




Assessing computational thinking in libraries

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ABSTRACT

Background and Context: Computational thinking (CT) is an essential skill for all youth to succeed in our technology and information-rich world. While CT has a growing presence within K-12 classrooms, libraries play an essential role in introducing these critical skills to all.

Objective: Assessing learning in libraries is difficult given their informal nature. This is especially true when trying to assess a new and ill-defined construct like CT. A first step towards better supporting informal educators is to identify the motivations for bringing CT into informal spaces and to understand the current state of assessing CT in public libraries.

Method: Thirty-seven interviews with library staff from across the United States were conducted and analyzed.

Findings: This work reveals the variety of motivations justifying the inclusion of CT programming for youth in libraries, the challenges associated with assessing CT in libraries, and identifies the assessments library staff would like to be able to conduct for their own CT-related programming.

Implications: This work advances our understanding of the current state of CT assessment in public libraries and lays the groundwork for future work seeking to meet the needs of those tasked with bringing CT to youth beyond the classroom.

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Introduction

As the presence and importance of technology expands, it is essential that all children growing up in an increasingly digital landscape have a foundational understanding of computing. This includes not just how to use computational devices, but an understanding of what computing can do and how to express ideas in computationally meaningful ways. Often captured under the term *Computational Thinking* (CT), these ideas include broadly useful concepts and practices from the field of computer science including problem decomposition, abstraction, algorithms, pattern recognition, and concepts related to computer programming (Curzon, 2019; Grover & Pea, 2013; Wing, 2006). While CT has a growing presence in K-12 classrooms, informal spaces such as public

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libraries, museums, and youth community centers also play important roles in providing opportunities for children to develop these essential 21st-century skills.

The role of informal spaces, like public libraries, in introducing youth to CT stems from the flexibility and openness afforded by such settings. Where schools and teachers are constrained by rigid schedules and externally defined learning outcomes, informal spaces such as public libraries have the freedom to provide more open-ended learning experiences and can incorporate more novel technologies and innovative pedagogical approaches (Subramaniam et al., 2018a). Public libraries are well-suited for CT learning activities that draw on novel technologies (e.g., robotics toolkits, emerging digital media) (Garmer, 2014) and play an essential role in providing physical access to such technologies (Davis et al., 2018) and offering intellectual support in the form of CT programming to underserved youth in their communities (Braun & Visser, 2017). Additionally, schools often limit potential CT learning experiences to a subset of students or are unable to provide such experiences at all (Wang et al., 2016) whereas libraries serve all in their communities¹.

While libraries share characteristics of other informal learning contexts like museums, after school clubs, and summer camps, libraries play a critical role in bringing CT to all learners given their ubiquity, accessibility, and the role they already play in supporting communities. In the United States, people visit public libraries more often than they go to the movies (1.35 billion visits vs. 1.25 billion admissions) (American Library Association, 2019), with most public libraries (76.52%) serving a population area of fewer than 25,000 people (IMLS, 2019). This situates libraries at the forefront of innovation and experimentation when it comes to creating effective and engaging ways to introduce youth to CT as in the United States, “the library is the only place that is truly accessible and inclusive for all” (American Library Association, 2019, p. 6).

At the same time, there are challenges that accompany bringing CT into informal contexts. Central among them is the question of assessment. While the goals and learning outcomes of instructional experiences in libraries are distinct from those of classrooms, it is important for librarians to understand if and how their CT programming is succeeding. The challenge of conducting assessments in public libraries is compounded by the variety of formats of CT learning experiences offered, the “drop-in” nature of these experiences, duration of these experiences, and the unavailability of appropriate tools to conduct such assessment. This paper seeks to explore the challenges of assessing CT in libraries. Given the importance of all youth developing foundational CT skills and the potential that public libraries play in introducing these ideas, it is essential that we understand how to take full advantage of libraries as part of the larger goal of bringing CT to all. To make progress on this goal, we pursued the following set of research questions:

Why do public library staff seek to bring computational thinking into their libraries? What are their goals for the computational thinking programs they offer?

What challenges do libraries face when assessing computational thinking?

How would public library staff like to assess computational thinking?

To answer these questions, we interviewed public library staff serving youth from across the United States, asking them about their goals and experiences in conducting CT programs in their libraries, the challenges they encounter when assessing CT, and any

aspirations they might have for CT assessment. These interviews included library staff from rural, suburban, and urban contexts.

This work advances our understanding of why libraries are seeking to incorporate CT in libraries and their potential for innovative and impactful CT programming. We gain insight into the challenges associated with assessing the CT experiences that currently happen in libraries. In addition to laying the groundwork for future work that support those bringing CT to youth in libraries, this work sheds light on the gaps that exist within the currently used CT assessment tools and allow us to explore other modes of assessments to help libraries reach their full potential as powerful venues for helping all youth have positive CT learning experiences.

This paper continues with a review of the literature this work builds upon. Next, the paper presents the method used for this study followed by the findings section, broken into three sections that align with the three driving research questions for this work. The paper concludes with a discussion of implications, limitations, and future work. Specifically, the discussion looks across the result sections identifying ways in which goals and assessments do and do not align, highlighting the need for future work on CT assessment instruments to best support library staff in fulfilling their critical role in bringing CT to a wide swath of the youth population. Collectively, the contribution of this work is an understanding of why libraries are seeking to incorporate CT into their youth programming, the challenges they face in doing so, and insight into how they hope to evaluate the CT programming they offer.

Literature review

In this section, we begin by explaining our focus on libraries as contexts where CT learning occurs and then review the two bodies of work that this work draws most directly from and that we seek to contribute to. First, we discuss prior research bringing CT into library contexts followed by a review of the state of CT assessments with an emphasis on efforts to design and conduct assessments of CT in informal settings.

Libraries as contexts for learning

Public libraries have evolved to meet the needs of their communities, including the K-12 populations. While customary services such as book checkouts and reader advisory, and legacy programs such as story times and book clubs continue, public libraries have evolved “to distinctive and purposeful programming, resources, and services, both inside the library and out . . .” (American Library Association, 2019, p. 19) serving diverse needs in their communities, including contribution to cultivating competencies and interest that are necessary for pursuing careers in computing (Subramaniam et al., 2018b). Importantly, nearly all public libraries offer access to computers and free wifi for all visitors (American Library Association, 2019).

Public libraries play a significant role in supporting communities. In the United States, 96% of the population lives within a public library legal service area (American Library Association, 2019), indicating that public libraries are institutions that can be physically accessible to a vast majority of communities. Globally, more there are more than 380,000 libraries with internet access than 430,000 public and

community libraries serve 132 countries around the world (IFLA Library Map of the World, 2020). These libraries serve 551.3 million users around the world with 4,376.9 million total visits (IFLA). Libraries are particularly important as resources for materials and technological resources in rural areas and also provide a significant amount of programming for youth (Davis et al., 2018; Phillips et al., 2019). In 2016, public libraries offered 503,334 programs for young adults (ages 12 to 18) and 2.85 million programs for children ages 11 and under (IMLS, 2019). Further, the more rural the library is, the more children and young adults' programs are offered (IMLS, 2019). With 113 million attendees to public library programs in 2016, (American Library Association, 2019) libraries are in a position to provide access and computer-based programming to youth who may not have access to the technology at home or in their school (Martin, 2017).

While public libraries have been offering technology-enabled programs for youth for more than a decade (Braun et al., 2014; Lee, 2019; Subramaniam et al., 2018a), libraries are increasingly offering programs tailored to the development of interest and competencies in STEM, with 76% of the state library agency chief officers stating they either are planning on implementing or have ongoing STEM programming efforts at their state (Rose, 2015).

Many of these programs that intend to develop competencies and interests in STEM leverage design principles of the connected learning framework (Hoffman et al., 2016; Subramaniam et al., 2018a) to design their programs to be authentic to youth, interest-driven, fun, and not be like "school". Increasingly, this programming includes concepts or practices associated with computational thinking (Subramaniam et al., 2019).

Computational thinking in libraries

Although there are many definitions of CT, in this paper, we define CT as a set of concepts and practices from the field of computer science that are useful when using computers and technology to solve problems. This includes problem decomposition, developing and using abstractions, debugging, defining algorithms, and concepts grounded in the practice of programming such as iteration, parallelization, and conditional logic (Curzon, 2019; Grover & Pea, 2013). Wing (2006) states that "computational thinking is a fundamental skill for everyone, not just the computer scientists" (p. 3) and argues that CT be taught along with other essential skills such as reading and writing.

As discussed above, public libraries have become a hub for informal CT learning in communities. As facilitators of lifelong and informal learning, libraries have become major players in promoting digital literacy for youth in their community (American Library Association, 2020; Taylor et al., 2018). As the need for CT education expands, libraries have found ways to include CT into their programming. For example, the American Library Association (ALA) partnered with Google for the Libraries Ready to Code (RtC) initiative and provided grants to 250 libraries to implement coding and CT programs (Braun & Visser, 2017). In addition to grant initiatives like RtC, CT is being included library training programs (Taylor et al., 2018) and continuing education efforts like the Train the Trainer program (Young Adult Library Services Association, 2018), and the Future Ready with the Libraries program (Young Adult Library Services Association, 2016) offered by the Young Adult Library Services Association (YALSA).

Wing (2006) argues that CT is for everyone and that it is not limited to computer science but has everyday applications. Many librarians build on this idea when it comes to planning, advertising, and facilitating their CT events. Much of the library staff that plans and facilitates CT programming are new to the concepts involved; therefore, when deciding how to facilitate these programs or start a code club, many library staff look to low cost and easy to use tools and activities that they can use in their library (Braun & Visser, 2017). Some library programs focus on teaching programming skills using block coding programs like Scratch (Braun & Visser, 2017). Others facilitate the learning of CT concepts using various tools (Guidara, 2018; Lee & Recker, 2018; Prato, 2017; Wing & Meyers, 2014). For example, robotics is a common way to facilitate CT education in libraries. Products like Dash Robots, Ozobots, and Lego Mindstorms are used in CT programs and provide an easy entry for library staff who have little to no experience in CT skills and education (Prato, 2017). Library staff also use tools like Raspberry Pi and paper circuits as an easy way to teach computational skills without requiring previous knowledge of CT, and in the context of paper circuits, a low-cost alternative to other tools (Lee & Recker, 2018; Wing & Meyers, 2014). Similarly, many libraries offer “unplugged” activities, using pen and paper as another low cost, low stakes alternative to these tools. (Guidara, 2018; Prato, 2017). Library staff also use ready-made curricula, such as Google’s CS First and Girls Who Code to facilitate their programs (Braun & Visser, 2017).

Despite the current efforts across the US to bring CT to libraries, we do not yet have a clear picture of all the different types of programming that is being held, nor do we fully understand their motivations and goals in hosting these programs. In addition, CT is still a relatively new term for the library profession, which affects the adoption of CT programming by library staff and their ability to facilitate CT learning.

Assessing computational thinking

In this section, we review the *what* and the *how* of assessing CT. In their review of existing CT assessments, Tang et al. (2020) found that “many studies chose to measure programming or computing concepts as representations of CT skills” (p. 18). Brennan and Resnick (2012) identify three areas of CT to assess: computational concepts (i.e. sequences, loops, conditionals), computational practices (i.e. testing and debugging, reusing and remixing), and computational perspectives (i.e. observing shifts in perspective). There are many different approaches and tools used to assess CT. Some examples include selected-response tests (e.g., Grover et al., 2015; Weintrop et al., 2014), portfolio assessment (e.g., Brennan & Resnick, 2012); questionnaires or surveys (Mouza et al., 2016), interviews (e.g., Berland & Lee, 2011), design scenarios (Brennan & Resnick, 2012), and pre- and post- tests (Arastoopour Irgens et al., 2020). CT has also been assessed through less tangible means, for example, Lee and Recker (2018) assess their paper circuits program by having participants share their projects with the group, or through informal competitions and exhibits.

Shifting out focus to informal spaces, like after school programs, workshops, and summer programs, the research shows a mix of formal and informal assessment tools. These informal CT programs often used formal assessments, like worksheets, to measure a participant’s knowledge and understanding of CT concepts. (e.g., Mouza et al., 2016; Pugnali et al., 2017; Wu, 2018). Pugnali et al. (2017) assessed CT skills based on the Positive

Technical Development Framework that is focused on six aspects of CT engagement: Communication, Collaboration, Community Building, Content Creation, Creativity, and Choices of Conduct. The use of formal assessments is often coupled with other forms of assessment like portfolios of participants' projects and observations (Mouza et al., 2016; Wu, 2018). Informal learning spaces also employ non-formal assessment tools to assess learning and the attitudes of youth who participate in their programs. For example, Denner et al. (2012) assessed the portfolios of video games created by their participants. Other work in informal learning spaces has assessed participants' knowledge and attitudes through participant reflections, including the work of Thomas et al. (2017) who reviewed their participant's daily reflective journal to gain more insight into the attitudes and thoughts of their participants.

Assessment in libraries can be a challenge as the library is an informal learning space that is not well suited for traditional modes of assessment, even less so than other informal spaces which may be more structured in format. However, this does not mean there are not efforts to assess library programs. One example of work seeking to assess library programs is the Public Library Association's (PLA) Project Outcomes. Project Outcomes is a toolkit designed to help libraries measure their impact in a community. The toolkit provides surveys, a survey management tool, and easy to use ways to measure and analyze outcomes. The toolkit focuses on seven different areas of library service including community engagement, digital learning, education/lifelong learning, early childhood literacy, and job skills (PLA). Traditionally, attendance is a primary means of assessing library programs (American Library Association, 2020; Cole et al., 2013; Garmer, 2014). However, within the library field, there is a big push to measure the success of a program beyond looking at the numbers. Cole et al. (2013) refer to this as outcomes-based assessment. In their example, Cole et al. (2013) establish outcomes for their summer reading program and then use surveys at the end of the program to evaluate how/if these outcomes were met.

Since libraries are informal learning spaces, assessments also tend to be informal; mainly with anecdotal evidence and verbal feedback. In their work on capturing connected learning in libraries, the Connected Learning Alliance uses talkback boards to capture learning in libraries. Talkback boards are poster-sized displays that provide a few statements (i.e. *"Today I discovered an interest or talent that I didn't know I had"*) that participants use a sticker to indicate the statement they most agree with (Penuel et al., 2019). These statements serve to capture the desired outcomes of the program (Penuel et al., 2019). Another way libraries assess their programs is by using verbal feedback and surveys, like in Wing and Meyers (2014) Raspberry Pi programs.

Many assessments for CT in K-12 involve types of formal assessments like testing and surveys that are not conducive for informal spaces like libraries. With the limitations of library environments, the challenge then becomes how do library staff know that their participants are learning and that they are meeting their goals for CT programming. While there is research on how to get CT programming into libraries, CT assessment in libraries is either one small part of a bigger study, or not discussed. By focusing on CT assessment in public libraries, this paper seeks to understand the current CT assessment practices in libraries, the challenges that come with assessing CT in libraries, and what library staff would like to assess in their CT programs.

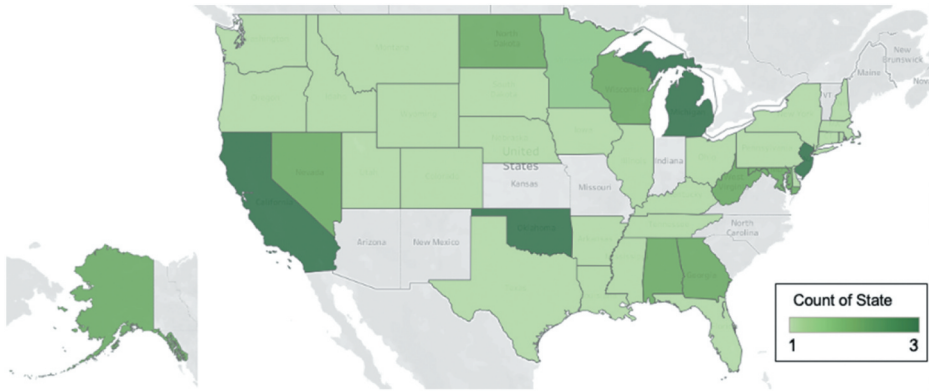


Figure 1. Distribution of participants by state.

Methods

To better understand the current landscape of CT activities in libraries, we interviewed 37 youth-serving library staff from across the United States (US) (Figure 1). Participants were recruited mainly through the mailing lists of ALA and YALSA, from the professional networks of the research team, and project partners. We collected information about the participants, such as their position, their location, population served (self-identified as rural, suburban, urban), and how many years they have been in their position as part of the sign up process. A summary of participant characteristics can be found in Table 1.

We conducted semi-structured interviews via phone or video conferencing software. These virtual interviews were recorded and lasted between 30–60 minutes. Interviews served as the primary methodology given the intent to obtain a national view of CT in libraries. Semi-structured interviews are well suited to capture the voices of library staff and their experiences and challenges in offering CT programs in libraries which are the focus of this research. The interview protocol covered topics such as the interviewee's experience with CT and computer science, the programs they ran at their library that included CT, the populations they worked with, the challenges they faced, and how they currently measured the success of their programs. Interviews were then de-identified and

Table 1. Demographic information for the 37 study participants.

| Population Density | # of Participants | Average # of Years Experience | Job Title |
|--------------------|-------------------|-------------------------------|---|
| Urban | 8 | 13 years | Youth/Teen Librarian (4) IT/Technology Librarian (3) Branch Manager (1) |
| Suburban | 14 | 7.8 years | General Librarian (5) Youth/Teen Librarian (5) IT/Technology Librarian (3) Branch Manager (1) |
| Rural | 15 | 6.6 years | Youth/Teen Librarian (9) Branch Manager/Director (3) General Librarian (2) IT/Technology Librarian (1) |

transcribed. The full protocol is available as an online supplement. Participants signed consent forms before their interview date and were offered a 25 USD Amazon gift card in return for their participation. We obtained institutional approval for human subject research prior to the start of data collection.

We employed thematic analysis (Boyatzis, 1998) to create a coding scheme aligned with our research questions. This methodological approach was used as we wanted to better understand the state of CT and how it is being assessed as experienced by those who are actually designing and running CT programming within libraries, rather than bringing a particular framework from the academic literature to shape and organize responses. To create a codebook, the research team individually coded a transcript and worked together to create an initial codebook. We then used this codebook to code an additional two transcripts individually, then met to discuss the results of our coding, making adjustments and clarifying code definitions as needed. The final codebook contained 16 codes that captured topics such as library demographics, resources used in CT activities in the library, the goals of CT activities, the challenges the library staff faced running these activities, and the assessment tools used for these activities. The codebook was then applied to all 37 interviews by one member of the team with an additional team member reviewing and modifying the coded transcripts as needed. Disagreements in coding were noted in memos in the analysis software and were later discussed and resolved between researchers (Smagorinsky, 2008).

To address the research questions in this paper, we specifically focus on four codes that emerged in our analysis: CT Assessment, Aspirational CT Assessment, Challenges, and CT Motivations/Goals/Outcomes. CT Assessment and Aspirational CT Assessment were used to capture participant's current efforts in assessment, their thoughts on assessing their programs, and the ways they wish they were able to assess their programs. The Challenges code captures a variety of challenges librarians identified when it came to running CT programming including staffing problems, staff knowledge, funding, infrastructure, and challenges with assessment. Finally, CT Motivations/Goals/Outcomes captures the various motivations librarians have for their CT programs, the goals they hope to accomplish, and the outcomes they would like to see in the youth participants.

Findings

The findings section is broken down into three sections, each of which answers one of our driving research questions. First, we present motivations for libraries to incorporate CT into the programs that they offer. Next, we present the challenges library staff encounter in trying to assess the CT programming at their libraries and then we conclude by presenting how library staff aspire to assess CT.

Motivation for bringing computational thinking into libraries

Why do library staff seek to bring CT into their libraries? What do they hope to accomplish in doing so?

As part of the interview protocol, we asked participants why they thought learning CT was important for youth, the goals they had for their programs, and the skills and attitudes they hoped to develop as a result of their programs. We asked these questions

Table 2. Themes from library staff responses asking about motivations for bringing CT into their libraries.

| Code | Sample Quote |
|------------------------------------|--|
| Positive CT Experiences | <i>"I want them to walk away like knowing that they can do this. It's not just for like certain people, it's not just for people who are like really into science or really into engineering, like anyone can do it."</i> (Andrea ² – rural, Midwest) |
| Conceptual Learning | <i>"I'm wanting them to develop basic coding skills."</i> (Brittany – rural Southwest) |
| Career Preparation | <i>"The goal really for me for our program is for youth in [our community] to have a good future"</i> (Cait – urban, West coast) |
| Relating CT Programming to Schools | <i>"We felt we'd be able to offer the kid's something that they are not getting at school, and the parents were really interested in it"</i> (Brad – suburban, Northeast) |
| Access to Technology | <i>"My first goal is just to make something available to kids who maybe would not normally have access to it"</i> (Sandra – rural, Midwest) |
| Foster Collaboration | <i>"I will only get six [robots] out for a group of 12 [kids] because they have to share because that's part of working as a team and that is something that's a life skill."</i> (Molly – suburban, Southeast) |

to better understand the motivations behind bringing CT into libraries. In reviewing the responses to these questions, we found justifications that aligned with the larger literature around CT as well as some library-specific goals for their CT programming. [Table 2](#) provides a sample quote for each theme identified.

Looking across the responses, some motivations cited are not unique to CT, but common to many types of library programming, such as the desire for positive experiences with the content of the programming or to prepare youth for their futures. In other places, the motivations have particular characteristics that uniquely intersect with CT, such as future career preparation and access to technology that is essential for CT learning experiences. We present motivations that are common across library programming as well as those unique to CT to present the fullest picture of why library staff are working to bring CT into their buildings.

The most common reason our interviewees cited for introducing CT into the programming offered at their libraries was to allow youth to have positive early CT experiences and develop favorable perceptions and attitudes towards CT. For example, Tyler, from a suburban library in Northeastern US responded: *"Well, first and foremost, I just want to make it fun for the kids so that they have a good time and a good experience with engineering and computer programming concepts and that they feel engaged and that they feel like they're learning."* Other responses were related to specific attitudinal or dispositional goals. For example, several library staff referenced introducing CT as a means to help develop desirable dispositions such as perseverance, *"Definitely them learning that mistakes are good. That's been something that has been a real focus for us. To keep going, to persevere, that mistakes aren't bad, that that's how we learn"* (Jenna, rural library in the Northeastern US). Confidence was another frequently cited attitudinal outcome. When asked what skills or attitudes she hoped to develop, Cait, who works in an urban library in the Western US responded with the single word *"confidence"*, when asked to elaborate she continued *"Confidence in, in this new technology, in technology and thinking in a computational way."*

A second cited reason for bringing CT into the library was to help youth learn foundational ideas related to computing and technology. Along with the quotes in [Table 1](#) demonstrating the goal of conceptual understanding, library staff also focused

on the relationship between the technology youth see and use every day and the learning goals of their CT programming. *"The kids are using this technology every day. It'd be great if they knew what went into what they're using"* (Brad, suburban Northeast). Similar motivations can be seen in other comments focusing on digital media broadly rather than the technological aspects: *"not only do I want kids to understand how media is created, so they can understand the messages that are coming from that media. I want them to be able to evaluate it, analyze it ... In order to do that, they need to know how media works whether it's a book or some digital tool. And one of the best ways for kids to better understand how those tools work is to be able to create using that tool. And that ultimately allows them also to communicate with that tool"* (Caroline, rural Western US). These motivations are interesting as they closely relate to communication and information dissemination, objectives central to the missions of libraries as resources for creating an informed citizenry.

The economic potential of CT-related jobs was also raised as a motivation for programming. For example, Phyllis, a librarian from an urban library in the Southeastern US, stated a goal of her CT programming was to *"impact [young people] so they have a brighter future and so they will consider computer science because there's a lot of money in it"*. Another variant of this goal was a broader motivation to prepare youth for the increasingly technological landscape irrespective of future profession. This can be seen in this response from Alice, an urban librarian from the Midwest, who said: *"the big goal would be to have all students in our county study computational science in elementary school so that they have, that they are better prepared for the future."* Here we see the goal of CT extend beyond professional preparation to the larger goal of being prepared for whatever shape our technological future may take.

Another goal for CT programming in libraries was framed around the relationship between libraries and schools. In some cases, the motivation was to prepare youth who come to their CT programming for future computing classes in their schools while Molly, a suburban librarian from the Southeastern US, expressed this in her response: *"We want them to be prepared before they get to high school ... so [youth are] already exposed to it before they are exposed in the classroom"*. Other times, library staff viewed their CT programming as serving a complementary role to that of schools. Kimberly, a rural librarian from the Western US, stated: *"we're reinforcing what they're getting from the schools and schools are reinforcing what they're getting at the library"*. This sentiment of library programs supporting and supplementing schools was also raised in relation to contexts where local schools do not offer computing-related courses. *"The initial reason we really wanted to offer these programs are because the school system in our town doesn't have any coding classes for kids. So they don't have a computer science class."* (Brad – suburban, Northeast). It is important to note that library staff did not view their goal as replacing schools or the role they play, Brad pointed this out in saying: *"we're not going to be able to teach them something that a school can teach ... [our CT program] is only once a month"*, but rather librarians saw their role as helping youth in the community engage with the powerful ideas of CT and to provide access to tools to let them do so.

In discussing the relationship with schools, library staff highlight unique affordances of libraries that make them distinct from conventional classroom contexts. For example, the fact that learning in a library is not formally assessed was viewed as a feature that would help kids explore new ideas they might be hesitant to in a school-based context: *"the*

goals right now are to introduce CT concepts to kids in really stress-free ways or low-stress ways. They're not being tested. So that and exposed them to different kinds of projects and tools that they might be interested in learning more about." (Caroline, rural Western US). The view was echoed by Nicole (suburban, Western US) who said "[youth] don't need another classroom setting especially if they're moving into middle school and high school where they have the rotating classes, rotating teachers, all of the things that they're learning. They have to sit still. They have to pay attention, and that's not what the library is. We don't need to fill that in their lives. They already have enough of that." These quotes highlight the distinct and complementary role of libraries as contexts for learning CT.

A final noteworthy motivation from these interviews was in the way library staff viewed their own institutions as a community resource when it came to the topic of CT and related technologies, specifically in response to issues of access to tools and technology. *"I think the main goal is still access. We want to give access to technology that is expensive and difficult to obtain for lower-income families"* (Nicole – suburban, West coast). This focus on access for underprivileged youth also came up in relation to the previously discussed topic around the preparation for the future, as can be seen in this response from Holly, a rural librarian from the central US, *"I think that to be successful in life and to break out of your cycle of poverty, they have to be able to really understand computers."*

Challenges of assessing computational thinking in libraries

What challenges do libraries face when assessing computational thinking?

Before discussing CT assessments specifically, we begin this section by briefly reviewing the approaches to assessment of library programming currently in use in libraries as reported by our 37 interviewees before shifting to the challenges they raised that are specific to trying to assess CT. Overall, the most common approaches to assessing library programming are taking attendance and tracking retention across sessions. The motivation for this approach was put succinctly by Brad (suburban Northeastern US), who said: *"it's successful if we get kids there"*. In general, this form of assessment is not problematic for CT-related library programming but provides little insight into the goals cited above such as attitudinal or learning outcomes. Beyond these numbers, other approaches for assessment referenced in our interviews included observations, surveys or questionnaires, impromptu interviews, and anecdotal feedback. Some of these approaches can provide insight directly related to the goals of CT programming, especially when incorporating existing CT-related surveys. For example, Caroline, a librarian from the rural Western US, said *"we did a program with NCWIT . . . they actually have a pre- and post-survey particularly looking at attitudes reviews"*, but, as will be discussed below, there are challenges associated with conducting this type of assessment in libraries.

The interview protocol used in this study included a number of opportunities for interviewees to voice the challenges they face in trying to assess their CT programming. This included questions such as "what challenges or constraints do you face with your CT programming?" and "how do you know if your program is successful"? One of the central challenges of assessing in libraries is rooted in the structure of the learning experience and the explicit recognition that libraries are not schools, so while learning is often a goal, assessment cannot feel like a school test. This can be seen in how Jenna, a rural librarian from the Northeast US, responded to a question about assessment *"Because we're*

a library ... our goal is lifelong learning. Whereas if I were a school, I might be more concerned that, did a particular skill get learned? Did a particular concept get understood? So I don't approach our evaluation in the way I would if I were in a school." A former school librarian turned public librarian (Nicole, suburban Western US), also identified this difference in goals as it relates to learning *"If I were still in the like, 'I must teach these kids' mentality, then I would love it if they could get certain competencies checked off. But I also recognize that as a public library, that isn't my job"*. This difference has implications when it comes to the question of assessment. Whereas schools focus on content mastery and skill development, as stated above, libraries end up relying on less intrusive measures of success (e.g., attendance or retention) that provide little in the way of insight into measuring desired outcomes such as engagement or interest development. The result of this difference is that CT assessments developed for formal contexts may not be suitable for informal settings like libraries.

Other library staff identified CT assessment challenges associated with the characteristics of CT content and how it does not easily align with existing assessments, the way that mathematics or reading proficiency might. For example, as Matt, a rural librarian from the Northeastern US, said, *"I think there's big picture assessment with computational thinking. You got to understand where you start and where you're headed, finding out the steps that you need to get in between and breaking that down into not just what a computer would do, little bits and pieces at a time, to put those together, and then creating a toolbox where you have different tools and different pieces of logic and different pieces of computational thinking you can assemble together"*. It is not immediately obvious what an assessment for *"understanding where you are heading"* or *"assembling different pieces of logic"* would look like. This relational concern can also be seen in quotes from library staff related to the ways that CT intersects with other content areas and learning objectives, e.g., *"So if we could, making the connection in between computational thinking and social-emotional learning, that would be something that would be valuable because I think there are connections"* (Alice, urban Midwestern US).

The newness of CT and CT-related technologies was also raised as a source of challenges for assessment in libraries. This can be seen in comments related to the concepts and technologies themselves, e.g., *"Like a 3D printing program, the concept of 3D printing is often new to everyone in the room regardless of their age"* (Jenna, rural Northeastern US). This same concern was raised with respect to those currently working in libraries, as Brittany, a rural librarian from the Southwestern US, stated, *"I think the biggest challenge sometimes is just mine and my staff's own knowledge ... especially coding or just really understanding different types of programs that could utilize computational thinking"*. A second librarian (Matt, rural Northeastern US) echoed a similar experience, saying *"Most of what we're doing is being implemented by people who have very little to no computational thinking experience"*. This is not necessarily always a negative, as Jean, a suburban librarian from Northeastern US, pointed out, *"We're teaching ourselves just as much as we're teaching them, which honestly is sometimes better because then they get the luxury of being able to teach us, which always is very empowering when you're able to teach an adult something that they didn't know. So I think the kids really enjoy that. We're all learning it together."* This has direct implications for assessment, as in the absence of existing CT assessment specifically designed for informal environments (as stated above),

it is then left to the library staff themselves to develop assessment, but the general lack of prior experience with the content makes this particularly challenging.

Logistical challenges of assessments were also raised by the library staff we interviewed. For example, Sandra, a rural librarian from the Midwestern US, responded *"I have a really hard time getting them to take a survey. I'm about ready to start bribing them with candy. It's hard to get them to do that and I think part of it is, is that I tend to hand them the survey about the time they need to leave, so that's hard. But I can't really give them the survey in the middle of things, before I'm all done, can I?"* This struggle also relates to the earlier discussion of the tension between assessment and informal settings where youth are choosing to participate, so engagement and fun are important considerations.

To summarize, the primary challenges to conducting assessments voiced in the interviews were the lack of clarity around the nature of CT or how to assess it, tensions between assessment and the informal nature of libraries; not having the CT knowledge or experience to develop effective assessments, and general logistical challenges associated with assessing a relatively new content area. Having reviewed the motivations for bringing CT programming into libraries and the challenges of assessing it, we now turn towards questions that gave the interviewees the opportunity to talk about what they wish they could do when it comes to assessing CT in their libraries.

Aspirational computational thinking assessments

How would public library staff like to assess computational thinking?

As part of the interview protocol, library staff members were asked how they would like to assess their CT programs. In asking this aspirational CT assessment question, we gain insight into where libraries are hoping to go with the assessment of their CT programs and shed light on the gap in assessment that currently exists.

The most common response given to what libraries would like to assess in terms of CT can be described as measuring long-term impact. As Caroline (rural Western US) succinctly put it: *"Assessment isn't about what happened in six weeks. It's what happens over years and years."* As for what longitudinal assessment might look like, Brittany from the rural Southwestern US said: *"It would be really neat to be able to follow these kids through high school to see if the fact that they were involved in a coding club outside of their formal education in school if that made any difference"*. A second interviewee, Lisa, a librarian from the rural Midwestern US, mentioned how she would like to see their patrons become mentors for future programs: *"I think if they were to start coming in and if we could grow them into teen volunteers who came back to help mentor the younger kids, that would be one thing, but I don't know how you express that."*

A second aspirational goal of CT assessment mentioned by interviewees was to measure gains in knowledge of CT content and how the library programming helped students learn CT. As stated by Jeremy from an urban library in the Western US: *"Like before you came to the program, what was your understanding of these concepts and practices about computational thinking and how did that change at the end of the program?"* This goal for CT assessments can also be seen in Cole (suburban Midwest), who rhetorically asked: *"can [the child] actually demonstrate that there was an understanding of a concept or some comprehension or as I mentioned before, like some vocabulary that they picked up that they understand?"* In these responses, we see rather school-like views of

assessment serving as a means to measure content mastery. However, as Lila, a librarian from the suburban Southeastern US, notes, this can be challenging given the amorphous nature of CT, saying *"I feel like some of my goals are so abstract that I'm not sure the kids could really viably tell me."*

Another form of assessment library staff were interested in was not focused on content mastery or learning, but rather gaining insight into youth's areas of interest and perceptions of the CT programs currently run, or, as Jean from the suburban Northeast puts it, *"seeing what the kids actually want to be doing"*. The goals of such assessments were stated to be both as a way to understand the learning experience but also to serve as a way to inform future program design, as Lauren, a librarian from the suburban Northeast US, said, she would like to ask the youth that visit her library: *"what was your favorite thing about the lesson? What are you still confused on? What would you like to know in the future? Like that kind of thing, which would help me kind of build the next classes."* This same sentiment can be found in Holly's response where she says that she is looking for a *"kind of metric [that] will tell me if I'm hitting the right spot and help me design future programming"*. A third example of this can be seen with Julia, a librarian from the rural Southeastern US, who said she would like *"a kind of a cumulative evaluation at the end of the programs to see just anonymously what they thought. How did, did you, did this work for you? Did your children enjoy this? What would you like to see in the future?"* This comment is interesting as it seeks the input of both the kids and their parents for assessing the program. While there are surveys that exist to assess attitudes towards computing that could be useful for shedding light on this desired information (e.g., the Computing Attitudes Survey (Dorn & Elliott Tew, 2015)), they have primarily been designed for formal learning contexts (or other contexts where youth can be required to complete them, like computing camps) so do not fit well in the free-choice setting of a library.

Library staff also articulated a desire for developmentally appropriate assessments, *"I would like to, I would love for, to have something that was developed for elementary students, specifically learning computer science, in afterschool programs, specifically or even generally"* (Alice, urban Midwest). This need was raised due to the fact that libraries support a range of ages and will have youth at different ability levels participating in the same activity, meaning a one-size-fits-all assessment might not be appropriate.

Finally, it is worth noting that several participants did not have an answer to this question, suggesting they do not spend much time thinking about assessments or prioritizing them in their work. This was succinctly captured in how Matt, a librarian from the rural Northeastern US, responded to our aspirational CT assessment question: *"I'm open to any ideas, but there's nothing that I have a burning desire to do as far as measurement goes"*. We include this not to disparage the library staff but to shed light on the emphasis some library staff place on assessment and measurement relative to the large set of responsibilities, goals, and challenges they face in their jobs.

To summarize, aspirational CT assessments shared by the library staff included assessments to measure gains in knowledge of CT, a way to measure the long-term impacts of CT programming in libraries, developmental- and age-appropriate assessments, and instruments to gauge interest in CT programming in libraries.

Discussion

Alignment between goals and desired assessments

In analyzing the responses given by library staff to questions related to the goals and motivations for their CT programming and mapping them on to the types of assessments that they wish were available, we find general alignment between the two. Library staff cited conceptual learning gains, positive attitudes, and experiences towards CT, and preparation for future learning and careers as key motivators for bringing CT into their libraries. At the same time, when asked what they would like to assess, we find a similar list: content mastery, interest development, and measuring long-term impacts of participation in CT programming (i.e. impacts on future school coursework and career choices). This presents a consistent vision for the purpose of CT programming in libraries and a clear alignment between what library staff want to do and what they want to measure in their programs.

However, in reviewing the assessment approaches currently in use and what is being measured, we find a disconnect between these aforementioned goals and the assessment strategies currently in use. Library staff reported mostly relying on attendance and retention numbers to assess programs. These numbers may serve as a proxy for demonstrating interest, but they provide little insight into determining whether the CT programming was successful in achieving these goals (e.g., conceptual learning, positive perception towards CT). Other cited assessment strategies currently in use, such as observations or impromptu interviews, are closer to the types of aspirational CT assessments mentioned (e.g., greater insight into emerging interest) but these current strategies in practice lack the systematicity or structure (e.g., interviews or observation protocols) that are important for providing a clear and consistent understanding of the impact of CT programming.

It is also worth mentioning that one of the explicitly stated goals for bringing CT into libraries, that of providing access to tools and technology that youth may otherwise not be able to experience, was not mentioned in response to the interview questions around desired assessments. Whereas most of the other motivations speak to some sort of change in the program attendees over time (i.e. learning a new skill, developing a new interest), the goal of physical access does not have a temporal dimension, but instead captures in-the-moment events (i.e. a youth using a technology they otherwise may not have had). In this way, the assessment of access need not be administered more than once (i.e. is not longitudinal) and can be captured through the currently used strategies at the library (e.g., attendance, observation, impromptu interviews), which means it may be an easier metric to capture as it is not subject to the challenges related to retention and structure of library programming that many of the other dimensions rely on and can be challenging for libraries.

Difficulties in assessing some stated goals

One of the findings of this study is the inherent challenge of assessing some of the stated goals for CT programming in libraries. For example, if the goal of a library program is to better prepare youth to pursue technology-related careers, how do you know if the program was successful in achieving this? This is not just a question of timeline and

logistics (i.e. there being a potential decade-long year gap between the CT program and the youth settling into a career) but more fundamental questions of causality and measure of impact. The various experiences and factors that feed into the decisions of an academic major or what career to pursue are complex to be able to measure the impact of something like participating in a library program in a meaningful way. The point here is not that the stated goals are unimportant or that library CT programming cannot have the desired impact but rather a recognition of the current limitations of assessment as it relates to such goals of library programming.

A second difficulty around assessing some of the stated CT goals is not nearly as intractable as the first but nevertheless one that needs to be recognized. The recency of the emergence of CT and the introduction of CT programming in libraries, coupled with the continued uncertainty around exactly what constitutes CT is a source of difficulty in assessing CT. This difficulty goes beyond the potential lack of expertise within a specific library but a recognition that we as a community of researchers and scholars do not yet know how to effectively assess some of the central tenets of CT. For example, how do you assess a person's mastery of the use of abstraction? Or their ability to effectively decompose problems or create modularized solutions that are more easily reused? Likewise, practices such as debugging and effective use of trial-and-error are central tools in the CT toolbelt but similarly lack reliable, valid assessments. We raise this point so as to align the challenges faced by libraries and library staff around the challenges of assessing CT with those of other educators and education researchers. In aligning these groups, we hope to highlight ways that advances made around CT assessment in one context may also be applied in the other. We see this as bidirectional, innovations from the informal learning communities may advance assessing CT in formal contexts and vice versa. Linking these two communities may serve as one way to help address some of the difficulties identified by the library staff interviewed in this study.

Assessing computational thinking in libraries versus schools

Throughout the interviews, the library staff we interviewed often discussed their relationship with schools. At times, this was in order to highlight similarities in the form of goals as it relates to CT and potential ways the two can complement each other. At other times, schools were brought up as a contrast to libraries and the nature of learning in library contexts. In particular, differences were brought up with respect to slightly different goals between the two, and the differences as it relates to the different forms assessment can (and should) take.

For example, several library staff pointed out how enjoyment and engagement are central goals of CT programming in libraries in a way that need not be a central concern for teachers in schools where attendance is compulsory. This has direct implications for assessment. If the assessments being administered in the library are "school-like" (i.e. pen-and-paper surveys), then youth will not take them, or will not take them seriously, rendering the data useless. This means an alternative form of assessment needs to be used, where the assessment itself is either engaging or is embedded within the activity itself. This is a growing area of interest in CT and there has been some recent work focused

explicitly on formative CT assessment that prioritizes playfulness and engagement, such as the Beats Empire project (Basu et al., 2020).

Another interesting distinction raised about the differences between schools and libraries that has direct implications on the nature of assessment relates to the stated goals. Whereas schools largely prioritize conceptual learning and skill development, library programming also has an emphasis on interest development and developing other “soft skills” (e.g., communication, collaboration, perseverance). As a result, assessments designed for school contexts that reflect the priorities of schools (i.e. conceptual understanding) may not be a good fit for libraries given this difference in goals (along with the fact that pen-and-paper assessments are a poor fit for the informal nature of libraries). This is consequential as many of the assessments that currently exist, especially the subset that have been validated, have been created with school contexts in mind, rather than informal or interest-driven learning that libraries strive for.

Audiences and implications

This research has two primary audiences with different implications for each. The first audience is individuals working in or with libraries to offer CT programming. This work can provide a framework for reflecting and rethinking current and future CT programming, the goals of such programming, and potential ways to rethink how, why, and when the programming is being offered. The implications of this work to those audiences is to help those doing this work situated their motivations, challenges, and assessment goals relative to others in a similar position and help provide a language for future discussion and orient future efforts to bring CT into their libraries. The second is those seeking to support the creation of tools, curricular activities, and assessments for libraries. We commenced this work by capturing the voices of public library staff who are responsible for bringing CT into libraries to answer these research questions. In doing so, we synthesize the needs of library staff so as to inform those seeking to help them, in particular, this work provides a road map for future work, specifically as it relates to CT assessments for libraries.

Situating the contribution of this work within the literature review presented at its outset, this research advances our understanding of libraries as a context for engaging youth with CT broadly while specifically contributing to our understanding of challenges and opportunities related to assessing CT programming in libraries. This work bridges existing scholarship on the state of CT in libraries (Subramaniam et al., 2018b; Taylor et al., 2018) with the growing body of research on how to assess CT (Tang et al., 2020; other articles in this special issue). In focusing on assessment, it adds another dimension to the discussion that up to this point has been more focused on questions related to how to bring CT in libraries (e.g., Braun & Visser, 2017). Broadening the literature to include questions of assessment can help inform and improve the important work already done. A central finding of this research is highlighting the disconnect between the motivations library staff have for bringing CT into their libraries (e.g., positive CT experiences, conceptual CT learning, career readiness, access to technology) with the forms of assessment most frequently employed (e.g., attendance and retention

measures, surveys). This disconnect is partially explained by the various challenges cited in bringing CT into libraries (e.g., informal nature of library programming, difficult to measure outcomes, lack of existing assessment tools). In identifying this disconnect, and further articulating the types of assessment library staff would like to use to evaluate the CT programming (e.g., learning gains, increased interest, long-term impact), this work both contributes to our understanding of the current state of assessing CT in libraries while also laying out a roadmap for future work.

A roadmap for future work

One of the goals of this work is to understand the current state of CT assessments in library contexts so as to set a research agenda for future work. In asking library staff questions related to the goals of their CT programming as well as their hopes for aspirational CT assessments and the challenges they currently face in assessing their programming, we gain insight into exactly what the needs are for a community of CT educators faced with meaningful, pertinent, and pressing assessment challenges. The findings from this work reveal an immediate need for more CT assessments that can be employed in libraries that can capture aspects including interest development, shifting perspectives towards computing and CT, and conceptual learning. At the same time, these assessments must adhere to the norms and constraints of library contexts. This includes the informal, opt-in nature of programming in libraries and a recognition that the person who may be administering the assessments might be as new to the subject area as the youth being assessed. While these may be significant challenges, so too are the potential benefits of succeeding in making progress towards useful CT assessments for libraries given the critical role they play in bringing CT learning opportunities to communities around the world. Future work of this research team will involve designing, developing, and testing such assessments in libraries that are actively offering various types of CT programming through a participatory approach (Subramaniam, 2016; Yip et al, 2019). As CT and its related concepts and practices become increasingly prevalent, and the role of libraries continues to grow, having accurate, informative, and adaptable CT assessment can go a long way in ensuring the CT programming happening in libraries around the world achieves its full potential.

Conclusion

The emergence of CT as an educational movement has resulted in a renewed focus on creating pathways for youth to meaningfully engage with technology and the powerful computational ideas that enable it. Increasingly, libraries are playing a significant role in providing CT learning opportunities to youth. As CT learning programs in libraries grow and mature, it is important that the people running these activities have the ability to assess whether or not the programming is achieving its goals. With this work, we focused on libraries as contexts for CT engagement and investigated what the goals of CT programming are in libraries and what challenges libraries face in trying to assess their current CT programming. We also presented findings as to what libraries would like to be able to assess. In doing so, we advance

our understanding of the current state of CT programming in libraries and provide insight into why and how libraries are providing CT programming. This research contributes to the literature seeking to understand the various ways we can deliver on the goal of bringing CT to all youth and lays the groundwork for future research seeking to equip library staff with the tools they need to provide effective, engaging, and successful CT programming to the youth they serve.

Notes

1. We use the terms “programming” and “programs” in this paper to describe structured activities offered in libraries (e.g., “library programs” or “CT programming”). This is a common vernacular in library scholarship.
2. All names are pseudonyms.

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References

- American Library Association. (2019). *State of America's libraries 2019. Public Libraries*. News and Press Center. <http://www.ala.org/news/state-americas-libraries-report-2019/public-libraries>
- American Library Association. (2020). *State of America's libraries 2020. Issues and trends*. News and Press Center. <http://www.ala.org/news/state-americas-libraries-report-2020/issues-trends>
- Arastoopour Irgens, G., Dabholkar, S., Bain, C., Woods, P., Hall, K., Swanson, H., . . . Wilensky, U. (2020). Modeling and measuring high school students' computational thinking practices in science. *Journal of Science Education and Technology*, 29(1), 137–161. <https://doi.org/10.1007/s10956-020-09811-1>
- Basu, S., Disalvo, B., Rutstein, D., Xu, Y., Roschelle, J., & Holbert, N. (2020, February). The role of evidence centered design and participatory design in a playful assessment for computational thinking about data. In *Proceedings of the 51st ACM Technical Symposium on Computer Science Education* (pp. 985–991). <https://doi.org/10.1145/3328778.3366881>
- Berland, M., & Lee, V. R. (2011). Collaborative strategic board games as a site for distributed computational thinking. *International Journal of Game-Based Learning*, 1(2), 65–81. <https://doi.org/10.4018/ijgbl.2011040105>
- Boyatzis, R. E. (1998). *Transforming qualitative information: Thematic analysis and code development*. Sage Publications.
- Braun, L., & Visser, M. (2017). *Ready to Code: Connecting youth to CS opportunities through libraries*. The American Library Association's Office for Information Technology Policy.
- Braun, L. W., Hartman, M. L., Hughes-Hassell, S., Kumasi, K., & Yoke, B. (2014). The future of library services for and with teens: A call to action.
- Brennan, K., & Resnick, M. (2012, April). New frameworks for studying and assessing the development of computational thinking. In *Proceedings of the 2012 annual meeting of the American educational research association, Vancouver, Canada* (Vol. 1, p. 25).
- Cole, N., Walter, V., & Mitnick, E. (2013). *Outcomes + outreach the california summer reading outcomes initiative* »The Public Library Association. <http://publiclibrariesonline.org/2013/05/outcomes/>
- Curzon, B. (2019). Computational thinking. In S. A. Fincher & A. V. Robins (Eds.), *The Cambridge handbook of computing education research* (pp. 513–546). Cambridge University Press.
- Davis, K., Subramaniam, M., Hoffman, K. M., & Romeijn-Stout, M. (2018). *Technology use in rural and urban public libraries: Implication for connected learning in youth programming*. Connected Learning Summit.
- Denner, J., Werner, L., & Ortiz, E. (2012). Computer games created by middle school girls: Can they be used to measure understanding of computer science concepts? *Computers & Education*, 58(1), 240–249. <https://doi.org/10.1016/j.compedu.2011.08.006>
- Dorn, B., & Elliott Tew, A. (2015). Empirical validation and application of the computing attitudes survey. *Computer Science Education*, 25(1), 1–36. <https://doi.org/10.1080/08993408.2015.1014142>
- Garmer, A. K. (2014). *Rising to the challenge: Re-envisioning public libraries*. Aspen Institute. <https://csreports.aspeninstitute.org/documents/Aspen-LibrariesReport-2017-FINAL.pdf>
- Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher*, 42(1), 38–43. <https://doi.org/10.3102/0013189X12463051>
- Grover, S., Pea, R., & Cooper, S. (2015). Designing for deeper learning in a blended computer science course for middle school students. *Computer Science Education*, 25(2), 199–237. <https://doi.org/10.1080/08993408.2015.1033142>
- Guidara, M. (2018). Rethinking computational thinking for public libraries' youth programs: challenges and recommendations. *Pennsylvania Libraries: Research & Practice*, 6(2), 75–85. <https://doi.org/10.5195/palrap.2018.188>
- Hoffman, K. M., Subramaniam, M., Kawas, S., Scaff, L., & Davis, K. (2016). Connected libraries: Surveying the current landscape and charting a path to the future [White paper]. The ConnectedLib Project.
- IFLA Library Map of the World. (2020). Retrieved September 17, 2020, from <https://librarymap.ifla.org/>

- IMLS. (2019). *Public libraries in the United States fiscal year 2016*. The Institute.
- Lee, V. (2019). Libraries will be essential to the smart and connected communities of the future. In V. Lee & A. Phillips (Eds.), *Reconceptualizing libraries: Opportunities from the learning and information sciences*. (pp. 9–16). Routledge.
- Lee, V. R., & Recker, M. (2018). Paper circuits: A tangible, low threshold, low cost entry to computational thinking. *TechTrends*, 62(2), 197–203. <https://doi.org/10.1007/s11528-017-0248-3>
- Martin, C. (2017). Libraries as facilitators of coding for all. *Knowledge Quest*, 45(3), 46–53. <http://files.eric.ed.gov/fulltext/EJ1125376.pdf>
- Mouza, C., Marzocchi, A., Pan, Y.-C., & Pollock, L. (2016). Development, implementation, and outcomes of an equitable computer science after-school program: findings from middle-school students. *Journal of Research on Technology in Education*, 48(2), 84–104. <https://doi.org/10.1080/15391523.2016.1146561>
- Penuel, W. R., Widman, S., Wortman, A., Chang-Order, J., Repko Erwin, M., Harris, M., & Van Horne, K. (2019). *Rockwood makerspace at multnomah county library*. Connected Learning Alliance.
- Phillips, A., Lee, V., & Recker, M. (2019). Small town librarians as experienced learning engineers. In V. Lee & A. Phillips (Eds.), *Reconceptualizing libraries: Opportunities from the learning and information sciences*. (pp. 158–169). Routledge.
- Prato, S. (2017). Beyond the computer age: A best practices intro for implementing library coding programs. *Children and Libraries*, 15(1), 19–21. <https://doi.org/10.5860/cal.15n1.19>
- Pugnali, A., Sullivan, A., & Umashi Bers, M. (2017). The impact of user interface on young children's computational thinking. *Journal of Information Technology Education: Innovations in Practice*, 16(1), 171–193. <https://www.learntechlib.org/p/180753/>
- Rose, R.N. (2015). *Survey of chief officers of state library agencies*. American Library Association
- Smagorinsky, P. (2008). The method section as conceptual epicenter in constructing social science research reports. *Written Communication*, 25(3), 389–411. <https://doi.org/10.1177/0741088308317815>
- Subramaniam, M. (2016). Designing the library of the future for and with teens: Librarians as the “connector” in connected learning. *The Journal of Research on Libraries and Young Adults*, 7(2), 1–18. http://www.yalsa.ala.org/jrly/wp-content/uploads/2011/02/Subramaniam_Designing-the-Library_Final.pdf
- Subramaniam, M., Johnston, M., Taylor, N. G., Moore, J., Magee, R., Drouillard, C., & Sanchez, J. (2018b). Expanding LIS Youth Services to embed computational thinking. *Association for Library and Information Science Education (ALISE) Conference*, Denver, Colorado.
- Subramaniam, M., Kodama, C., Baylen, D. M., Burton, M., Fabicon, J. K., Hincks, K., Moniz, R., Smith, D., & Visser, M. (2019). *Computational thinking in libraries: Case studies of youth programs in action*. The American Library Association's Office for Information Technology Policy.
- Subramaniam, M., Scaff, L., Kawas, S., Hoffman, K. M., & Davis, K. (2018a). Using technology to support equity and inclusion in youth library programming: Current practices and future opportunities. *The Library Quarterly*, 88(4), 315–331. <https://doi.org/10.1086/699267>
- Tang, X., Yin, Y., Lin, Q., Hadad, R., & Zhai, X. (2020). Assessing computational thinking: A systematic review of empirical studies. *Computers & Education*, 148(April), 103798. <https://doi.org/10.1016/j.compedu.2019.103798>
- Taylor, N. G., Moore, J., Visser, M., & Drouillard, C. (2018). Incorporating computational thinking into library graduate course goals and objectives. *School Library Research*, 21. http://www.ala.org/aasl/sites/ala.org.aasl/files/content/aaslpubsandjournals/slr/vol21/SLR_IncorporatingComputationalThinking_V21.pdf
- Thomas, J. O., Rankin, Y., Minor, R., & Sun, L. (2017). Exploring the difficulties African-American middle school girls face enacting computational algorithmic thinking over three years while designing games for social change. *Computer Supported Cooperative Work (CSCW)*, 26(4–6), 389–421. <https://doi.org/10.1007/s10606-017-9292-y>
- Wang, J., Hong, H., Ravitz, J., & Hejazi Moghadam, S. (2016). Landscape of K-12 computer science education in the US: Perceptions, access, and barriers. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education - SIGCSE '16* (pp. 645–650). <https://doi.org/10.1145/2839509.2844628>

- Weintrop, D., Beheshti, E., Horn, M. S., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2014) Interactive assessment tools for computational thinking in high school STEM classrooms. INTETAIN 2014, Chicago, IL.
- Wing, D., & Meyers, E. (2014). Easy as pi: Designing a library program to support computational thinking in preteens. *BCLA Browser: Linking the Library Landscape*, 6(3). <https://www.bclabrowser.ca/index.php/browser/article/download/632/803>
- Wing, J. (2006). Computational thinking. *Communications of the ACM*, 45(3), 33–35. <https://doi.org/10.1145/1118178.1118215>
- Wu, M. L. (2018). Educational game design as gateway for operationalizing computational thinking skills among middle school students. *International Education Studies*, 11(4), 15. <https://doi.org/10.5539/ies.v11n4p15>
- Yip, J. C., Lee, K. J., & Lee, J. H. (2019). Design partnerships for participatory librarianship: A conceptual model for understanding librarians co-designing with digital youth. *Journal of the Association for Information Science and Technology*, 71(10). <https://doi.org/10.1002/asi.24320>
- Young Adult Library Services Association. (2016). *Future ready with the library: Connecting with the communities for college and career readiness services*. <http://www.ala.org/yalsa/future-ready-library>
- Young Adult Library Services Association. (2018). *Transforming teen services: A train the trainer approach*. <http://www.ala.org/yalsa/train-trainer-project>