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**WORK AT THE BOUNDARY: A RESEARCH-PRACTICE PARTNERSHIP
TO INTEGRATE COMPUTER SCIENCE INTO MIDDLE SCHOOL
SCIENCE**

By

Amelia Rose Callahan

B.S. University of California, Santa Cruz, 2015

A THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Teaching
(in Physics and Mathematics)

The Graduate School

The University of Maine

August 2020

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An Abstract of the Thesis Presented
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The Maine Center for Research in STEM Education (RiSE Center) is currently developing a partnership between university education researchers, computer science faculty, and middle school science teachers throughout the state. The goal of this partnership is to develop a set of lessons that integrate computer science concepts and practices into existing science curricular materials. This STEM+C partnership brings together individuals who have a wide range of experience and comfort with computer science and teaching middle school. This study focuses on the partnership's early stages through its initial summer collaborations. We designed and administered interviews prior to the module design process to gather information about participants' initial impressions of collaboration, computer science, the overall project, and their role in the partnership. Using grounded theory techniques (Charmaz, 2006), we categorized these preliminary responses and used information about the respondents to predict where boundaries might arise during collaboration of the larger partnership.

Preliminary analysis of interview transcripts revealed differences in how individuals in the partnership spoke about aspects of the project including science teaching and computer

science. We examined these potential misalignments in communication among members of different subgroups in the partnership. Such misalignments constituted group boundaries (Akkerman and Bakker, 2011), where communication may be difficult or misconstrued by either party and where strategies may be needed to facilitate communication. Based on prior research, we predicted boundaries between university researchers and K-12 practitioners (Robinson and Darling-Hammond, 1994). In addition, we anticipated that participants who were computer science novices might have conflicting definitions of computer science, as suggested by Winitzky, Stoddart, and O'Keefe (1992) and Barr and Stephenson (2011). We anticipated that school district affiliates who served on planning committees for the project may act as boundary spanners who ease communication across the researcher-practitioner boundary, because they work more closely with university affiliates than the participants not involved in the planning process. Differences in interview responses, as well as changes in computer science definitions, revealed that a boundary may exist between participants who were involved in planning the collaboration, regardless of affiliation, and those who were not. The difference may be based on access to information about the project as a whole as well as details of the planning team's efforts to define computer science for themselves before bringing the concept to the summer collaboration process. These findings suggest the need for clear communication protocols throughout the formation process of any such partnership, as well as explicit role definition for those designated to communicate information across a boundary.

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CHAPTER 1

INTRODUCTION

In 2018, the Science, Technology, Engineering, and Mathematics (i.e., STEM) Council of the Maine State Legislature convened a computer science education task force with the mission of “develop[ing] an informed strategy to integrate computer science into the State’s proficiency-based high school diploma requirements, as well as expos[ing] all students to computer science as a basic skill and potential career path” (Maine STEM Council, 2018). According to the Task Force report, despite 71% of new STEM-related jobs being in computing, only 30% of the 203 Maine schools who responded to a Code.org survey offered any kind of computer science. To move Maine forward in computer science education, the task force set a goal of expanding computer science to all Maine schools by 2021. They also recommended the adoption of an existing set of K-12 computer science standards, such as those put forth by the Computer Science Teachers Association (CSTA, csteachers.org). The CSTA Standards (CSTA, 2017) set a learning progression for K-12 education surrounding computing systems, networks and the internet, data and analysis, algorithms and programming, and impacts of computing. These areas are not domain-specific, and can lend themselves to intersection with other content areas across all grade bands.

1.1 Integrating Computer Science into Science

As of 2019, the state of Maine aligns its science instruction with the Next Generation Science Standards (NGSS Lead States, 2013), which are based on *A Framework for K-12 Science Education* (National Research Council, 2012). The goal of the *Framework* is to give all students the opportunity and tools to appreciate the beauty of science, participate in public discourse around related topics, to consume science- and technology-related information with discernment, to continue to learn about science outside of school, and to pursue the careers of their choices, whether STEM-related or not (National Research

Council, 2012). The *Framework's* focus on creating opportunities for students to continually build and revise their own knowledge and to develop authentic science and engineering practices (National Research Council, 2012) firmly establishes it in situated learning theory and social constructivism (as the two theories are outlined in Driscoll, 2000a and 2000b). One important consideration in situated learning theory is that learners develop knowledge by doing what experts do (Driscoll, 2000a). Increasingly in science, experts engage in computational problem-solving (Barr and Stephenson, 2011). The focus of the NGSS on authentic science experiences opens the door for a host of connections with computer science and computational thinking; in fact, the NGSS explicitly include “Using mathematics and computational thinking” in their Science Practices, creating an opening for integration with computer science. Integrating computer science into science creates the opportunity to take advantage of already existing science materials, teacher strengths, and pedagogical content knowledge in order to bring computer science to students. In addition, science provides a doorway for computer science and computational thinking into K-12 instruction that might not have room for an entirely separate computer science course.

1.2 Focus on Middle School Science

Integrated instruction at the middle school level makes sense for a number of reasons. Previous research supports the cultivation of positive student experiences with STEM at the middle school level to increase the chances of success in future STEM careers (Tai, Liu, Maltese, and Fan, 2006). Furthermore, the structure of typical middle school science instruction allows more room for computer science integration than high school instruction, because high school teachers are often harder-pressed to meet external pacing guides than middle school teachers. According to the NGSS Science and Engineering Practices, students are expected to do the following in high school:

- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system.

- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations.
- Apply techniques of algebra and functions to represent and solve scientific and engineering problems.
- Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world.

(National Research Council, 2012)

Given these expectations, middle school is an ideal time to integrate computer science and support student success in high school and beyond. As outlined in the Task Force Report (2018), successful integration at any level requires trained, well-supported teachers of computer science who employ evidence-based tactics to help their students learn. To meet these needs at the middle school level, we formed a research-practice partnership.

1.3 Research-Practice Partnerships

Research-practice partnerships are an increasingly common form of collaboration among researchers and practitioners (in fields such as education, medicine, and psychology) who share a common goal (Coburn and Penuel, 2016). Research-practice partnerships are distinct from other forms of partnership because they are long term, involving more than a single meeting or short-term study; they focus on problems of practice that are meaningful to multiple stakeholders; they are committed to mutualism (benefits for *both* researchers and practitioners); they intentionally employ strategies to foster partnership; and they produce original analyses (Coburn and Penuel, 2016).

One of the most significant benefits of bringing practitioners into the research process is a reduction in the disparity between current research theory and current best practices in the field (Coburn and Stein, 2010; Roderick, Easton, and Sebring, 2009). This bridging of the research-practice gap can increase the likelihood that research findings will actually be

implemented into practice. Teachers and researchers who regularly interact are more likely to view each other as trusted sources of information; teachers are more likely to incorporate new techniques from someone that they trust. Additionally, collaborative research has been shown to benefit from the diversity of perspectives that interact when researchers and practitioners engage in research and problem-solving together (Bryk and Gomez, 2008).

1.3.1 The STEM+C Partnership

In response to the need for highly-trained educators to integrate computer science into science instruction (Maine STEM Council, 2018), the Maine Center for Research in STEM Education (RiSE Center) established a research-practice partnership comprised of forty-four individuals, including university science education and computer science faculty, staff, and graduate students, K-12 school administrators, and middle school science teachers. Over the course of two weeks of professional learning in the summer of 2019, this STEM+C partnership created one integrated module in each of the three areas of middle school science: earth science, life science, and physical science. The modules were modified from the Lawrence Hall of Science's SEPUP materials (Science Education for Public Understanding Program, sepuplhs.org) and incorporate concepts from the domains of computer science and computational thinking in an effort to increase student understanding of the science content while learning computer science.

Although research-practice partnerships like the RiSE Center's STEM+C collaboration are generally agreed to be beneficial, their presence is relatively new in the education research community. A review of the literature reveals gaps in our understanding of strategies employed by successful partnerships to navigate the difficulties of forming and establishing these collaborations, why such partnerships sometimes fail, and what other consequences might arise from partnership work beyond the desired change in outcomes (Coburn and Penuel, 2016). This thesis seeks to document and analyze the initial formation of the STEM+C partnership, from pre-collaboration interviews through the

completion of summer professional learning. We examine tensions and differences between different groups of participants based on responses to baseline interviews, exit slip surveys, and our own field notes from the summer collaboration.

1.3.2 Design-Based Implementation Research

B. Fishman, Penuel, Allen, Cheng, and Sabelli (2013) highlight a particular subset of research-practice partnerships called *design-based implementation research* (DBIR). DBIR has antecedents in evaluation research, community-based participation research, design-based research, implementation research, and social design experiments (B. Fishman et al., 2013). The goal of DBIR partnership work is to create innovations that can be adapted to a wide variety of classrooms and contexts, as well as durable partnerships that can withstand fluctuations in funding and personnel changes (B. Fishman et al., 2013). DBIR strives to develop capacity for knowledge related to both learning and implementation, and aims to develop sustainable change (B. Fishman et al., 2013). A key feature of DBIR is its commitment to change at multiple levels; it works to develop not only tools and practices for learners but also the necessary support needed for teachers and other leaders to implement these tools (B. Fishman et al., 2013).

The STEM+C partnership developed a set of integrated lessons to be implemented by the teachers in the partnership, but one of its long-term goals is to produce lessons that can easily be adapted by teachers across the state of Maine and beyond. Some of the project's secondary research questions investigate the necessary teacher supports for implementing computer science in middle school science and strategies for creating a lasting community of practice for these teachers. These concerns and emphasis on understanding both the design and implementation processes are also evident in the STEM+C project, which allows us to analyze this project using some of the tools that have been leveraged to examine DBIR partnership work in the past.

1.3.3 Work at the Boundary

In DBIR and similar partnerships, participants from distinct groups (in our case, university faculty, staff, and graduate students; and school district employees) work in close partnership with one another to attain a shared goal. Borrowing from anthropology, we can frame the partnership as work within a *trading zone*, a place to debate and exchange ideas, where participants engage in “place-making” or the building of collaborations, new organizations, or coalitions for action or reform (Penuel, Coburn, and Gallagher, 2013). Because a trading zone exists at the intersection of two distinct groups, it can be thought of as *boundary work* (Star and Griesemer, 1989).

The concept of boundary work comes from cultural historical activity theory (Engerström, 2015) and situated learning theory (Wenger, 1998). According to Akkerman and Bakker (2011), “a boundary can be seen as a sociocultural difference leading to discontinuity in action or interaction.” With this in mind, conflict resolution at boundaries between sociocultural groups becomes a matter of overcoming *discontinuities* due to differences, rather than overcoming differences themselves (Akkerman and Bakker, 2011). This model aligns with the RiSE Center’s partnership strategies: they do not attempt to turn teachers into perfect researchers or vice versa, but instead value the different and unique contributions that both groups bring to their joint work on a project. In partnership work, boundaries are evident in miscommunications between members because of their background in different groups; to take a dialogical perspective, meaning is made in the discussion that comes from conflict at the boundary (Bakhtin, 2010). I am choosing to focus primarily on the university-school district divide, but there can also be boundaries within those two larger groups. These boundaries can become evident through closer analysis of interview transcripts and exit slip responses.

1.3.3.1 Boundary Objects and Boundary Spanners

In talking about boundaries, it is common to talk about boundary crossings, boundary objects, and boundary spanners. Boundary crossings usually refer to an individual's transitions and interactions across different communities of practice (Suchman, 1994). Boundary objects, on the other hands, are artifacts that actually *do* the crossing by essentially serving as a bridge between two groups (Star and Griesemer, 1989). In the STEM+C partnership, the act of participating in what is ultimately an education research project could be considered an act of boundary crossing for the computer science faculty on the grant; they are working outside of their traditionally defined role as a computer scientist in order to be a part of this curriculum development and professional learning project. The CSTA standards for K-12 computer science could be considered a boundary object, in that they provide a set of computer science principles that are potentially accessible to all communities that are part of the partnership, and could serve as a basis for consensus language surrounding a working definition of computer science. Finally, boundary spanners are *people* who can move fluidly across the boundaries between groups (Penuel, B. J. Fishman, Cheng, and Sabelli, n.d.). Boundary spanners are sometimes also called “brokers” (Wenger, 1998) because they broker or promote interactions between other community members who may not move across the boundary quite so comfortably. If we consider the boundary between university researchers and middle school teachers, the teachers who are on the project's leadership team and the researchers with previous middle school teaching experience could be considered boundary spanners or brokers.

1.3.3.2 Transformation

Research-practice partnerships are engaged in learning at the boundary between researchers and practitioners. One mechanism for learning at boundaries between groups is *transformation*, which can lead to profound changes in the groups' practices. The first step in a transformation is consistently identified as confrontation with some lack or problem

within both communities' current practices (Akkerman and Bakker, 2011). Next is the recognition of a shared problem space where the work will be undertaken, which is followed by hybridization: the creation of something that shares characteristics of both communities of practice (Akkerman and Bakker, 2011). This hybrid object can be a boundary object, like new tools or signs or a model, or a completely new boundary practice that stands in between the partners practices (Akkerman and Bakker, 2011). Part of the STEM+C project's work is the development of a hybrid or shared language to develop the work that they are undertaking (Penuel, Coburn, et al., 2013), which can be investigated by comparing participants' initial definitions of computer science to their final definitions, after two weeks of collaboration. In the event of successful hybridization, we can expect to see individual definitions converge toward consensus after the group has finished creating their integrated modules. Other important aspects of successful transformation include crystallization, or cementing what has been learned, and continued joint work at the boundary—purposeful dialogue and collaboration between members at the boundary (Akkerman and Bakker, 2011).

Penuel, Coburn, et al. (2013) use analysis of the language in recorded interviews and conversations to identify boundaries in a developing partnership and highlight the development of a hybrid language that spans the boundary between university researchers and K-12 teachers. Participants' descriptions of their personal motivation, visions of success for various aspects of the project, and definitions of computer science in pre-module-design interviews all relate to the ways that they frame the project. Framing differences across groups can highlight boundaries (Penuel, Coburn, et al., 2013). Comparing participants' responses from before and after the module design period can give us insight into the formation of this partnership and the early collaboration process, as well as the changing views of the module designers. Thus, our work contributes to knowledge of the partnership *process* rather than final outcomes, and of the partnership's participants rather than the target audience of the shared work.

1.4 Anticipated Boundaries

The literature suggests we may anticipate two kinds of boundaries within the STEM+C partnership: an expert/novice divide, and a school/university divide. Differences in personal goals and visions for the project, as well as definitions of computer science—the concept at the core of the STEM+C work—could potentially lead to conflict as partnership members navigate their different understandings of their shared work.

1.4.1 School District vs. University Affiliates

Although research-practice partnerships are a relatively recent conceptualization, schools and universities have been partnering for years. Previous research into school-university partnerships has established a boundary between university faculty and school district personnel. This boundary can be attributed to a variety of reasons—differences in culture, differences in experience with K-12 learners, differences in institutional and personal priorities (Robinson and Darling-Hammond, 1994)—all of which can lead to communication difficulties. As a specific example, Robinson and Darling-Hammond (1994) suggest that school district personnel often adopt a more practical approach to problem-solving, while university affiliates have often been socialized to approach problems through a more theoretical lens. Additionally, different views on teaching and learning can lead to miscommunication across boundaries (Winitzky et al., 1992). These potential differences between university affiliates and school district affiliates have impacted the RiSE Center’s framing of the STEM+C partnership since its inception, and we expect to see evidence of this boundary in our data.

1.4.2 Computer Science Expert vs. Novice

Because computer science education is a relatively young field with limited avenues for official certification, many computer science teachers also teach other disciplines (Lalwani, Hamlen, Bievenue, Jackson, and Sridhar, 2018). As a result, the burden of bringing

computational thinking to the classroom is often laid on teachers with little or no experience in computing, which risks conflating computational thinking with computer science or mathematics (Sands, Yadav, and Good, 2013). Mathematics and science teachers often struggle to apply computational thinking in a way that makes sense with their content (Barr and Stephenson, 2011). When Sands et al. (2013) asked a group of elementary and secondary teachers to select terms related to computational thinking from a list, the majority of teachers included every listed option—from logical thinking and solving problems, to using computer applications and doing mathematics. Many mathematics and science teachers may even shy away from computational thinking topics that they associate too closely with computer science, such as conditional logic, recursion and iterative logic, and data structure efficiency (Weintrop et al., 2016). This lack of clarity could be one cause of the widespread opposition to greater implementation of computational thinking and computer science in schools (Grover and Pea, 2013). Within the STEM+C partnership, differing and potentially conflicting definitions of computer science among the participants could lead to differences in opinion about the best way to incorporate computer science into science. However, Lalwani et al. (2018) also found that targeted reflection and professional development around computer science was able to counteract common misconceptions. We might expect, then, a wide variety of initial definitions of computer science from the interview data; we would hope to find that two weeks of professional learning and collaboration might help bring the partnership members’ definitions closer to one another.

1.5 Research Questions

With these anticipated boundaries in mind, we used the following questions to ground our investigation into the formation of the STEM+C partnership:

1. Based on analysis of interviews of partnership members from before the module design process, what initial boundaries and tensions can we identify?

2. How do responses to the final exit surveys echo the initial boundaries identified from the interviews?

CHAPTER 2

METHODS

2.1 STEM+C Project Overview

The STEM+C partnership brings together more than 40 individuals, including university faculty, staff, and graduate students, and K-12 administrators, technology integrators, and middle school science teachers. Over the course of three years, the partnership will develop, implement, evaluate, and revise modules that integrate computer science concepts into middle school science instruction. The purpose of the larger study is to evaluate whether the incorporation of computer science will improve student learning of the science content. To investigate this, the project is using a two-cohort model (Fig. 2.1). During Year 1, Cohort 1 teachers met during the spring and summer to collaborate and develop the integrated modules. During Year 2, Cohort 1 taught the integrated modules in their classrooms, while Cohort 2 taught the original, non-integrated science materials as usual. Both cohorts met in the summer of 2020 to revise the integrated modules, and both cohorts will teach the resulting integrated materials during Year 3. The present analysis spans February 2019 through the end of July 2019, from the development of the protocol for the interviews administered prior to the module design process, through the completion of the interviews and the end of two weeks of collaboration and professional learning that culminated in the creation of the three integrated modules. This research was conducted in accordance with protocols approved by the University of Maine Institutional Review Board.

2.2 Predicting Boundaries from Interviews

Before the large partnership designed integrated modules over the summer, we interviewed participants to gather information from the very early collaboration process. Topics covered in the interviews included school technology resources and access to

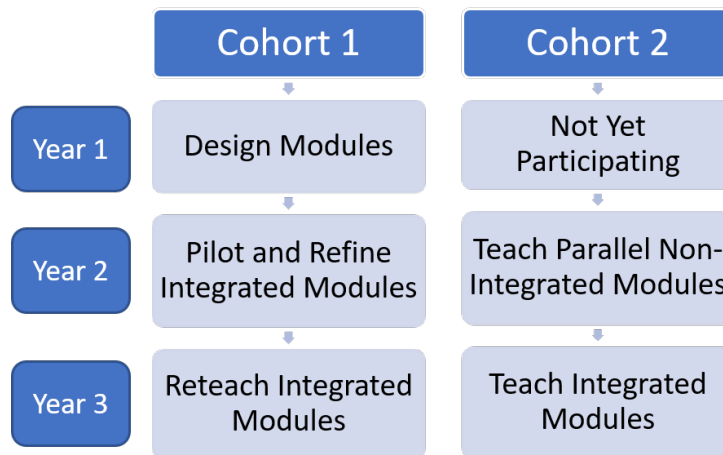


Figure 2.1. STEM+C Project Timeline. (Millay et al., 2019). Each teacher cohort participates in different ways during the project. This thesis focuses on the module design process during the summer of Year 1.

technological support, administrative support of teacher or faculty participation in the project, participants’ feelings about working in partnership, their background in science and computer science, etc. The protocols were designed to give project organizers a sense of participants’ background, impressions, and access to resources as they planned professional learning experiences. They were not designed specifically for this study. The complete interview protocols can be found in Appendices A and B.

From February 2019 through July 2019, we interviewed 44 participants (faculty, staff, graduate students, teachers, and administrators) in the STEM+C partnership. Interviews were conducted by the project’s Research and Evaluation Coordinator and the author (a graduate research assistant). Interviews followed a semi-structured format; all participants were asked the questions in the appropriate protocol, but there was room for both sides to elicit clarifications or make tangential comments. Interviews lasted from less than half an hour to over an hour, depending on the participant and interviewer. Because of the diverse composition of the partnership, some participants had worked with their interviewer before, while others met their interviewer for the first time at the beginning of the

interview. All participants were provided with an informed consent form and a partial interview protocol (without Item 2, a personal definition of computer science) in advance. Of the 44 participants interviewed, 26 participated in the module design process.

Audio from interviews that took place in-person was recorded on handheld digital audio recorders. Both audio and video from interviews that took place over Zoom were recorded via Zoom's built-in recording option. Interviews were primarily transcribed by several graduate research assistants (including the author) and the Research and Evaluation Coordinator, although several transcriptions were outsourced to paid transcription services to save time. In the interest of completing transcription quickly enough for the research team to incorporate the data into the professional learning planning process, transcribers were instructed to capture the words spoken in the interview but not necessarily extraverbal sounds such as "um," "uh", or laughter. Completed transcripts were uploaded into Dedoose, a qualitative data analysis platform (Dedoose version 8.3.17, www.dedoose.com).

Analysis of the interview transcripts from the 26 participants addressed Research Question 1, providing insight into initial boundaries and preliminary tensions between members of the partnership. We focused on the questions we thought would reveal differences in goals or desired outcomes for the project, because these differences could become relevant during collaboration. Participants who describe different visions of what the group is moving toward, or even use different language to describe similar outcomes, may not agree on the best path forward (Penuel, Coburn, et al., 2013). With this in mind, we analyzed transcripts of responses to the following interview questions:

1. What motivated you to participate in this project?
2. How would you define computer science?
3. In what ways do you integrate computer science into your science classroom?
4. How would define success for yourself [and your students] in this project?
5. [How would you define success for teachers and students?]
6. How would you define success for the project as a whole?

The bracketed text in Item 4 is from the interview protocol for school district affiliates. Item 5 was only asked of university affiliates. Item 3 supplements Item 2 by giving participants an opportunity to contextualize their definition from Item 2. From Section 1.4, we can anticipate a wide variety of answers to these two items depending on each participant's comfort level and previous experience with computer science. Items 4, 5, and 6 are places where we might see a school/university boundary, as participants from these two groups may have different priorities for themselves and the project overall.

We limited our analysis for each question to the participants' answers to the questions at hand. For example, even if a participant talked about why they joined the project in response to some other question during their interview, we analyzed only their response that directly followed a prompt from the interviewer to answer that question, before they moved on to the next question. We categorized responses utilizing grounded theory techniques (Charmaz, 2006). Generally, we used an approach similar to focused coding as described by Charmaz (2006), first summarizing each interviewee's responses to the questions of interest, then comparing categories of responses that emerged from those summaries to explore differences among the groups. We did not seek to determine why people responded in a certain way, or to make claims beyond this particular group of respondents. Final categories of responses can be found in Appendices C through H.

Once the interview data had been categorized, we compared response categories across groups. Our initial analysis examined differences across the university/school district divide, both because the language of the interview predisposed participants to think about that boundary and because the research supports the existence of communication difficulties across it (Robinson and Darling-Hammond, 1994). In addition, we considered responses from the boundary spanners: teachers who were involved in planning committees, and thus in more regular contact with the university affiliates than teachers who were not involved in the planning.

2.3 Identifying Boundaries in Final Exit Surveys

For the final exit slip of the summer professional learning, participants were given the option to attach their name or remain anonymous. (Only one participant who responded chose to remain anonymous.) We asked all participants how they would define computer science to their students at that time. As with the interview data, we employed modified grounded theory techniques to categorize these written responses. We compared these data and categories to the categories from the definitions of computer science given in the interviews. This allowed us to compare participants' initial definitions of computer science to their final definitions and look for evidence of development of a shared language to describe the core of the partnership. We also asked participants to use a 7-point Likert scale to retrospectively rate their initial level with computer science before the summer collaboration and to rate their current comfort level after the collaboration process. In addition, we asked participants to use a 4-point Likert scale to rate their satisfaction with the integrated module their group developed and, separately, with the project overall. We assigned these responses to the same groups as our interview analysis (university, school district affiliates on the planning committee, and school district affiliates not on the planning committee) for comparison.

Computer science is a key component of the STEM+C partnership and its mission, and a core part of describing the work participants are doing. Comparing participants' initial and final definitions of reported comfort with computer science provides insights into the impacts of the collaboration process on the collaborators, not just the students they are seeking to impact. Definitions of computer science may also impact participants' criteria for success. Participants' estimation of their own feelings about the success of the module design process as well as of the project as a whole are related to their personal motivations and definitions of success from the interviews. Differences in reported feelings of success and in computer science growth between professional groups may provide insight into whether the partnership is addressing the needs of all its communities.

CHAPTER 3

SPRING AND SUMMER CONTEXT

In an effort to contextualize any results and add to the body of literature providing a deeper look into what takes place during the early stages of a research-practice partnership, I am including a summary of the events of the collaboration and module design process during Year 1, from May to July 2019.

3.1 Group Composition

Cohort 1 gathered together with the partnership's university-affiliated members for the module design process over two weeks in the spring and summer of 2019. The summer's collaboration involved fifteen school district employees and eleven university employees from a variety of backgrounds. Because middle school science is typically divided into the domains of earth, life, and physical science, we divided the collaborators into three content-area groups.

The Earth Science group consisted of one graduate student, one Cohort 2 teacher who sat on the Leadership Committee, and four Cohort 1 teachers. The Life Science group was comprised of one science/education faculty member, one math/science faculty member, one technology integrator, and three Cohort 1 teachers (one of whom was a Co-PI on the project). The Physical Science group was made up of one science/education faculty member, one graduate student, one Cohort 2 teacher who sat on the Leadership and Professional Learning Committees, and four Cohort 1 teachers. Two computer science faculty members, the PI for the STEM+C grant, three staff members, and the school district administrator floated among groups as needed. Table 3.1 summarizes the summer participants by professional affiliation.

University Affiliates	School District Affiliates
3 science/education faculty	1 curriculum coordinator
2 computer science faculty	1 technology integrator
1 math/science faculty	13 middle school science teachers
3 staff members	
2 science education graduate students	

Table 3.1. List of the STEM+C summer participants by job title and professional affiliation.

3.2 Spring and Summer Collaboration Summary

Between the months of May and September, collaborators gathered for three Saturdays and seven weekdays to develop their materials. A review of the data shows the collaborators spent a total of just over sixty-six hours to develop their materials. We divided their time into the following categories:

- **targeted professional learning (PL):** used to denote direct instruction time, where someone was standing in front of the room directing learning about a particular tool or method
- **sandbox time:** used to denote minimally-structured time during which participants were free to explore a new technology or tool on their own or within a given set of constraints
- **lesson development:** including any time content area groups were given to focus specifically on the development of their own content materials
- **metacognition:** time spent reflecting upon the group's own learning, or how their students might approach the tasks
- **lesson modelling:** lessons were presented in full or in part with the intent of showing exactly how it might be implemented in a classroom
- **break time:** intentional break time, usually lunch or snack
- **project / future prep:** time spent brainstorming how to use future time or communicating project-level information
- **norming time:** time explicitly spent on group dynamics and maintenance

Please note that these categories do not include any team meetings for planning purposes or off-the-clock conversations between group members.

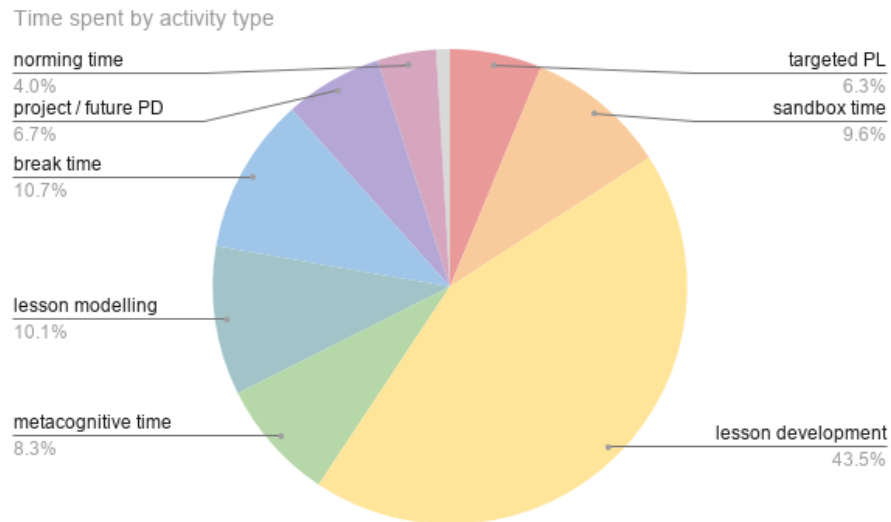


Figure 3.1. Proportion of time participants spent in different activities from May 2019 through July 2019.

In total, the group spent nearly 28 hours in lesson development, 7 hours engaging in metacognition, 6.5 hours modelling lessons or participating in modeled lessons, 6 hours in sandbox time, 4 hours planning for the future, 4 hours in targeted professional learning, and 3 hours working consciously on group dynamics.

3.2.1 Spring Meetings

The initial two meetings during the spring were intended to familiarize the partnership members with the goals of the project and each other. The first activity, called “The Beast”, focused on teambuilding and communication. Members were assigned to teams of four, and each teammate was assigned a role. Following the constraints of their roles, teams essentially replicated a given arrangement of office supplies through a complicated chain of communication because group members’ communication was constrained. After the activity, teammates introduced each other by highlighting something important the person they were introducing brought to their team.

After a short break, the group moved upstairs for a brief overview of the project, including research and teaching perspectives. One of the teachers on the leadership team started his introductory segment by asking participants to discuss with a neighbor how the Beast activity could be incorporated into their own classrooms. The partnership coordinator led a brief discussion to set norms for the group, after which a graduate student and a science education faculty member provided a brief overview of pre-module-design interview responses. A computer science faculty member led a lesson demonstration about predators and prey while the other participants acted as students, followed by some reflection for use in the classroom. Two computer science faculty members copresented a brief overview of computer science and how it is commonly seen in the professional world.

After lunch, participants divided into their content area groups and rotated through four 15-minute stations offering examples of computer science tools that have been used in science classrooms before (Arduino sensor kits, Scratch programming, Computer Science Unplugged resources, and ArcGIS for mapping). After stations, participants brainstormed initial goals, strategies, and indicators of success for the project, posted them on sticky notes on posters, and discussed trends. Content area groups were given about half an hour for brainstorming time—to give the professional learning team an idea of where initial interests were leaning—and after sharing, the last part of the first day was dedicated to a discussion about the experimental design of the STEM+C research project.

The group kicked off the second Spring meeting with a quick overview of the day's agenda and a revisit of the group norms from last time. The project coordinator and a graduate student led a discussion about the CSTA standards for K-12 computer science, the structure and format of the standards themselves, and what areas the group might have used in the first meeting. Next, the group revisited and started to condense the goals, strategies, and indicators of success from the first meeting, followed by input from project organizers about the language used in the grant proposal to define project goals and indicators of success. Following this discussion, participants broke into their content area

groups for approximately 30 minutes to review the original, unmodified curriculum materials and start to think about what units might lend themselves to computer science integration.

After a break, participants chose one of two hour-long “sandbox” or exploration sessions, one about QGIS and data mapping, and one more about Scratch. Once participants had tinkered with these tools, the whole group came back for a discussion of what materials or instructional support participants thought they might need during the summer collaboration. After lunch, the group split to another set of stations about sensors and Computer Science Unplugged. This was followed by a quick and inconclusive discussion of grain size for the project: whether the new modules replace a single lesson or integrate into an entire series of lessons might better be left to the discretion of the content area groups. Content area groups separated for about one hour of brainstorming, broken up by group shareouts halfway through. By the end of the brainstorming time, groups had outlined at least two rough ideas for directions that their modules could take. Finally, the large group revisited their initial list of summer needs, completed an exit slip, and was dismissed until July.

3.2.2 Summer Collaboration

3.2.2.1 Week 1

The first day of the seven-day summer collaboration period began with a review of group norms and overview of goals for the week. After an overview of the day’s agenda and a reminder to use the “parking lot” to store non-urgent questions for later consideration, the content area groups met briefly to revisit the tentative plans they had set during the previous meeting. The large group then received a brief introduction to block-based programming in Scratch before they spent an hour working on an “About Me” project. Each content area group was then given a predetermined task to explore how Scratch might be used with the content they had indicated in their tentative plans. After lunch,

the group engaged in a Computer Science Unplugged lesson, followed by an hour of sandbox time with Edison robots and another hour of time with the Concord Consortium's Common Online Data Analysis Platform (CODAP, codap.concord.org), a graphing application. Content area groups debriefed for approximately 30 minutes at the end of the day, after which each group shared with the large group.

The second day began, as usual, with a review of the group norms and the agenda for the day. Next, the group reflected on the computational thinking strategies and approaches they utilized in the previous day, as well as the teaching strategies they found to be effective or worth trying in their own classrooms. They then received one hour of direct instruction on Arduino boards, followed by a little over an hour of time to collaborate while attaching and programming a light sensor for the Arduino base. After lunch, members participated in a Computer Science Unplugged activity, discussed the project moving forward (goals, strategies for achieving goals, assessment criteria, etc.), and spent the remainder of the afternoon brainstorming in content area groups. At the end of the day, each content area group shared their progress with the large group.

Day three began with a review of group norms and setting of goals for the day. After a brief reflection on computational thinking strategies, the large group discussed potential lesson plan templates and essential elements to include therein. Day three was the first solid work day where participants devoted the majority of their time to lesson development. Content area groups broke for lunch, a Computer Science Unplugged activity, and a brief check-in regarding progress toward goals for the day, but otherwise worked straight through the afternoon on designing their integrated modules.

Day four was the final day before a week break. The day began with a reflection on computational thinking and an overview of the current draft of the lesson plan template, after which content area groups broke up to continue working on their integrated modules. The large group reconvened for lunch, a Computer Science Unplugged activity, and a discussion about assessment, then continued working in their content area groups on their

modules, this time with a focus on assessment. For some groups, this involved lining up progression charts similar to a workshop one participant had attended on Assessment for Learning, and for others this involved explicitly crafting assessment questions. At the end of the day, content groups gave updates on their progress and on what they needed to get done when the partnership came back together next.

3.2.2.2 Week 2

The first day back from a week-long break, day five, was mainly spent in content area groups, preparing materials to demonstrate portions of their modules for the large group the following day. Because a few members had not been available the first week, the day started with a quick round of introductions, an overview of the week to come, and a revisit of group norms and goals. Then the content area groups worked through the afternoon, breaking for lunch, and finished the day by updating the large group on their progress and completing exit slips.

During the penultimate day of the summer collaboration, content area groups led the other participants through portions of their integrated modules. Almost immediately, members split into content area groups for about one hour and 45 minutes of time to gather and prepare their resources. The Earth Science group presented first; they led the integrated lesson they had designed for an hour and fifteen minutes, followed by questions and comments for about ten minutes. After lunch, the Life Science group led a portion of their module for just over an hour of lesson time and received large-group feedback for about ten minutes. The Physical Science group rounded out the day with just over an hour of demonstration time and ten minutes of questions, after which the large group completed exit slips and went home to recharge before their final day of collaboration.

The final summer day was spent adjusting lesson plan formatting to match the common template and making sure materials were ready to pass to graduate students before the piloting process began in the fall. The day started with an agenda review, after which

participants spent time discussing the computational thinking strategies employed that week and how they might be best conveyed to students, as well as a discussion of the pedagogical content knowledge they felt was necessary to teach computer science and how the adult participants' knowledge might be assessed. Content area groups spent the next few hours finalizing their modules, with a break for lunch and a brief discussion of school year logistics: sending out a letter to parents, scheduling graduate student teaching partners to take classroom data in the fall and offer extra hands as the teachers pilot the new materials, etc. After time to finish up what content groups were working on, the group engaged in one final reflection and adjourned for the rest of the summer.

CHAPTER 4

RESULTS

4.1 Boundaries from Interviews Administered Before the Module Design Process

We analyzed transcripts of responses to the pre-module-design interviews to provide insight into the motivations and goals of participants, as well as their initial definitions of computer science. Participants' descriptions of their goals and motivations reflect how they frame their work, which can be used to identify boundaries (Penuel, Coburn, et al., 2013). We compared themes in the responses from university affiliates, school district affiliates who were not part of the project leadership, and school district affiliates who were part of the leadership team. Because of the time they spent working closely with university affiliates to plan the module design process and associated professional learning, this latter group was hypothesized to be boundary spanners. In order to preserve the anonymity of participants in a relatively small partnership, we focus our analysis on these three groups of participants rather than investigating responses at an individual level. These group affiliations are displayed in each of the figures in this section. Bar segments representing responses from university affiliates are blue, bar segments representing responses from school district affiliates who were not involved in the planning process are yellow, and bar segments representing school district affiliates who were involved in the planning process are red. It is important to note that because of our coding process, one person's response can fall in more than one category, although we did not count a response more than once if a participant repeated a theme within their response to the same question.

4.1.1 Motivation

When we asked participants ($n = 26$) what motivated them to participate in the project, the two most frequent responses were having been asked to participate and an interest in integration (Fig. 4.1). Participants in each group voiced interest in integration. Each of the four university affiliates who mentioned being recruited were asked by the project’s Principal Investigator (PI). Two of the three school district affiliates said they had been recruited by their colleague who was a co-PI on the grant, and the final school district-affiliated participant was recruited by their colleague who was not involved in the planning process.

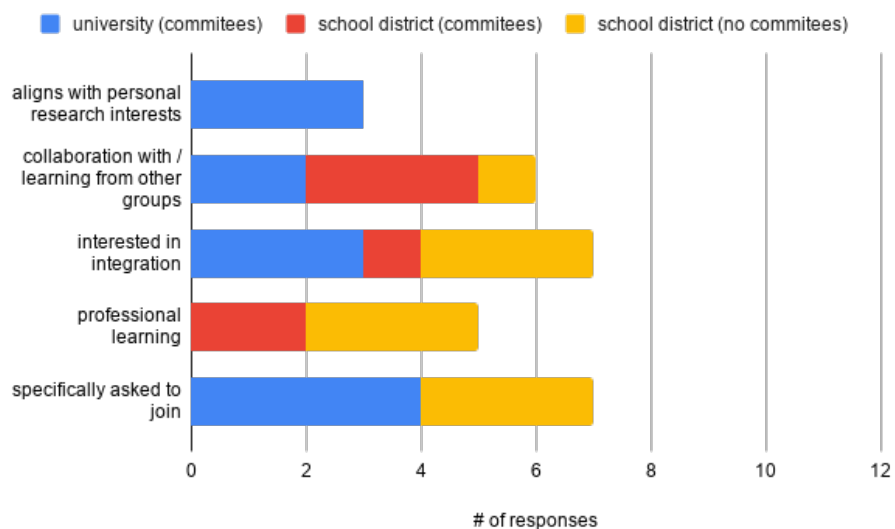


Figure 4.1. Frequency distribution of participants’ responses to the question “What motivated you to participate in this project?” Participants may have provided a response that falls into more than one category. A total of 26 participants responded. All university affiliates were part of planning committees (blue bar) while some school district participants were part of planning committees and others were not.

Overall, the responses indicated a willingness to learn, shaped by the culture of affiliation. University representatives, whether they had backgrounds in education research or computer science research, mentioned being motivated by personal research interests. Inservice school district employees mentioned looking forward to the professional learning, regardless of committee affiliation. The third most common response category, after

interest in integration and recruitment by someone else, was an interest in collaborating with and learning from other groups (science/education researchers learning from teachers, teachers learning from computer scientists, etc.) These responses indicate that project participants were motivated by a desire to learn.

4.1.2 Success for Self

When we asked participants to define success for themselves in this project, the most common theme was continued learning: again, participants from all groups prioritized their own growth in knowledge (Fig. 4.2).

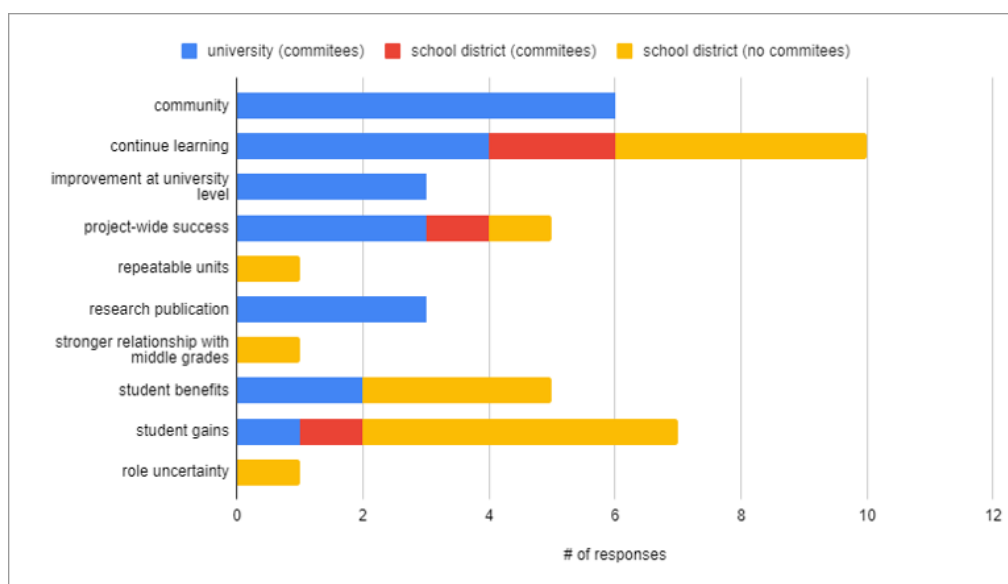


Figure 4.2. Frequency of responses to the question “How would you define success for yourself in this project?” Twelve university affiliates, ten school district affiliates, and four school district planning committee members were interviewed.

Beyond this, though, responses tended to align with participant affiliation.

Understandably, university affiliates were the only ones to cite research publications or improvement of university instruction as part of their personal measures of success. School district affiliates associated their own success with student success, such as engagement or increased content knowledge, or with increased opportunities for students, such as increased access to computer science or expansion of what students view as career possibilities. This

difference—more school district affiliates aligning their personal success with classroom outcomes while university affiliates describe other aspects of the larger project—suggests a difference in how school district affiliates and their university counterparts frame the project, which could indicate a boundary between the two professional groups.

4.1.3 Success for Students

The question about participants' definitions of success for students in this project was different than the other two questions, because it was not phrased in exactly the same way for all participants. University affiliates were asked “How would you define success for teachers and students in this project?”. We asked their school district counterparts, “How would you define success for yourself and your students in this project?”, language that may explain the strong ties evident between personal success and student success in Figure 4.2. Across all groups, participants most frequently equated student success with engagement and learning computer science (Fig. 4.3).

In these responses, school district affiliates reported similar answers, regardless of committee affiliations. As indicated by the asterisk (*), only one school district affiliate on the planning team gave a response that was categorized as something different than other school district affiliates' responses. In this case, the predicted boundary spanners gave responses most in line with their own professional community. School district affiliates also emphasized the important of students learning science content, which was interestingly not specified in most university affiliates' responses, even though the goal of the STEM+C partnership is to evaluate whether computer science helps students learn science. Participants from school districts also had a wider variety of themes in their visions of student success, including student persistence in problem solving and gaining knowledge that can be transferred and applied to other areas of their lives.

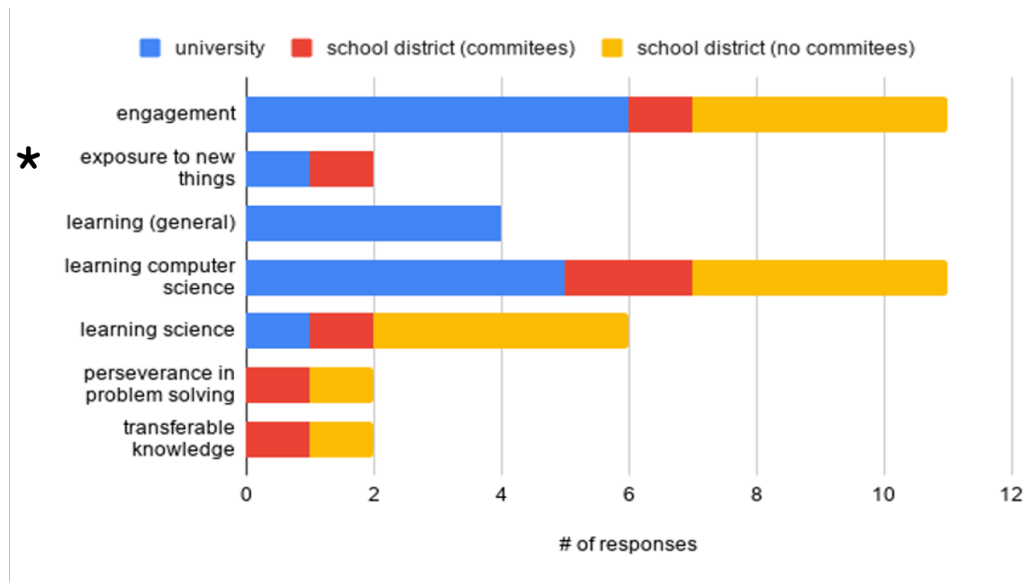


Figure 4.3. Frequency of responses to the question “How would you define success for students in this project?” 10 university affiliates, 11 school district affiliates, and 4 school district planning committee members responded in total. The asterisk indicates the only response category wherein a school district affiliate involved in the planning process did not give a response that was categorized similarly to their fellow school district affiliates. Participants may have reported more than one criterion for student success.

4.1.4 Success for Project

When we asked, “How would you define success for this project?”, participants overall reported similar criteria for project-level success as personal success. Consistent with the other visions of success, participants in all three groups mentioned the importance of improving student outcomes (i.e., engagement and content knowledge). Additionally, participants in all groups saw value in modules that could be reused or used by other teachers.

School district employees’ responses often focused on the classroom, while university-affiliated participants spoke of faculty engagement, informing policy, spurring subsequent research, and building a sustainable partnership with the project. As with the other questions about success, participants’ descriptions of project success aligned with professional affiliation. School district affiliates who were also a part of project leadership

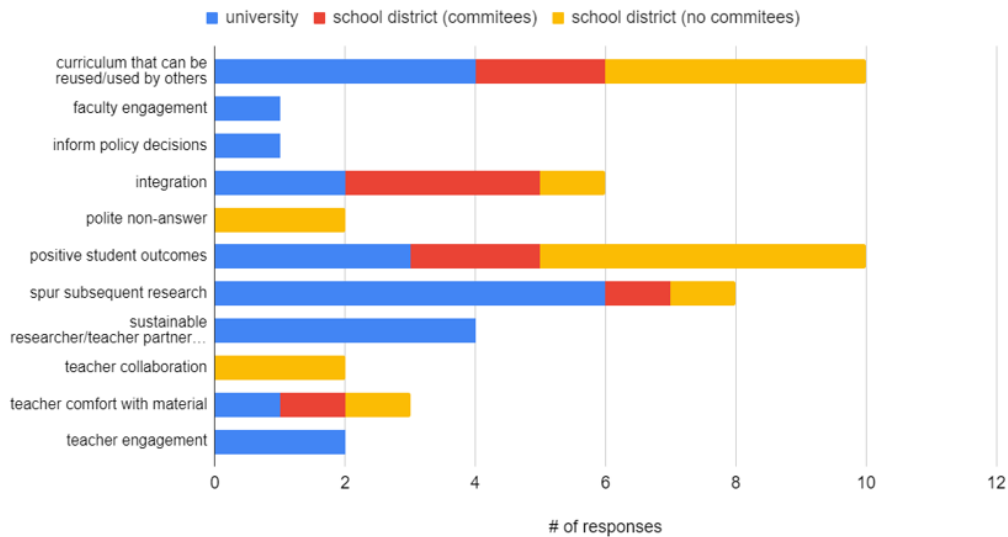


Figure 4.4. Frequency of responses to the question “How would you define success for this project?” 11 university affiliates, 11 school district affiliates, and 4 school district planning committee members responses in total. Participants may have reported more than one criterion for project success.

answered like their fellow school district affiliates, not their university-affiliated collaborators.

4.1.5 Initial Definition of Computer Science

Computer science is one of the central parts of the STEM+C partnership. We asked participants how they would define computer science before the beginning of the summer collaboration and the subsequent opportunity to further their own understanding (Fig. 4.5). To operationalize their definitions, we also asked participants how they were currently or had in the past integrated computer science into their science classrooms (Fig. 4.6). Based on the findings of Weintrop et al. (2016) and Sands et al. (2013), we might expect to find a range of potentially conflicting definitions.

Across all groups, participants posited that computer science was programming or creating applications (Fig. 4.5); 14 out of the 26 respondents reported initial definitions of computer science that included some reference to coding. Nearly that number expressed uncertainty, whether they said “I don’t know” or “I’m not sure” as part of a more detailed response or

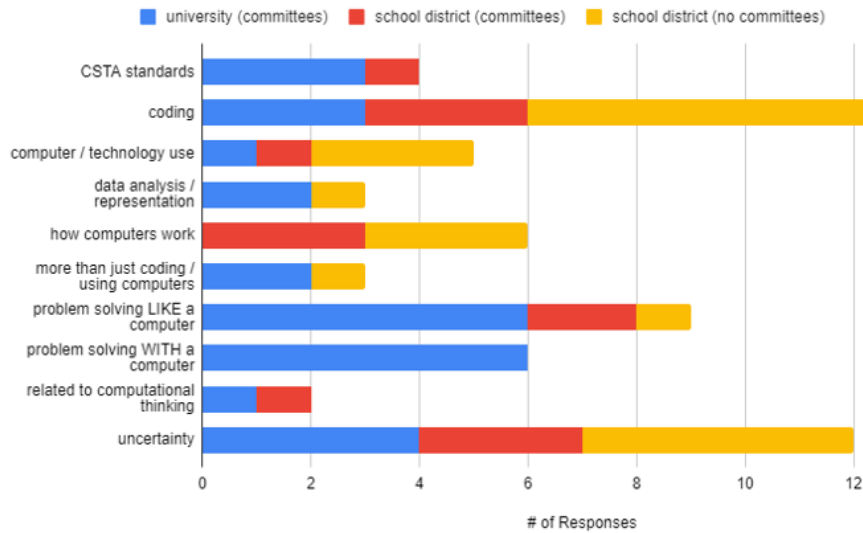


Figure 4.5. Frequency of responses to the interview question “How would you define computer science?” 10 university affiliates, 11 school district affiliates, and 4 school district planning committee members responded in total. Participants may have reported more than one aspect of their definition.

did not include an attempted definition. School district employees in particular thought of computer science as “how computers work.”

One difference arises from participants involved in planning committees: teachers who first joined the project in the summer would not have encountered the CSTA standards before the interviews, therefore only university affiliates and the school district members involved in planning the project referenced the CSTA standards in their initial definitions. Other responses from this group support the idea that members of the planning committees may have been in a different point of their conceptualization of computer science, because they started to articulate that computer science was related to problem-solving more broadly than just creating programs or using technology. Note the contrast between the definitions teachers provided (Fig. 4.5) and the explanations of how computer science is currently integrated into their classrooms, which typically focus on computer, application, or other technology use (see the categories marked with an asterisk (*) in Fig. 4.6). Aside

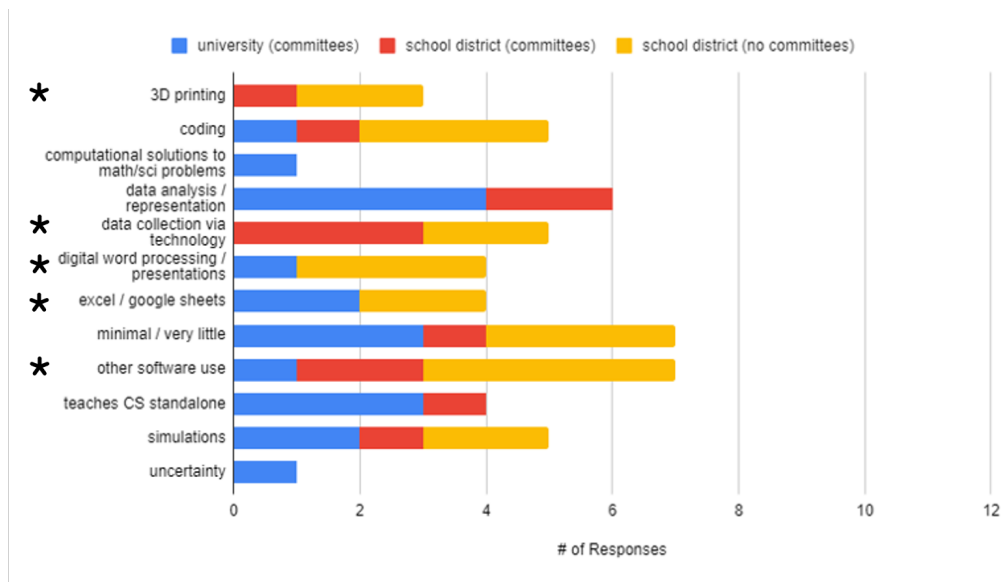


Figure 4.6. Frequency of responses to the interview question “How do you currently incorporate computer science into your science classroom?” Asterisks indicate common themes (see text for details). 11 university affiliates, 11 school district affiliates, and 4 school district planning committee members responded in total. Participants may have reported more than one aspect of integration.

from the mentions of the CSTA standards and computational thinking from planning committee members, responses from members of all three groups vary.

4.2 Boundaries in Final Exit Surveys

At the end of the summer professional learning and module design process, we asked participants to answer several questions that probed their feelings about the modules their group had designed, the STEM+C project as a whole, and their developing understanding of computer science. Comparing boundaries evident in these final responses gives us insight into how the group has evolved from the beginning to the end of the early collaboration period, which is under-studied in the literature (Coburn and Penuel, 2016). The evolution of personal definitions of computer science is related to a research goal of the larger STEM+C project, which in part aims to explore the supports necessary to create effective teachers of computer science as it is integrated into middle school science. In addition, changing knowledge of the *collaborators* rather than their students contributes to gaps in

the literature (Coburn and Penuel, 2016). Finally, as a core concept of the project, computer science is one possible area to investigate the development of a shared or hybrid language to describe the partnership’s shared work (Akkerman and Bakker, 2011).

Examining participants’ reported feelings of success and the boundaries indicated therein provides an overall impression of this phase of collaboration. Were the boundaries suggested by participants’ motivations and definitions of success before the module design process echoed in participants’ overall feelings of success afterward? This information could shed further light on the partnership formation process.

4.2.1 Definition and Comfort with Computer Science

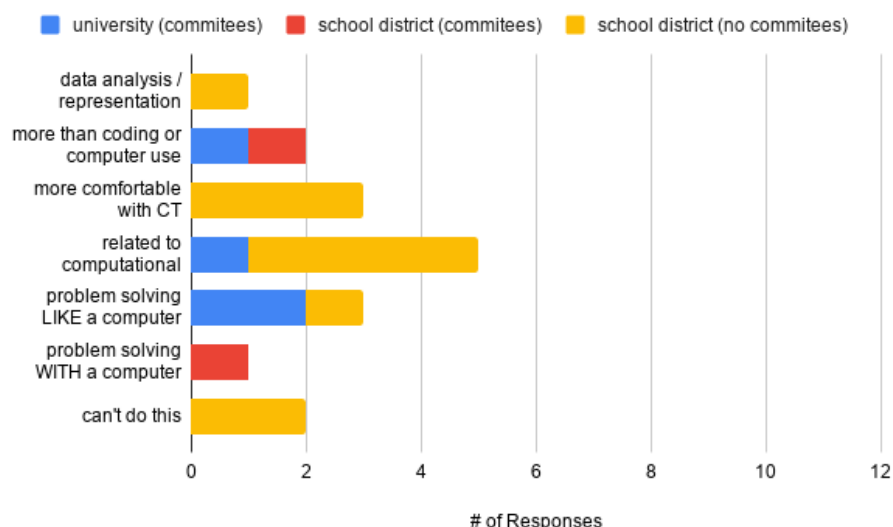


Figure 4.7. Responses to the final survey question “At this point, how would you define computer science to your students?” The responses represent three university affiliates (blue), two school district planning committee members (red), and eleven school district affiliates who were not involved in the planning process (yellow). Participants may have reported more than one aspect of their definitions.

As part of the end-of-summer exit survey, we asked participants to define computer science as they would define it for their students (Fig. 4.7). Unlike in the interview responses, none of the collaborators explicitly equated coding with computer science in their final definition (Fig. 4.7). The partnership’s shift to emphasizing computational

thinking over computer science, adopted early in the collaboration process, is reflected here in the uncertainty about computer science. The category “can’t do this” included responses of “I can’t do this,” when prompted to define computer science. Three responses explicitly stated that they were more comfortable with computational thinking than computer science, and three responses said that they were unable to create a solid definition for computer science—none of these six participants were involved in the collaboration planning process.

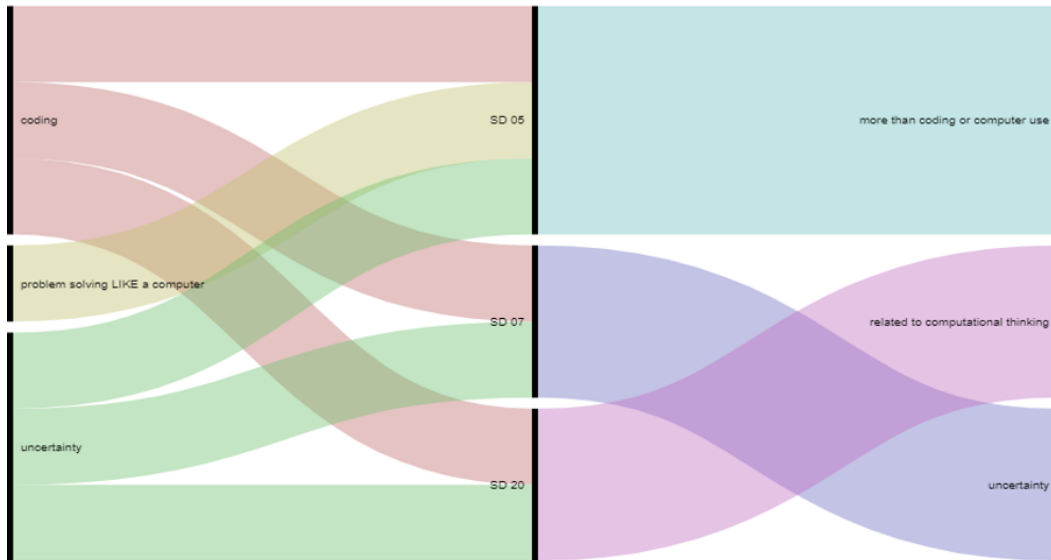


Figure 4.8. Example of the structure of a chart depicting the evolution of participants’ definitions of computer science. We lined up participants’ initial definitions of computer science from interviews with their definitions from final exit surveys. The bars in the center represent individuals; the bars on the left and right are categories of initial and final definitions, respectively. This graphic is intended to demonstrate how the larger graphic can be interpreted; see text for details.

We also created a diagram to depict the evolution of participants’ personal definitions of computer science. Figure 4.8 illustrates how to read the more complex figure that follows. Each solid black bar in the center represents one participant. The black bars to the left of the graph represent response categories from participants’ personal definitions of computer science as recorded in transcripts of pre-module-design interviews. The black bars to the right are response categories from participants’ written description of how they

would define computer science to their students from the final exit survey. Using this chart, then, we can trace individual definitions as well as patterns in responses. For instance, in the small graph we can see that SD20's initial definition of computer science included coding and some verbalized uncertainty, while they indicated in the final exit survey that computer science was related to computational thinking. Among the three participants shown in Figure 4.8, only one verbally indicated uncertainty in their final response, even though all of them did initially.

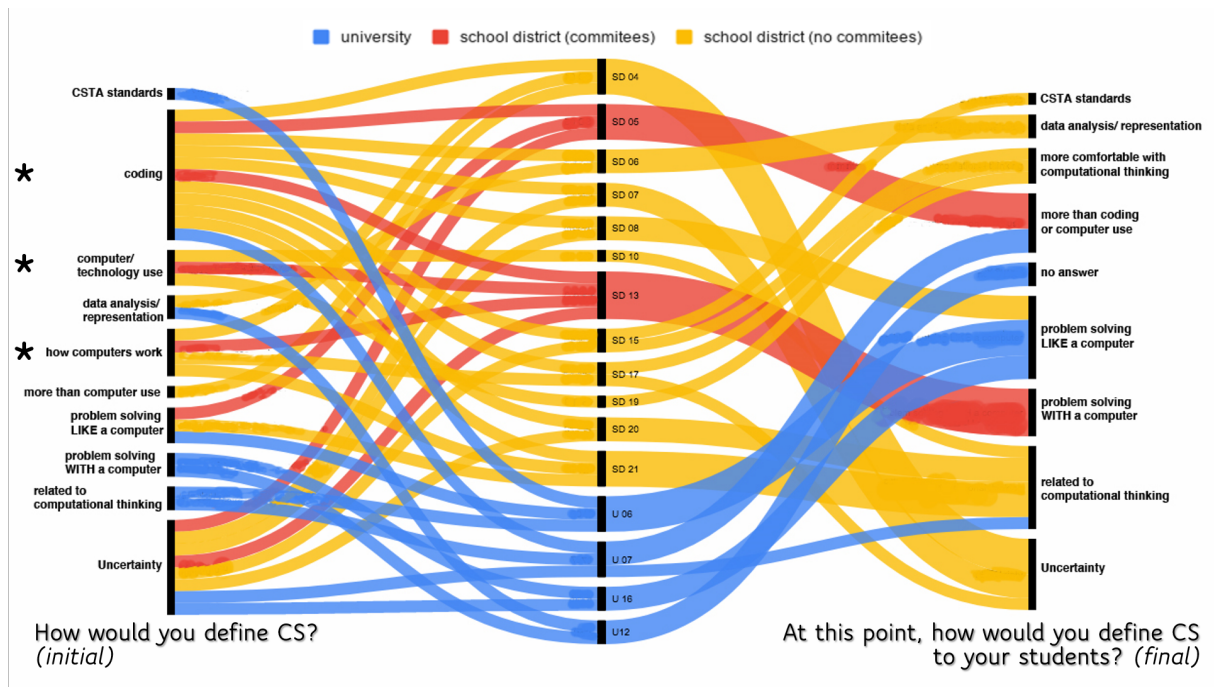


Figure 4.9. Evolution of participants' definitions of computer science. We lined up participants' initial definitions of computer science from interviews with their definitions from final exit surveys. Data from each participant who completed a final exit survey has been included here. Asterisks indicate categories that were evident in participants' initial definitions of computer science but not in their final definitions.

Not every participant who responded to the request for interviews completed a final exit survey. Of the 11 university affiliates, 4 school district affiliates involved in the planning process, and 11 other school district affiliates who completed pre-module-design interviews, only 4 university affiliates, 2 school district affiliates involved in the planning process, and 10 other school district affiliates submitted a final exit survey. Because of this,

it is difficult to make conclusions about all of the university affiliates or the school district affiliates involved in the planning process. However, we can examine trends in school district affiliate responses and large-group patterns.

I would like to highlight three trends in Figure 4.9. First, there are fewer categories evident in participants' responses to the item from the final exit survey. Admittedly, the change in format (written vs. oral) and question (a definition for students vs. a personal definition) may have impacted responses. However, it is particularly interesting to note that "coding," "computer/technology use," and "how computers work" were evident in pre-module-design interview responses but not in final exit survey responses. Similarly, fewer participants verbally indicated uncertainty (8 responses in the interviews vs. 3 in the exit surveys). Finally, the exit survey responses indicate a shift in school district affiliate definitions toward computational thinking and the CSTA standards, which were only mentioned by university affiliates in the interviews. This trend suggests that school district affiliates had begun to adopt the language introduced by the project leadership to describe computer science in the middle school science classroom.

In addition to giving a definition of computer science, participants used a 7-point Likert scale to rate their past and current comfort with computer science at the end of the two-week collaboration process (Fig. 4.10). Every participant reported either constant or increased comfort with computer science at the end of the summer. Participants involved in the planning process rated themselves as equally or more comfortable with computer science initially than other participants. Furthermore, participants not involved in the planning process tended to report larger gains (spanning more Likert levels), although without additional questioning it is difficult to compare the magnitude of change across multiple participants. In combination with data on the changing definitions of computer science, these data suggest that even before the integrated modules were implemented in the classroom, adult participants reported that they either maintained or increased their knowledge of and comfort with computer science during the module design process. We

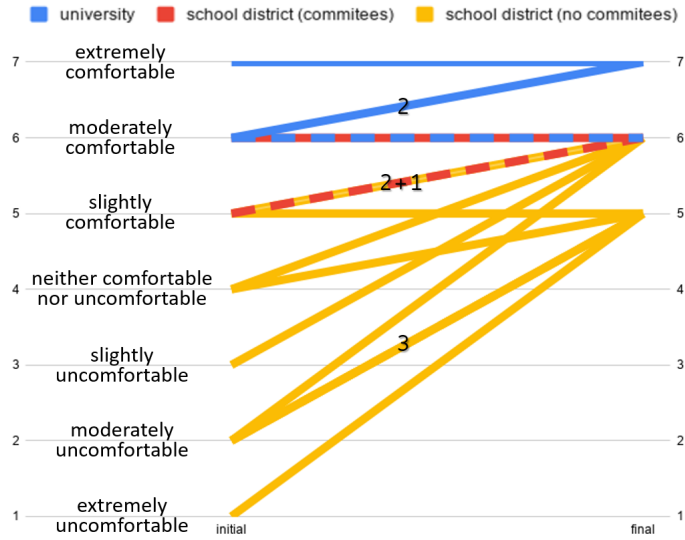


Figure 4.10. Reported change in comfort with computer science from the beginning of the collaboration to the end. The responses represent three university affiliates (blue), two school district planning committee members (red), and eleven school district affiliates who were not involved in the planning process (yellow).

can also start to see the development of a shared language to discuss computer science, although the confusion about computational thinking mentioned by Sands et al. (2013) is evident as well.

4.2.2 Satisfaction with Modules and Project as a Whole

We also asked participants to use a 4-point Likert scale to rate their satisfaction with the modules their group had designed (Fig. 4.11). Across the board, participants felt very positive about their work; everyone who completed a final exit survey reported feeling either *satisfied* or *very satisfied*. When we asked participants to rate their satisfaction with the project as a whole (Fig. 4.12), although more people reported feeling *very satisfied* with the overall project than with their group’s modules, fewer people reported feeling *satisfied*, and three participants reported feeling *a little satisfied*.

For each of these items, the total number of responses was smaller than the number of interview responses, so it is not as easy to see patterns in responses along committee membership lines. Only six people who were involved in the planning process completed an

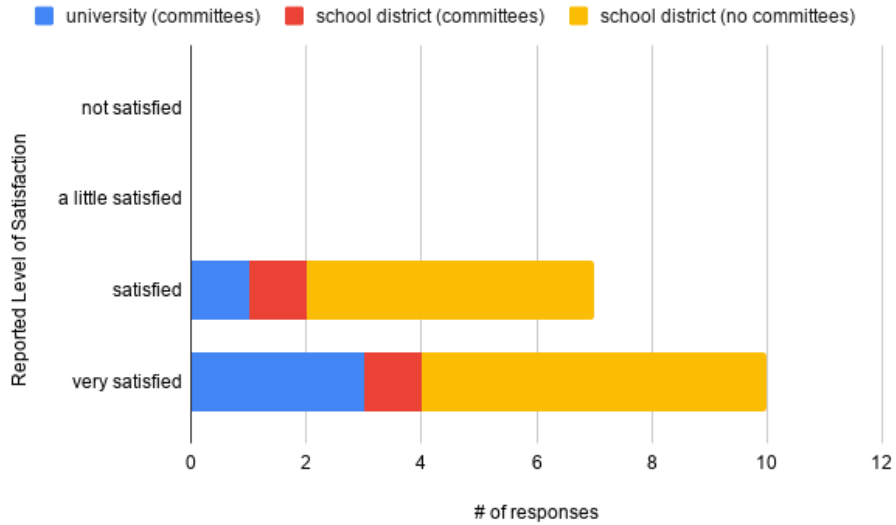


Figure 4.11. Frequency of responses to the final survey question “How satisfied are you with the module your group designed?” The responses represent four university affiliates (blue), two school district planning committee members (red), and eleven school district affiliates who were not involved in the planning process (yellow). One anonymous participant also indicated that they felt very satisfied with the module that their group had designed.

exit survey. However, it is interesting that there is more of a spread in reported satisfaction with the project overall than with the module design process. Responses indicate that everyone who submitted a final exit survey was at least satisfied by the module design outcome, and at least a little satisfied with the project as a whole, regardless of their initial definitions of success.

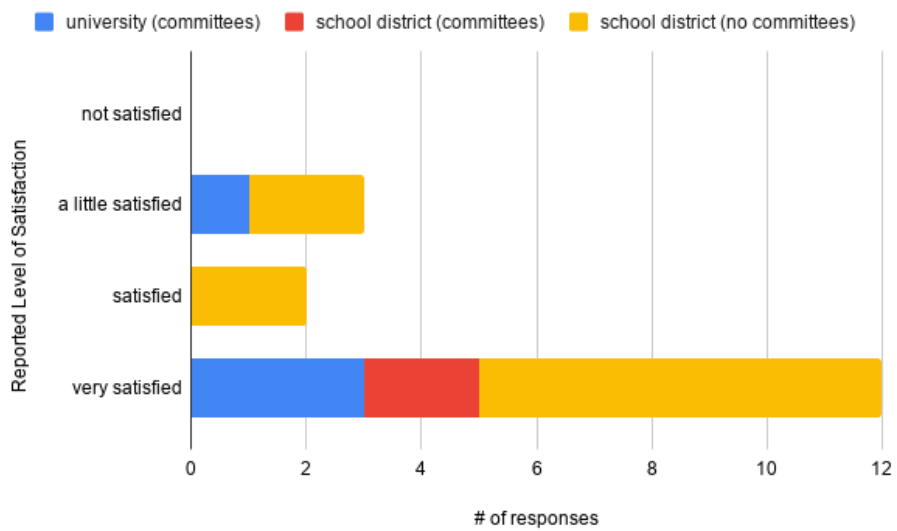


Figure 4.12. Responses to the final survey question “How satisfied are you with the STEM+C project overall?” The responses represent four university affiliates (blue), two school district planning committee members (red), and eleven school district affiliates who were not involved in the planning process (yellow). One anonymous participant reported feeling very satisfied.

CHAPTER 5

DISCUSSION

We set out to investigate boundaries and tensions during the formation of a research-practice partnership centered on the incorporation of computer science into existing middle school science materials. Our work was informed by existing literature surrounding research-practice partnerships, which often focuses on the outcomes and impacts thereof, rather than their formation and early stages (Coburn and Penuel, 2016). Previous research into school-university partnerships leads us to predict tension at the boundary between university and school district practices (Robinson and Darling-Hammond, 1994; Winitzky et al., 1992), which may be evident as differences in language used to describe the work of the partnership and participants' priorities and motivations (Penuel, Coburn, et al., 2013). Prior research about teachers' conceptions of computer science and computational thinking suggests that there may also be tension around the definition of computer science given that we brought together collaborators with a wide range of prior experience with computer science (Lalwani et al., 2018; Sands et al., 2013). Because in a research-practice partnership, the purpose of work at a boundary is not to diminish boundaries but to communicate more effectively across them, we might anticipate the development of shared language for collaborators to describe their common work (Akkerman and Bakker, 2011). We analyzed transcripts of participants' responses to pre-module-design interview questions about motivation and success as indications of boundaries present before the module design process. We also used exit survey responses to investigate post-collaboration boundaries and to capture the post-module-design impressions of the group as a whole.

5.1 Boundaries from Pre-Module-Design Interviews

We analyzed participant responses by employment affiliation because of the professional culture boundary suggested by Winitzky et al. (1992). The data shows some differences along these lines; each profession tended to define success for themselves according to personal professional priorities, for example (Fig. 4.2). When speaking of personal motivation and criteria for success, school district affiliates who worked closely with university affiliates during the planning process still voiced answers similar to their fellow school district affiliates. In general, university affiliates emphasized project-level goals (community, research papers, etc.) while school district affiliates—regardless of committee affiliation—emphasized impacts in the classroom. These differing priorities support the presence of the professional boundary supported by Robinson and Darling-Hammond (1994) and Winitzky et al. (1992).

5.2 Boundaries from Final Exit Survey Responses

All participants who responded to the final survey, regardless of professional or committee affiliation, reported either increased or maintained levels of comfort with computer science after the collaboration. In addition, all respondents reported feeling at least satisfied with the module design process, and at least a little satisfied with the STEM+C project overall. Because of the differences in response rates for final exit surveys as compared to the pre-module design interviews, it is difficult to make conclusions about shifting boundaries from these data. However, the school district affiliates who were part of the project leadership and did respond, reported a similar initial and final comfort with computer science as the university affiliates. This suggests that in terms of computer science, the predicted boundary spanners responded more like members of the “other” group. In combination with their profession-aligned descriptions of motivation and success in the pre-module-design interviews, this supports the idea that school district affiliates on

the project leadership committees are, in fact, serving as boundary spanners. Further inquiry is needed to confirm this suggestion, though.

5.3 Limitations

In the interest of time, we chose to focus on transcript analysis of participants' immediate responses to interview questions—or in the case of survey data, only the written responses to the question of interest. The interview data contain an additional wealth of information, both within the transcript as well as in the nonverbal data stored in the full recordings. There is information our analysis did not take into account, which could impact our results (Mishler, 1986). In addition, while comparing pre-module-design interview responses to final exit survey responses, patterns could be impacted by the medium (Mishler, 1986). For example, participants might be less likely to verbally indicate uncertainty in a written response when they are given ample time to compose their thoughts. Our analysis was focused on capturing participants' general sentiments, but was not exhaustive; we did not test for theoretical saturation or assess inter-rater-reliability as recommended in Charmaz (2006).

When focusing on the adult participants in this project, we work with a small sample size. In addition, not everyone involved in the planning or summer collaboration was equally involved. For example, within the planning teams, some teachers were unable to consistently make meeting times, and some computer science faculty members were only involved in the weeks immediately preceding the summer collaboration; not all voices were equally present throughout the planning process. Exit slip responses from during the collaboration process reflected the struggle to integrate people who had missed the formation during Week 1 into the finalization process during Week 2; a week's absence further complicated the already wide range of how informed project participants were about project-level goals.

In dividing the group based on affiliation and committee membership, I obscure some nuances. One participant, for example, is often referred to as a computer science faculty member, despite their official title as a professor of science and math. As both preservice teachers and fledgling education researchers, graduate students are apprentices in both spaces, while not always a full member of either group. Most of the school district employees are classroom teachers, but there was also a district administrator with some classroom experience and a technology integrator who was very new to the classroom. In addition, splitting along employment affiliation obscures the effects of computer science expertise, which is harder to codify based on the information we collected but could be considered to be a strong impact on participants' visions of success and therefore their overall sense of satisfaction from the collaboration.

5.4 Implications for Future Work

Future partnerships might take the professional boundary evident in our partnership into consideration as they design collaboration, and take intentional steps to foster communication across it. Future research could explore the boundaries evident in the STEM+C partnership as the second cohort of teachers joins the collaboration process. I would be interested to hear participants' impressions of their own and others' roles in the partnership, to probe whether the other collaborators see boundary spanners as bridging two groups. Alternately, further research might investigate more closely participants' developing understandings of computer science and how they relate to any common language used to describe the integration process to students, or investigate the use of boundary objects such as the concept of computational thinking during collaboration.

Based on language in interview responses describing motivation for participation and criteria for success, our data support the existence of the professional boundary suggested by Robinson and Darling-Hammond (1994) and Winitzky et al. (1992) at the beginning of the STEM+C partnership. Although we cannot conclusively speak to the behavior of

school district affiliates involved in the planning process as boundary spanners from this data below, in conjunction with field notes and impressions from the course of the summer workshop, I would suggest there is the beginning of evidence of their responding more like their university-affiliated counterparts on matters of computer science. If this evidence is substantiated by future work, then in this particular partnership, because school district affiliates involved in the planning process sometimes have attributes similar to their school district colleagues and other times use language more similar to university affiliates, these participants would be acting as boundary spanners.

Although we cannot make claims about the transformation of boundaries within this partnership from the beginning to end of the module design process, we did find that regardless of professional or committee affiliation, all participants who completed a final exit survey reported a steady or increased comfort with computer science at the end of the summer collaboration. In addition, all participants in this group reported feeling that the project overall was at least a little successful, and the module design process was at least successful. Coupled with the outline of the summer collaboration period, this information adds to the research on the process of forming a research-practice partnership and on the potential impacts of collaboration upon the collaborators.

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APPENDIX A

INTERVIEW PROTOCOL: SCHOOL DISTRICT AFFILIATES

Items of interest to this document are **bolded**.

1. What do you currently teach and how long have you been teaching?
2. What was your background prior to teaching?
3. What degrees, certificates, or endorsements do you have?
4. What previous experiences have you had with working in partnerships with University researchers? What benefits do you anticipate from working in partnership? What challenges do you foresee, or is there anything you are concerned about in terms of working in partnership with researchers?
5. **What motivated you to participate in this project?**
6. What is your current understanding of what this project is about?
7. **How would you define computer science?**
8. What professional learning experiences have you had with computer science?
9. **In what ways do you currently integrate computer science into your science classroom?**
10. How do you envision computer science being more productively integrated into science instruction in K-12 classrooms? What technology do you think is needed?
11. What technology or computer resources do you have access to, that can help integrate computer science into science instruction?
12. What computer science opportunities do students have access to through your school or community?
13. To what extent do you feel supported in participating in this project?
14. What factors do you see limiting our ability to integrate computer science into K-12 science instruction?

15. What knowledge, skills, experiences, and other strengths are you bringing to contribute to this project?
16. **How would you define success for yourself and your students in this project?**
17. **How would you define success for this project?**
18. Do you have any concerns or questions?
19. What are you excited about?

APPENDIX B

INTERVIEW PROTOCOL: UNIVERSITY AFFILIATES

Items of interest to this document are **bolded**.

1. What is your current professional position and how long have you been in this position?
2. What degrees, certificates, or endorsements do you have?
3. What preparation and prior research have you had in conducting education research?
4. What previous experiences have you had with working in partnerships with teachers? What benefits do you anticipate from working in partnership? What challenges do you foresee, or is there anything you are concerned about in terms of working in partnership with teachers?
5. **What motivated you to participate in this project?**
6. What is your current understanding of what this project is about?
7. **How would you define computer science?**
8. What professional learning experiences have you had with computer science?
9. **If applicable, in what ways do you currently or have you in the past integrated computer science into your science classroom?**
10. How do you envision computer science being productively integrated into science instruction in K-12 classrooms? What technology do you think is needed?
11. To what extent do you feel supported in participating in this project?
12. What factors do you see limiting our ability to integrate computer science into K-12 science instruction?
13. What knowledge, skills, experiences, and other strengths are you bringing to contribute to this project?
14. **How would you define success for yourself in this project?**
15. **How would you define success for teachers and students?**

16. **How would you define success for this project?**
17. Do you have any concerns or questions?
18. What are you excited about?

APPENDIX C

RESPONSE CATEGORIES: MOTIVATION

What motivated you to participate in this project?		
Code	Example	Notes
aligns with personal research interests	“I am really interested in interdisciplinary thinking and partnerships between formal classroom educators and other resources in the community.”	Researcher states that project aligns with their professional interests.
collaboration with / learning from other groups	“I enjoy working with the RiSE Center.”	Specifically cites collaboration with groups of which they are not a part.
interested in integration	“I think it’s a little bit more realistic in terms of science instruction, I mean I think that computer science is something that scientists use or are naturally using and implementing and are taking advantage of in a lot of different ways[...]So bringing in the computer science is a really great way to do that.”	States that they are interested in integrating computer science into science.
self professional development	“That sounds awesome, that sounds like a great way to both learn something new that’s useful and have some professional growth.”	Expresses that they’re interested in continuing their own learning.
specifically encouraged by someone to join	“[Project PI] asked me.”	Mentions that they were recruited by a specific individual affiliated with the project.
student benefits	“But I think overall any opportunity I can provide for my students to help them have a better future in the STEM fields, that may spark their interest in the STEM field, I really want to take advantage of.”	Focuses on passive opportunities afforded students, rather than things they achieve.

What motivated you to participate in this project?		
Code	Example	Notes
student gains	“I want kids to learn what I think is going to be some of the most important learning there is for this generation, which is coding.”	Student gains are things the students are involved in—learning, engagement, etc.—rather than the passive elements of student benefits.

APPENDIX D

RESPONSE CATEGORIES: DEFINITION OF COMPUTER SCIENCE

How would you define computer science?		
Code	Example	Notes
coding	“It was just all about coding. That’s all I had in my head, was coding.”	Mentions coding, programming, or creating programs.
computer / technology use	“Implementing software, like Excel or using specific tools like either microscopes or the 3D printer.”	References computer or technology use but does not specify a purpose.
CSTA standards	“For the purposes of this project I am currently defining computer science as those things spoken about in the CSTA standards.”	Names the CSTA standards specifically.
data analysis / representation	“Using programs to develop models, graphing, you know, that whole area of science.”	Mentions analyzing or visualizing data.
how computers work	“I think of someone who knows how [computers] actually function.”	Can mention software or hardware, but focuses on <i>how</i> it does what it does.
more than using computers or coding	“More than just using computers in the classroom.”	Says “more than” or “not just”; a direct statement of what computers science is not.
problem solving LIKE a computer	“It’s really about a way of thinking, a way or strategy to solve problems, coming up with critical thinking skills, or how are you going to solve this problem, breaking down problems to solve bigger problems.”	Emphasis is on the thinking process; does not necessarily require a computer.
problem solving WITH a computer	“Using computers in an analytical way that made everything more efficient.”	Emphasis is on using the computer to accomplish a task or solve a problem.
related to computational thinking	“There’s also other parts that go into it that don’t seem specific to computers, like computational thinking, it seems you can do that other places, too.”	Explicitly names the concept of computational thinking.

uncertainty	“I have no clue.”	Says “I don’t know” or “I’m not sure,” etc.
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APPENDIX E

RESPONSE CATEGORIES: CURRENT COMPUTER SCIENCE

APPLICATION

How do you or have you integrated computer science into your science classroom?		
Code	Example	Notes
3D printing	“It’s more explicitly like this is computer programming, this is 3D printing, it’s not like using those as stools to teach something else.”	
coding	“I do teach Scratch in Applied Science, and we do some Unplugged stuff now—writing a program with arrows on how to draw something from a graph.”	
computational solutions to math/science problems	“I gave problems early on with the option of people doing a computational solution.”	
data analysis / representation	“There’s obviously a lot of computing that goes into life science data.”	Specifically talks about analyzing or visualizing data using technology.
data collection via technology	“We do use sensors sometimes, like motion sensors and stuff like that.”	
digital word processing / presentations	“I graded assignments that they submitted as Google Docs, and then they had all of their feedback stored in the cloud.”	
excel / google sheets	“I got to teach them a little bit of relevant world skill, I guess coding in Excel is pretty useful.”	Usually mentions Excel or Google sheets but not very specific about what was done with them.
minimal / very little	“Well, in respect for how they work and how you program one, very little, because I don’t know anything about it. I use them all the time, but it’s kind of like I drive a car but I certainly wouldn’t be able to fix it.”	
other software use	“The Cahoots are something I’ve done, they’re a newer thing.”	Mentions use of another kind of software not covered in the other codes.

How do you or have you integrated computer science into your science classroom?		
Code	Example	Notes
teachers computer science as a standalone subject	“They are still often separate activities rather than integrated activities.”	This code also applies to university professors who teach computer science but not science.
using simulations	“Some years I’ve used OE-Cake, they try to relate the liquid and solid simulators to properties of matter and describe them.”	Mentions the use of a simulation but does not have to specify extent of use.
uncertainty	“I feel like probably yes I did, but I’m not really sure specifically where that would have come out.”	

APPENDIX F

RESPONSE CATEGORIES: SUCCESS FOR SELF

How would you define success for yourself in this project?		
Code	Example	Notes
community	“Is this building a community, is the community cohesive? Is it a community that’s working strongly together, those sorts of things, so the community quality.”	Can also talk about supporting teachers/faculty/other adult partnership members.
continue learning	“And for myself, too, that my understanding is broader and deeper.”	Related to “self professional development,” above.
improvement at university level	“To have a long-term increase in diversity and students from Maine schools coming into our computer science program.”	Emphasizes connection between middle school work and university improvement.
project-wide success	“Success would look like accomplishing the evaluation goals that we set and accomplishing the research goals that we set in terms of designing the instruments, gathering data, analyzing the data, being able to use that data to tell a story so that we really document what we’ve done in the project.”	Aligns with larger project goals.
repeatable addition to the curriculum	“The ability to learn something new that could be maintained in my curriculum.”	Something that can be used more than once.
research publication	“It would be pretty cool to get a Master’s thesis out of it.”	Mentions wanting a personal research publication.
role uncertainty	“I really don’t know, because I’m still not really completely sure what I’m going to actually be doing.”	Indicates that they are not sure of their role in the partnership.
stronger relationship with middle grades	“Success for me would be building a stronger relationship with the middle school grades, whichever grade it is.”	

student benefits	“But I think overall any opportunity I can provide for my students to help them have a better future in the STEM fields, that may spark their interest in the STEM field, I really want to take advantage of.”	Focuses on passive opportunities afforded students, rather than things they achieve.
student gains	“I want kids to learn what I think is going to be some of the most important learning there is for this generation, which is coding.”	Student gains are things the students are involved in—learning, engagement, etc.—rather than the passive elements of student benefits.

APPENDIX G

RESPONSE CATEGORIES: SUCCESS FOR STUDENTS

How would you define success for students in this project?		
Code	Example	Notes
engagement	“Maybe something that would engage my students more than we are currently engaging them.”	Mentions student engagement, excitement, or high interest.
exposure to new things	“But also working with something new and different it says hey, you can learn in a new and different way.”	Mentions students being exposed to computer science, coding, or robotics, but not necessarily learning it.
learning (general)	“Just if they can demonstrate that they’ve learned something from the process.”	Mentions student learning but, does not specify in what area.
learning computer science	“A long-term fluency in computer science that set them up to learn more skills later down the road.”	Specifies that students are learning computer science.
learning science	“Is it going to help them learning the material in a more in-depth or complex way? Because at the end of the day, that’s what we need to do, we need to cover the standards and make sure that they understand the concepts.”	Mentions student learning of science or (for teachers) meeting standards—the CSTA standards had not been introduced at that point.
perseverance in problem solving	“A lot of kids these days are more anxious, more quick to give up more quick to just kind of surrender and say I don’t know, it’s too hard, I can’t do this. So for me I measure success as if I can sort of temper that behavior with okay, this didn’t work out, I’m going to go try to converse with my other peers and maybe try another crack at it.”	Speaks of students continuing through struggles.

transferable knowledge	“It’s that transfer of knowledge and application of their learning, where... we see it frequently in learners of every age but I'm thinking of it in the K-12 schools, okay this kid can do this and this in a silo, but when we ask them to apply it, we just get that blank look.”	Emphasizes the importance of being able to apply any new knowledge to other contexts.
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APPENDIX H

RESPONSE CATEGORIES: SUCCESS FOR STUDENTS

How would you define success for the project as a whole?		
Code	Example	Notes
clear data	“I would hope that the data comes out and it’s clear. That’s what would be successful. Not that I want it to be right or wrong, just that there’s not a lot of noise.”	Does not mention specific results but does emphasize data, so is not a polite non-answer.
curriculum / resources that can be reused or used by others	“We come up with something useful, that either we use or we can share with other teachers.”	Mentions expanding beyond the original group, disseminating resources to other teachers, reusing them in their own classroom, etc.
faculty engagement	“Having it take off and having just so much excitement about it from the faculty participants and the teachers.”	Specifically mentions university faculty.
inform policy decisions	“And I guess in a perfect world, it would help inform some statewide policy around how computer science can fit into K-12 science education.”	Mentions potential impacts on education policy.
integration	“Designing the modules we said we would design, so doing the integration we said we would do.”	Mentions tying in with science, or integration, or lesson design, etc.
polite non-answer	“Just that it is able to accomplish its goals and I know there are different stages, that there would be enough information, that...whatever data it is that you are looking for, that you would have enough to look through, and make a determination.”	Basically says “that we do whatever the project needs to do to be successful” without indicating what that success looks like.
positive student outcomes	“Try to show that integrating computer science helps students learn science.”	Similar to student gains above; mentions student achievement, engagement, learning, etc.

spur subsequent research	“Enough to spur subsequent research, and that could be a boon to the field of education research.”	Mentions documentation or data with the emphasis on building a foundation for future work.
sustainable researcher/teacher partnership	“Building and maintaining that kind of working relationship with the teachers we are working with I think is important.”	Emphasizes the partnership, or continuing to work together, etc.
teacher collaboration	“Honestly I think as long as [collaborating together] goes well, it’s so easy for schools to accidentally silo themselves off from everybody else and not be doing the same things or talking about the same things or even teaching the same things.”	Emphasizes collaboration among teachers specifically, not the partnership overall.
teacher comfort with the material	“If we can look back and see that it made a positive impact on the teachers as far as maybe how they feel about integrating technology, whether they were uncomfortable going to comfortable.”	Mentions teachers feeling comfortable with material and teaching it.
teacher engagement	“Evidence that we’ve been able to engage more students and teachers by doing this sort of partnership and by pursuing the integration approach.”	Mentions teacher engagement and involvement.

BIOGRAPHY OF THE AUTHOR

Amelia (Mia) Callahan grew up in southern California and received their Bachelor's of Science in Physics (Astrophysics) from the University of California, Santa Cruz, in 2015. It was while teaching astronomy at a summer camp during college that they realized their favorite part of doing science was getting other people excited about it. With this in mind, they spent two years running the Environmental Education program at Deer Flat National Wildlife Refuge before deciding they wanted more formal training in teaching. After a year working with the California Science Center, Mia moved to Maine in the summer of 2018 to pursue their Master of Science in Teaching degree. They are an NSF Noyce Teaching Fellow and are thrilled to be teaching 7th and 8th grade math and science at Trenton Elementary School in the fall. Mia Callahan is a candidate for the Master of Science in Teaching degree from the University of Maine in August 2020.