9	16	28	26	21	23
# Students	50	73	230	289	326	272	224
% Female Students	60	47	58	53	60	63	52
% URM[3] Students	66	52	71	72	81	69	66
% BIPOC[4] Students	1	12	21	17	35	36	25

[1]This Academic Year (AYxx) annotation identifies the last two digits of the year of the Spring Term. Therefore, the academic year starting in Fall 2018 and ending in Spring 2019 is AY19.
[2]COVID-19 Impacted Years.
[3]Underrepresented Minority (URM) includes females and non-white ethnic categories except Asian and white/Asian.
[4]Black, Indigenous, Persons of Color (BIPOC) includes all non-white ethnic categories.

> successful in lab settings, it made them feel like they belonged. The feeling of belonging was absolutely vital for black students. So, we had specific teacher training created... [the training] really helped the teachers understand some of the differences in culture and to think beyond their personal experience. [Email correspondence, SC CEO, November 11, 2024].

6.3.3 Program outcomes

6.3.3.1 External assessment metrics

The current Science Coach Program outcomes were first implemented in the 2019–2020 academic year. Key metrics, including awards at innovation competitions and science fairs and scholarships earned since program inception, are shown in Table 5.

Table 5 shows select program outcomes relating to the external assessment of participant capabilities in conducting STEM research and effectively communicating STEM disciplinary content in refereed competitions and fairs. Although records about participation details are incomplete in years before Phase II Implementation, students won between one and 18 local, regional, and state awards, up to three national and international awards, and between $45 K-114 K in scholarships each year. Starting in the Academic Year 2020, Table 5 shows the participation record of students completing their project, competing in more than one competition, and advancing to next-level fairs, including the International Science and Engineering Fair (ISEF), the most recognized and prestigious fair worldwide. According to the SC CEO, during COVID-19 impacted years, Science Coach rapidly responded to changing requirements by adding to the AIM Student curriculum guidance on presenting research virtually. SC students won more awards than they would have otherwise because of this guidance. With the four-to-five-fold increase in student participation between Phase I and Phase II years (see Table 4), SC student

TABLE 5 Science Coach outcomes for 6th–12th grade participants from academic year 2008 to 2024.

Outcomes	AY08-18 (average)	AY19	AY20[1]	AY21[1]	AY22[1]	AY23	AY24
% of Students completing their project	Not Available (NA)	NA	93	79	79	81	93
% of competition Students competing in more than one competition	NA	NA	56	86	88	64	93
% of Students participating in a fair and advancing to next level	NA	NA	17	32	39	22	22
% of Students advancing to the ISEF (Int'l Science and Engineering Fair)	NA	NA	6	9	7	5	7
% of 6th-12th Grade Students intending to declare or having declared a STEM-related post-secondary major	NA	NA	81	89	88	81	87
# Awards- Local/ Regional/State	3.8	2	87	169	144	79	227
# Awards- National/ International	1.8[2]	2	5	14	7	3	5
Average # awards per student enrolled in SC	0.084	0.055	0.40	0.63	0.46	0.30	1.03
Scholarships Earned (includes non-STEM related scholarships)	$60K[3]	$144 K	$253 K	$734 K	$327 K	$1.3 M	$730 K

[1]COVID-19 impacted years.
[2]No more than three awards in any one year.
[3]Scholarships were not documented until AY15.

performance at innovation competitions and science fairs has increased dramatically, as demonstrated by the average number of awards per student increasing from 0.084 in Phase I to 0.30–1.03 in Phase II Implementation.

6.3.3.2 Student persistence toward STEM fields and careers

While it was significantly expanding its program offerings in 2018–2019 (see Table 2), SC instituted a questionnaire system in the 2019–2020 academic year for internal program monitoring. These records include four questionnaires per year for students, teacher-coaches, and head coaches. Because teacher incentive stipends are programmatically tied to student questionnaire completion, students are consistently encouraged to complete the questionnaires and do so at a modest rate of 51%. However, by visual inspection of individual responses to questions, students complete questions at a much lower rate. Analysis of student surveys shows that of the 12th-grade students matriculating from the program since 2019 ($N = 612$) who shared their college degree choice in the final questionnaire ($n = 234$), 91.5% ($n = 214$) of all students and 90.3% ($n = 149$) of URM students self-reported that they were pursuing a STEM degree or career after participating in one or more years of Science Coach.

Given the question of student persistence in the program and the potential effect on STEM degree selection, we identified all 12th-grade students since AY20 and traced their participation histories to produce Table 6.

Table 6 shows the number of students in the SC program, number of 12th grade students, and number of URM students in each of the last 5 years of the program. The table identifies the number of URM and non-URM 12th graders who completed one, two, or three or more years of the program. Student participation histories show that as students persist through one, two, and three or more years in the program, the effect on continued URM participation in SC within the existing student pool increases by approximately 10% each year. URM participation rates at the high school level are higher than non-URM participation rates and increase as students persist in the program. The SC CEO attributes the pattern of URM participation rates as seen through the lens of her personal experience as follows:

> Many URM students are risk-averse, and many have never even had the opportunity to do science experiments much less authentic research. It often takes multiple years of exposing them to the scientific method before they are ready to take on anything as in-depth as authentic research. We have created a program that

TABLE 6 Persistence history of URM and non-URM 12th grade students in Science Coach (2019 to 2024).

School Year	# of 6th–12th Grade Students	# of 12th Grade Students	# of 12th Grade URM	# of 12th Graders who completed X Years of SC						% of 12th Grade URM	% URM of 12th Grade Students Persisting X Years in SC		
				1 Year		2 Years		3 Years or more					
				URM	Non-URM	URM	Non-URM	URM	Non-URM		1 Year	2 Years	3 Years or more
2019–2020	230	134	97	90	36	6	1	1	0	72%	71%	86%	100%
2020–2021	289	149	106	77	39	29	4	0	0	71%	66%	88%	NA
2021–2022	326	124	95	62	26	25	3	8	0	77%	70%	89%	100%
2022–2023	272	101	74	58	20	8	5	8	2	73%	74%	62%	80%
2023–2024	224	104	67	50	30	9	6	8	1	64%	63%	60%	89%
Total	1,341	612	493	337	151	77	19	25	3	72%	69%	80%	89%

> starts with invention and gets them believing in themselves and their own personal STEM abilities by doing invention. After they gather some confidence, we add measurement functionality and the scientific method to the invention process [to] move [students] towards doing an authentic research project…we move [students] from an invention mindset to authentic research. Basically, students have to learn to start thinking creatively and innovatively, and then we teach them the rest of the skills that are needed to do advanced research. It's a rather long road, but if you start with invention, it makes it really fun and achievable. [Email correspondence, SC CEO, November 11, 2024].

In her correspondence with researchers, the SC CEO extended this discussion to share her insights about the relationship between invention and research as defined locally in the SC context:

> Truthfully, this is where I really believe in the role of invention in scientific research. There's always an element of inventing and creativity and looking at a problem differently that is absolutely essential to scientific breakthroughs. When you start with invention, and then you wrap around ways to measure the effectiveness or measure the outcomes of the invention in a repeatable manner, and use protocols that have already been tested, an invention goes to a whole new level. Invention without measuring effectiveness is just an idea. Invention is where all science research starts. The invention education world could add another level of rigor and credibility by extending their curriculum to include measuring and validating using scientific methodology and engineering processes. [Email correspondence, SC CEO, November 11, 2024].

7 Findings and implications

7.1 Overtime development of a school and community-based ecosystem

The SC program has evolved over time to provide both direct and indirect support systems tailored to meet the specific needs of teacher-coaches and students, which has been essential for maintaining student engagement and persistence in STEM pathways. This evolution reflects the organization's responsiveness to identified needs, as evidenced by ethnographic interviews with the CEO. SC's provision of resources, such as research-specific professional development, analytical instrumentation, customized curricula, and a network of research teacher-coaches, directly supports educators, enabling them to confidently guide students in implementing a sound research methodology. Coordinated through SC, local partnerships with research laboratories, STEM disciplinary mentors and SMEs, and community leaders extend the classroom into the community to provide students with authentic research and problem-solving experiences. These partnerships serve as a bridge to professional STEM fields, allowing students to build confidence and self-efficacy in STEM, which are critical for persisting in these fields. This multifaceted support structure aligns with the Impact Genome Project's emphasis on moving students from *interest* to *proficiency* and, ultimately, *persistence* (Impact Genome Project, 2019).

It's important to recognize that bringing the school and community together to develop SC's local or regional use-inspired ecosystem is not a rigid structure that can be wholly taken up and imposed in another community. Rather, this dynamic model requires a commitment to building these local networks over several years, thereby meeting student and teacher needs in conducting authentic STEM research and invention. The principles of design demonstrate a contextually responsive model, underscoring the importance of flexible program designs that can adapt to changing educational landscapes and leverage local knowledge and resources where each community can take up SC's ecosystem as its own.

7.2 Six guiding principles

The SC program's effectiveness can be attributed to its adherence to six foundational design principles, each strategically implemented to support students' long-term commitment to STEM fields. Guided by a framework grounded in the Impact Genome Project's theory of change, SC's suite of program offerings collectively addresses the need to foster student *interest*, *proficiency*, and *persistence* (Impact Genome Project, 2019) in STEM and STEM-related careers. SC's end-to-end design attracts students to STEM and actively supports their growth and confidence as students develop interest, proficiency, and their ability to persist. Specifically, by allowing students to self-select research areas, SC fosters student ownership of their learning and the intrinsic motivation that helps students persist through inevitable failures when tackling real-world problems. Engaging with a diverse, locally anchored network of people who expose students to various disciplines and ways of thinking broadens students' understanding and appreciation of STEM fields and connects them with potential career pathways. The SC model goes beyond simply exposing students to STEM professionals and showing/telling students about STEM careers. STEM professionals engage with students around the students' research and, in doing so, send important messages or contextual signals to students about their belief in the students' abilities. These contextual factors, in turn, support students' self-efficacy and outcome expectations for themselves (Wang et al., 2023; Lent et al., 1994). Honoring teacher-coaches as professionals emphasizes SC's commitment to sustainable educational practices by ensuring educators feel valued and supported. This approach acknowledges teachers' pivotal role in student development, encouraging student persistence and a positive learning environment. A focus on building a community of belonging for students and teachers underlines the significance of developing a STEM cultural identity encouraged through innovation competitions and science fairs; students are more likely to pursue STEM if they feel confident that they can meaningfully contribute to the field. Finally, belonging extends beyond disciplinary interests to fostering group social interactions such as 'having a research team pancake breakfast' before school and forging an inclusive space where the whole student feels included and supported within the ecosystem.

7.3 Impact on student outcomes and URM student retention

A notable outcome of the SC program is the higher retention rate of underrepresented minority (URM) students compared to non-URM students, indicating the program's effectiveness in supporting historically marginalized groups. The evidence suggests that SC's support structures may mitigate URM students' unique challenges. Positive outcomes are consistent with SCCT, which holds that self-efficacy and positive outcome expectations of the students, fostered by the ecosystem actors in the SC model in Figure 1, are tied to students' career interests and choices (Wang and Duan, 2021). The program's various components work together to support STEM efficacy and belonging, which counteract URM barriers to entry and foster persistence in STEM. By offering an inclusive environment and pathways for continuous skill development, SC helps students from diverse backgrounds navigate and overcome these barriers. However, further research is needed to ascertain *why* URM students stay in the program at a higher rate than non-URM students. For example, as students matriculate through high school, they become more selective in how their time is spent. It could be that non-URM students have broader opportunities of which they take advantage.

7.4 Implications for use-inspired research and invention in K12 contexts

This study extends the term 'use-inspired' to authentic research and invention in secondary contexts where school and community-based STEM disciplinary and research resources are brought to bear, enabling students to create a technical solution to a local problem. This study also demonstrates that some teachers are interested in giving their secondary school students these opportunities and students who are willing to engage in use-inspired research and invention. Teachers and students could do this work through SC's collaborative infrastructure- a research and invention ecosystem model that brings structure to the processes and practices required to support the collaborative work of different actors. This SC model offers a blueprint, or telling case, of ways educational institutions and community organizations can work together to establish sustainable and mutually beneficial partnerships that enhance STEM education through use-inspired research and invention. SC's adaptive strategies for identifying and addressing resource gaps show a commitment to continuous improvement and responsiveness to participant feedback. This flexibility is a necessary part of the SC model, which has allowed SC to meet evolving educational needs. The SC approach and systems model could benefit other STEM programs aiming to increase retention and persistence in STEM pathways. However, if engaging students in use-inspired research is needed to address STEM workforce needs, and if providing opportunities for learning requires types of resources and support provided by SC, then policymakers must grapple with ways of creating fiscal incentives and mechanisms for funding the necessary infrastructure at scale.

8 Conclusion

This study provides a detailed (re)presentation of SC's research and invention ecosystem, the principles of design that guide it, and evidence for how it supports middle and high school students engaging in research and invention. SC's model for 6th–12th grades offers a framework based on a use-inspired ecosystem for supporting educators and students as a STEM pathway to degrees and careers. SC's success relies on educators' recognition of its value, much as this study was enabled by the SC CEO's collaboration with ethnographers. In both cases, the willingness to collaborate is essential for driving SC's mission forward. SC provides a valuable use-inspired model for bridging local schools and communities toward fostering long-term STEM interest and proficiency, preparing students to pursue STEM degrees and careers. Further insights into the value of the SC approach could be obtained in future studies by examining the lived experiences of students, especially URM students, in the program.

Data availability statement

The data analyzed in this study is subject to the following licenses/restrictions: Non-identifiable (coded) data from existing student profiles and questionnaires was approved as secondary data to be accessed and analyzed by researchers by Castle IRB for this study. Requests to access these datasets should be directed to jill@sciencecoach.org.

Ethics statement

The studies involving humans were approved by Castle Institutional Review Board. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. FB: Formal analysis, Writing – original draft, Writing – review & editing. SC: Methodology, Writing – original draft, Writing – review & editing. JO: Resources, Writing – review & editing, Data curation.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. The publication fee and IRB were funded by Science Coach. As Science Coach is a non-profit organization, all authors contributed to this effort pro bono. As the informant for this study, Science Coach CEO had the following involvement with the study: (1) providing access to Science Coach survey data and historical documentation; (2) consenting for and participating in study interviews in accordance with the approved IRB protocol; and (3) providing member checking (e.g., insider feedback) during the analytic process of data construction.

Acknowledgments

The authors are thankful for being brought together by the Lemelson Foundation who sponsor the annual InventEd Conference which initiated this collaborative effort between ethnographers (first and third authors) and the CEO (fourth author) of the program under study.

Conflict of interest

MK is employed and the sole proprietor of Kalainoff Consulting and Research, LLC.

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

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Agar, M. (2006). An ethnography by any other name. *Forum qual. Soz.forsch.* 7:4. doi: 10.17169/fqs-7.4.177

Bloome, D., Carter, S., Christian, B., Otto, S., and Shuart-Faris, N. (2010). Discourse analysis and the study of classroom language and literacy events: A microethnographic perspective. New York, NY: Routledge.

Bybee, R. W., and Landes, N. M. (1990). Science for life & living: an elementary school science program from biological sciences curriculum study. *Am. Biol. Teach.* 52, 92–98. doi: 10.2307/4449042

Couch, S. R., and Kalainoff, M. Z. (2024). Transforming a national invention education program through a strength-based approach. *TechTrends* 68, 589–609. doi: 10.1007/s11528-024-00953-2

Couch, S., Skukauskaitė, A., and Estabrooks, L. B. (2019). Invention education and the developing nature of high school student's construction of an "inventor identity". *Technol Innov* 20, 285–302. doi: 10.21300/20.3.2019.285

Ellen, R. F. (Ed.). (1984). Ethnographic research: A guide to general conduct. London: Academic Press.

Green, J. L., Baker, W. D., Chian, M. M., Vanderhoof, C., Hooper, L., Kelly, G. J., et al. (2020). Studying the over-time construction of knowledge in educational settings: a microethnographic discourse analysis approach. *Rev. Res. Educ.* 44, 161–194. doi: 10.3102/0091732X20903121

Green, J., Dixon, C., and Zaharlick, A. (2003). "Ethnography as a logic of inquiry" in Research in the teaching of the English language arts. eds. J. Flood, D. Lapp, J. Squire and J. Jensen (Mahwah, NJ: Lawrence Erlbaum), 201–224.

Heath, S. B., and Street, B. V. (2008). On ethnography: Approaches to language and literacy research. New York, NY: Teachers College Press.

Holmes, K., Mackenzie, E., Berger, N., and Walker, M. (2021). Linking K-12 STEM pedagogy to local contexts: a scoping review of benefits and limitations. *Front. Educ.* 6:693808. doi: 10.3389/feduc.2021.693808

Hughes, R. M., Nzekwe, B., and Molyneaux, K. J. (2013). The single sex debate for girls in science: a comparison between two informal science programs on middle school students' STEM identity formation. *Res. Sci. Educ.* 43, 1979–2007. doi: 10.1007/s11165-012-9345-7

Impact Genome Project. (2019) The STEM Genome: Identifying the core components of success along the pipeline. Version 1.0. Available online at: https://assets-global.website-files.com/638e7cfe9cc09c1cc7d446f6/63bda15b9143bce9eb50bbff_2019-STEM-Genome-Gene-Report.pdf [Accessed October 14, 2024].

Johnson, D. R. (2012). Campus racial climate perceptions and overall sense of belonging among racially diverse women in STEM majors. *J. Coll. Stud. Dev.* 53, 336–346. doi: 10.1353/csd.2012.0028

Kalainoff, M. Z., and Chian, M. M. (2023). "Unfolding principled actions for ethnographic archiving as an axis of development" in Interactional ethnography: Designing and conducting discourse-based ethnographic research. eds. A. Skukauskaitė and J. L. Green (New York, NY: Routledge), 187–212.

Kalainoff, M. Z., Couch, S. R., and Cima, M. (2022). Lemelson-MIT student prize retrospective. Available online at:https://lemelson.mit.edu/sites/default/files/2022-12/StudentPrizeWinners_Impacts.pdf. Accessed April 20, 2024.

Lent, R. W., Brown, S. D., and Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice and performance. *J. Vocat. Behav.* 45, 79–112.

Mohtar, L. E., Halim, L., Rahman, N. A., Maat, S. M., and Osman, K. (2019). A model of interest in STEM careers among secondary school students. *J. Balt. Sci. Educ.* 18, 404–416. doi: 10.33225/jbse/19.18.404

Patton, M. (2002). Qualitative research and evaluation methods. *3rd* Edn. Newbury Park, CA: Sage.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., and Moller, S. (2018). Race and gender differences in how sense of belonging influences decisions to major in STEM. *Int. J. STEM Educ.* 5:10. doi: 10.1186/s40594-018-0115-6

Science Coach (2024). Science Coach. Available online at: https://sciencecoach.org. (Accessed 15 July 2024).

Skukauskaitė, A. (2017). Systematic analysis of layered meanings inscribed in interview conversations: an interactional ethnographic perspective and its conceptual foundations. *Acta paedagog. Vilnensia* 39, 45–60. doi: 10.15388/ActPaed.2017.39.11466

Skukauskaitė, A., and Couch, S.R. (2024). "Supporting teachers to lead invention education with high school students" *Quality Education for All*, 1, 326–347. doi: 10.1108/QEA-08-2024-0070

Skukauskaitė, A., and Green, J. L. (Eds.) (2023). Interactional ethnography: Designing and conducting discourse-based ethnographic research. New York, NY: Taylor & Francis.

Stokes, D. E. (1997). Pasteur's quadrant: Basic science and technological innovation. Washington, DC: Brookings Institution Press.

National Science Foundation (2020). STEM Education for the future: A visioning report. A report by the STEM Education for the Future Subcommittee of the Advisory Committee of the Education & Human Resources Directorate of the National Science Foundation. Available at: https://nsf-gov-resources.nsf.gov/files/STEM-Education-2020-Visioning-Report.pdf?VersionId=tUx9eN9NEXtNHIghTfPOA7L81c28KMs7 (Accessed March 15, 2025).

Wang, N., and Duan, W. (2021). What factors affect high school students' scientific career expectations. *J. Educ. Sci. Hunan Univ.* 20, 39–48. doi: 10.19503/j.cnki.1671-6124.2021.04.006

Wang, N., Tan, A., Zhou, X., Liu, K., Zeng, F., and Xiang, J. (2023). Gender differences in high school students' interest in STEM careers: a multi-group comparison based on structural equation model. *Int. J. STEM Ed.* 10:59. doi: 10.1186/s40594-023-00443-6

Zhang, H., Couch, S., Estabrooks, L., Perry, A., and Kalainoff, M. (2023). Role models'influence on student interest in and awareness of career opportunities in life sciences. *Int. J. Sci. Educ., Part B* 13, 381–399. doi: 10.1080/21548455.2023.2180333