CONNECTED LEARNING SUMMIT

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Edited by Danielle Filipiak and Jeremiah H. Kalir

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1. “Working Theories” of Learning

A Study of Informal Educator Sensemaking with the Connected learning Principles

WADE BERGER

Abstract: Informal educator’s implementation of the connected learning principles requires them to engage in a process of sensemaking. This study sought to find how informal educators thought about the connected learning principles and what they would do to use them in their future programs. Prior research informs us that sensemaking involves a process of connecting new ideas to personal experiences and social-commonsense. This process is illustrated through examples from 23 interviews with informal educators who reviewed an implementation guide for the connected learning principles. I develop a construct of *working theories* to outline how, in addition to personal experience and social-commonsense, informal educators discussed future learners and contexts during the interviews. Through qualitative examples, I show that *working theories* contain future-oriented elements where informal educators expanded upon ideas from the connected learning principles. The future-oriented elements of *working theories* push the current understanding of informal educator sensemaking; these elements have implications for the design and implementation of informal educator professional training around shared ideas about teaching and learning.

Introduction

I work with informal educators – mentors, librarians, youth workers, museum docents, and a wide range of other professionals who support learners in out-of-school or informal settings. I used to be one of them, and I recognize the growing need to support informal educator learning. I have seen first-hand how, unlike their classroom counterparts, informal educators have limited access to university level, pre-professional training. In the place of formal training, informal educators rely on sparse opportunities for on-the-job learning, which can be limited, as informal educators are often the only employee (or the only educator) at their organization. Outside of their own organization, informal educators enjoy minimal professionalization such as unions, associations, or professional development programs (Robinson, 2019; Starr & Gannett, 2015). Despite these challenges, informal educators create ambitious programs, provide meaningful youth services, and develop innovative pedagogy. As a source of professional growth for informal educators, especially through the connected learning principles, the connected learning community has an opportunity to better understand how they learn to do this work. The connected learning principles originated from a set of ethnographic findings about youth participation in digital media-centric programs (Ito et al., 2013). Researchers and informal educator network leaders have worked to transition these principles from the research to a shared set of ideas about teaching and learning that could orient informal educators’ work. To this end, Dyson and Larson (2019) introduced a connected learning Implementation Guide for the connected learning principles (see example in Table 1).

Approach [Principle]	What This Might Look Like	Resources
Support peer-to-peer sharing of expertise	Encourage collaboration based on shared interests and skills instead of established social circles. When receiving a participant's request for help, give their peers a chance to volunteer their own knowledge and expertise.	Social media has become a powerful tool for supporting social connection. Google's *Be Internet Awesome / Sé genial en Internet* is a multilingual campaign for establishing positive norms for online interactions.

Table 1. One Connected learning principle with examples and guiding ideas from Dyson and Larson's (2019) Connected learning Implementation Guide.

This guide presented a unique opportunity to answer the following research question: *How do informal educators make sense of shared sets of ideas around teaching and learning*? To answer it, I investigated how informal educators grapple with the connected learning principles and think about how to make use of them in their programs, activities, and teaching practices. By focusing on educator sensemaking, I am drawn less to understanding how informal educators acquire expertise or master competencies, as seen in studies investigating competencies of informal teaching (Garst et al., 2016; Vance, 2010). Instead, I focus on how informal educators integrate ideas about learning as they plan for mentoring youth.

Educator sensemaking builds on the work of Ross (2013, 2016) as well as Bevan and Xanthoudaki (2008), who argue that informal educators debate and unpack ideas about teaching and learning. This work also uses research on classroom teacher learning, including the "ideology in pieces" model proposed by Philip (2011), which views educator sensemaking as a process containing emergent collections of ideas that educators use to think about their own teaching. Through qualitative analysis, I show how informal educators in my sample made use of a construct I call *working theories* to make sense of the connected learning principles. These *working theories* contained personal experiences with learning and social-commonsense ideas about learning directly following Philip (2011). My study stretches the concept of "ideology in pieces" to argue that, within the interviews I conducted, informal educators also forecasted how they believed an idea from the connected learning principles would work with learners they will mentor in the future, an idea closely aligned with the concept of "expansive learning" (Engeström, 2014, p. 74; Santo et al., 2015).

Background

When thinking about ideas around teaching and learning, informal educators often reflect on their own memories as learners (Allen & Crowley, 2012) and as teachers (Hatton, 2014). Ross (2013, 2016) argued that informal educators use these prior experiences to make decisions when faced with tough dilemmas of mentoring. In similar work with classroom teachers, Philip (2011) argued that they regularly check their own experiences with the world when reflecting on challenges of their work, viewing these experiences as valuable inspiration for pedagogical decision-making. In cases presented by Ross (2013), informal educators told stories and articulated how those experiences helped them to solve dilemmas with learners. In their decision-making process, informal educators often draw on the prior experiences of their colleagues (Ross, 2016). Shared storytelling is an example of how personal commonsense only partially accounts for educator sensemaking, as it offers "little for understanding people's sensemaking about their social world" (Philip, 2011, p. 300). Informal educators also make use of shared stories about teaching and learning. These kinds of shared educator stories are an element of social-commonsense – "socially communicated assumptions or experiences of others" (Philip, 2011, p. 301). Informal educators reproduce social-commonsense in their own thinking and problem-solving processes. These shared ideas of thinking around teaching and learning can be as valid as personal experience in educator sensemaking. Social-commonsense ideas gain value within a community of educators when these ideas are continually reproduced and based on the social capital of those reproducing them (Hall, 1982). Social-commonsense ideas about teaching and learning are useful to informal educators as they offer guidance, heuristics, or a historical account of success through which informal educators can solve common or routine problems already faced by their peers (Ash et al., 2012). Research around social-commonsense with classroom teachers has investigated common tools, shared assumptions, and identities that informal educators gravitate towards (Kazemi et al., 2009; Lampert, 2010).

Informal educators create new ideas about teaching and learning during sensemaking when they apply ideas to their unique contexts and future learners (Engeström, 2014; Santo et al., 2015). Thinking about unique contexts and their future learners can cause informal educators to bend or stretch ideas from their personal experience and social-commonsense to "learn something that is not yet there," a notion defined by Engeström as "expansive learning" (2014, p. 74). Sometimes this happens because the source idea (from personal experience or a social-commonsense) does not apply exactly to their unique need. Elsewhere, informal educators are trying to solve a challenge that requires the creation of new knowledge. This can be seen in the study by Santo et al. (2015), where informal educators were trying to learn how to build a makerspace for youth. As they tapped their social networks, did research, and began building their makerspace, the group of informal educators also stretched ideas of what a makerspace was and created new ideas about what it could be. These makerspace educators ultimately refined what a makerspace could be for the entire field. The study by Santo et al. (2015) implies that we must also include expansive processes – a cycle of creating new solutions through thinking about the future – when we study educator sensemaking. *Working theories*, as presented here in my study, demonstrate how future-oriented thinking works in parallel to personal experience and social-commonsense when informal educators engage with shared ideas like the connected learning principles.

Methods

Through a collaboration with a network of informal educators deeply tied to the Connected learning principles, I was able to recruit 23 participants for a talk-aloud interview and a demographic survey. The purpose of the survey was to ensure participants were well distributed in years of experience, size of organization, and neighborhood served by their organization. The primary focus of the interviews was the talk-aloud section, where I presented one sheet of the connected learning principles (an adapted version is seen in Table 1). I asked the participants to read from the sheet and then to talk about what they encountered and what they were thinking as they were reading. These interviews were semi-structured – as the participants were talking about the connected learning principles, I mostly asked elaborating questions, including things like, "What did you mean by that?" or "Why did you talk about *x*?" Using recordings and transcripts of these interviews, I analyzed sensemaking through a qualitative lens where I could use in vivo codes to honor what participants said in their own words – what they felt was important to say in the interviews (Miles et al., 2014). This focus on rich description of sensemaking pushed my analysis towards the processes and categories within the participants' responses. The construct of *working theories* developed through a combination of the in vivo codes and the nuances in processes found in participants' responses to Connected learning principles.

Findings

The construct of *working theories* serves as a metaphor for the processes informal educators went through during these interviews. The idea of *working theories* conveys how participants "worked" on their responses as they talked; it denotes how elements of their talk were useful or "worked for them," and acknowledges that informal educators' talk consisted of evidence to theories they had about the connected learning principles. In the first case provided below, I present an entire *working theory* to illustrate it as a process – a series of connected statements that illustrate the steps a participant went through while talking about the connected learning principle.

Working Theory Process

I present a *working theory* from Kurt – an informal educator at a large museum who reported at the beginning of the interview that he was very familiar with the connected learning principles. Kurt made sense of the principle I presented through a *working theory* that I have named "authenticity meter." Kurt discussed an "authenticity meter" as he responded to the "prescribed recipe-style approach" of this connected learning principle (Table 2). His statements immediately followed him reading the connected learning principle out loud. In the transcript, note that Kurt wanted to care about a student's own processes and journey (see lines 4-6).

> I love that… that it's not a recipe-style approach with predetermined outputs. I think that also makes it, makes what we're doing feel like school. If we have predetermined outputs, if it's too recipe-style, if it's too "you must fill out this," "you must hit these marks," then the **authenticity meter** goes off, and it stops being about caring about students' process and the authenticity of like, asking a question of the scientific process, and more of what we're placing on expectation on the students, and it separates from the student's own journey.
>
> I mean, you can also call it a "bullshit meter." I mean, I think that students, teens especially, but even younger kids, have a really keen awareness with honesty. I think also, teens can get really jaded with schoolwork, busy work, and work-for-work-sake, and anything that might resemble that, in a place where they're volunteering to go to, is going to be met with difficulty. They didn't choose to come here because it was like, cool. They came here because it's something different. It's informal. It's [a] museum, like, unknown exploration can happen here... And if they know that, there's real purpose and meaning and relationships that they are encountering each time they show up. There's something different about it that wouldn't happen in their normal chemistry class.
>
> I'm trained in acting; that's where my MFA is. And… you show up on stage not completely true and authentic, to take on your part or role, [then] you can't really connect to the truth of that character, and that play, or film, or the script. And your audience can detect that too. You know, when you see a bad actor... You know, when you've had a bad teacher, they have a hard time connecting to the truth...
>
> So, if you can find a way to connect the authenticity of the work that you're doing, and convey that to your students, that authenticity is another means of trust building. You're excited about this. This means something to you, this could possibly mean something to me. And that only comes with doing something that's actually fully authentic.

Table 2. Kurt's "authenticity meter" in response to this connected learning principle: "Project-based learning (PBL) is one way to support learner interests. Ensure that PBL isn't a prescribed, recipe-style approach with predetermined outputs."

I asked Kurt to define "authenticity meter" (see Table 2, lines 8-16), which began with the alternative name (line 8). He went on to conclude that teens get jaded with busy work and that is why they might choose to participate in museum programs like the ones that he offers (lines 9-11). He reflected on what he thought teens' experiences would be in programs that were "authentic" and what informal educators might broadly believe are differences between museum programs and classrooms (lines 13-16). Up to this moment in the interview, Kurt's assertions were not explicitly backed by stories from his own personal experience with learning or teaching, but instead backed by prevailing ideas he had about how informal learning can be filled with "unknown exploration" or "real purpose and meaning and relationships" (line 13 and line 14, respectively). However, as he continued, Kurt moved to share stories from his training to be an actor and completing a master's degree in fine arts (lines 18-22). He built a metaphor where he argued that just as an audience knows an actor isn't authentic (lines 18-20), students know a teacher isn't authentic with them (lines 21-22). Kurt argued that trust is being built (line 25) between educators and learners, and it requires work on behalf of the educator. Through this metaphor, Kurt borrowed an idea held by his colleagues in the acting world to argue for how an educator should be authentic with learners. Kurt concluded his response by making an argument about what an educator should be doing when working with learners, using the pronoun "you" to direct other educators to think about his opinion on this principle (line 24).

Looking through the entire response, we can see how Kurt named an idea and then 1) talked about it along with other ideas of learning, 2) told a story about how it made sense to him, and 3) indicated that elements of the connected learning principle, such as avoiding a recipe-style approach, should also include authenticity and trust building if educators want to find success. Across the interviews, I found examples of informal educators responding to connected learning principles with the same kinds of elements as Kurt demonstrated here. In some interviews, there were variations in the order of these elements, differences of intensity of one element over the others, or omissions of some elements. In this paper, I intend to focus on providing rich descriptions of these elements, with an intent to explore nuances between educators' responses in future work. In the following sections, I articulate what each element surfaced for each informal educator, and what informal educators were able to do when they brought these elements into the conversation around the connected learning principles.

Working Theories Contained Personal Experiences

Each of these interviews contained stories from lived experience. Kurt talked about his acting career. Jarrett, an informal educator who ran a youth-entrepreneurship program, told stories of playing basketball after school and of his time in a dual-language elementary school. Eugene, who led web-based urban planning activities with youth, told stories about attending zoning committee meetings. And Rain, a lead of teen programs at a large museum, told stories about youth who had been in her programs in the past. These were stories about the informal educators' experiences as learners in classrooms and informal settings. Alternatively, participants told stories from their time as educators, reflecting on moments from their time mentoring youth or older learners. These stories represented tools the informal educators used to "make sense of, define and figure out" (Philip, 2011, p. 301) the guidance provided by ideas they were encountering in the connected learning principle. Storytelling gave Kurt a chance to articulate why he valued authenticity so much, and to show that authenticity was deeply connected to relationships – something that he felt was present in the relationship between an actor and an audience. For Jarrett, his stories helped him express how much his learning as a kid was tied to both in-school time and out-of-school time. Eugene was able to demonstrate the real-world similarities between his conversations in civil planning to the conversations he thought youth could have in his programs. These stories were anchored in a vivid memory of the informal educators' belief about teaching and learning.

Working Theories Contained Social-Commonsense

Alongside the vividly articulated memories, and in cases when stories were not even told, the informal educators reproduced social-commonsense ideas about teaching and learning in response to connected learning principles. They reproduced what they thought were commonly held beliefs or assumptions about what good learning could look like or might require. As we saw with Kurt's responses, he referred to broad ideas about what museum learning could be and addressed how relationship building could be good for youth learning. Similarly, Rain tied her responses to the connected learning principles to what she labeled as ideas about "diversity and inclusion." Another commonly mentioned belief was about the differences between the learning needs of youth in in-school vs. out-of-school settings. Ideas about how out-of-school learning needed to be different were particularly important for Aida, an educator whose work took place in both settings, and Marikita, who spent years in a classroom before moving over to run arts-based programming. Some of the participants chose social-commonsense ideas, which they clearly use often when talking about their work, such as Rain, who indicated that "diversity and inclusion" were key drivers of her professional life. Others arrived at socio-commonsense ideas in the interview only after recognizing a direct connection to the personal experience stories they were telling.

Participants brought up social-commonsense in response to the connected learning principles so they could articulate ideas that were guiding their thinking about the principle I asked them to discuss and their thinking about their practice. These ideas are part of their historical record as an informal educator, binding their individual thinking, and their personal experiences, to broader ideas held by their colleagues, collaborators, and the wider field. For an example of this, we can return to Jarrett, and his response to the connected learning principle: "Take active initiative to learn about and support diverse student interests to better understand youth priorities and values without pandering to trends in youth popular culture." Jarrett began with his story about playing basketball as a kid, but then pivoted to connect this story to broader ideas about mutual trust, better unifying bonds (between youth, or between youth and educators), and the importance of building connections based on differences and similarities between learners. These broader ideas about teaching and learning allowed Jarrett to conclude his interview by stating the priorities he and his organization are trying to achieve, arguing that "we want to make sure we're authentic in what we're building, but also have the commitment to understanding what young people are going through and trying to bridge that gap between things we know are important that… could open doors for them later on." His "gut" was telling him these were areas guiding him and his colleagues as they sought to improve the lives of young people.

Working Theories Contained Future-Oriented Thinking

As personal experience and social-commonsense were guiding the participants' thinking during these interviews, it was also clear that informal educators were thinking about the broader uptake of the connected learning principles by the field. They did not specifically state things like, "I would use this principle in my Saturday robotics club," but instead expressed expansive learning around the principles (Engeström, 2014; Santo et al., 2015), articulating why their views (of the connected learning principle) were important and how additional elements could extend or improve the connected learning principle. If participants intended just to understand the connected learning principle as it was written and implement it verbatim in their program, then they did not make those plans explicit in these interviews. Instead, participants, like Kurt, Jarrett, and Rain, told me about ways that the connected learning principle could work by 1) showing what they felt was important about the principle, 2) adding additional ideas to the principle, and 3) forecasting how it should be taken up with these additions. Kurt and Jarrett both expanded on connected learning principles to argue that elements of authenticity and mutual trust were also required. Rain pushed every part of the interview to include her ideas about "diversity and inclusion."

This is perhaps best seen in a response from Kendra, who was a youth worker at a community-based youth center. As Kendra responded to the connected learning principle – "Nurture ongoing partnership and collaboration in person and online" – she pivoted away from only talking about developing partnerships and collaborations with youth. She contended that this principle also needed to focus on organization-to-organization partnerships and collaborations between youth workers. She argued that "there's a lot to say about what collaboration does" and that "there's not one person or one program or community that can provide everything a child needs or youth needs." I was surprised by this response during the interview, because I had not considered this connected learning principle beyond thinking about its goals for youth relationship building, and I had not yet heard any informal educator discuss it in the same way as Kendra did. However, Kendra articulated an expansion of the principle which she found valuable, as something that should be taken up more broadly in the field. Ultimately, what would work for Kendra, and for other participants who stretched the ideas in the Connect Learning principles, was a combination of their idea of the connected learning principle (as it was written and with their view of it) plus their expansive ideas of how learning works, all while considering their unique context and learners.

Conclusion

Studying informal educators' use of *working theories* allows us to look at informal educator learning across 1) personal experiences, 2) social-commonsense, and 3) future-oriented processes. It shows how informal educators integrate these three elements alongside each other as a process to think through shared ideas like the connected learning principles. As we remember that informal educators have limited access to professional training (Allen & Crowley, 2014; Robinson, 2019), *working theories* have several implications for the design and research of informal learning educator learning opportunities. This is especially important as researchers continue to advocate for improving the access to professional training for informal educators and for closer investigations of how learning happens within professional training (Ash & Lombana, 2012).

We can start by acknowledging that their sensemaking around ideas like the connected learning principles results in much more than just "learning" those principles. Notably, 14 of the participants indicated that they had learned simply by participating in the interview. This shows that sensemaking is an ongoing endeavor and a process that needs to be supported. Informal educators need help navigating their prior personal experiences with learning to connect them to ideas they have for their current and future work. It is also crucial that we recognize the importance of future learners in this sensemaking. The ways in which informal educators consider their future programs and learners drives new solutions and new ideas that could potentially outpace currently published guidance around the findings behind the connected learning principles.

We can do more to honor and elevate new solutions that informal educators create when they do not take up the connected learning principles the same ways that others do. I would encourage the connected learning community to foster broad, career-long learning opportunities around the connected learning principles. This community has an opportunity to encourage members to talk with each other about their *working theories* and to host community-wide conversations that will help informal educators debate and be critical of social-commonsense ideas held throughout the field (Bevan & Xanthoudaki, 2008). Studied in future work, conversations between informal educators, analyzed through a micro-genetic approach such as interaction analysis (Hall & Stevens, 2015), might show how informal educators learn *from* and *with* each other as they surface, clarify, and debate *working theories* in conversation.

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2. Methods Of Engaging Teens In Conversations About Personal Digital Data

Public Library Context

LEANNE BOWLER; MARK ROSIN; IRENE LOPATOVSKA; AND LAURA VROOM

Abstract: This paper reports on research that asks, *how might youth data literacy be supported through informal, after-school activities at the library*? The goal of the project is to build a youth-oriented model of data literacy that incorporates social-awareness, critical approaches, and "goodness of fit" into informal STEM learning about data. To this end, the project has been working with teen co-designers to build and test a range of data literacy activities that, according to teens, would be both meaningful, fun, and worth their time in a voluntary, drop-in setting like the library. In this paper, we present a preliminary inventory of the data literacy activities created and tested alongside two teams of teen co-designers in 14 Data Labs during Spring and Fall 2021, to be used as a tool to support future designers of data literacy activities at the library.

Introduction

Today's young people have never been more surveilled and tracked through their digital data traces than any previous generation. Data literacy –the ability to read data, understand the context of data, and critique data – is therefore a life skill for today's youth. Data literacy is about more than computation and statistics. It is a new and emerging form of literacy comprised of a complex array of skills, knowledge, humanistic reasoning, and ethical concerns. It includes a set of dispositions that facilitate the ability to find meaning in data beyond statistical and mathematical arguments (Finzer, 2013, p. 5; see also Deahl, 2014;Gray, Gerlitz & Bounegru, 2018 Tygel, & Kirsch, 2015). A person who is data literate tries to explain *why* specific actions are being taken with data, not just what and how.

How can this form of STEM learning be supported? According to Connected Learning principles, as well as the general principles of informal learning, young people gain knowledge, wisdom, and life skills within a broad learning ecosystem that includes home, online environments and communities, and formal schooling, as well as a multitude of informal, after-school organizations such as the public library (Ito et al., 2019, National Research Councils, 2015). This paper reports on the "Data Literacy with, for, and by Youth" project that looks at public libraries and asks, *how might youth data literacy be supported through informal, after-school activities at the library*?– The larger goal of the project is to build a youth-oriented model of data literacy that incorporates social-awareness, critical approaches, and "goodness of fit" into informal STEM learning about data. The problem is complex: concepts, skills, and dispositions associated with data literacy are multifaceted and often abstract. Given the drop-in, sometimes fast and furious, setting of after-school activities at the public library, what might this learning look like? By our estimation, the best way to start answering this question is by asking teens themselves. The project is thus grounded on the principles and practices of participatory design, or sometimes called co-design, giving teens an active role in the design process.

There is no canonical definition of "participation" or "co-design" and in fact, there are many models of participatory design. Young peoples' roles can scale up – from being assigned a task and then moving toward shared decision-making, or from tester to full design partner (Bowler et al, 2021; Druin, 2002; Hart, 1992; Yip et al., 2017). All these roles can occur within the same design project, as was the case with the "Data Literacy with, for, and by Youth" project.

The project has been working with teams of teen co-designers to test and build a range of data literacy activities that, according to teens, would be both meaningful, fun, and worth their time in a voluntary, drop-in setting like the library.

Due to COVID-19 restrictions, such as the closure of public library buildings and requirements for physical distancing, all design sessions with teens, as well as data literacy activities, were held online using digital tools. This paper presents a first look at some ideas for data activities generated though our participatory design work with teens. We begin with a preliminary inventory and description of the methods and online activities tested and developed alongside 14 teen co-designers in 14 online design sessions (called Data Labs in this project) during Spring and Fall 2021. The teens' preferences and recommendations are highlighted.

Data Literacy

Data literacy refers to the collection, analysis, interpretation, and use of data. It has typically been theorized in the context of formal education, focusing on discrete skills associated with data science such as computation, numeracy, and statistical analysis, or the use of graphs and applications such as Microsoft Excel (Reeves & Honig, 2015). School-based learning around data is often shaped by concerns about curricular needs, state standards, and academic pathways towards college and professional education, while informal, after-school learning fits into the broader context of life. How would young people *prefer* to learn about data in their everyday lives (and within their communities) and, how might those preferences translate into meaningful after-school data literacy programs for teens?

Work in the data literacy field needs to be situated in the context of life-wide learning – making connections between data and "real life" so that teens can give personal meaning to data. A powerful platform for developing such meaningful experiences with data may be in the interest-driven, nonformal learning that happens outside the K-12 classroom, as modeled in Connected Learning (Hoffman et al., 2019; Ito et al., 2019;), a framework that connects youth interests, relationships, and opportunities to STEM learning (Nacu et al., 2016; Pinkard et al., 2019). In the world of nonformal learning, public libraries are already providing Connected Learning experiences with data through digital media labs and youth hackathons, although data literacy is rarely identified as a planned outcome (Dankowski, 2018; Deahl, 2014; Fontichiaro, 2015). The development of practice guidelines that are grounded in a youth perspective on data literacy are still needed.

Data Labs

During Spring and Fall 2021, two series of Data Labs were conducted via the Zoom platform – six sessions during Spring 2021 followed by eight sessions during Fall 2021 – with seven teens in each series, for a total of 14 teens. The focus of these two series of Data Labs was on personal digital data. (A later series of Data Labs, not discussed in this paper, focused on open data in civic data repositories). Teen co-designers were recruited by our community partner Brooklyn Public Library. We note that the teens who participated in the Data Labs may not have been the typical "drop-in" audience at the public library – teens who just want to hang-out with friends and goof around. The teens who participated as co-designers in the "Data Literacy with, for, and by Youth" project were working as interns at the library and earned credit hours at school for their time, as well as a gift certificate from Amazon. Some of the teens were students at competitive technology high schools in New York City so the word "data" in the program title might have attracted teens already interested in data science. Nevertheless, the teens lived in the community, were library-users themselves and, much like teens who serve on Teen Advisory Boards at many public libraries, they had their peers in mind as they moved through the design process in the Data Labs. The teens attended all sessions within each series of Data Labs so they could fully participate in the design process.

The two series of Data Labs followed a similar pattern. The first session introduced data literacy and the goals of the project. Team members spent some time getting to know each other through icebreaker activities to build social connectivity, an important component in after-school engagement (Bartko, 2005). For example, in one icebreaker, all team members filled a shared Google Jam Board with Post-it notes and images of things such as their interests, hobbies, and favorite media. In addition to revealing shared interests and sparking discussion, this activity allowed researchers to tailor future Data Lab content around topics that would feel more relevant to and better engage the teens. In another icebreaker, team members shared their morning routine and imagined how an algorithm would predict the course of their day based on variables in this routine.

The middle three sessions focused on deepening teens' knowledge of data literacy concepts (e.g., data privacy, data footprints, surveillance, algorithmic assumptions, personalization, and data rights), trying out various ways to play with these data concepts, connecting data literacy to teen's identities and everyday lives, and brainstorming new approaches for an after-school activity (Figure 1). In each series of Data Labs, the teens worked toward a final product – a sample data literacy activity that they thought other teens or tweens would like. In the final session, teens presented their program to other teens, and had a chance to reflect on their project.).

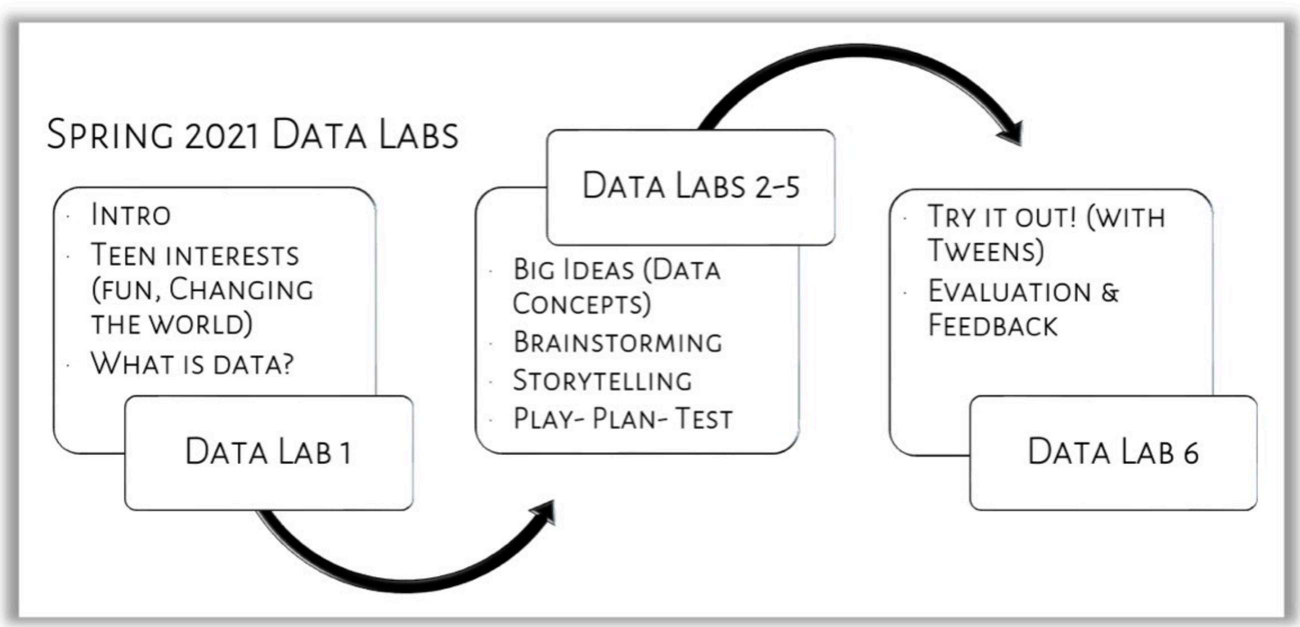

Figure 1. Data Labs, Spring 2021 – Six sessions.

For the teen designers, games with an element of competition were highly appealing, although we inferred that for at least one teen, doing poorly correlated with an unenjoyable experience overall. Teens in both Series 1 and 2 designed an online game about data using Kahoot, a game-based learning platform. Another group of teens created a prototype for a board game modeled on Monopoly, which they called *Data-opology*, while a third group suggested that libraries should purchase or subscribe to commercial online games about data and then stream the games online during an after-school teen program, allowing teens to socialize in chat. As it turns out, we did locate an online game about data, called *Orwell: Ignorance Is Strength* (Osmotic Studios, 2018), approved of by the teens. Various online activities, games, brainstorming, and ideation activities used during the two series of Data Labs were compiled into a preliminary inventory of these activities that can assist future designers with methods of exploring data literacy online and creating data literacy acitvities at the library (Table 1) .

Throughout the Data Labs, the flow of activities cycled between explorations into basic data concepts, activities to connect data concepts to teen lives, and open-ended brainstorming and ideation about "ways to play" with data concepts at the library. Learning new content, while at the same time, applying that new content to the design of an activity for other teens is a difficult task – *Apply* being one of the higher tiers of Bloom's taxonomy in the cognitive domain (Anderson & Krathwohl, 2000; Krathwohl, 2002). This is especially true for teen learners in a limited-session after-school context. Since the project was committed to youth participation, it consciously balanced learning activities alongside brainstorming and creative activities. As such, we invoked a constrained design approach that provided, on the one hand, an introduction to new data concepts and examples of data activities, while on the other, opportunities for open-ended design (see Table 1 for examples of activities and data concepts). Weekly audits of youth interaction helped to keep teens at the center of the process (For more details about our position on youth roles in the design of STEM learning, see our article *The Meaning of "Participation" in Co-Design with Children and Youth* (Bowler et al., 2021).

Method	Application to Data Literacy
Brainstorming activities in Google Docs	Teens build a database of data trivia questions and then use those questions in a Kahoot game.
Brainstorming activities in Google Jamboard	Teens brainstorm a list of data topics important to young people.
Chat	Teens respond to verbal prompts via chat. For example, teens chat about data in their everyday lives.
Collaborative Storytelling	Teens collaborate on a data privacy, story about a day in the life of a teen. They identify where data fits into the story, recording the story in a Google Doc.
Creative activities in Google Jamboard	Teens build a persona based on data points drawn from their own lives, and then explore assumptions about the persona made by algorithms.
Demonstrations	The "Trace My Shadow" website is demonstrated, and teens are then invited to explore the tool themselves. "Trace My Shadow" estimates your digital traces.
Games	In two teams, teens, investigators, and librarians play an online game of Data Jeopardy, answering questions about basic data concepts such as data literacy, digital footprint, metadata, algorithmic bias, privacy, and surveillance.
Group discussions. Teens respond to verbal prompts in a group discussion.	Teens discuss the strategies they use to take control of their own data.
Hands-on with data	Teens conduct a text analysis of a website of their choice, using Voyant-tools.org, to show how text in social media can be datafied.
Mini lectures created in Google Slides, presented by adult facilitator	Some topics for the mini lectures: "Ways to play with data" "How long can platforms keep your data?
Mini surveys created in Google forms	Teens rank their favorite data activities in a survey created in Google forms. Results presented to group, followed by discussion after.
Videos	"What even is an algorithm?", a YouTube video about algorithms and how they track and personalize our online experiences.

Table 1. The inventory of data literacy activities is organized by method (or modality of activity) and how the method was then applied to data literacy.

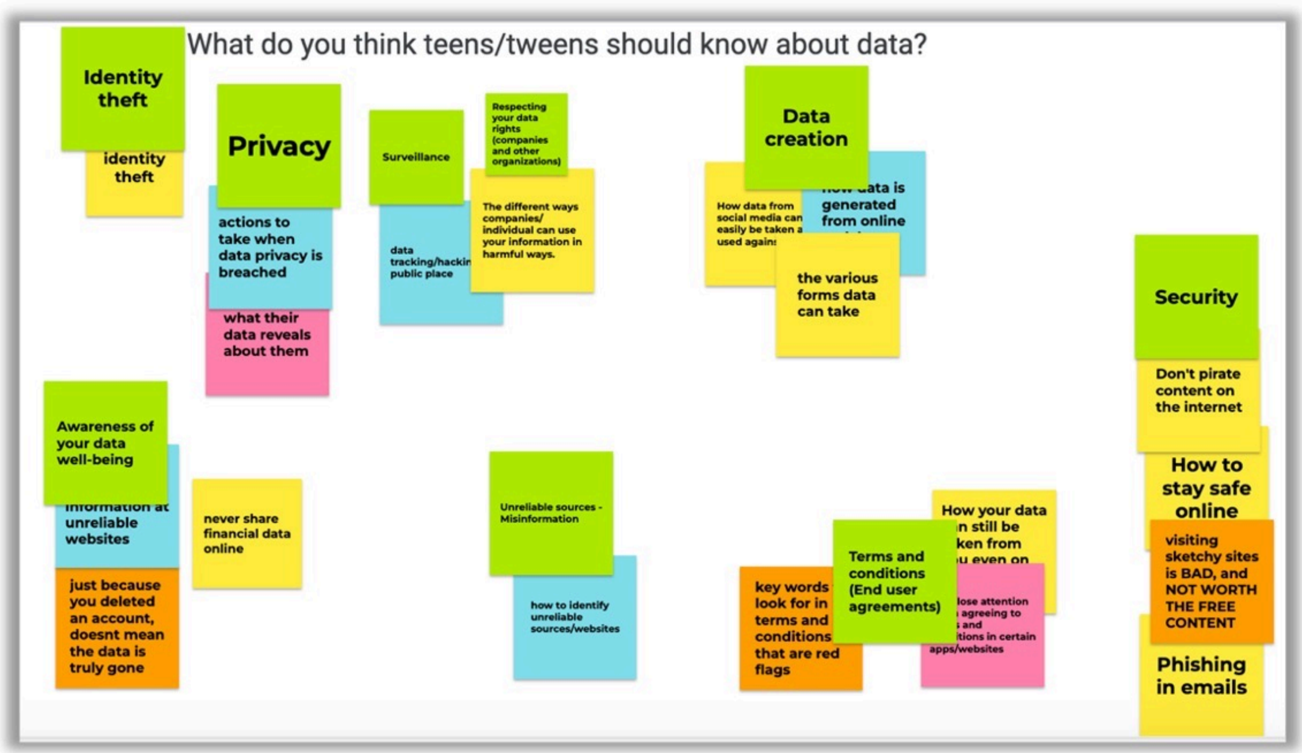

Figure 2. Brainstorming activity in Jam Board: "What do you think teens/tweens should know about data?" *Data Labs, Fall 2021.*

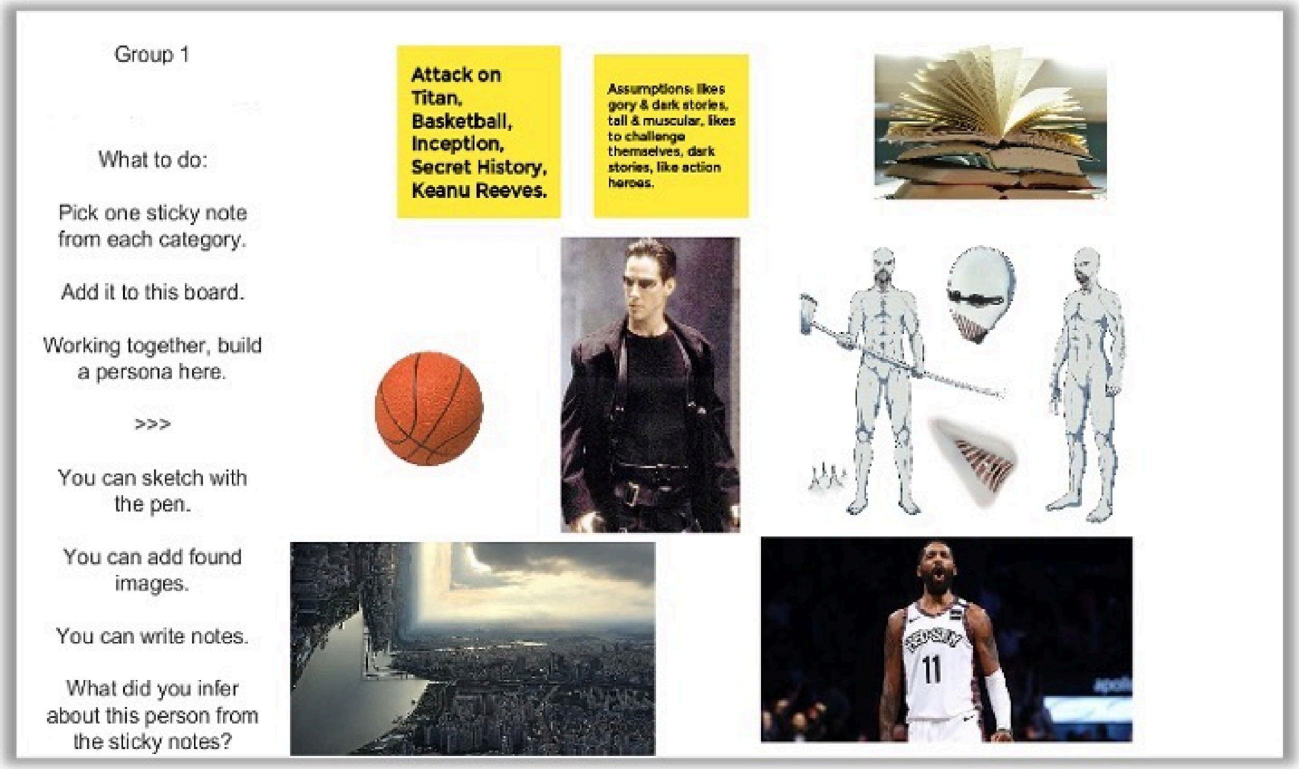

Figure 3. Creative Activity in Jam Board: Algorithmic assumptions made through data. Spring 2021.

Teen Feedback on Data Literacy Activities in the Data Labs

What did we learn about these activities from our teen collaborators? Each week we asked teens to tell us what they liked the most. A content analysis of their answers shows that teens preferred (and recommended for other teens) data literacy activities that were interactive, hands-on with data, allowed for brainstorming, and offered an element of design. In an exit survey at the end of the Fall 2022 series of Data Labs, teens were asked to rank their favorite data literacy activities. The top four activities were interacting in chat and breakout rooms in Zoom, and brainstorming (either talking together or using visualizing tools like Jam Board; see Figure 4). Collaboration and connectedness were the driving themes.

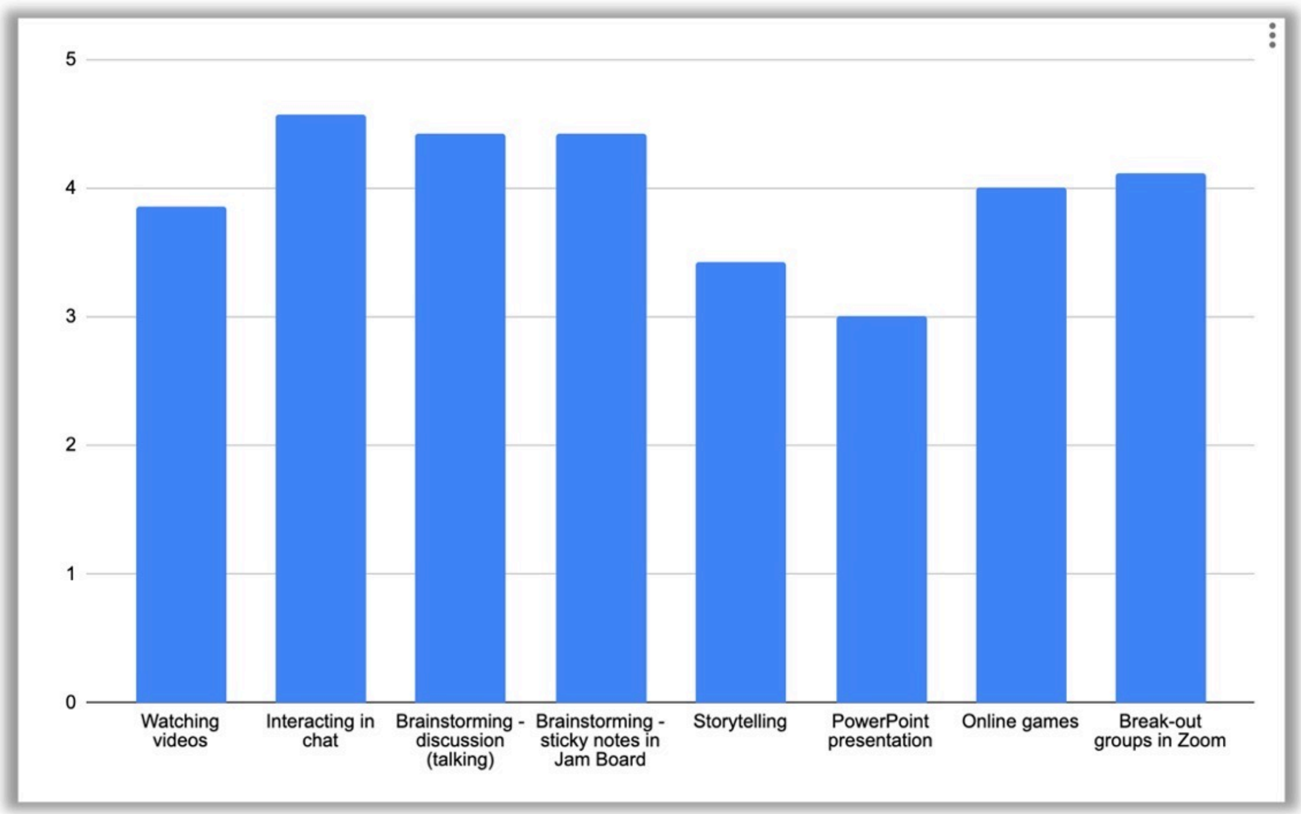

Figure 4. Preferred data literacy activities. Data Labs, Fall 2022.

When asked what they thought the most important thing that librarians should keep in mind when planning data literacy activities, teens elaborated on interactivity and connectivity, stressing the importance of friendship, fun, and unstructured play:

> The most important thing to keep in mind when planning data literacy activities for teens at the library is to remember what activities they already enjoy doing such as playing games online with friends .
> The most important thing to keep in mind is to keep it fun and not too structured .
> I recommend ensuring that they incorporate competition of some sort and make it somewhat social so that they can be with friends/meet new people their age.

Perhaps not a surprise, teens do not want library activities to look like school! So the issue for libraries is to find the sweet spot between the communication of complex STEM concepts associated with data versus the expectations that teens bring to the public library. Overall, the Data Labs created opportunities for critical data literacy, engagement, and co-design through discussion, data activities, design activities, and ongoing feedback. Instances of engagement in activities and the teens' enthusiasm during the Data Labs were helped by building rapport between the teens and adults. Fun conversations, chatting about interests, and forming inside jokes led to more participation and engagement. This engagement in turn led to critical feedback about how to redesign or improve activities as instances of co-design.

We note that, while the overall level of teen engagement with data activities was high and the teens' reactions were generally positive, the online environment of Zoom shaped interactions and relationships in ways that were surprising. Consistent with anecdotal testimony from other facilitators in peer after-school youth programs, we found the teens were unenthusiastic about using their cameras in Zoom. Whole conversations were conducted via chat rather than through talk – teens were evidently more comfortable communicating in a written modality. In contrast, teen input into verbal conversation was often stilted and, at times, constituted no more than 9% of the total audio transcript (meaning that the adult facilitators often dominated verbal interaction). We speculate that chat created a back channel that liberated teens from the traditional expert/novice power roles normally seen in the classroom, where one adult talks and students listen. It is perhaps worth considering the advantages of online conversations for participants who are more comfortable with textual forms of expression. Engaging a wider range of teens with data literacy at the public library might mean facilitating multiple channels of communication, all within a context of playful, creative, and social learning experiences.

Conclusion

With this paper we offer practitioners some starting points for exploring data literacy in online, after-school learning at the public library. Drawing on elements of Connected Learning, the "Data Literacy with, for, and by Youth" project used a variety of digital technologies that offered teens opportunities for playful and creative learning while connecting to their out-of-school lives, interests, and broader learning ecologies.

Including teens in the design process, as was done in this project, was a powerful way to understand the teen point of view, resulting in an articulated list of their likes and dislikes, as well as their own set of designs for future data literacy programs at the library.

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3. Using Paper Circuits in Elementary Schools to Promote Understanding of Sustainable Islands Through STEAM Activities

PAOLA GUIMERÁNS; IVA SON LI; AND MARTA CABRERA

Abstract: Each year, the Research, Innovation and Society Information Canarian Agency (ACIISI) commemorates the "Semanas de la Ciencia y la Innovación en Canarias" (Science and Innovation Weeks in the Canary Island) to promote science and technology throughout the islands. The main objective of this project is to raise awareness of the importance of the Sustainable Development Goals (SDGs) applied in the island context by carrying out a maker challenge. For the 16th edition of this event, we implemented a paper circuit activity to spark ideas for a more sustainable island among participating elementary school students. The one-day "Light up your idea for sustainable islands" event was a maker-based STEAM activity that connected 1,026 students from Fuerteventura and Lanzarote to explore and share ideas regarding more sustainable islands and construct circuits. Our findings indicate that the activity was inspiring for participants, who learned how hands-on activities creating paper circuits can contribute to the development of sustainable ideas. This paper highlights the implications of providing paper circuit activities to promote an understanding of sustainability in island development and enhance elementary school students' interest in STEAM-related subjects. We also discuss some of the challenges associated with implementing paper circuits in school settings using video conferencing tools, as well as future research directions.

Introduction

The Canary Islands are ultra-peripheral regions within the European Union and autonomous regions of Spain, comprising eight islands grouped into two provinces. The economy has faced dramatic changes during the COVID-19 pandemic because the economy of the islands is mono-structured and largely dependent on tourism. In the past, the maximization of incoming tourist flows was the key instrument for economic growth and well-being; however, a more diversified business structure based on an information society will be required for the future. The goal of growing the economy is inextricably linked to the goal of preserving the environment in a sustainable manner, and both are United Nations Educational, Scientific and Cultural Organization (UNESCO) biosphere reserves. Every year, ACIISI—the entity responsible for monitoring progress toward the Sustainable Development Goals (SDGs) in policies related to the Ministry of Economy, Knowledge, and Employment of the Government of the Canary—celebrates Science and Innovation Weeks in the Canary Island (Gobinerno de Canarias, 2020). This event is a program of free in-person and online activities for the islands to promote science and technology. In 2020, the program adjusted to the COVID-19 pandemic reality and combined the online and face-to-face activity formats in safe environments that complied with health standards. With our expertise in STEAM (science, technology, engineering, arts, and math) education, we have been participating in Science and Innovation Weeks since 2015 by proposing and implementing activities for school students and their teachers to promote maker-based STEAM education for economic diversification. As part of the 16th edition of Science and Innovation Weeks in the Canary Island, held in November 2020, we proposed the online maker challenge "Light up your idea for sustainable islands" to promote sustainability awareness in the island context. This study analyzes this maker-based STEAM activity.

Maker-based STEAM paper circuit activity to promote education for SDGs

The development of 21st century skills is a key objective of the SDGs for education systems throughout the world. Such skills will enable citizens to adequately adapt to the labor market and to the future of society. To achieve this objective, the Canary Island educational system has begun to define a new teaching model in which the development of skills related to creativity and innovation are linked to the acquisition of STEAM skills to prepare future generations for the labor market and society as a whole (Allina, 2017; Maeda, 2013). A key aspect of this model is its influence from maker education (Halverson & Sheridan, 2014). Maker education promotes a constructionism methodology (Papert, 1980) and includes not only the teaching of content but also the development of certain skills and types of thinking in broader disciplines, such as computational thinking. This educational method was initially developed by a computer scientist (Wing, 2006) to expand computer problem-solving to other disciplines that can be applied to everyday life.

Paper circuits, also known as soft circuits, have grown in popularity over the past few years due to the emergence of the maker movement, which has provided opportunities to engage students in crafting, engineering, and computing activities (Rosenfeld & Sheridan, 2014). Several scholars have identified project-based learning in the context of paper circuits as a STEAM methodology that engages students in meaningful maker projects (Martínez & Stager, 2013). In education, paper circuits can mean something as simple as making an electrical circuit with a single LED and making it shine inside a pop-up card, but it can also refer to more advanced projects that require programming and involve multiple sensors, sounds, lights, and motion (Qi & Buechley, 2010; Qi & Buechley, 2014 In this sense, paper circuits and similar types of crafting circuits activities such as e-textiles, represent innovative and engaging ways to introduce individuals, particularly young learners, to the principles of electronics and circuitry through hands-on exploration and creative expression (Kafai et al., 2014; Peppler, 2013). One study found that the ability to create and test paper circuits quickly offers a stimulating opportunity to engage students in engineering techniques while also evaluating learning (Tofel-Grehl et al., 2016, p. 51). Another study found that paper circuits kits "provided participants with a limited set of materials that made them comfortable to work with creatively by drawing and crafting. This allowed for self-expression while tinkering with electronics" (Guimeráns, 2012, p.355). In fact, some authors have argued that learning by making crafting circuits favors not only access to the construction of digital media and electronics but also the development of critical thinking (Kafai & Peppler, 2013), intelligence, and creativity through hands-on activities (Lee & Recker, 2018). Other studies have found that the artistic component of soft circuit activities is a particularly appealing and accessible method to engage new and diverse audiences in STEAM fields (Qiu et al., 2013).

Most of today's challenging global issues require collaborations between STEAM disciplines. Thus, this new interdisciplinary approach to learning can be used toward the education for sustainable development objective of the SDGs (UNGA, 2015). Like other countries in the United Nations, Spain has committed to promote the SDGs and Education for Sustainable Development (ESD; Rieckmann, 2017), and promoting STEAM education has been established as an educational priority in Spain (Medina et al., 2021). This paper examines whether paper circuits are effective tools for educators to use to promote STEAM in the classroom.

Research Questions

Based on STEAM education practice and paper circuit kits for sustainability education, this study attempts to answer three research questions: 1) How much have students learned about sustainability as a result of the maker challenge? 2) What kinds of behaviors do students exhibit during the video conference session, such as problem-solving, collaboration, confusion, etc.? 3) How do students perceive these activities as supportive of their future careers and contributing to equity in STEAM?

Methods

Research during the COVID-19 pandemic has been restricted due to limitations of physical contact. This study leveraged videoconferencing for the qualitative research component (Boland et al., 2021) to observe children's interactions and engagement with the kits, peers, and teachers. Semi-structured interviews with teachers were conducted, and teachers were asked to fill out surveys.

Instruments

For the "Light up your idea for sustainable islands" activity, 1,026 kits were created. The purpose of these kits was to serve as a tool for participants to better understand the SDGs. Each student was given an individual kit in accordance with COVID-19 prevention guidelines in the centers, and the students were not allowed to share materials. All videoconferences were conducted through Zoom, also known as Voice over Internet Protocol (VoIP) or mediated technologies (Archibald et al., 2019).

Participants

A total of 1,026 students from Fuerteventura (n = 526) and Lanzarote (n = 500) in Canary Islands, Spain, aged 9–12 and in fourth to sixth grades participated in a maker challenge to learn and share ideas for more sustainable islands. In total, 12 primary schools from Fuerteventura and 10 from Lanzarote participated in the challenge. A total of 22 schools with 22 teachers interacted virtually in real time and chatted with each other during the challenge.

Procedure

Phase 1: Design, distribution, and dissemination

This project was designed as a maker activity for students to learn how to build an electronic circuit and acquire knowledge of basic electronics and manipulative skills, such as drawing, cutting, and gluing. Participants worked on their fine motor abilities through hands-on activities as they tinkered and discovered how to turn on the LED. Activity kits were supplied to each participating teacher to distribute to each of their students. The kit consisted of a template, 3V battery, copper tape, LED, and a metal clip. The purpose of these kits was to serve as a tool for participants to better understand the SDGs.

Phase 2: Virtual teacher training

Before carrying out the challenge with the students, teachers participated in a Zoom session conducted by the researchers to learn about the activity and learn how to create a circuit on paper. This time was used to discuss the SDGs in the local environment and to explain the importance of integrating activities into the classroom that allow students to reflect on the SDGs. During this training, all teachers completed their circuits on paper and were pleased with the challenge. The majority were surprised by the novelty of the activity. At the end of the training, teachers were provided with a link to more information about the challenge.

Phase 3: Virtual student challenge

To participate in the challenge, all students were asked to have a computer, screen, speakers, and internet connection to follow the video conference and interact with the speakers. A total of 22 schools were connected to interact in real-time through chat during the challenge. The challenge began at the scheduled time, but one school was unable to connect due to technical problems.

First, the researchers spoke to the students about the importance of the SDGs. Then, the students were sketching their ideas on sustainable lifestyle on their islands (Figure 1, left) and making a light-up 3D house card (Figure 1, middle). Most of the educational materials for the SDGs depict green landscapes that may be difficult to understand for a school population that lives in an arid island climate. For this reason, the kit included a color illustration of the application of the SDGs in a landscape similar to the islands. For example, a depiction of the water cycle included desalination of seawater and renewables and recycling integrated into the typical architecture of the island. Subsequently, the students were asked to reflect on the SDGs for 5 minutes and draw their ideas about how to make the island more sustainable. Participants were encouraged to reflect on the importance and responsible use of sustainable resources, as well as how those resources are produced and reach their homes. At the end of this activity, students were given an opportunity to "light up" their ideas and reflections. The maker's challenge was to build a circuit on paper using the materials in the kit. Students showed how they had turned on their circuits on the Zoom screen (Figure 1, right).

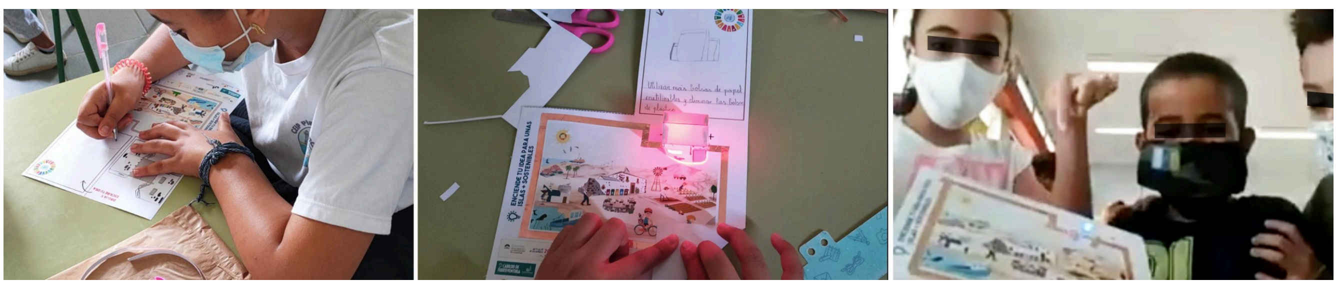

Figure 1. Students building and lighting up the circuit and sharing on Zoom

Students were invited to reflect on what happens when the energy of the battery is used up. We encouraged them to recycle the 3V batteries and to think of an alternative energy source, such as solar panels or rechargeable batteries, to use in this activity. Finally, the teachers provided photos of the challenge in a shared photo gallery.

Data collection

Survey responses were collected and semi-structured interviews were conducted with teachers after the student session. Zoom videos were recorded for all interview sessions. Teacher and student focus groups and interviews were audio recorded, and field notes were made during observations. The types of data collected include open-response survey questions, focus group interviews, and videos, which were transcribed by the researchers. All data sources provided rich information for the case study. The next section of this paper discusses conducting qualitative data analysis using video conferencing tools.

Results

Making an electrical circuit on paper was a novel and enjoyable way for students to learn about and reflect on sustainable development and conduct investigations into concepts at the intersection of art, science, and technology. Students developed a basic understanding of electricity and were asked to create an electrical circuit on paper to demonstrate how electricity is transmitted. In addition, 22 teachers responded to 10 survey questions. Questions 1–6 included an evaluation of the teacher's experience in the study. Overall, teachers were very satisfied (95%) or satisfied (5%) with the building circuit activity; very satisfied (82%) or satisfied (18%) with incorporating drawing components to discuss the SDGs; very satisfied (82%) or satisfied (18%) with the pretraining for teachers; very satisfied (90%) or satisfied (10%) with the materials in the project kits; very satisfied (82%), satisfied (5%), or neutral (13%) with the student challenge session; and very satisfied (72%), satisfied (14%), or neutral (14%) with the Zoom experience.

In questions 7–10, teachers were asked about specific elements of the activity process. Teachers responded that they liked the "Light up your idea for sustainable islands" framing extremely (90%) or very much (10%). They reported extremely (95%) or very much (5%) believing that students were motivated by the proposed activities, and they observed that students were extremely satisfied (73%) or very satisfied (27%) with their participation in the 1,000 paper circuits for an island challenge. Additionally, 100% of teachers emphasized the importance of the pretraining session for teachers. Teachers' key observations and feedback included the following:

Teacher 1: We appreciate that we have helped students begin to reflect and think of new options to improve the sustainability of the islands and learn about SDGs.

Teacher 2: We believe that this activity has been innovative and has made visible maker activities that many centers were not aware of.

Teacher 3: The students were overwhelmed at times and being able to solve their doubts with one person alone was a bit complicated. Even so, I am very happy with the activity and the students too.

Teacher 4: We observed a high degree of satisfaction in the students, who were attentive and successfully completed the task. The result showed a 100% attendance rate and 100% completion of the tasks among attending students.

Discussion

The key results of the qualitative assessment, which involved observing the students during the activity, are presented below. Overall, the students helped or mentored each other when peers around them were having a difficult time with circuits.

1) *How much have students learned about sustainability as a result of the maker challenge?*

Students were informed about how to connect what they learned during the session with their environment. For example, water is the primary energy source in Fuerteventura. Students learned that the islands are a small territory that heavily relies on the sea for water, rather than rain. This lesson emphasizes the importance of saving water cost and usage and the importance of renewable energies and a circular economy. Students were very motivated to share their ideas, drawings, and final projects with connected schools on the two islands. At the end of the session, students were able to discuss the island's water crisis and the significance of conserving energy to improve long-term sustainability. Students were aware that the goal of the exercises was to help participants better understand global issues related to the SDGs. Some of the students were able to conceptualize solutions for a more sustainable lifestyle. One student wrote, "That is a machine that takes the plastic and converts it to trees" along with his drawings. Another student added a note to his drawing that said, “This machine absorbs pollution, for example, if you throw plastic bottles into the sea, it collects them” (Figure 2).

Figure 2. Students’ drawings in response to SDGs

During the maker challenge, children learned how to light up their ideas and gained knowledge of basic electronics and manipulative skills. This activity was appropriate to develop students’ critical thinking and creative thinking skills and to encourage them to reflect on their understanding of sustainability in developing the island.

2) *What kinds of behaviors do students exhibit during the Zoom session, such as problem-solving, collaboration, confusion, etc.?*

Based on our naturalistic observation and field notes, the students became fully involved in the task, and hits and misses were quickly resolved individually or by asking classmates for help. Numerous students excitedly shared their final projects by showing them to the cameras, repeatedly saying “Look at mine!”, and students in other schools were able to see and share these moments. These activities were new and exciting because they involved simultaneous interaction with students from other schools; therefore, students paid close attention and followed the researchers’ and teachers’ directions to build the light-up house. We also observed tutoring moments. For instance, when one student was having trouble working with a paper circuit, another student offered to help him after finishing her own. We observed that these actions of collaboration and communication offered students an opportunity to discuss and practice conflict resolution and work together in a school atmosphere. In fact, the virtual collaboration that took place between the institutions via Zoom was an essential component of this study because the affordability of this approach reduced the travel cost for teachers and students and enabled flexible scheduling.

3) *How do students perceive these activities supporting their future careers and equity in STEAM?*

Traditionally, in the West, technology has been associated with masculinity (Ortner, 1972). In fact, circuit building has traditionally been associated with STEAM education. In this activity, rather than a traditional approach to learning about electricity, all students had the opportunity to enhance their understanding of electricity through a maker-based STEAM activity. Inclusive language was used (e.g., “los ___” instead of “las ___”) throughout the sessions to ensure that all students felt comfortable and included in developing solutions to protect their own island through drawing, the maker activity, and discussion. Regardless of gender, student participants demonstrated technical mastery by correctly completing their circuits and expressed satisfaction with the activity. When drawing solutions, students were able to think for themselves and generate reflection and creative ideas connected with the reality of their local environment. Promoting a growth mindset or developing a maker mindset has a tangible connection to real-world professions and widens students’ perceived options for the future. STEAM education is necessary to inspire and empower children growing up in these islands to be exposed to a variety of career options and understand future opportunities linked to sustainability in the Canary Islands.

Conclusion

The study was implemented using a cost-effective large-scale workshop delivered via videoconference (Zoom) to demonstrate an innovative didactic approach. New tools and materials were incorporated and inclusive language was used to break traditional stereotypes of the STEAM field. The local perspective on the SDGs implemented in the development of the workshop materials and the use of gender-inclusive language emphasize the importance of everyone's involvement in the sustainable development of the islands. The results of this study also highlight the potential of paper circuit activities as an effective approach to promote students' learning about electronics and creativity. In this activity, participants felt intrinsically motivated to build circuits with the atypical materials provided because they were able to create their own designs. Finally, maker activities provide students with the opportunity to acquire scientific and technological knowledge through practices that make learning more appealing. These activities empower students to expand their ideas of future STEAM career options that will enhance the sustainability of the islands.

Future Directions

After the workshop, the research team and teachers discussed potential steps for future directions. First, initial training sessions for teachers are essential to maintain consistency throughout the workshops in different schools. Second, offering multiple sessions rather than one-day challenges would help students more deeply understand the situation of the islands. The workshop activities could be improved by allowing students more time to work, either through a single longer session or multiple sessions. Third, it would be optimal to use recyclable batteries or solar panels in future workshops to promote sustainable living. Finally, the built-in secure recording feature of Zoom demonstrated considerable potential for qualitative research, and this solution could be particularly effective with small groups because it could provide more thorough transcriptions. We consider STEAM education necessary for students in the Canary Islands to feel empowered and challenged to perceive the world differently and play a part in making the islands more sustainable. The aims of this study were to support students in the Canary Islands in understanding their habitats and economy from an SDG perspective and to engage students in a STEAM-based maker activity.

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4. Unlocking Hidden Rules of Office Hours

A Game Jam on the First-Generation College Students' Experiences

MATTHEW FARBER AND WILLIAM MERCHANT

Abstract: Office hours can be a positive experience, a time for students to connect one-on-one with instructors, where mentorship opportunities arise, and when meaningful relationships can flourish (Nadworny, 2019). However, some college students, such as first-generation populations, may be unaware of these opportunities (Jack, 2019). This case study engaged participants to design interactive game systems on how first-generation students perceive and experience office hours using the open-source online tool Twine. Data, including game artifacts and survey responses, were analyzed through the Elements of Connected Learning, specifically, how game jams harness participants' interests, opportunities, and relationships. Research questions guiding this study included: What themes emerge from the student-created game jam artifacts? What were the students' experiences and perceptions in participating in the game jam? How do students perceive the final game jam product? How do students perceive a game jam as an approach for harnessing students' voice? Findings suggest that Twine game jams can be used to teach hypertext coding skills but also as an approach to surface how undergraduate students make meaning of the systems they must navigate in college. When constructed as student-authored games, these systems appear to have hidden rules, particularly for first-generation students.

Introduction

For some college students, office hours may be viewed as a time to visit professors or instructors only when grades are falling or absences are excessive. However, office hours can be a positive experience to connect one-on-one with faculty. Office hours can also be where mentorship opportunities arise and when meaningful relationships flourish (Nadworny, 2019).

College office hours can be intimidating (Nadworny, 2018; 2019). Some students may feel a sense of intimidation when meeting one-on-one with college professors (Jack, 2019). Further, students may simply be told when and where office hours occur without any explanation beyond a syllabus statement about what they are (Guerrero & Rod, 2013; Jack, 2019). As a result, there may be a "roadblock to inclusion and belonging, one that impedes access to places where connections are made, bonds are forged, and information is shared" (Jack, 2019, p. 84).

At the university where this study took place, the university has a policy for office hours. Some, but not all, colleges, schools, and departments within this university have policies. The university's policy does not detail the purpose of office hours. The board policy of the university where this study took place states:

> All instructional staff members whose responsibilities involve students are expected to schedule a reasonable number of office hours for student conferences. Office hours should be scheduled at times convenient to both students and instructors with the additional option of prearranged appointments for students when there is a schedule conflict. The number of office hours is to be determined at the appropriate administrative level, and office hours should be a matter of common knowledge.

In some universities, office hours are "rarely defined, and many students have no idea how important they are beyond their stated purpose" (Jack, 2019, p. 83). Thus, expectations of office hours may remain hidden (Jack, 2019; Nadworny, 2019). This can be exacerbated with first-generation populations of students, those who are the first in their families to enter a four-year college degree program ("Defining First Generation," 2017).

In this study, researchers organized a one-day game design event, inviting students to reconstruct their experiences navigating office hours. This study aimed to surface how students view and understand office hours through game design. Tools used to design games can be used to share and self-express lived experiences, particularly in how games can model how systems interconnect and inter-react (Dishon & Kafai, 2020; Schrier, 2019).

Using a qualitative case study design, we examined three primary research questions. By designing games themed on college office hours experiences, we analyzed:

1. What themes emerge from the student-created game jam artifacts?
2. What were the students' experiences and perceptions in participating in the game jam?
3. How do students perceive the final game jam product?
4. How do students perceive a game jam as an approach for harnessing students' voice?

Theoretical Framework

This study sought to understand the lived experiences of first-generation college students when navigating the hidden rules of office hours. The theoretical foundation for this study was built on the Elements of Connected Learning, a model that includes three components—interests, relationships, and opportunities ("About Connected Learning," n.d.). The Elements of Connected Learning stem from interest-driven and peer-supported practices found informally outside of schools, such as in online communities of practice, libraries, and museum spaces, and sometimes in formal settings, such as schools and college classrooms (Ito et al., 2013).

Connected Learning can harness digital media learning "to more easily link home, school, community and peer contexts of learning; support peer and intergenerational connections based on shared interests; and create more connections with non-dominant youth, drawing from capacities of diverse communities" (Ito et al., 2013, p. 4). Further, Connected Learning can increase youth's "access to knowledge, providing timely feedback and individualized learning experiences, and connecting youth to a network of individuals who have expertise in an area of shared interest" (Davis & Fullerton, 2016, p. 98).

The Elements of Connected Learning have been applied in game-based learning and design settings. For instance, Quest to Learn, a school in New York City, is guided by the Elements of Connected Learning and a "game-like" teaching philosophy (Ito et al., 2013, p. 35; Ito et al., 2019). Since its inception, the school has developed to include more opportunities for student game production, which is also project-based in its pedagogical approach (Kafai & Burke, 2016).

Method

We used case study methodology to develop a list of elements and common themes that could then be further empirically studied. One of the primary goals was to amplify first-generation student voice around navigating the hidden rules of office hours.

Data were collected during a one-day game jam event, in which artifacts produced by participants as well as field observations and participant feedback through share-out sessions were collected. A game jam is a "rapid prototyping event that typically takes place over a few days or a weekend, where game developers are given a theme and need to develop a game within the time frame" (Schrier, 2019, p. 4). Game jams also can present multiple entry points; one team member may be interested in narrative design, while others may focus on aesthetics.

The game jam was hosted in a classroom at the university's main library on a Saturday in October 2021. All data were anonymized for the purpose of research. Specifically, we analyzed narrative content created from the game jam, direct observation of game jam activities, and a post-game jam survey.

Each participant worked individually to code hypertext games using Twine, a free and open-source interactive fiction writing application. In Twine, both text and hypertext are visually represented as square nodes connected by lines. Each node is coded to connect and interconnect according to hypertext rules, which presents itself as choose-your-own-adventure sections of a narrative. Twine translates passages on a web browser; subsequent web pages do not exist until (or unless) the player interacts with hypertext, thus creating the story as they click, mouse over, or otherwise provide input.

At the game jam event, participants first played a curated set of hypertext games and then were led through a brief lesson on authoring hypertext fiction. The curated games included the horror fiction game *the uncle who works for nintendo* and the semi-autobiographical depression and social anxiety simulator, *Depression Quest*. A discussion was also led on the emotional affordances of hypertext fiction. Participants were shown how hypertext fiction could afford player emotion, such as limits of choice and agency, the strength of a narrative, and the convention of writing in the second-person voice ("you") to draw the player into the narrative. The use of the second-person voice is a convention of interactive fiction writing that began in the 1980s (Hoffman, 2019; Salter, 2016). Ideas also discussed included the importance of strength of narrative that led to player choice, multimodal aesthetics that may enhance the written narrative (e.g., font, color, embedded images, video, and sounds), and how constraints in player agency can deliver a message or moral to the player (Salter & Moulthrop, 2021).

Data Analysis

The game design artifacts were coded and analyzed for a deeper understanding of youth's lived college experience, the systems that impact their lived experience, and their ability to express and experiment with those systems through the process of game design. Additionally, basic descriptive statistics of game jam preferences and participants' perceptions were recorded in a post-game jam survey. Data were analyzed through the Elements of Connected Learning.

Findings

This section shares findings that are descriptive and presented separately by each participant's artifact and response. The case studies are explanatory, meaning that each is descriptive and illustrative. Explanatory case studies "explain how or why some condition came to be" (Yin, 2017, p. 287). After analyzing each, a thematic analysis is shared in the Discussion section.

Participants

Participants (n = 6) were recruited from a scholarship and support program that prepares educators skilled in culturally and linguistically diverse practices within a college of education located in the Mountain West region of the United States. Participants were undergraduate students. Not all members of this program were first-generation students; according to the program's director, many members are, or they likely work alongside peers who identify as such.

We had an open recruitment with this program, then asked participants to enter their demographics in a survey that resulted in 50% self-identifying as first-generation students and 67% as Latinx. All participants selected yes to at least one of these characteristics. The participants were also evenly split between first- and third-year class standings.

Upon conclusion of the game jam, some participants gave written permission to be de-anonymized to have authorship credit for publishing games beyond this study. Participants also consented to the stories being shared for research; one voluntarily shared further details in an article published by the university.

Each game is shared next, followed by a brief synopsis of each game's narrative and participants' post-survey response. Names were removed to preserve anonymity. Findings are sorted by the name of each published Twine game artifact that the participants individually produced.

Office Hours at Clormine Academy. This game (https://gamingsel.itch.io/office-hours-at-clormine-academy) explores anxieties and fears related to how a professor may judge a young student, time management decisions, and other topics based on being a "rookie" in his fantasy-based school of wizardry. Some themes that emerged were making possibly embarrassing mistakes such as entering an incorrect classroom, misunderstanding an assignment and syllabus, and not being able to find a professor's office. Ultimately, the final interaction with the professor the participant has been searching for is unexpectedly pleasant, indicating that his fears around the encounter were unfounded and not necessary.

When reflecting on his experience creating the game, this participant noted his enjoyment of developing the story. Additionally, he enjoyed the fact that he felt as though he was learning "coding" as many of the elements of the game, such as decision options, images, and sounds, require text-specific prompts and symbols within the Twine hypertext system. This participant's only stated criticism was the wish for more time to develop the story and added multimodal elements.

Office Hours at UNC. This game (https://gamingsel.itch.io/office-hours-at-unc) began with a reflection on the participant's status as a first-generation student and "knowing nothing about college life." The character in this game is struggling with homework and decides to attempt to visit her professor during office hours. Difficulty finding the office, fears around interrupting the professor, and "asking for too much help and looking stupid" were some of the main challenges in the narrative. How the player responds to these issues results in largely two outcomes, attending office hours, receiving help, and passing the class or giving up, not attending class, and failing.

This participant's self-reported favorite part of the game jam event was creating her game, which she said was a "fun and good experience" that could be used in other educational scenarios. The participant also would have liked more time but also appreciated that it was an activity that didn't take up the whole day.

Office Hours Conflicts. The narrative of this game (https://gamingsel.itch.io/office-hours-conflicts) included confusion in navigating campus buildings. There was also an emphasis on the interpersonal interactions between students and professors. Noting many potentially awkward situations such as not knowing if she should knock on the office door or just enter, not having a place to sit, and being invited to use a chair full of papers. This participant made extensive use of animated GIFs and audio that added to the senses of anxiety and relief as her character made her way to the professor's office, concluding with an unexpectedly positive interaction.

When reflecting on her experience with the game jam, this participant noted that the most challenging part was thinking up a story. The reported favorite part was incorporating visuals into the design. She self-evaluated her final product as "super cool" and also appreciated the "coding" aspect of the process.

The Quest for Office Hours. This participant's game (https://gamingsel.itch.io/the-quest-for-office-hours) took a look at first-year college experiences in the shape of a school for wizards containing many fantastical academics such as "Professor Fizzwhip: The snarky and intimidating potions master" and "Professor Quill: The knowledgeable magical historian who drones on and on in a monotone voice." According to the rules in the story, the player's character must meet with all of the school's wizards within one week. Each wizard had a unique storyline in the game. The Twine included embedded GIFs to express some content, such as being lost in confusing buildings and finally entering the faculty's office.

In the post-survey, this participant noted that time limitations of the game jam became an issue and that at least an extra hour in order to add a layer of audio to the game was desired. As a student in the teacher education program, the participant noted the "value in game jams" for her future classroom. She stated, "Twine can engage students in crafting rich narratives and even be used as tools for reviewing concepts."

Tiny AI on Campus. This game (https://gamingsel.itch.io/tiny-ai-on-campus) began with the player receiving an email about being eligible for a scholarship program that jumped from the emotion of excitement for the possible opportunity to the emotions of anxiety about the interview, frustration with technology, and relief upon being accepted. Upon arriving at college for the first time, she expressed the emotions of leaving her family and the excitement of participating in activities provided in the first weeks of school. She bonds with similarly confused first-time students and finally is faced with a range of activities to decide between (see Figure 1). Ultimately, all options result in a looped narrative where all outcomes leave the student feeling "overwhelmed."

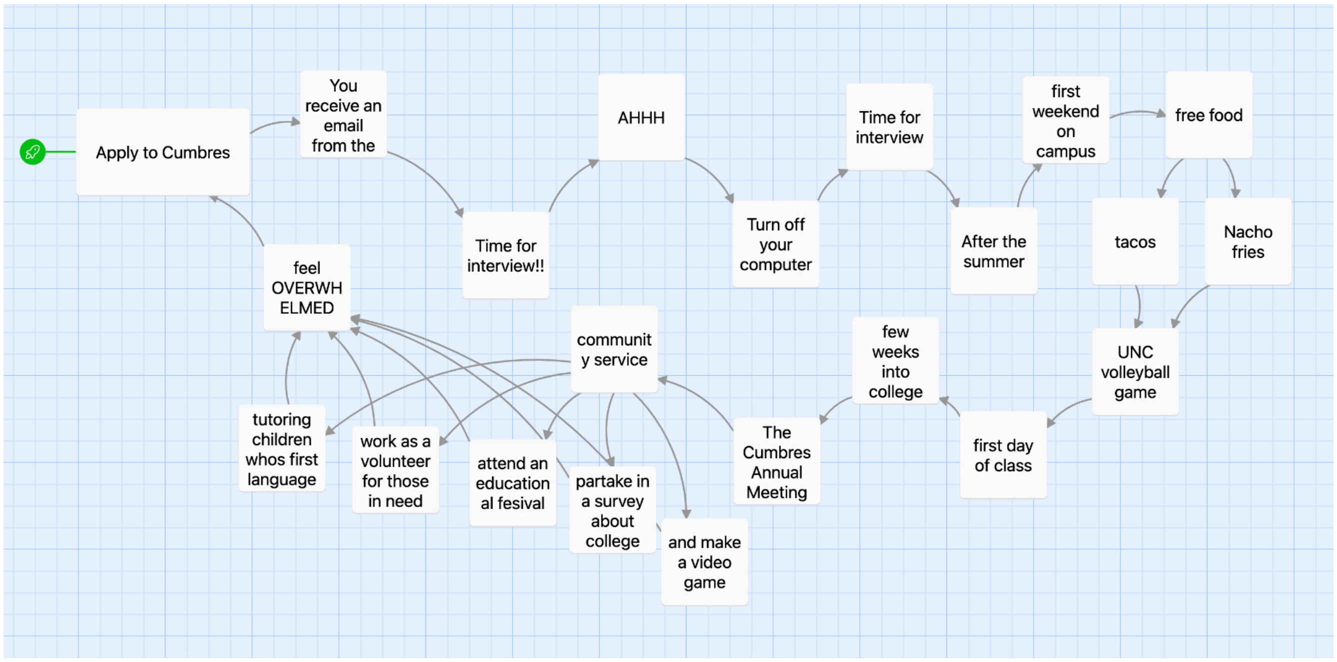

Figure 1. Screenshot of "Tiny Al on Campus" Twine screen

The participant mentioned in the post-survey some frustration with the detail-oriented aspects of the game jam. This participant also desired additional time, which might have allowed her to develop her story more to include options to change characters and have "side challenges/side stories." Ultimately, this participant reported enjoying becoming proficient with the Twine platform and saw game jams as a more interesting "storytelling event."

After the game jam, this participant was contacted by the university's news and media department for an article covering the event. With participants' consent, the researchers contacted the news and media department. The participant report in the article is shared here as additional data. She stated,

> I've been to my advisors' office hours a couple of times, so I kind of incorporated that in my game. I really enjoyed it. It started as a blank slate, and you start writing passages of what you want in the game, then you hit enter, and it incorporates it, and then it keeps the flow of the game going.

Office Hours. In this game (https://gamingsel.itch.io/office-hours-unfinished), the narrative began with the player entering college, wondering how different it might be from high school. The player is failing some classes and is faced with the options of dropping out, reviewing course materials, or getting help from her roommate. Each option begins to lead to alternative storylines but most end unfinished.

Unfortunately, in the process of saving the first game draft, this Twine was accidentally deleted, and the participant needed to start over after much of the game jam had already transpired. Besides this technical problem, this participant reported in the post-survey that she enjoyed and was most challenged by coming up with a story she thought others would like to play through.

Discussion

After analyzing each game produced by participants, common content themes emerged in the findings. This section discusses themes that surfaced across each game and about the game jam event itself, all shared through the lens of the Elements of Connected Learning.

First, the narratives led players to intentionally feel confused about what to do. For instance, some games gave players conflicting sets of instructions on how to navigate college from different faculty characters in each game. Other games led players to possibly feel awkward or embarrassed by the inability to navigate college or office hours. In the games, the narrative often included passages about students fearing professors who might be mean or possibly unforgiving. However, the narratives often shifted to sharing how professors are actually compassionate to new students.

The game jam itself afforded opportunities for participants to author narratives on their own experiences. In some cases, narratives may have been rooted in a sort-of self-study. Two of the games, *The Quest for Office Hours* and *Office Hours at Clormine Academy*, featured wizards-as-students, storylines not unlike the fiction in *Harry Potter* novels. Like fanfiction writing more generally, the game jam itself became an opportunity for these interests to manifest as interactive hypertext fiction (Ito et al., 2019).

The game jam event itself afforded opportunities for interests but also for relationships to develop. Regarding the relationships, one of the participants stated that she would take part in another game jam, "calling it a fun way to learn about technology." She continued, stating, "especially since the pandemic, I think a lot of kids of all ages are now learning off of technology, and for my generation, we grew up on technology, so I think exposure to it is fairly vital just because that's what's out there in the real world."

In the post-game jam survey, many participants expressed that they desired more time to develop their games. Although the event itself was scheduled for five hours on a Saturday, and game jams are often brief experiences, limits of time were a consistent response. Other responses included an appreciation of the process itself as an approach to learning hypertext coding and storytelling as a possibly valuable classroom tool.

Conclusions

The purpose of this study was to give students an opportunity to reconstruct their experiences navigating office hours, which is part of the college experience. As a game design tool, Twine was not used for teaching hypertext coding or hypertext language but as an approach to harness self-expression.

Our findings suggest that game jams can be used to teach hypertext coding skills but also as an approach to surface how undergraduate students make meaning of the systems they must navigate in college. Students were procedurally able to reconstruct the systems that they navigate in college. When constructing player-driven hypertext games, systems appeared to also have hidden rules, particularly for first-generation students.

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5. Connected Learning to Engage Elementary Students in Data Science

DANIELLE HERRO; 'JOBA ADISA; AND 'DARA ABIMBADE

Abstract: This paper details a research-practice partnership (RPP) between an elementary school and learning science researchers from a nearby university with a common goal of increasing data science literacies among rural elementary students. Drawing on connected learning and using the CT-STEM (computational thinking–science, technology, engineering, and math) taxonomy of practices (Weintrop et al., 2016) we co-developed data science units that teachers subsequently implemented in their classrooms. Connected learning was used to envision the units and provide more equitable learning for students. In that regard, we worked with teachers to draw on students' interests when selecting relevant, real-world problems to solve during the design of data science units, and to provide learning opportunities mirroring what students enjoy and engage in outside of school. Qualitative methodology guided the data collection and analysis of observations, teachers' reflective journals, interviews, and curriculum artifacts. In this paper, we focus on three of seven primary themes describing the teachers' approach when co-designing and implementing relevant data science units. Our research assists other elementary educators in considering ways to increase data science literacies in meaningful, impactful ways for students.

The Importance of Data Science in Our Daily Lives

Data science is an important STEM (science, technology, engineering, and math) literacy helping people make informed decisions in their daily lives. Data skills and practices assist people of all ages to better understand risks (e.g., exponential spread of disease, getting the best rate for a loan, decrease in pollinators) for individuals and the larger society (National Science and Technology Council, 2018). Developing this literacy at an early age is important to foster long-life analytical and problem-solving skills, yet limited research exists on data science teaching practices at the elementary level to guide educators (National Science and Technology Council, 2018). In part, this is because advancing STEM-related skills in elementary schools is difficult as teachers are required to teach subjects outside their preparation, have limited technology support, and may struggle to integrate and implement STEM-related computer science and engineering standards (Yadav et al., 2016). Data science is rooted in investigating "data collected from social and environmental contexts in which learners often find themselves deeply embedded" (Wilkerson & Polman, p. 1, 2020). It requires skills like computational thinking (CT), which harnesses the power of computing to decompose problems and analyze data towards solving open-ended problems, yet CT is also new to most elementary curricula and not widely studied (Shute et al., 2017).

The growing need for data science education led to the development of initiatives aimed at training teachers to integrate data science concepts into their curriculum and enhance students' data science literacy skills. For example, researchers at Stanford University developed an online program to facilitate K-12 teachers' understanding of data science concepts and provided supporting strategies for integrating these concepts into their classrooms (https://www.youcubed.org/data-big-ideas/). A separate Introduction to Data Science (IDS) program led by the University of California Los Angeles provides professional development (PD) to support local high school teachers' integration of data science practices such as data analysis and interpretation, statistical modeling, and CT into their mathematics classes (https://www.ucladsec.org/ids-in-the-media). While important, the curricula are not typically developed collaboratively with teachers and may not address specific needs of the students or fully consider the context of the community (e.g., available resources, locally important issues).In sum, data science education is crucial for the health of society, yet the impact of data science education on learning among elementary-aged students remains largely unexplored. In this study, we worked with rural elementary educators to co-create an integrated data science curriculum centered around developing interest-based topics and activities for students.

The Need to Increase Data Science Education in K-12 Schools

The increasing reliance on data and computing in everyday practices necessitates developing literate citizens who can work with data and algorithmic computational methods beginning at an early age. However, data science education for young learners, especially elementary and middle school children, rarely prepares them for this societal need (Kjelvik & Schultheis, 2019). Elementary learners acquire little to no experience with data science and usually arrive unprepared to deal with computational problems when at higher levels of education (Martinez & LaLonde, 2020). Studies have attributed this to students' infrequent engagement with data (Lee et al., 2021), abstract mathematics curriculum (Finzer, 2013), or teachers' lack of data science preparation that hinders their ability to integrate data science practices into their lessons (LaMar & Boaler, 2021). These literacy practices include data collection, aggregation, sorting, and classification to make data-based decisions. However, creating and implementing effective data-rich learning environments can be complex and requires collaboration between researchers, the computer science community, and educators. Including data science as another subject is not always feasible with busy teaching schedules. Because data science cuts across all disciplines, rather than creating data science as a separate subject in K-12, it makes sense to support teachers in assisting learners to develop data skills across several disciplines. Effective practices include using digital computational tools, making data more accessible, and helping learners easily manipulate and visualize data (Finzer, 2013). Supportive resources such as PD, digital environments, curricular materials, and communities of practice are needed to successfully integrate data science into K-12 education (Martinez & LaLonde, 2020).

A Framework Teach Data Science

To help educators identify how to approach teaching data science and computational practices, researchers offer several definitions and frameworks (Grover & Pea, 2013). Weintrop et al. (2016) proposed a CT-STEM taxonomy of practices to help define CT for math and science and assist researchers and educators to focus on the application of data and computational practices in STEM areas. The taxonomy was created by analyzing interviews with STEM professionals to identify existing real-world instantiations of CT and related practices, and reviewing existing inventories, standards documents, and exemplary educational activities. The taxonomy consists of four strands: data practices, modeling/simulation practices, computational problem-solving practices, and systems thinking practices. In our work with teachers, we primarily used the data practices strand of collecting, creating, manipulating, analyzing, and visualizing data to help them understand the connection between CT practices and data science (see Figure 1).

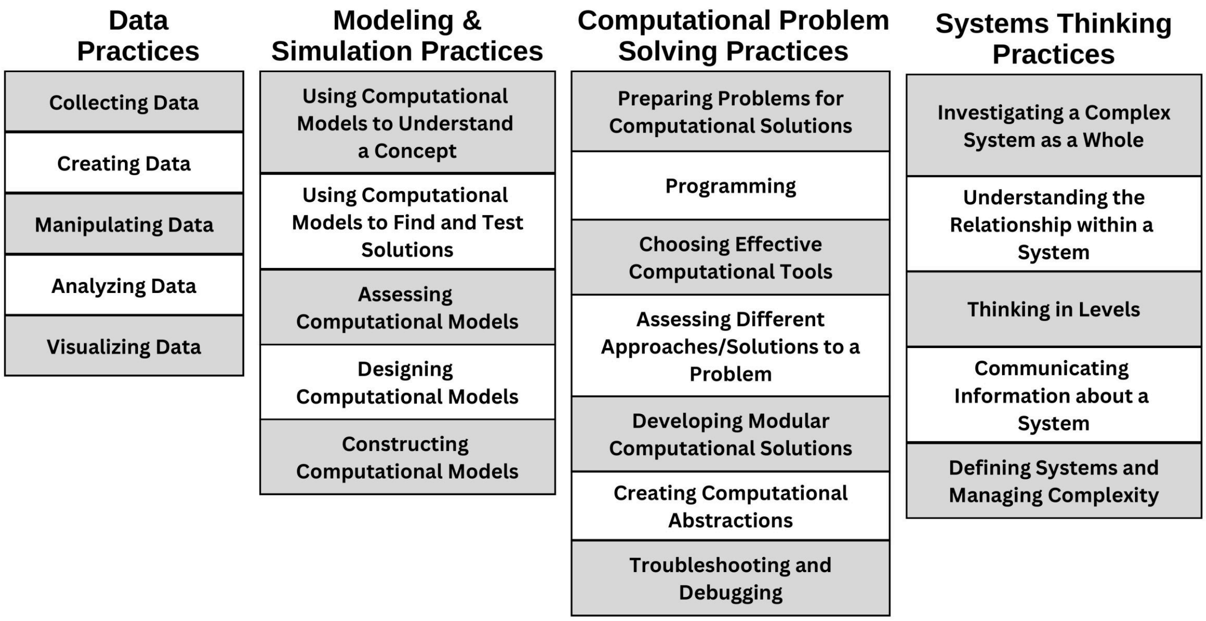

Figure 1. Computational Thinking in Mathematics and Science Taxonomy (Weintrop et al., 2016).

Connected Learning to Guide Data Science Experiences for Children

We envisioned our work using connected learning theory (Ito et al., 2013; referred to as "connected learning") as we believed it could guide ways to ensure more equitable participation, particularly for students not typically involved or interested in data science. Connected learning (CL) suggests effective learning environments draw on personal interests and social support to overcome adversity and acknowledge an individual's contributions (Ito et al., 2013). CL also suggests that learning and interest are linked, and when youth are encouraged to pursue their interests, there are positive outcomes such as academic achievement, career success, and increased engagement. It attempts to address the gap between in-school and out-of-school learning by recognizing diverse pathways to build and express knowledge. In this research-practice partnership (RPP) we purposely collaborated with teachers to create interest-based, locally relevant data science problems to solve and use extension activities (comics, video creation, 3-D modeling, music) to include topics they cared about, activities they enjoyed, and to foster creativity and expression. We also relied on principles of Universal Design for Learning (UDL) to help teachers situate CL in their classrooms. UDL is an instructional framework that supports students with a variety of learning needs (Center on Applied Science Education Technologies, CAST, 2018). UDL provides a framework for teachers to design their instruction to assist students in engaging with and accessing the curriculum, as well as demonstrating their knowledge. It provides multiple means of engagement (e.g., student choice), representation (e.g., text, video, simulations), and action or expression (e.g., writing, drawing, videoing).

Context of our Study and Research Partnership

Cooper Creek Elementary School (all names are pseudonyms) is a public, rural STEM school in the Southeast serving 458 students in prekindergarten to fifth grade. There are 23 teachers, 2 administrators, 2 instructional coaches, 9 specialist teachers (e.g., virtual education, music, physical education), 1 guidance counselor, and 1 special educator. The school's population includes 68 Black students, 86 Hispanic students, 258 White students, and 46 students who identify as multiracial. Of those students, 455 (99%) are free-lunch eligible. The student-teacher ratio is 14.8 students to one teacher.

Our participants include 9 teachers (1 male and 8 females) between the ages of 24 and 45. They taught at the same elementary school in various roles and were recruited by the research team through their principal. The research team has two professors in Learning Sciences, a professor of Quantitative Methods, a professor of Special Education, and three graduate students. As part of a multiyear funded study aimed at offering data science curricula for elementary students in rural populations, we worked with Cooper Creek teachers in Grades 3, 4 and 5, to co-create a data science curriculum for their students. Teachers worked with us during a 4-day intensive summer PD focused on an introduction to data science for young children. We assisted them in identifying student interests and writing data problem scenarios. Teachers were introduced to a simple data science cycle (clean, understand, and communicate the data), engaged in embodied data science activities, used a web-based data visualization tool called Tuva (tuvalabs.com/) to manipulate and explain data, participated in rotating workshops focused on graphic novels/comics, Tinkercad (https://www.tinkercad.com), and video creation to help children further explore data science problems and augment learning activities. Over 4 days, the teachers co-created data science units with our team that were aligned with state standards and included performance-based formative and summative assessments. Subsequently, they taught the units over 8 to 10 days in Fall 2021.

Research Question 1 (RQ1): How does PD supported by connected learning assist teachers in understanding and creating a data science curriculum?

Research Question 2 (RQ2): In what ways is connected learning enacted during the data science implementation?

Methodology

We used basic qualitative research to "understand the meaning people have constructed" (Merriam, 2009, p. 13). It guided our data collection and analysis and assisted in answering our research questions. To that tend, qualitative data were used to understand how the PD assisted teachers in understanding data science literacy, how they created the curricula and implemented the curricula, and ways the process and implementation aligned with CL. Our data sources included: (1) observations during PD to note design choices and challenges encountered while designing curriculum, and during implementations to observe how teachers' used data practices and integrated interest-based, student-centered, relevant activities; (2) reflective journals with prompts completed at the end of each day during the PD and once a week during the implementation process; (3) group interviews to engage in discussions capturing how the PD experience impacted knowledge of data science and implementation practices, as well as potential benefits and challenges of implementing the units in classrooms; and (4) artifacts including each data science unit (see figure 2) and photos to assist in documenting the process.

Week 1:

Day 1	Day 2	Day 3	Day 4	Day 5
Understanding the data problem scenario Activities (1) Google Slides Presentation. (2) Present the data problem scenario (3) Hook (UDL)-Show the first minute of Mr. Beast Adopt a Dog Video-https://youtu.be/YQDDm9HLkV4 (4) Real world connection: Write characteristics of a dog you would like to adopt. (Jamboard) **Toolkit/Resources:** Padlet or Jamboards Share Data Dog Rubric Video https://docs.google.com/presentation/d/1zaoBaShxhnd3ZwTPjdJ36cHX4pPubjnvRNGxN8pPMFo/edit?usp=sharing *** Bring in a vet on this day or Pet Club Leader. Goal: many connections, invested in the scenario, bring in experts/real-world connection	**Brainstorming questions** Activities (1) Google Slides Presentation (2) Introduce the Pop-Up Framework (brainstorm questions, view data set, refine questions) (3) Brainstorm questions - ST will write questions on sticky notes and put on parking lot (4) View data set (in Tuva or spreadsheet) - Here is the excel data set for your lesson - (5) Refine questions - be sure each group has their question that can be answered by data set **Toolkit/Resources:** Dog data set paper/post-it notes or digital Tuva log in - Man's Best Friend Goal: Understanding what questions can be answered with data	**Exploring and visualizing data** Activities (1) Google Slides Presentation (2) Share Google Doc (3) Review scenario (real world connection) (4) Explore/view categorical and numerical variables- excel (5) Build/construct data using human data points. Build Example: explore data to answer your driving question about dog breeds. (Have students create their own data set work) (6) Assign groups to build a graph with assigned variables. (7) Exit Slip - (Write one problem or success that you had.) Jamboard Link **Toolkit/Resources:** Tuva-Man's Best Friend Goal: Embodied/physical ways to understand constructing graphs, how to choose visualizations depending on categorical/numeric variables	**Visualizing Data: Using Tuva** Activities (1) Google Slides Presentation (2) Guided instruction with Tuva (3) Create a new graph using data points in TUVA (4) Create a flipgrid explaining your graph. https://flipgrid.com/3a23fe73 **Toolkit/Resources:** Tuva-Man's Best Friend	**Answering the question** Activities (1) Google Slides Presentation (2) Choose a question from day 2 (3) Make a visualization that answers the question (4) Also research other factors that would play into your data. Why did you choose your data? What traits did you explore? Did you need more data? What did you use? (5) Sources: pebblego, kiddle, discus, discus kids) (6) Exit slip (what visualization did you choose, why? reflection) Padlet link - https://padlet.com/ryanglenn/uj19r98qbdmtmozi **Toolkit/Resources:** Tuva-Man's Best Friend FA https://padlet.com/ryanglenn/uj19r98qbdmtmozi **Assessment Rubric:** https://docs.google.com/document/d/1_SkuDuhlqwXAcl3Yspmp_8_GBfRL8e2NR138JLRTAlw/edit?usp=sharing

Figure 2. Screenshot of Week 1 of co-created data science unit.

Data Analysis

Three members of the research team independently conducted an intensive reading of all qualitative data, creating memos of participants actions and statements (Charmez, 2003) related to understanding and describing the curriculum co-creation process and implementation. Initial, broad patterns in the data we discussed guided a priori and open coding. Data were imported into Maxqda (https://www.maxqda.com/) software for organization and analysis. We used a thematic analysis doing a second reading of the data, beginning with transcribed interviews, reflective journals, and observations, and drawing on the a priori codes from our memos to code and categorize all data and note emergent codes. Data were coded and triangulated across data sources until reaching saturation. Our team met several times to compare and winnow codes, discuss and form categories, and reach consensus (Cascio et al., 2019). The categories were then analyzed and developed into themes. Finally, the artifacts were analyzed as secondary sources to better understand how the teachers created and implemented their data science units.

Findings

Our analysis revealed seven separate main themes that emerged related to understanding the data science process, including making design and implementation choices and considering students' interests and learning. We focus on three themes related to CL; we acknowledge overlap between the themes.

Theme 1: Making the Data Science Process Relevant

All nine participating teachers discussed the effectiveness of using a data science framework and template to help define data science and provide a model to create their curriculum. The teachers believed embedding the data science problem within a relevant scenario where students could brainstorm and refine questions, play with the data, and tell their story would be effective for instruction. They suggested this framework enhanced their own understanding of the data science cycle (clean, understand, and communicate the data), and would likely be appealing to their students if they could connect it to local issues. This was evidenced in discussions and journal reflections where they noted how they learned about data sets to pose a real-world problem and thought it would engage their students. Teachers reflected saying things such as, "I designed a unit that will be interesting to my students by making it relevant/important to them, connecting it to real life, and using a topic that they already enjoy and know some about" and "I loved the framework and presenting materials this way. Kids will love numbers when tied to things they are interested in." In final reflections describing their completed unit, all teachers talked about using their topic (pet adoption, social media, popular music, water usage) to encourage students to explore data, ask questions, use Tuva to analyze and visualize the data, and present their story using a variety of digital options. This quote from Anna exemplifies a typical response:

> My module is designed to have students analyze musical elements from popular songs from the past decade (2010-2019). My students will be acting as music producers and will have to pitch their idea for a hit song to a local musician. Their pitch must be data-driven and their conclusions on what makes a popular/successful song will be drawn from the data of popular songs. I will be using Tuva for visualization of data, but also doing some unplugged activities creating data graphs. I will also be using Jamboard for collaborating, Flipgrid for some checkouts, and exit slips for checkouts as well. For creating their data story that they share, they will have a choice of using Google Slides, creating a video, or creating an infographic (digital or on paper).

During implementations, the students discussed how data affected them in real-life situations. For example, the students used data in Tuva to choose a dog for their family based on attributes such as breed, good with children, life expectancy, weight, and others. The teachers created a relatable context that enabled the kids to easily apply their knowledge to their day-to-day lives. One student said, "I didn't know my bulldog would only live 10 years and now I'm sad." The kids discovered several dog qualities from exploring the data that allowed them to make informed decisions. When asked to talk about dogs they liked, students responded, "cute dogs, Pitbull, dogs that protect my family." Some wanted to use data to "choose the best dog" for their family. The kids found the lessons authentic as the examples encouraged an awareness of how their choices fit within a greater societal context. For example, in a class examining water conservation, a student said, "So if you ever take a shower, you should probably take a short shower because we're obviously running out of fresh water since 97% of the Earth is saltwater and 3% is freshwater." Another explained the danger of having salt water stuck on grass that animals eat, saying "And if animals eat that, eat grass, and they eat that salt it could be able to poison them."

Theme 2: Design and Implementation Choices based on Student Interests

The teachers chose to collaboratively design their data science units in grade level teams, which impacted their content choices, yet they were intentional about considering students' interests. When the third-grade team considered a data science problem related to choosing the best dog for a family based on data, they discussed how their students' loved animals, and that many were involved with the school's Pet Club. The team collaborated to incorporate educational standards and design activities (e.g., creating a 3D model of a structure to house the animal based on the outcome of the students' data analysis), basing the activities on their student's interest with building things.

The fourth-grade team discussed their students' interest in social media before settling on a data science problem related to using data to decide and individual's most useful social media platform. The team then went back to the fourth-grade math, English Language Arts, and social studies standards and decided to integrate them and co-teach the unit. Several teachers reflected on ways they addressed students interests in unit design choices saying things like "I think it's important to give them something they are interested in that could lead to a career," or "We chose social media because it's applicable to students' lives." Referring to an extension activity where students could choose to tell their data story through a comic, a teacher said, "My students will absolutely adore reading comics/graphic novels. Many of them are strong artistically and very creative, so this is an opportunity for them to express their learning."

During implementation, the teachers believed that the kids' in-school and out-of-school interests made them think more clearly, make informed choices, understand content deeply, and remember learning content more accurately. One teacher reflected, "Kids had the opportunity to choose the dog they wanted and were able to talk about it. "The teachers also allowed the students' presentation choices, classmates to work with, and products to be created. Students told their data stories using Pixton (comic creation), Google Slides, or posters, and some decided to use Flipgrid and sticky notes.

Theme 3: Recognizing the Connection between UDL and Connected Learning to Differentiate and Extend Student Opportunities

A clear theme that emerged across data sources was the importance of differentiating instruction for students through UDL and extension activities that aligned with CL. Our research team intentionally offered workshops on UDL and asked teachers to consider integrating UDL in their units. We also incorporated opportunities to try digital tools such as Pixton, TinkerCad (digital modeling), and video creation to help tell the students' data stories and demonstrate different skills and ways of knowing. One teacher discussed the importance of being intentional in the curriculum design to "reach all students in different ways." Many used the term "accessibility" when talking about the importance of offering data science-learning opportunities that would appeal to all students. During group interviews several teachers discussed UDL to "level the playing field," "make it fair and accessible," and "give options and provide scaffolding" when teaching data science. In interviews and journals, every teacher commented about listening to students and offering choices to engage them in learning. Teachers wrote in their reflective journals about using UDL and extension activities. One said, "We are allowing students to use a variety of tools to represent their data story." Another commented,

> The kids wanna express "how" they're thinking. You know, she's gonna get up there and dance, I'm going to do a poem, she's going to sing [referring to an activity revolving around UDL concepts during PD]. I don't know. But it's a good way to get them to *show* what they can do.

When enacting UDL during the implementation the teachers focused on representing data science concepts in multiple ways to engage learners and build on their prior knowledge. A third-grade teacher used unplugged data sciences activities where kids sorted and identified different dog attributes on post-it notes before proceeding to visualize it using Tuva. The fifth-grade teachers also followed a similar pattern, giving students the choice to pick some data points, represent them on post-it notes and using the post-it notes to plot a graph as a whole class. Eventually the data points were plotted on graph paper. In this way the teachers were able to scaffold learner's data knowledge for them to draw on before working with the computational tool. When explaining key data concepts and terms to the children, teachers attempted to activate their background knowledge (a UDL strategy) by relating it to ideas the kids were already familiar with in their previous classes or even in other subjects. For example, when explaining the difference between categorical and numerical data, teachers leveraged students' familiarity with words and numbers to explain that categorical data were in form of "words" while numerical data were in form of "numbers." As the children progressed in the lesson, the teacher also encouraged them to start using the "big words" like experts do. One teacher told the kids "I don't want you using word or number anymore, now you know the big words, categorical or numerical".

The teachers also used rubrics and self and peer evaluation to provide agency for students. This helped connect the lesson objectives to self-regulation and peer-supported work. Students collaboratively assessed themselves and others, tracking their final goal and helping tell data stories. In one class, the kids developed their own criteria of what a complete data story should consist of and the social rules to follow when their peers were presenting. Although the teachers presented the lessons through different approaches and engaged students through various hands-on and group activities, we did note constraints for learners in terms of the number/types of technologies they could use to express their data science ideas. As such, students visualized data solely using Tuva (although the tool allowed them to use several types of visualizations) and they created their data stories using teacher-sanctioned technology choices.

Discussion and Significance

While designing their units, we saw teachers readily engage in CT-STEM data practices (Weintrop et al., 2016) as they collected and analyzed data about themselves, located and cleaned data from other sources, discovered different ways to visualize data using digital and nondigital resources, and explored different tools for telling data stories. They transferred their experiences to data science units for students. We noted how often the teachers discussed what they deemed developmentally interesting or appropriate for their students in a manner that aligned with CL (Ito et al., 2013) as a starting point for developing their units. Student interest and relevance was at the forefront of many design choices, discussions, reflections and implementations in this study. The emphasis on writing relevant problem scenarios, UDL, and extension activities to further encourage student expression and interests was apparent in the implementation of the units. The importance of helping their students feel successful was echoed in ways the teachers in this study felt successful – by drawing on familiar technologies and experiences and building on them to increase data science literacies. The teachers drew on students' prior knowledge for data science topics and activities, but also relied on what students knew and cared about when giving them learning and presentation choices. That said, student choices were sometimes constrained by teachers' limiting the number and type of choices. Still, drawing on prior knowledge and familiar or preferred experiences to foster success is encouraging as it indicates a commitment to making data science relevant to their learners (Koirala & Bowman, 2003) and may assist young children in identifying and understanding data science literacies.

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6. Design For Learning About Computing Systems Through Unblackboxing

Co-Creating Physical Computing Materials With Youth And Educators

SHERRY HSI; HYUNJOO OH; AND COLIN G. DIXON

Abstract: This paper shares work from an ongoing CSforAll research project that is generating design knowledge from workshops with educators and youth aimed at designing inclusive and responsive computing education. We describe our participatory design process working with an interdisciplinary design team, six Black youth (ages 11–14), and two educators who interacted with and co-created materials and activities using Unblackboxing Cards, a set of card-based sensing technologies for learning about computing systems. Using mixed methods and workshop recordings to understand both youth and educator participation, we observed how designing with Unblackboxing Cards supported learning of computing system concepts and new computational practices, while providing room for personally meaningful narratives. More importantly, when participants were situated as active contributors to activity development, this provided entree and pathways into computing experiences that honored resources and ideas that learners (youth and educators) brought to the design process. This collaborative design research approach, while messy and often emergent, encouraged exploration, ownership, and risk taking. It also helped to surface new possibilities and directions for future research and learning material designs of unblackbox computing systems for inclusive and responsive education.

Introduction

A continuing goal in education is to diversify and broaden participation in computer science and computing-related activities, especially among traditionally underrepresented youth (Guzdial et al. , 2012; Margolis & Goode, 2016). One popular approach to computing education uses physical computing materials like creative robotics and e-textiles to engage learners to develop personally relevant hands-on projects. These constructive "making" activities expand the breadth and reach of computing by appealing to new communities who share interests, resources, practices, and knowledge with each other through social and material interactions (see Qi et al., 2018).

To research physical computing materials for education, participatory design methods can be used to directly involve users in the collaborative design (co-design) of the materials, systems, and information technologies (DiSalvo et al., 2018). Young people can gain direct experience in design practices, learn to critique and shape technological futures, and experience connecting to tools, materials, and representations of computing systems.

Informed by co-design methods, maker-oriented education, and culturally responsive computing, we aim to create new physical computing materials and activities that necessarily support inclusive and responsive computing education for youth. To be responsive to a diversity of youth, including those from traditionally underrepresented computing groups, we aim to design learning technologies and activities that build on students' interests, identities, stories, and cultural backgrounds. In particular, our design and research work aim to understand how youth and educators can develop an understanding of computing systems through interaction with materials and activities that they help co-create, and to contribute to new design knowledge about inclusive and responsive designs for computing education.

In this paper, we share our research approach and formative results from workshops with a small cohort of middle school-aged youth (ages 11–14) and a pair of educators who worked with researchers to create and modify Unblackboxing Cards, a working prototype for a paper-based physical computing toolkit. We focus on middle school adolescents because youth develop a strong sense of self and shape their identities around this age. Reports also find that less than a third of students in Georgia, where core members of our design team live, engage in any computing activities, exacerbated by a lack of middle school teachers prepared to teach computer science (Guzdial et al., 2012). We show how youth and educators engage in meaningful learning experiences through interaction with craft-oriented physical computing materials, then discuss the opportunities and challenges that emerged in creating responsive and inclusive computing education. Further, we reflect on our co-creation process with youth and educators as they built their understanding of computing systems and computational practices.

Background and Related Work

Inclusive and Responsive Design Practices

Since the introduction of programmable e-textile-based microcontrollers like the Lilypad Arduino, researchers have demonstrated how these materials can broaden participation in and perceptions about computing and provide support for equity in computing (Fields et al., 2018; Kafai et al., 2014; Richard et al. 2015). Physical computing with sewing and craft materials opens creative possibilities for youth's learning; however, maker-based education and maker culture more generally has been critiqued for reinforcing exclusive ideologies and patterns of privilege that favor middle and upper middle class White families (Blikstein, 2020; Okerlund et al., 2018). Designing for diversity and equity in computing acknowledges that inequities within designed materials can reinforce gender bias or replicate narrow definitions of learning and knowing (Holbert, 2016; Kafai & Peppler, 2014). In contrast, culturally responsive pedagogies and computing practices, including instructional activities that invite the voices of learners and ways to share their knowledge, can create space for more inclusive participation and creative production (Gay, 2018; Litts et al., 2021; Pinkard et al., 2020). In our context, we view inclusion as being welcoming of the wide range of identities, genders, backgrounds, and differences in learners. Thus, to design for inclusion, we as designers take a proactive stance by enabling interactions that not only invite users and respond to the cultures, practices, broader interests, and values of the user but also actively attend to critical ideologies and practices that can redress inequities. We also draw on studies of how materiality can affect equitable and inclusive education (Keune & Peppler, 2018).

Unblackboxing: Changing the Opacity of Computing Systems

Designing tools and materials that help young people understand and modify normally "black boxed" objects and processes has been a long-time goal of constructionist learning and making, yet we argue that unblackboxing as a design goal must go beyond technical or computational aspects of computational making. Our approach of "unblackboxing" refers to a design stance that values the beauty and transparency of seeing the inner workings of technical and computational systems, including social and educational systems, as well as electrical and mechanical systems. Unblackboxing purposefully makes less opaque selected components of blackboxed technologies so learners can investigate, interrogate, understand, and appreciate their parts, purposes, and complexities (see Clapp et al., 2016; Berg et al., 2000). We hypothesize that if young people are able to see and interrogate multiple systems – social, material and computational – upon which powerful tools rely, they may gain a greater sense of possibility that they can modify the tools and cultures of computing to reflect their own purposes, values, and identities.

Design Considerations for Unblackboxing Activities and Materials

In the production of new computing education materials, our design process applied inclusive design and unblackboxing ideas across physical materials design, instructional activities development, and instructor facilitation. Initially, design researchers intended to create a prototype kit of conductive and resistive craft materials to highlight aspects of computing, as well as project activity cards that could be made into sensor inputs and actuator outputs to work with the Circuit Playground Express (CPX) microcontroller. Design prompts were left open to invite a wide range of narratives, while computational material designs were governed more by unblackboxing ideas. Table 1 shows the influence of how the two strands were applied across material design, activities development, and workshop facilitation.

Uncertainties arose in how to balance instruction and scaffolding for novices in computing, and how much of the core technological platform should be prototyped upfront versus keeping the material choices and user interactions emergent from the co-design process, which could lead to too much frustration as educators and learners struggle with untested materials. During this process, researchers drew from computer science learning standards to identify learning goals around computational concepts and practices that we worked to support in curricular materials. For example, with sensing technology, we intended to show how a sensor input turns some kind of change in the world (a finger pushing a button, a bend in material, a change in light) into a recognizable change in electric circuit, and then into digital information that becomes parts of runtime programs or code. It was also important that learners be able to identify and understand where they might find computing devices with these kinds of components and functions in the world, and how they are relevant to everyday life and concerns.

Team discussions among HCI (human-computer interaction) designers, STEM (science, technology, engineering, and mathematics) maker educators, and learning scientists led to the articulation of four design considerations to serve as guiding design heuristics (DC1-DC4).

Learning Design Layer	Unblackboxing	Inclusive Design
Materials design	Year 1 Prototyping Unblackboxing cards: *Make* sensors, *In the World*, *STEM Connect*	Year 2 Co-design with educators
Activities development		Design cards (message, map, user-made) Materials archaeology Making & modding sensors
Facilitation	Question asking Troubleshooting Circuit tracing	Social glue (shared music lists, jokes) Critique and co-design sessions

Table 1. The main design stance underlying the creation of each of the learning design layers.

DC1: Enable easy entrée and exploration. Creative learning is supported by tinkering with easy-to-interact parts and materials to enable beginners to construct their narratives. This principle includes making the kit easy and exciting to get started with, and to facilitate new kinds of making and ideas without spending time with code syntax or programming instructions. Cards cut lines, holes, and shapes make explicit what learners can manipulate, hide, or explore.

DC2: Make computing investigable. To investigate underlying computing system concepts, principles, and functions, cards expose places circuit materials to make system functions more transparent. Materials design encourages curious learners to better connect representations of a computing system to system behaviors, and/or trace how components work so they can modify them depending on their goals.

DC3: Support interchangeability and extendibility. We aim to enable users to substitute or extend parts in the kit with parts and materials they have on hand. Designs should encourage practices of reconfiguration, modification, hacking, and repurposing that build on learner resourcefulness and creativity. Material flexibility and adaptability should inspire and expand the range of expressive ideas and projects for beginners.

DC4: Open space for personal stories and expertise. We aim to put personal, learner-voiced narratives at the center of projects and put to use the knowledge that learners bring with them from their lives, cultures, and communities. The interests, histories, stories, and other assets of youth should be resources for individuals engaging in the production of computational artifacts, as well as for the field of computing as it moves toward more equitable and inclusive practices.

Workshops

We are currently developing this work in two strands: youth workshops conducted as online summer camps, and educator co-design workshops that focus on professional learning and developing shared resources for inclusive and responsive computing education. While we recognized the potential challenges to introducing a physical computing workshop with novice learners remotely during COVID-19 pandemic, we nonetheless aimed to conduct an initial study to see how youth would respond to our co-design approach of materials, activities, and facilitation that applied unblackboxing and inclusive design ideas, and to inform subsequent iterations of the technologies and activities.

Youth Workshops

In Summer 2021, six youth (3 boys, 3 girls) between the ages of 11 and 14 participated in a 5-day online "summer camp," after a research content and assent process. All youth were from areas surrounding Atlanta, Georgia, and identified as Black. The workshop was free to attend and all materials were provided. Two instructors (one middle school teacher, a White woman, and one graduate student, a Black woman) facilitated the online synchronous workshop while two researchers (a Chinese American woman and a White man) observed. Participants joined activities remotely online. Youth took a pre-workshop survey with questions about their background in computing and computing-related activities. All workshop sessions were recorded. Sources of data included conversations, chat streams, student-created projects, a pre/post survey, and one-on-one recorded interviews with youth, conducted by research team members immediately after the workshop and again 5 months later. At the end of each day, instructors and researchers debriefed about the workshop and put their observations and reflections into a shared document.

To provide a basic starting point for making, learners were given four types of paper cards (*Make*, *STEM Connect*, *In the World*, and *Design* cards) along with a CPX microcontroller, and conductive, resistive, and nonconductive craft materials for making sensor inputs. These materials were intended for learners to imagine, then make and program computational artifacts. To introduce the week's activities, the workshop theme asked youth "What lights you up?" Participants worked on three interactive projects scaffolded by prompts printed on cards and support from educators. The first "message" project asked youth to compose an interactive artifact that shared a message or story that communicated some of their unique strengths and perspectives. We posed the question, "Now that you have these new technological tools to amplify your voice, what do you want to share with the world?" The second design project asked learners to make a map that lit up places that were special to them. For the final project, youth could either revisit and extend their previous project or make a completely new project re using the kit components. With either option, students programmed new project interactions and built the artifact.

Several activities were specifically designed to be culturally responsive and to show computing's utility in the world, such as learning about arts and community action in computing, a presentation by an inspirational innovator, and activities where they connected personal objects and everyday resources to computing. For example, youth did a "Materials Archaeology" scavenger hunt in their homes to locate and document ten things they could use for prototyping of computationally-enhanced objects.

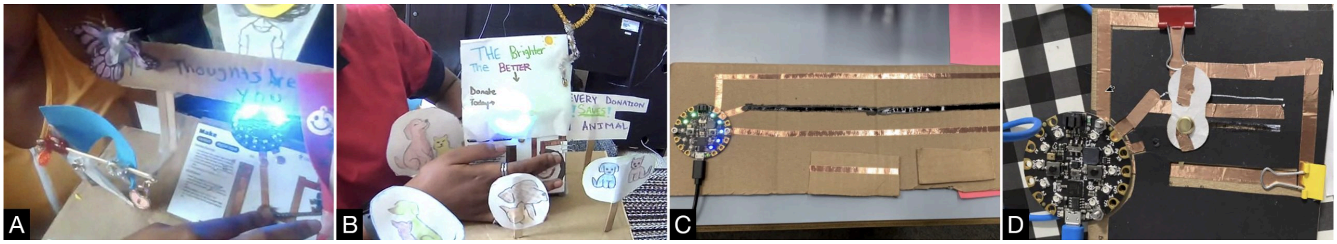

Figure 1. (A-B) Youth message project examples: (A) encouraging people with depression, and (B) fundraising for animal shelters; (C-D) teachers' modifications of potentiometer sensor inputs.

Educator Workshops: Small group PL

In the second year of the project (Winter 2022), we recruited two teachers to engage in an extended co-design workshop (3-4 months each session). Teachers were selected based on the diverse population of students at their public school and on car-driving distance of researchers to enable in-person collaboration and tool sharing. Two female teachers (one White, and one White and Hispanic) were selected to join the first Winter/Spring cohort, with more cohorts to follow. They received two kit sets, a stipend, and other maker materials.

Our first goal was to engage teachers as learners in order to use and improve the Unblackboxing Cards and activities. We hoped to use their perspectives to focus in on which computing concepts the kit could best address, and to help us refine (and rethink where necessary) card and activity designs. We used co-design as a strategy for development of our computational and pedagogical resources, as well as a strategy for educator learning and development. This second goal of teacher professional learning around computer science (CS), and in particular physical computing concepts and practices, is especially important given that many CS teachers in schools serving marginalized communities may be new to teaching CS with little previous experience with electronics and physical computing. This was true of our first two teachers, who we hoped could help us develop our materials and strategy for later educator professional learning experiences.

Researchers and teachers met virtually every 2 weeks, with intervening weeks dedicated to time for the teachers to design, reflect, and collaborate with their students. Introductory sessions focused on project goals and frameworks for equitable computer science education, physical computing concepts and troubleshooting, and definitions and goals of unblackboxing. As teachers became more familiar with computing and the kit, sessions focused on modifying, creating, and adapting to both kit components (cards and code) and activities, then testing them with their classes and clubs.

Results, Discussion, and Reflections

Inclusive design means positioning learners as designers, supporting learner agency, and reminding them they can do meaningful things. This was evidenced by youth who successfully constructed sensor cards with copper tape and craft materials, fashioned custom cardboard, and programmed their Circuit Playground Express (CPX) boards. Each project was unique, covering both serious topics – with messages about fighting world hunger, renewable energy, depression during COVID-19, and foster care advocacy – and more playful, speculative ideas – like zombie hunters and origins of the word and color orange.

In our analyses of one-on-one interview transcripts, summer camp youth described how the projects felt personally meaningful to them and remarked on how the actual making enabled their messages to feel more powerful. Half of the youth also remarked that the openness of cards enabled them to figure things out and design in a way that felt personal.

> RJA (youth, F): I really liked how we got to do the message project… [because] I feel like when you actually like show your vision, it's better than just saying it, because it's one thing for me to say that I want to help dogs or I want to help, um, animals with, um, abuse and stuff, and another when you can actually display it, and for people to see your message.
>
> MH (youth, M): No blueprints, I mean like, uh, … You can, you can build it, you can do it however you want. Kind of, yeah. As long as it's functional.
>
> IW (youth, M): [My highlight was] that we can make our own type of messages when we're coding the stuff. I liked that very much…. My idea was – because many people suffer daily from depression from home life, work, school, etc. So I drew a picture of a woman who is smiling, and in a bubble above her head I put "I am not happy" because that is usually how it is.

Youth were observed to engage in computing practices and reported that they learned some computing system concepts from applying the Unblackboxing Cards, even if some of the materials like copper tape and fragile circuits caused some frustration. The set of *Make*, *STEM Connect*, *Design*, and *In the World* cards was successful in engaging youth in new computing practices and inviting them to explore and investigate as they created. As the youth moved from sensor card construction to embedding the cards in personal projects, they had to figure out how to make a new circuit with copper tape, as well as modify MakeCode to get the CPX to behave in the ways they imagined. These practices for youth were still memorable in the 5-month follow up interviews.

With respect to the co-design process as design researchers, we faced challenges in negotiating what aspects of the to-be-designed layers should be co-created with youth and educators who had some familiarity with coding in Scratch but were unfamiliar with physical computing and circuits. In traditional user-centered design, designers prototype most if not all aspects of a technology, then engage participants in usability testing. We straddled participatory design and CS pedagogies by engaging participants in both brainstorming possibilities with unblackboxing sensors, and providing enough background resources and coaching so they could engage in hands-on making and problem solving. Most encouraging were remarks from the youth about the activities feeling different from what they expected computing to look like, and different from past experiences with computing education, such as with robotics activities that felt narrow and prescribed. Similarly, in teacher workshops, educators found unique and personal purposes for using Unblackboxing Cards, including a classroom sign to tell students when they could come visit a teacher, and a dial to gauge how students were feeling. Teachers deconstructed the card-based analog potentiometer card sensor, then invented their own version of it as a way to understand how it worked and how to program it (see Figure 1, C-D).

As our research project progresses, we are continuing to do workshops with more cohorts of educators and youth, engaging them as co-designers to explore both new domains of inclusive computing education and uncharted design spaces. This collaborative design research approach, while messy and emergent, was supported for participants' learning while encouraging exploration, ownership, and risk-taking. Situating everyone as active contributors to card development provided new pathways into and through computing experiences that personalized learning and honored the resources that learners, educators, technology designers, and researchers all brought to the design process. This is surfacing new possibilities and directions for future research and learning material designs to help unblackbox computing systems for inclusive and responsive education.

In summary, our research into designing inclusive and responsive computing education, while still in the formative stages, is generating insights into understanding how youth can connect and relate to computing. Through making with materials like Unblackboxing Cards that open computing system components to investigation, and with co-created activities and facilitation supports, educators can provide new space for personally meaningful and culturally responsive narratives while scaffolding learners' computational practices.

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7. Exploring the Use of Fiber Crafts With Soft Robotics for Connected Engineering Learning

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Abstract: Soft robotics is an emerging field with promising inroads for inclusive approaches to STEM learning because of the range of creative materials and cultural practices that soft robotics invites to robotics. We investigated one promising way soft robotics could foster connected learning, as part of engineering learning by integrating creative fiber crafts productions with pneumatic actuators and observing engineering practices with the tools and materials. Particularly, fiber crafts materials have increasingly become valued design materials within engineering and soft robotics. Yet it remains underexplored how these materials can be introduced to engineering education to foster more inclusive learning that is connected to youth interests and practices. Drawing on a connected learning approach, this study examines the use of a fiber-crafts based soft robotics activity within a US middle school setting toward demonstrations of engineering practices and connected learning design principles. At the intersection of soft robotics and fabric, we present three cases that show that making fabric a core of a soft robotics learning activity can legitimize youth practices by connecting emotions, familiarity, and personal interests with core engineering practices.

Introduction

To address inequities within engineering, it is important to identify and design environments that build on interests and practices of youth in ways that directly connect to the discipline (cf. Master & Meltzoff, 2020; Hachey, 2020; Mulvey et al., 2022). Soft robotics, which can include silicone-based pneumatic actuation, are an emerging and promising direction to support equitable approaches to engineering (Jackson et al., 2021). Silicone-based pneumatic actuation can involve the making and using of particularly designed airtight containers that expand when inflated. Such pneumatic actuators can be combined with a range of other materials, such as fiber crafts, which have been associated socio-culturally with underrepresented people in STEM, especially women and girls (e.g., Barber, 1995). Additionally, fiber crafts present a promising source of innovation through mechanical properties (Cappello et al., 2018) as well as decorating as a form of technology innovation (Keune et al., 2022). Fiber-crafts based soft robotics also present a promising context for connected learning (Ito et al., 2013; 2020) including to legitimize and revalue material cultural practices of a broader scope as core to engineering and innovative technology design. One way pneumatic actuators have been researched in educational contexts is through the facilitation of the step-by-step production of a silicone-based soft actuator based on an open-source soft robotics toolkit (see Holland et al., 2014; Jackson et al., 2021). Yet it remains underexplored how pneumatic actuators can serve as creative design materials with which youth can explore mechanical structures of fiber crafts as a way into engineering learning.

In the present study, we asked: **How can the socio-material properties of a fabric-based pneumatic actuation activity bring about elements of connected learning environments?** By building on the connected learning model (Ito et al., 2013; 2020), particularly the design principles of (a) *legitimization of youth interests*, (b) *meaningful contributions made to real communities*, (c) *making progress or achievement visible across settings (Ito et al., 2020, p. 51-61)*, we explored the design of a fiber-crafts based soft-robotics activity within a middle school setting in the United States. We conducted two iterations of two sessions that were part of a longer course about fiber crafts for STEM learning (see Keune, 2022; Keune & Peppler, 2020). We analyzed video data that recorded the interactions and semi-structured interviews with youth based on a subset of the elements of connected learning environments (Ito et al., 2020) that are aligned with how youth practices with the materials supported practices of the engineering design process (NGSS).

We found that making fabric a core of a soft robotics learning activity legitimized youth practices by connecting emotions, familiarity, and personal interests with core engineering ideas. This has implications for the further design of the facilitation of soft robotics activities within educational settings. We close with recommendations of advancing connected learning design principles to consider making progress or achievement visible across individual project settings within the same physical settings.

Background

The current study is part of a larger body of work that looks at creative crafting materials that are historically linked to groups of individuals that are underrepresented in STEM fields, such as women in engineering (e.g., Peppler et al., 2020). The goal of the present study was to see how the material properties of a fabric-based pneumatic actuation activity can encourage connected learning within engineering learning. The motivation to begin the design process with fiber crafts as the material driver for the activity was to generate an engineering context that is approachable for all students. In fact, recent research in the learning sciences has begun to show that designing contexts for STEM learning by starting with materials that are socio-cultural, and with socio-historical practices associated with people who are underrepresented in these domains, such as women in engineering, can be relevant for all students rather than excluding some (Keune et al., 2021).

Soft robotics in education

Within K-12 educational contexts, robotics as a larger area of creative making have been considered a context for young people to learn STEM concepts in effective and equitable ways (Rahman, 2021; Bers, 2008). Robotics can help students understand STEM ideas through illustrative and iterative design (Jamali, 2019). One example of a robotics kit used in educational contexts is the LEGO WeDo 2.0 robotics kit, a 280-piece kit that includes a motor, two sensors, and a smart hub used for mathematics and competitions, among others (Jackson et al., 2021; Jamali, 2019).

Soft robotics is a growing area of engineering and represents an alternative to an area of engineering that is dominated by rigid materials (Hawkes et al., 2021). Combining mechanical engineering, computer science, and electric and electronic engineering, soft robotics introduce soft materials like silicone rubber to robotics, with the motivation to create bio-inspired mechanisms (Trimmer, 2014; Shibata et al., 2021). Possible applications for these devices range from transportation systems that can endure harsh conditions or exoskeletons that can be attached to people with motor complications to aid movements (Whitesides, 2018).

One area of soft robotics is pneumatic actuation, which refers to the various tools and instruments that convert energy, typically in the form of compressed gas or liquids, into control motion, and has been used in the biomedical field or food industry to handle fragile items. Pneumatics connect biology to engineering, for instance, by making it possible to replicate muscle movement, although not muscle mechanisms (Whitesides, 2018). This opens possibilities to work with materials that can inflate or deflate as well as grab objects in more natural ways. For instance, the open-source Soft Robotics Toolkit builds on the idea of producing a complex mechanism by breaking it down into its parts and connecting them together into a working system that moves independently (Holland et al., 2014). People can 3D print molds for creating silicone shapes that can be animated through air flow (Berndt et al, 2019).

Soft robotics allows for varied designs that can be used to appeal to a wider audience, or interest students for STEM fields in different approaches (Jackson et al., 2019). One example is how in soft robotics the unique mechanical qualities of fiber crafts have been used to innovate robotics devices for space travel (e.g., Xiong et al., 2021; Nguyen et al., 2019). This is significant because it frames materials that are not commonly associated with engineering but instead with socio-material practices of people underrepresented in engineering (e.g., women) as a core source of innovation within the field.

In the present study, we build on this opportunity that soft robotics brings to engineering learning and investigate the design of a fabric-based pneumatic actuator activity that honors and embraces youth's interest as well as socio-cultural practices of underrepresented groups in engineering. In this activity, youth created personally meaningful designs by exploring the properties of woven and sewn artifacts through inflatable silicone-based shapes.

Connected learning for designing inclusive engineering learning

To promote inclusive STEM learning, more support is needed to create learning environments that promote and celebrate culturally relevant and personally meaningful educational experiences (e.g., Mulvey et al., 2022; Hughes et al., 2020; Ireland et al., 2018). The connected learning model is useful for exploring STEM design activities toward fostering equity within engineering because the model considers the interests and passions of young people as a powerful starting point for fostering deep and long-lasting learning opportunities (Ito et al., 2020). Connected learning has an equity-oriented mission, which recognizes and honors the practices of young people as catalysts for engagement (Ito et al., 2020).

Connected learning includes four elements: (1) *Sponsorship of youth interests*, which recommends the recognition of youth passions through mentorship and resources, (2) *shared practices*, which highlights the importance of collaborative creation, competition, and joint research, (3) *shared purpose*, which highlights the importance of shared values and culture, and (4) *connections across settings*, which builds on learner networks to provide access to opportunities and communities. Developing learning and educational settings that promote the four elements through design principles can foster connected learning (Ito et al., 2020; p. 53). We focused on the following Connected Learning design principles for this study: (a) *Legitimization of youth interests, values, and practices*, because it brings forward design opportunities that connect to the familiar, an approach that has also been shown to support girls in engineering, (b) *meaningful contributions made to real communities*, which implements user-centered design approaches where youth design for others, related to higher number of engineering practices displayed by girls (Peppler et al., 2021), and (c) *progress or achievement is visible across settings*, which includes acknowledging youth for their domain-related practices by providing tools to share their work online with others (Keune et al., 2019). We are particularly interested in understanding how connected learning design principles can guide the design of a fiber crafts-based soft robotics activity and, in turn, how the socio-materiality of the designed soft robotics activity supports elements of connected learning. Better understanding of how the design embodies such design principles would help identify meaningful strategies for fostering engineering contexts that can support all learners.

Methods

This qualitative video-based research was conducted within a middle school setting in the midwestern United States. The study stands in the larger context of research on fiber crafts as a context for generative STEM learning (e.g., Peppler et al., 2020). To study the possibilities of combining pneumatic actuators as a way to animate soft structures of fiber crafts, the research facilitated two 70-minute sessions with two groups of six students each. The teachers allocated the students to the groups based on the friendships and interests of the students. The first group was joined by two boys and four girls, and the second group was joined by two girls and four boys. During the course, students worked on a craft table and used silicone materials and air sources for pneumatic actuation of fiber craft artifacts that were provided to the students.

The first iteration instructed students to familiarize themselves with the structure of a sewn design by removing stitches from a flat folded sewn twisted square. This made it possible to open the folded fabric and to close it back up. The stitches added memory to the fabric that opened flat and closed back up into the twisted square shapes. In session one of the first course iteration, youth explored circular and rectangular pneumatic actuators that could be attached to manual air sources (e.g., syringes connected to tubes, hand-sized bicycle pumps). Then, youth connected the fabric pieces to the actuators by sewing to transform the fabric's shape and to engage the mechanics of its folds. Afterwards, youth created their own pneumatic actuators by cutting out shapes from silicone rubber sheets and gluing them together before they connected fiber craft artifacts to their own actuator designs.

The second iteration provided youths with sewable actuators. During session one, students familiarized themselves with fabric artifacts and their mechanical features by removing stitches that held the artifacts' folds in place. Then, youth experimented with sewable actuators, which included a thin outer border with holes that could be sewn through to attach the actuator to the fabric. Attaching the fabric artifacts and the actuator made it possible to transform the fabric shape when inflating and deflating the actuator.

Data sources

We used two types of video data: (1) Videos captured in a 360° camera mounted on the ceiling top of the working tables for each group and (2) semi-structured interviews that discussed youth's creations. We used the 360° camera to get an overview of how the students engaged in the activities and interacted with each other. The interviews were taken while the 360° camera was recording, which meant that they provided a closer look and better image quality for individual students at a time along with a semi-structured interview that prompted the students to talk briefly but in-depth about their projects.

Data analysis

First, we created narrative summaries of the events in the 360° videos by focusing especially on three focal cases. We selected three cases that exemplified specific experiences with the fabric materials throughout the activities. We created a table for transcribing their interactions with each other and how they progressed in their projects. We then analyzed this information to observe relevant details in each iteration and discussed what the cases suggested for the further design of the soft robotics activity. In the analysis we explored how the youth engaged with engineering ideas and practices (e.g., planning and carrying out investigations, developing possible solutions, optimizing the design solution) based on US National Science standards (NGSS).

We further analyzed the data to understand how the design of the activity, as witnessed through the interactions of the youth, presented connected learning design recommendations (see Ito et al., 2020), and how these intersected with the displayed engineering ideas. The design recommendations we focused on were: (a) *Legitimization of youth interests, values, and practices* because it implies designing for opportunities to connect to the familiar, an approach to design that has also been shown to support girls in engineering, (b) *meaningful contributions made to real communities*, which includes user-centered design approaches that make it possible for youth to design for others, associated with higher number of engineering practices displayed by girls (Peppler et al., 2021), and (c) *progress or achievement is visible across settings*, which includes recognizing youth for their domain-related practices by making it possible to share their work online with others (Keune et al., 2019).

Findings

Designing personalized actuators and narrating with actuators

Devanie was one of the youth who participated in the first iteration of the course, which implemented sewing fiber artifacts, exploration of actuators, and connecting the actuators to the sewn fiber artifacts. Devanie explored actuators in combination with fabric artifacts through narrative storytelling. During the first session, Devanie engaged in an engineering design process as she explored how the actuators work by connecting a sewn artifact to a pneumatic actuator and observing how it changed its shape when inflating the actuator. Throughout the session, she engaged in the engineering practice Asking Questions and Defining Problems (MS-ETS 1-1). For instance, she explained that she was surprised by how the fabric changed shape, although disappointed that inflating the actuator just made it flat. Yet she also was interested in how the fabric shapes went back to their original form when deflating the actuator. During the second session she focused on designing her own actuator. She went through multiple iterations of her actuator design, starting with a star, moving on to design a small heart shaped actuator before settling for a larger heart-shaped actuator. It was interesting to see how youth created a range of different actuator shapes only to see that they all inflated as round bubbles. This is an example of Optimizing the Design Solution (ETS1.C), one aspect of the NGSS engineering design disciplinary core ideas. The possibility to draw and create personal designs of actuators also supported the Connected Learning design principle of *making progress or achievement is visible across settings* because participants, including Devanie, could start with personal shapes and see how no matter which shape they chose the inflated actuators would be similar across youth and shapes without containing the personalized aspects.

Nearing the end of this session while she waited for her actuators to dry, Devanie experimented with the pre-made actuators in combination with woven fabrics. She used one of the woven fabrics to represent a blanket on top of an actuator. She then drew a face on a piece of paper and attached it to the blanket and explained that it looked like a breathing person in bed (Figure 1). "*I put this little thing [the blanket], on top of that [the actuator], and then I start blowing it up. Then it slowly, it looks like it's breathing underneath the blanket.*" It was practices like this that showed how the design of the activity supported connected learning elements, especially *legitimization of youth interests*. The way she pumped air into the actuator to move the blanked replicated a biological system of breathing. The fabric as a cover of the actuator was a way for her to make meaning of the robotics materials in familiar ways. The fabric became an object for designing with familiar practices. Through the activity design, she was afforded with space to legitimize familiarity as part of engineering. Additionally, the activity made it possible for Devanie to *make meaningful contributions to the community* at the table. Devanie was part of the conversations with her peers, asking and providing opinions on design choices, as well as sharing her project in humorous ways.

Figure 1. Devanie showing her breathing person

Devanie's engagement with actuators showed that the personalization of actuator shapes may be an interesting activity to further consider to support engineering learning. Across the group, the youths shared work with the actuators made progress and achievements visible. It needed the group doing the design activity and the repetition of the design activity across several projects to see how the simple and flat actuator designs by the youth did not differ significantly**.** In addition, the possibility to play with ready-made actuators following the design of personal actuators legitimized youth practices as part of engineering, and made it possible for Devanie to contribute to the table in narrative and humorous ways. It was the sequential engagement with actuators actuator design followed, by designing with actuators that supported and expanded engagement with engineering practices.

Connecting actuators with fabric to engage mechanics

Martina joined the second iteration of the course. This iteration of the course facilitated the exploration of pneumatic actuators made by Author 1 prior to the session in combination with sewn fabric artifacts. Youth did not create their own actuators. Martina's exploration with the materials focused on combining fiber crafts with soft robotics, which produced a space that was generative for engineering design disciplinary core ideas while also supporting connected learning elements.

Throughout, Martina focused on how to connect fabric with silicone, engaging in an engineering design process that involved the exploration of material properties and how they interacted with one another as well as iterative solution findings. This aligns with the engineering practice Asking Questions and Defining Problems (MS-ETS1-1), because she looked into how the actuators operated when having different shapes, tested them, and developed explanations as to why the actuators behaved the way they did. For example, she demonstrated how her project slowly inflated by using a bicycle pump. Doing so changed the folds of the fabric. Martina mentioned that she had not yet identified how to get the fabric to close back up and to fold back into the flat-foldable state. To get this right required paying close attention to the interactions of the two materials, constructing explanations, and designing solutions on the placement of the stitches that connected the fabric artifact with the actuator. This is related to the engineering design disciplinary core ideas Developing Possible Solutions (ETS1.B) and Optimizing the Design Solutions (ETS1.C), as she aimed to change the folds of the fabric and experiment with different shapes of actuators, comparing possible outcomes and choosing the best possible approach. Martina conducted a series of tests on how best to combine an actuator with a fabric to inflate and deflate the flat folding artifact, working with the mechanics of the fabric that the stitches had introduced to them. Martina selected a circular actuator that inflated into an hourglass (Figure 2). As she iterated on how to connect the fabric to the actuator, she made material-specific observations that were relevant for her further solution finding process. For instance, she observed that one part of the hourglass inflated more than the other and concluded that the shape of the silicon could affect the inflation and deflation of the fabric artifact depending on where the actuator would be placed.

> *"I just thought it was a really unique shape. And I noticed that one side is bigger than the other. I was kind of confused about why, but I'm not really sure why. So I think I might want to [understand] why one [inflated] side is bigger than the other.*

She inquired about the material properties of the actuators and was determined to understand why one of the sides inflated more than the other, although both appeared of equal size while inflated.

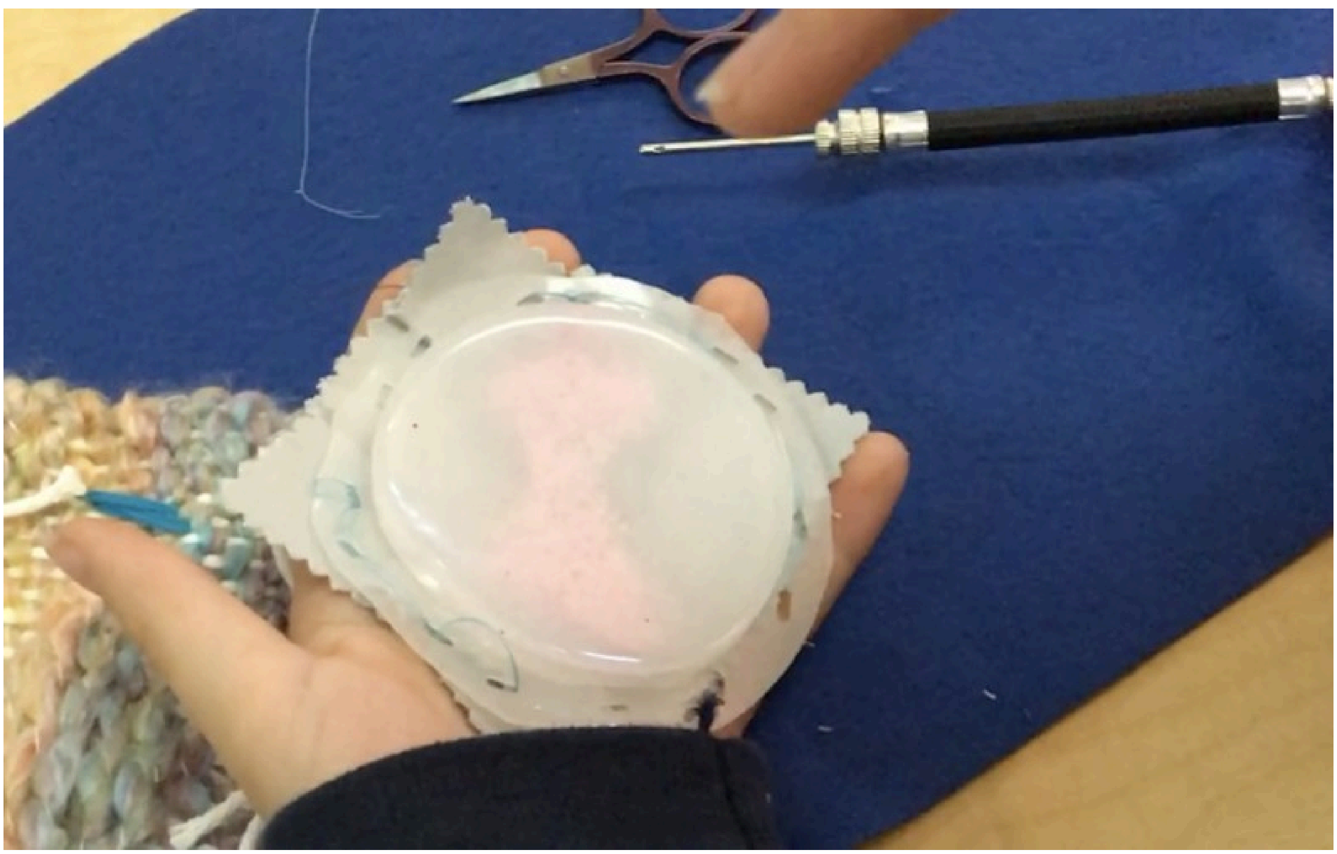

Figure 2. Martina showing her hourglass shaped actuator.

The focused characteristic of the activity, including the ready-made actuators along with the task of connecting them with pre-made fabric artifacts, led to an interesting consideration of the complex interplay of size, shape, and placement of actuators, as well as how pneumatic actuators could animate the mechanics that the stitches produced in the fabric. Yet, connected learning design principles were less present. Legitimization for youth interests was present in the activity because the activity made it possible to create and explore creative and personal projects together with peers. However, the focus on connecting familiar practices to the exploration that was so central to Devanie's case, as well as the focus on producing meaningful contributions to the community at the table, took secondary roles in Martina's case. Her case points to the utility of including sewable features to the actuators and for facilitating the activity with the specific purpose of inflating and deflating a flat-foldable artifact to foster engineering. The focused design of the activity reduced some of the connected learning elements within the case.

Discussion

This exploratory study points to the use of fabric-based actuators as a material that can support engineering learning as well as invite connected learning by bringing elements of familiarity, narrative, emotions, and previous knowledge of the participant youth to engineering activities. The analysis of both cases showed interesting inroads for designing and testing soft robotics tools and materials that are integrated with fiber crafts and supportive of connected learning. Having participants design their own actuators, like in Devanie's case, made it possible to explore the effect of a range of differently shaped actuators created across several youth participants. We consider this as representative of the connected learning design recommendation of making progress and achievements visible across settings, where one setting is a project by each youth and several settings are the projects of several youth in the same physical location (e.g., a craft table). From this point of view, we can recognize the shared inquiry into actuator designs as a form of connected learning. The observation points to ways to expand how we currently think of connected learning across settings. However, further work is needed to inquire into this.

Further, the study points to fiber crafted artifacts to increase approaches to engineering learning, including that fiber crafted artifacts may help familiarize engineering by suggesting integration of narrative approaches, like replicating biological systems (e.g., a sleeping and breathing person). Another design iteration should focus on how to integrate facilitation and material aspects that encourage narratives and storytelling with the materials together with explorations of the pneumatics, while also laying a focus on introducing fabric as having complex structures with mechanical properties that can be used to tell animated narratives. The study showed that for the activity of creating actuators, as well as for the activity of exploring ready-made sewable actuators, integrating narrative possibilities could increase the alignment of the activity with connected learning design recommendations and connected learning elements, thus inviting a wider range of approaches to engineering.

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8. Social, Emotional, and Cultural Supports for STEM Equity

Lessons from Informal STEM Learning Programs

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Abstract: This paper uses the connected learning framework to analyze equity-enhancing features of informal STEM (science, technology, engineering, and mathematics) learning programs: (1) sponsoring youth interests and identity, (2) shared projects and purpose, and (3) holistic and supportive relationships. The analysis highlights the unique strengths of informal organizations in advancing STEM equity, as well as the varied ways in which these strengths can manifest in diverse organizational settings.

Introduction

Efforts to broaden participation in STEM (science, technology, engineering, and mathematics) learning have increasingly recognized the influence of social and cultural factors, and the important influence of out-of-school environments. This paper examines the unique role that culturally responsive and socially connected informal STEM learning (ISL) programs can play in supporting STEM interest and engagement for Latinx youth, building on the connected learning framework (Ito et al., 2013, 2020). It draws from the All Together Now study, funded by the NSF Advancing Informal STEM Learning (AISL) program. The goal of the study is to identify ways that ISL programs can broaden participation in STEM by building STEM-relevant social capital and cultural connection for underrepresented youth.

The research team conducted observations and interviews at three ISL programs in Southern California with varied approaches and organizational contexts, serving predominantly Latinx youth. This paper describes features of these programs that support equity in STEM learning: (1) sponsoring youth interests and identity, (2) shared projects and purpose, and (3) holistic and supportive relationships. The analysis highlights the unique strengths of informal organizations in advancing STEM equity, as well as the varied ways in which these strengths can manifest in diverse organizational settings.

Conceptual Framework

This study builds on prior research on how informal and out-of-school learning supports development of STEM interests and persistence (Dabney et al., 2012; NAS, 2021; National Research Council, 2009, 2015; Steinkuehler & Chmiel, 2006). Informal environments are uniquely well positioned to provide these kinds of support because they are often interest-driven, embedded in the culture of a community, and cultivate caring relationships that transcend a specific class or program. To identify equity-oriented features of ISL programs, we draw on the connected learning research and design framework that centers on learning that is interest-driven, socially connected, and expands opportunity (Ito et al., 2020). It emphasizes how learning spans both formal and informal environments, including school, home, and community-based organizations. Connected learning is also an asset-based approach that centers on diverse youth interests, identities, and strengths, rather than taking a standardized or one-size-fits all approach. This study draws from evidence-based design elements of connected learning to analyze and understand how ISL programs support equity, specifically through interest-driven, culturally responsive, socially supportive, and project-based approaches.

Our study has an "appreciative inquiry" orientation (see appreciativeinquiry.champlain.edu), where we focused on programs that exemplify productive ways of manifesting connected learning approaches in equity-oriented practice. Our site selection and identification of examples is not intended as a "representative" set of programs and practices, but rather as an exemplary set that can inform the field in identifying positive practices and design features. This orientation to research-practice partnership and analysis is particularly well suited to pursuing equity through informal settings and connected learning approaches that must be tailored to the assets and culture of diverse communities.

Study Background

Sites. Research was conducted at three ISL organizations serving middle and high school students located in Southern California, which encompassed six physical sites (Table 1). The organizations were selected because they focus on achieving STEM equity goals in serving a majority Latinx population. They also embody key elements of connected learning, including project-based and interest-driven programming, a safe and socially supportive environment, and culturally responsive approaches.

Site	Location	# of Students	Main Characteristics
TGR Learning Lab (TGR)	Anaheim	200 every quarter	Afterschool learning center serving predominantly minority, low-income middle and high school students. TGR occupies a large, stand-alone campus with a golf course. Many students are bused in from local schools. In addition to their signature golf programs, they offer homework support, snacks, and a wide range of STEM programs that participants can choose from, including marine biology, universal sciences, robotics and video game design.
ListoAmerica	Santa Ana	50 per year	Member of the Clubhouse Network of technology-rich out-of-school learning settings established across the world. In addition to embodying the interest-driven approach to project-based learning that is the hallmark of the Clubhouse Network, ListoAmerica takes a culturally tailored approach, with a bilingual, bicultural staff strongly connected to their local Latinx community. Members can come by on a flexible, drop-in basis to pursue projects they are interested in, get help with homework, or just hang out with friends and mentors. Many members stay connected with ListoAmerica for many years, and even return as alumni during college and beyond.
Mathematics, Engineering, Science Achievement (MESA)	Anaheim	800 to 1,000 students in 28 middle and high schools in Southern California	National program that offers project-based STEM learning experiences with the goal of increasing enrollment in STEM college majors. Schools can offer MESA programs during school hours, as well as afterschool, on weekends, or in the summer. Participants in California MESA programs are over 90% Latinx. We conducted research in 1 high school and 3 middle schools in Anaheim that offered MESA programs as electives during school hours. Programs include computer-based projects such as animation or 3D printing, as well as woodshop and engineering projects. MESA educators have the freedom to adapt and draw from the national MESA curriculum.

Table 1. Sites and characteristics of three after-school and during-school STEM programs with Latinx populations for our study.

Participants. Demographic background was self-reported by participants as part of the interview. Students represented every grade level from 7th grade to junior in college (Table 2).

Participants	#	Gender	Age	Latinx	Asian	Multiracial	White	Black
Youth	110 1st Wave; 48 2nd Wave	42% Female 58% Male	13-21	62% - predominantly from Mexico	16%	15%	6%	2%
Educators	11	7 Male, 4 Female	N/A	64%	27%	N/A	9%	N/A

Table 2. Self-reported demographics of study participants and educators from two waves.

Data Collection & Analysis. Data collection consisted of program observations to observe unique program features of each organization, and youth and educator interviews. We interviewed 110 youth in first wave interviews, and 48 youth in second wave interviews between Spring 2019 and Spring 2020. Due to social distancing requirements of the COVID-19 pandemic, all research sites shifted online, and some closed their doors for long periods of time. Some interviews and program observations were conducted virtually as a result. Using the Dedoose platform, we analyzed data using open and axial coding methods to account for how youth and adults discuss youth interest, participation/persistence, and related outcomes. Program history, philosophy, activities, and organizational structures were also analyzed in this way, tracking connections between supports, activities, and outcomes. Field notes from observations were treated in a similar manner as interview transcripts and triangulated with interview interpretations.

Findings

We analyzed emerging patterns from the data according to three elements of connected learning that prior studies have demonstrated support positive equity and STEM learning outcomes: (1) sponsoring youth interests and identity, (2) shared projects and purpose, and (3) holistic and supportive relationships.

Sponsoring Youth Interests and Identities

Connected learning programs support equity through an “asset-based” orientation, meeting youth where they are and “sponsoring” their interests in a supportive, culturally responsive, and well-resourced environment. When learning grows out of personal interests and identities, young people can build connections between otherwise unfamiliar disciplines and home cultures and practices (Aikenhead & Michell, 2011; Pacheco, 2012). A culturally responsive and sustaining dimension is particularly important for youth who do not see their culture and identity reflected in the dominant culture of STEM (Alim & Paris, 2017; Gay, 2018; Gonzalez et al., 2005; Gutierrez & Rogoff, 2003; Morrell, 2007). Programs that focus on interest-driven, informal, and culturally connected approaches have demonstrated a positive influence on the development of and persistence in STEM learning (Dabney et al., 2012; NAS, 2021; National Research Council, 2009, 2015; Steinkuehler & Chmiel, 2006).

All the ISL programs in our study made efforts to connect to the culture and interests of their participants. For example, Ms. Linda, one of the four MESA educators we interviewed, implemented a sustainability project as part of her curriculum. She helped her students advocate for sustainable practices in their local community. Students lobbied for reusable soap and shampoo dispensers in local Anaheim hotels to reduce plastic waste. They created a campaign, wrote letters, and even went to the Anaheim Mayor’s office. She told us that she wants her students to “have a voice in their world and I want them to understand that. […] I want them to be aware of their environment.” This activity provided students an opportunity to identify a problem in their community and develop a solution. Ms. Linda used MESA to connect STEM with an economic, social, and political issue that speaks to her students and their communities directly. Daniel, a 13-year-old male, mentioned how he connected his learning at TGR to his community, and inspired others to take action: “In marine science, we learned about how plastic is endangering a lot of species in the ocean, and I told that to one of the people that lives in our neighborhood. [..] Then, a few months after I told her that, she made like a little group, and they started picking up trash and everything.” Projects like the ones discussed above, help connect STEM knowledge to larger societal and community-issues that students can relate to.

The asset-based orientation of building on Latinx youth identities and cultural competencies is evident in the case of Cianni, a 15-year-old female in Mr. Randy’s class. Cianni moved to California from Mexico a few years before starting MESA and is fluent in Spanish. She was selected as MESA class ambassador and is in charge of communicating about MESA to parents and other students. She told us that her bicultural background has been an asset in doing outreach in both Spanish and English:

> Ever since I moved here, I have felt lost because I’m very shy, and I can’t talk in public. MESA gave me the chance to be the class ambassador. I feel very comfortable with this class. I usually see myself as a leader in this class. […] Whenever a group of parents or students come to learn more about electives, I’m the one who stands up and talks about the class, like oh, this is MESA, and we usually build projects to learn more about engineering. They chose me because sometimes there are groups of students who don’t speak English, and I speak Spanish, so I translate everything.

ListoAmerica organizes events that bridge STEM and Latinx cultures and traditions such as Día de los Muertos and Cerebro (brain in Spanish). These events are open to students, parents, and community members and constitute opportunities to build trust with them, which ListoAmerica educators described as helping with program and STEM participation, retention, and success.

TGR organizes home visits so that educators learn about their students’ experiences outside of the program and develop more meaningful and long-lasting relationships. Ms. Danielle, the senior program manager at the Earl Woods Scholar Program at TGR – a program dedicated to college preparation –shared that her organization’s intention is to “really get to know the families on a more personal level [..]” Ms. Danielle describes how these home visits help the TGR team learn about the family dynamics and engagements students have outside of their ISL program, which helps them better understand their students’ needs and assets: “You see that sometimes students are maybe living in a one-bedroom apartment with nine other people, and they don’t have a place to actually study.” These understandings in turn inform the design of the Learning Lab space and schedule. She added that she learned from a mother during one of her home visits that on the weekends, her son “was waking up at five in the morning to help his dad collect cans and plastic bottles to help his family make ends meet. “At times, you know, he would have to hustle at school to sell Cheetos and candy, which is not allowed, but he had to somehow make it happen for him.” She learned of other initiatives that this student had engaged in that he “had actually been on the radio, talked about racial issues on the radio, but also merged it with the significance of being part of a mariachi band.”

Shared Projects and Purpose

All the programs in this study took a project-based, experiential learning approach. In connected learning environments, people come together in an authentic purposeful or creative activity, and learning is a by-product of that activity rather than the sole focus. Often, informal programs can more easily embody connected learning than formal environments because of the freedom they have to embrace open-ended, collaborative, project-based learning and not require assessment of individual learning outcomes. Participants often describe these authentic, project-based STEM environments as more motivating and psychologically safe because they are making genuine contributions to a shared and purposive project (Ito et al., 2018; NAS, 2021).

Educators described their ethos of experimental, project-based and inquiry learning. Ms. Linda from MESA emphasized a “try again” and “don’t give up” motto during the building and creation processes. She pushes students to embrace trial and error. She reminds her students about when they first learned how to write, and when “the letters are messy at first, and writing is hard as a young student, but then it becomes easier with practice.” Mr. Gus thinks that what draws his students at ListoAmerica is the “free-flowing” nature of the program as opposed to the “old traditional school” system that might “disengage” them: “I think that’s what attracts them. At first, kind of defensive, like if we’re going to tell them what to do. I think they associate it with school. I think that’s what they gravitate towards, that it’s not a school. It’s a hangout. It’s a clubhouse.”

In our interviews, youth noted appreciating the hands-on learning environment offered in their programs and how it was tied to them feeling like they can do STEM. For example, Amaya, a 15-year-old female, explained that she has a better understanding of her science projects at TGR because she is able to conduct experiments and see herself as a hands-on learner: “I like the lesson plans a little bit more than the ones at school, because the ones at school it’s like a book. It’s a little more free-flowing, and there’s a little more understanding when you do the experiments because I’m more of like a hands-on learner. Doing more experimenting helps.” Frank, a 16-year-old male from TGR, feels like the creative learning environment at TGR has been positively impacting his STEM learning: “In here, they let you expand your mind, use your imagination, and really try to express how you’re feeling, and express what you’re trying to build. […] it’s a place of designing and learning.”

Students described how this project-based approach was tied to feelings of psychological safety. Do’Jae, a 17-year-old female, said that through MESA, she learned that she “can do things and actually try, like and fail but if [she] puts in the effort, [she] will be good.” She added that in MESA, “I’m just myself. I’m able to learn. I’m able to push myself to challenges and be able to accomplish them.” MESA became a space where it was okay to not succeed or not to perform perfectly. She used to think that STEM wasn’t really for her, but MESA boosted Do’Jae’s confidence in doing STEM by providing her with a sense of psychological safety. Similarly, for Grant “having no pressure, no fuss attitude about there’s no right or wrong answers, no pressure on doing things like that, just approaching it with enthusiasm and like, it’s okay to fail. It’s okay not to understand it or be challenged. I think that’s what makes it worthwhile.”

Smaller class sizes and the informal, collaborative, and intimate setup also contributed to participants feeling comfortable and encouraged. For example, Mr. Gus discussed how the spatial organization at ListoAmerica contributes to creating a sense of community: “The open nature of this area is very much designed for them to interact and talk to each other. That concept, we call it creative chaos where they’re coming in here, and they’re interacting, and they’re clashing into each other. It builds that proximity with members here.**”** Similarly, Mr. Randy described small class sizes as an important benefit of the “MESA model:” “Since they are working in their groups, there is much more time to get to know them and try to have an impact on them. Versus, when I have 39 kids in a classroom and half of it is crowd control versus having that one-on-one.” The intimate scale and psychological safety of project-based programs and teams ties into the final characteristic of equity-oriented ISL programs that focus on holistic and supportive relationships.

Holistic and Supportive Relationships

The sense of psychological safety ties into another important element of connected learning environments: holistic and supportive social relationships that go beyond the boundaries of STEM subjects and courses. This includes caring adults with whom learners share interests and background, or what we describe as “affinity-based mentorship” (Ito et al., 2020, p. 34). When young people identify with a mentor and peers because of a shared interest, background, or identity, the relationship helps keep a young person engaged in the program or interest area (Barron et al., 2014; Larson et al., 2013). Youth from underrepresented groups are less likely to have family, friends, and mentors involved in STEM fields and interests, or to encounter STEM role models who share their cultural identity (George et al., 2001), despite the fact that they benefit more than mainstream youth when they have positive mentoring relationships (Bruce & Bridgeland, 2014; Schwartz et al., 2013b).

Studies suggest that informal programs are uniquely well suited to provide affinity-based mentorship because of the focus on shared interests and staff who often reflect the identities of the youth being served (Ben-Eliyahu et al., 2014; Maul et al., 2017). When youth were asked to name educators who supported their STEM learning, they named Black, Indigenous and People of Color (BIPOC) mentors most often. Melissa, an 18-year-old female from ListoAmerica, felt that because a majority of the people were Latinx at her ISL program, this contributed to "really hav[ing] a connection…I really do feel like it's a family here." Mr. Gus and Ms. Julie, two ListoAmerica educators, are uniquely positioned to connect with their students on a personal and cultural level. They identify as Latinx, were both first-generation college students, and come from similar socio-economic backgrounds as ListoAmerica members. Mr. Gus described a strategy for maintaining friendly and family-like relationships: "We don't call ourselves teachers, or we're not Mister whatever, so and so. We go by our first names. There's no hierarchy here with the members." According to Gayle, a 16-year-old female from ListoAmerica, educators are "more like my friends. They're more like an older sister and older brother helping us through high school and letting us know about this new technology that's being introduced." Mr. Andy, a former TGR student who is currently an educator at TGR, discussed how cultural connections with the staff at TGR played an important role in his connection with the program: "I was like, hey. It's weird seeing my teacher wearing Jordans, because I'm used to my other teachers being all professional. He was saying, hey, what's up man […] I felt like I knew this person […] There's a connection, I feel like he knows where I'm coming from and just of what I go through too."

In addition to the focus on shared interests and identities, ISL organizations can support relationships that develop over time and are not limited to a subject, course, or grade level. At TGR and ListoAmerica, youth can participate throughout their middle and high school years. In these environments, youth described how relationships with educators and peers were a reason for their persistence in their STEM programs. Daniel, a 13-year-old male, has been coming to TGR for several years. He described his relationship with Ms. Hope as his primary reason for continuing to attend STEM programs at TGR:

> She's my favorite. I think she's the only reason why I come. Ms. Hope is like my best friend. She's really always there for me. Like when I have any problems, she would come to me and be like, what's wrong? She would take me to her room, and we would talk. When I need somebody, she's always there. […] I see her every day. She's the best.

Six months later, during our second interview with Daniel, he added that one of the reasons why he still comes to TGR is the staff, "I got really close with them. I kind of consider them like my family."

Although MESA students do not have the option to continue in the program for as long as participants at ListoAmerica and TGR do, some also described the relationships in the class as "like family." For example, Martha, a 14-year-old female from MESA said: "My class is kind of like my family," because, "everybody knows each other, and they're all friendly and nice. I feel like if I describe it to someone, I would say it's like you being with your friends. Like collaborating, finding ideas, making stuff, like being with a family." Ms. Linda referred to her MESA class as her "family" on multiple occasions and shared with us that her running the class like a family is probably one of the main reasons that draws students to participate in MESA. Ms. Linda added that building trust was part of the "MESA family" approach.

MESA students also described how connecting about their lives outside of class created strong and holistic bonds. For example, Cristian, a 13-year-old male, appreciated that his educator organized "counseling groups" where students sit in a circle and pass a ball around and ask questions such as: "What was your favorite thing about the summer? What was your favorite thing about winter break? How do you feel about MESA?" His teacher did not only talk about the MESA class, but also asked about other courses and other aspects of their lives, which was helpful for "students that have a hard time with their family and everything and have a hard time focusing." The holistic and caring quality of the relationships in the ISL organizations we studied were tied to the educators' commitment to providing a safe and inclusive space where they can engage in projects as well as socialize. Mr. Gus from ListoAmerica shared that creating a "very friendly, open, and inviting" environment was crucial to him: "if we see a kid or member that's alone or something, even our members will approach them and build that friendship, introduce them. So, yeah, we definitely want to build that culture here of, we're all in this together, and we're all a family type of thing." Ms. Danielle from TGR mentioned that "as an organization, making connections with students and relationship building is really at the core of our foundation of everything." Ms. Suzie, also from TGR, expressed that "for some students, especially my returning students, this is like their safe space. Maybe both their parents are working, or no one is usually home…. This is a place where they can see their friends too from other schools." She added that providing a safe space where students know "there's an adult out there that cares about them, and they can come to whenever they need something" is one of the ways TGR can "make sure they do come back."

Conclusion

The goal of this paper was to highlight the unique contributions of ISL programs in supporting STEM interest and engagement for Latinx youth. We identified that through a connected learning framework with interest-driven, culturally connected, socially supportive, and project-based features, our selected ISL programs supported equity in STEM learning. This paper aimed to show that STEM support for nondominant youth can consist of offering STEM knowledge that connect to students' interests, cultures, and communities, creating a low-pressure and safe environment where students feel encouraged to experiment, and building relationships and providing emotional support. Ultimately, this study demonstrated that when advancing equity, STEM learning organizations should also develop and address cultural, social, and relational approaches. This paper offers an initial high-level framework and examples for understanding how some of the unique characteristics of ISL programs can support equity and inclusion in STEM learning. Additional research and analyses are needed to develop a more granular framework for specific programmatic and pedagogical features or ISL programs that support positive outcomes. In addition, the effectiveness of these approaches would need to be validated across a wider range of settings, at a time that is ideally more stable than when this research was conducted at the start of the COVID-19 pandemic.

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9. Challenges in Facilitating Computational Experiences in Informal Learning Environments

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Abstract: There is growing interest in implementing computational resources, technologies, and experiences in informal learning environments like museums, makerspaces, libraries, and community centers. In this paper, we highlight six shared challenges facilitators in three different informal learning contexts encountered in designing and implementing computational activities for their participants. These challenges touch on facilitators' identities, the relevance of existing materials, infrastructural constraints, visitors' perceptions of computational tools, issues of equity, and technical challenges.

Introduction

Informal education spaces are uniquely positioned to support learners, especially those historically and currently marginalized in STEM (science, technology, engineering, and mathematics) spaces, in developing confidence and interest in STEM and computing (Horn, 2018; Rahm, 2008; Roque, 2016). Carefully designed STEM activities center creativity, expression, and personal meaning-making, leading to STEM identity development and consequential learning for learners of all ages (Archer et al., 2022; Barton et al., 2017). We refer to the informal educators within these spaces as *facilitators* to reflect their roles in sparking, sustaining, and deepening learners' STEM experiences (Gutwill et al., 2015). Challenges arise as informal learning environments include making and tinkering spaces for creative interactions with new tools, technologies, and knowledge. At the institutional level, they may face budget constraints, copyright issues, and challenges in creating connections with their communities (Abbas & Koh, 2015; Slatter & Howard, 2013). Facilitators in these spaces also face challenges, such as not having enough staff to provide learners with one-on-one support (Abbas & Koh, 2015; Moorefield-Lang, 2015) or feeling that a wide range of disciplinary expertise is needed to support their learners' diverse interests (Bers et al., 2015).

Beyond this broad look at challenges informal making and tinkering spaces face, few articles have focused on challenges specific to implementing computing-based activities in these spaces. Braun and Visse (2017) and Martin (2017) highlight how librarians face challenges as they implement new coding initiatives, and note that librarians need resources such as high-quality professional development experiences to feel comfortable facilitating computational experiences. Riedy et al. (2019) found that computational materials in informal making and tinkering spaces can introduce tensions for facilitators, particularly when their goals as educators diverge from their learners' goals. Roque and Jain (2018) emphasize that adopting a "tinkering mindset" can help facilitators address some of the tensions and challenges that emerge when engaging learners in computing-based activities.

In conversation with existing literature, we ask: *what challenges do facilitators face in implementing computational activities in their spaces*? We are particularly interested in how challenges in informal STEM education spaces intersect with the tools, knowledge, and perspectives on computing held by facilitators and learners. To that end, this study aims to broaden the understanding of computing-specific challenges in informal STEM learning spaces by drawing on interviews with facilitators across various sites, including library makerspaces, a science center, and community technology centers. Making these shared challenges visible can support practitioners, designers, and researchers in grounding the design of computational activities and tools in the experiences of educators who engage their learners in these topics.

Method

Interviews

A pair of researchers conducted 90-minute semi-structured interviews with 16 interviewees from Fall 2020 to Spring 2022 with three organizations distributed across the United States: a network of makerspaces situated within public libraries (six interviewees) in the Mountain West, a making and tinkering space within a science center (five interviewees) in the West, and a network of community technology centers (five interviewees) throughout the US. These sites are part of an ongoing research project called "Facilitating Computational Tinkering" – a collaboration between university researchers and informal education spaces to design more equitable, social, and interdisciplinary ways of engaging with computing.

Leadership from each of the partner sites nominated a group of facilitators within their networks or institutions and we contacted each facilitator to invite them to participate in the interview study. Participants had a variety of backgrounds and roles in their organizations. The duration of facilitators' experiences in their current roles varied from less than a year to more than ten years. Except for one participant, none of the participants had formal educational or professional backgrounds in computing. The interviews took place over the video conferencing platform Zoom due to COVID-19 impacts. The main goal of the interviews was to uncover participants' goals, facilitation, and challenges of incorporating computing into their spaces. We grounded the interview by asking participants to share a computing or design-based activity. We also asked questions about their personal and professional goals, backgrounds, impacts of the COVID-19 pandemic on their practice, and how they think about equity in their spaces.

During their interviews, facilitators shared diverse examples of computational and design-based activities in their spaces. As a research team that believes in expanding notions of what "computing" can look like in informal spaces, we did not explicitly define computing in our interviews. Therefore, facilitators' explanations of computational activities varied widely. These activities included topics such as using computer software to create files for digital fabrication tools (e.g., laser cutters and 3D printers), engaging in video production, programming electronic tools like the raspberry pi, exploring coding platforms like Scratch, and combining programming tools with physical materials (e.g., programmable motors and instruments).

Analysis

Recordings of the interviews were professionally transcribed. A team of three researchers then engaged in an iterative cycle of analysis. We recorded initial impressions of the data by open-coding a subset of the transcripts and used memo-writing to keep track of emerging themes. These themes were brought together into an initial codebook. Broadly, this codebook captured themes of participant backgrounds, challenges, computing (including tools and materials, activities, and perspectives), goals, COVID-19 impacts, facilitation practices, and equity. We iterated on this codebook by coding interviews together, clarifying, and adding definitions as needed. After researchers reached a shared understanding of the codebook, they divided transcripts among team members and coded each transcript using the codebook.

For this paper's analysis, we looked at intersections between two codes, "challenges" and "computing," in the facilitator interviews. Challenges included moments where participants expressed feeling unsure what to do, encountering something they did not expect, encountering a dilemma, identifying a barrier, or any other unexpected or challenging issue – as explicitly specified by the participant and interpreted by our research team. Computing had three subcodes: tools and materials (materials for computing activity, technology-based tools, computationally produced artifacts, and other resources to support computing), activity (description of computational activity design, assessment, goals, and outcomes), and perspectives on computing (what facilitators believe counts as a computing activity). Segments in which these codes intersected were analyzed thematically, resulting in six themes, which we will explore next.

Findings

In our analysis, we identified six themes related to facilitators' challenges in incorporating computing into informal STEM learning spaces, which we illustrate in the following sections. We describe common challenges shared by *at least one facilitator at each site* (a total of at least three facilitators) to ensure that the challenges described are cross-cutting and not specific to a single site.

Facilitator's discomfort with computing

Facilitators reported varying levels of comfort, familiarity, and confidence with computation. Several facilitators described themselves as being less comfortable with computing saying things like, "I'm no expert at coding or Scratch or anything like that" and "[coding]'s not my strong suit." Brad, a community tech facilitator, described how this challenge intersected with the material and technology richness of his space:

> It's hard to meet the demands of every kid every day… I can't go from not knowing coding this week to… Yeah, I can teach someone next week about [coding]. So just trying to be an expert in several different areas can be a challenge…" (February 2021 interview)

Amy, a facilitator in a library makerspace, shared a similar discomfort. Amy positioned herself as a co-learner whose role is to help learners become experts, but noted that this strategy was not always well-received by some of the visitors in her space:

> I will say like, "I'm here to help you become an expert. I don't know everything, and there's probably gonna be things that we'll have to learn together, and that's totally fine." Which some people very much do not like. There are some adults who want me to say, "You're right, I do in fact know everything about computers and how they work"… (November 2020 interview)

Amy noted that some learners expected her to deeply understand computing. Brad described why that could be challenging in informal STEM spaces that are material and technology-rich – facilitators might be expected to have expertise with many different tools, machines, and materials in addition to computing.

Lack of accessible, adaptable, and relevant computational resources

According to facilitators, learners come to their spaces with diverse personal interests, varying technical and computational experiences, and different cultural and linguistic backgrounds. Facilitators valued this diversity and described the need to be prepared to adapt activities and to provide well-translated culturally relevant resources to support their visitors. For example, Cate, a community tech facilitator, explained how the language and reading skills embedded in some computational tools could create barriers for some learners:

> It's funny because I think coding is supposed to be like a universal language, but there's a lot of language involved with learning it, I would say. And so he [a participant in the space] was trying it and he was really engaged and

> bought in like, "Yeah, this is something I should learn," but there was just paragraphs of reading for him [to do with the activity], and that was difficult… (February 2021 interview)

In addition to literacy-related challenges, Jenna, a science center facilitator, described the challenge of facilitating coding activities for families in her space, stating, "It's harder with different activities, especially with coding one sometimes." Finally, Anna, a library makerspace facilitator, mentioned that it could be challenging to make connections between learners' interests and computing when other tools or activities in the space might better facilitate this connection:

> If people come in and wanna use the embroidery machine… it'd be pretty hard to be like, "Oh yeah, you could do this coding thing and make some weird designs," but they also see that it can make Pikachu so it's a hard sell… (February 2022 interview)

In this case, the goals of a coding activity may not align with visitors' goals, which in this context was wanting to recreate popular images on a fabrication machine. In short, the facilitators we interviewed were interested in and saw value in providing their visitors with opportunities to engage in computation. However, facilitators emphasized the importance of resources that are accessible, easy to adapt to different learners, and relevant to learners' goals.

Lack of one-on-one support in busy, "drop-in" spaces

Facilitators' workspaces are typically structured as drop-in spaces where visitors choose how long they stay in the space and how often they return. While many sites also offer workshop-style programming, facilitators spend much of their time with learners facilitating drop-in interactions. During drop-in time, facilitator-to-participant ratios can vary widely from one facilitator and a few participants to one facilitator and 20 or more participants. Typically, the facilitators we interviewed worked in pairs within their spaces.

Many facilitators, like Diego, a community tech facilitator, emphasized the challenge of trying to support many participants during drop-in times. Diego said, "Honestly anything over 20 students, it's just overwhelming, it's just really hard to pay attention to kids." Facilitators like Anna, a library makerspace facilitator, noted that facilitating computational activities during drop-in time can be particularly difficult because these activities are conceptualized as requiring more one-on-one facilitation. Reflecting on introducing a robot-building activity during their drop-in time, Anna described the challenge of supporting and sustaining kids' participation towards meaningful progress:

> It's hard finding that balance where if we're just busy helping other folks, how quickly can we get them the assistance they need and how much help can we give before they kinda lose interest… I definitely know that one-on-one [interaction] makes such a difference. (February 2022 interview)

Anna identified one-on-one support from a facilitator as helpful in guiding learners as they explored the kit, but noted that offering this support is challenging when the space is busy. This challenge was echoed by several facilitators, highlighting the importance of attending to facilitator and participant interaction structures, particularly when computational tools and materials are involved.

Visitors' associations of computational tools with school learning

Providing a space that feels complementary to but distinct from school was a goal that several facilitators shared. Traci, a community tech facilitator, described this goal by saying, "we're just there to allow them to find what they love and give them freedom…" Some computational materials, like certain coding environments, were described by facilitators as being in tension with this goal because their visitors perceived them as "too much like school." Cate, a community tech facilitator, shared that some of their learners viewed Scratch as a classroom tool:

> Sometimes kids just don't like it, especially because they think Scratch is used in the classroom a lot, and so they're like, "Oh, we do this in school, so I don't know if [we] wanna do this here"… [I] definitely sometimes have to convince the kids to use Scratch, 'cause they're not super into it right away." (February 2021 interview)

That said, learners' familiarity with Scratch from school can lead to additional challenges when facilitators attempt to use Scratch to engage learners in computing. Cate went on to describe how some of her learners are very familiar with Scratch and are looking for opportunities to learn different computational skills:

> And so, I think when kids think about doing Scratch outside of school they're like, "I already know it all. I just, I've already learned it, I don't need to do it again." […] for the kids who really start to learn coding, like who've done Scratch and really understand coding, they wanna do something that's more real, like something that they're gonna do, and especially those older teenagers, something that they're gonna use in a job… (February 2021 interview)

Beyond Scratch, Amy, a library makerspace facilitator, shared how teaching programming languages at her site can become a challenge for younger learners because teaching languages such as Python or JavaScript can feel too much like formal instruction:

> We absolutely have taught classes, especially for adults that are more of like, here is how to use Python, here is how to do JavaScript. But I feel like for kids and teens, it's a snooze fest. It's too much like school. (November 2020 interview)

In this way, supporting learners' computational interests can be a balancing act for facilitators who want to engage participants in expressive and open-ended computational experiences that children do not typically experience in school while still supporting skill development in new programming languages and other forms of computation.

Inaccessibility of computational tools and materials

Facilitators often spoke about the importance of providing their learners with access to computational materials and tools. However, facilitators noted that neither they nor visitors always had access to computers that could run the various software they wanted to promote in their spaces. For example, the library makerspaces included access to Chromebooks, which were not always compatible with the computational tools they wanted to use in activities. Anna, a library makerspace facilitator, noted that "we only have Chromebooks in our space aside from the free-standing computers… Chromebooks don't run anything." The Chromebooks limited the activities and workshops the facilitators could design and run.

Additionally, even if the spaces had access to appropriate technology, it did not mean that visitors had access to such technology outside of their visits. This disparity was viewed as an equity issue, as voiced by Leonardo, a science center facilitator:

> I mean, the big issue in question that is unresolved for me is access to materials and tools for computational stuff. And a lot of times there is just that hard limit of like kids don't have computers. And what's the answer to that. And how does that not propagate existing inequities that kids with access, they get even more access, and kids without access get left out. And as we think about how to work with populations of and collaborators… can we build in access to these tools, but in a way that… builds towards this becoming a permanent thing, that it's

> not just like, oh, you have access to this for the duration of this project, but then we take it away. (October 2021 interview)

Leonardo described a tension that several facilitators shared: they wanted to provide access to high-tech tools that are not typically accessible to visitors outside of their spaces due to the cost of the tool, but they also wanted visitors to be able to continue explorations they started in these spaces, at home. They worried that access to their spaces might become a form of gatekeeping, where some learners only have access to computational tools and materials at specific times.

Uninteresting technical challenges

Because technologies like computers and microcontrollers are often part of computational activities, facilitators and their visitors may encounter various technical challenges when engaging in computational activities. These challenges are sometimes described by facilitators as "uninteresting" or "unproductive" because, in the context of the activity, the challenges are unnecessarily frustrating and misaligned with many facilitators' goals for their visitors to engage with computing in fun and open-ended ways. Jenna, a science center facilitator, described an activity where learners got stuck during the setup of the activity instead of focusing on the actions that could be carried out through the code:

> I think of them as the sticking points, the points where it's actually really easy to lose people if it's not a smooth process. So if it's too hard to scan a Sprite into a digital project, that seems like a little moment, but actually it's a really important moment. (March 2021 interview)

Jenna worried that learners might lose interest and miss an opportunity to fully engage in the experience because of these uninteresting technical challenges. Leonardo, a science center facilitator, echoed this worry, stating:

> They were frustrated by the fact that in order to just turn on a light, you have to use a [programming environment on the iPad], like it was the most impractical switch I've ever devised. I just want this thing to be on, and now I have to go through this complicated [process]. (February 2021 interview)

In these cases, facilitators recognized the importance of paying attention to learners' frustrations during computational activities. When the challenges that learners encountered crossed a line into "unnecessary" or "uninteresting" rather than an important part of the learning, debugging, and problem-solving skills in computing, facilitators became concerned that these challenges might discourage learners from engaging in computation.

Discussion

To design high-quality computational learning opportunities for informal education settings, we must understand facilitators' barriers to incorporating and implementing computing. Informal learning spaces have the potential to meaningfully engage historically marginalized communities as facilitators craft learning experiences that are relevant and expand notions of what topics like STEM and computing can look like. However, striving towards these ends requires deep and critical thought about the challenges facilitators face, and potential solutions. Our results highlight six challenges that align with previous research on the challenges that facilitators navigate, e.g., facilitators' perceptions of their expertise impacting their comfort with facilitating certain activities (Litts, 2015) and informal learning spaces requiring a high level of adaptability and flexibility in facilitation (Koh & Abbas, 2015). However, our results dig deeper into how these challenges manifest in computing activities specifically.

Although the challenges we described were shared between sites, their details and level of impact varied. For example, facilitators in library makerspaces with limited funding found access to technology more challenging than facilitators in the science center, which had different sources of funding and visitor demographics. The community tech center had a free membership model, and facilitators anticipated that members would regularly visit. However, facilitators in the libraries and science center noted that while some visitors returned regularly, most were one-time visitors. Many of these challenges are complex and do not necessarily have simple solutions, as they are intertwined. For example, uninteresting technical challenges can intersect with a lack of one-on-one support for participants; a participant encountering a frustrating technical issue could experience even more frustration without one-on-one support from a facilitator. For these reasons, we believe that an in-depth understanding of these challenges requires attention to the complexity of practice within each institutional context.

The heterogeneity of the challenges also leads to variations in how facilitators at each institution may respond to them. The facilitators we interviewed are already exploring ways to address the challenges we raise here, such as leveraging networks of peers and mentors with computational expertise and limiting participant capacity during new computational activities to provide more one-on-one support. Prior literature may also offer suggestions for how to address some of these challenges, such as creating opportunities for computing-specific professional development opportunities (Braun & Visse, 2017) for and with facilitators, or designing and creating activities and materials that are culturally relevant for learners (Scott et al., 2010). Of particular interest to our research team is the goal of broadening what counts as computing in terms of materials, activities, practices, and knowledge that builds on the histories and everyday experiences of youth, families, and other community members such as facilitators. Computing does not require microcontrollers or text-based coding exclusively but can also involve everyday materials and personally relevant storytelling and activities (Tzou et al., 2019). We note that these solutions cannot be transplanted from one context to another. Researchers and practitioners must take the time to deeply understand the context, its limitations, and its affordances so that solutions can connect with existing practices and routines. Additionally, practitioners must play an active role in this solution-building process rather than it being driven solely by researchers (Hladik et al., 2021).

In our future work, we aim to collaboratively address these challenges with facilitators across these spaces by engaging them in the co-design of computational activities and making the solutions they have already designed visible. We hope the co-design process can support the development of facilitators' identities as designers, creators, and facilitators of computational learning experiences.

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10. Creative Storytelling with Machine Learning

New Pathway into AI Education

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Abstract: Recent efforts in computing education have emphasized opportunities to introduce foundational ideas in artificial intelligence (AI) to all children. Constructionist learning has been recognized as a promising learning approach to introduce computing to learners. To understand how constructionist learning experiences may support AI education, we conducted an online professional development workshop in which educators create a storytelling project using a tool PlushPal that turns everyday objects into interactive toys using machine learning. By analyzing the projects created by the educators as well as their reflection notes, we explored how machine learning may support learning through creative storytelling and for AI education. The findings of this study include a wide variety of ideas for AI integration in classrooms as well as troubleshooting challenges and resource needs.

Introduction

As more advanced artificial intelligence (AI) is introduced to our society, it has increasingly been recognized as a topic that all children should be exposed to from an early age. The introduction of AI in their lives can not only enable them to make more informed decisions as they interact with technologies in everyday life but also help them think critically about the application of AI in social systems, inspire interests in the field, and empower young people to be the next generations of researchers, designers, and developers of these technologies (Marques et al., 2020; Touretzky et al., 2019).

While there is discussion of what specific concepts about AI need to be taught at the K-12 level (Touretzky et al., 2019), direct engagement with AI technologies through open exploration has been considered to be an important approach in introducing AI to children (Kahn & Winters, 2021; Touretzky et al., 2019; Vartiainen et al., 2020). This approach that supports learning through creative construction of personally meaningful sharable artifacts is called constructionist learning (Harel & Papert, 1991) and has been recognized as a promising way to introduce computing to learners of all ages (Kafai, 2016; Tissenbaum et al., 2021). The application of AI through constructionist learning approaches can help learners engage with the technology through iterative exploration by being exposed to both possibilities and limitations (Kahn & Winters, 2021).

Technology-supported storytelling is an approach that has long been recognized as an educationally meaningful activity (Robin, 2008). Storytelling is one of the most common types of constructionist activities, where learners are asked to create a project that conveys a story of themselves or of the things they are learning. Computational construction technologies have great potential to expand such educational opportunities by providing a variety of materials and spaces for young people's creative explorations. Various types of computational construction tools have been designed and studied to support storytelling, such as the visual programming tool Scratch (Resnick et al., 2009) and the physical computing tool MakeyMakey (Silver et al., 2012) to name a few. Some projects, such as Cognimates (Druga et al., 2018) and Teachable Machine (Carney et al., 2020) have started exploring applications that enable children to create projects with machine learning (ML), but limited work has looked at the educational implications of ML-supported storytelling.

In this study, we explored the potential of applying ML to support storytelling in classrooms. We explored this theme by looking into the topic from educators' perspectives, inviting them to try out an ML-supported construction tool called PlushPal, work on storytelling activities, design a lesson, and reflect on the experience, examining the potential possibilities and limitations for their classrooms. The research questions (RQ) that guided our study were: (1) what are the ways the ML-supported tool contributes to storytelling? and (2) how may storytelling with ML support learning in classroom settings? The findings from this study contribute insights to the growing body of work exploring how AI should be introduced to young learners and be meaningfully integrated into the school curriculum. We provide documentation of educators' perspectives and ideas they believe will impact the successful implementation of new technologies.

PlushPal: ML-Supported Storytelling Tool

To explore our research questions, we employed an open-source web application called PlushPal that enables children to make their own plush toys interactive through ML. PlushPal was designed to capture complex movements in children's play involving plush toys. Movements that children make with their plush toys (e.g., dancing and swimming) are not supported in existing platforms that have limited capacity to capture higher-level gestural input. For instance, the physical computing extension of Scratch with an affordable microcontroller micro:bit (BBC, 2015) only allows users to detect predesigned simple movements such as *shake*, *jump*, and *move*. Advanced gesture recognition can greatly expand the creative potential for children to make projects that have personal relevance and meanings.

In PlushPal, children create ML gesture-recognition models using real-time accelerometer data from micro:bit attached to their plush toys. Using the PlushPal application, children can program a variety of sound feedback to be triggered by each gesture using the simple interface. (See Figure 1 for the interface and the steps to create a project on PlushPal.) Children can either upload a pre-recorded sound or create their own sound file by recording their own audio or using the text-to-speech function.

Type	Description
Explanatory	An educator provides an explanation.
Narrated (Figure 2a)	An educator narrates the story.
Performative	An educator performs as the toy.
Conversational (Figure 2b)	An educator converses with the toy.
Collaborative (Figure 2c)	A group of educators perform together using the gallery view of Zoom or having one educator narrating while the other educator performing with PlushPal.

Figure 1. PlushPal interface and steps to create a project.

When children record gesture samples, they can monitor what the accelerometer has detected and recorded visually as a graph of three colored lines representing multidimensional (x, y, and z-axis) accelerometer data (Figure 2a). Children can also monitor what PlushPal is currently detecting in real-time on the console in a similar manner. In addition, if the recorded gestures do not work as intended, children can open the more detailed Console panel that shows which sample PlushPal is detecting as the closest to the current gesture among all the samples that have been recorded (Figure 2b).

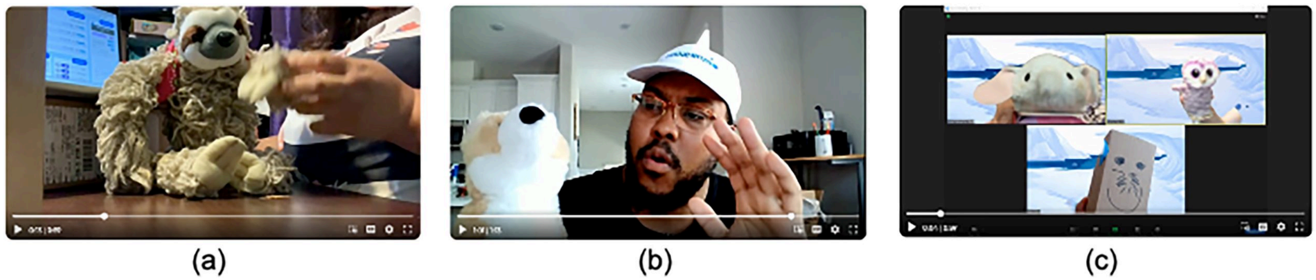

Figure 2. PlushPal gesture monitoring interfaces: (a) accelerometer data and (b) model details.

Methods

The purpose of this study was to gain a better understanding of educator perspectives and their ideas on integrating AI into their classrooms through a constructionist learning activity. Based on the perspective that meaning is socially constructed, we collected qualitative data that reflect each educator's thoughts and perspectives from the workshop and thematically analyzed them.

Participants and Contexts

We collected our data during a professional development (PD) workshop where PreK-12 educators remotely participated from 17 states in the United States. The workshop was hosted as the third day-long workshop of a week-long PD on maker education and computer science, specifically focused on micro:bit. All educators were provided with a micro:bit by the PD provider. A total of 39 out of 42 educators provided consent to participate in the study. This included 31 classroom teachers, 1 administrator, and 8 educators who work in other contexts. We designed a 4-hour online workshop using PlushPal and worked with a research assistant and three PD organizers to facilitate the workshop on the video conferencing platform Zoom. Each facilitator monitored the conversation in the main and breakout rooms and kept notes on their observations.

Workshop

The workshop consisted of three parts: (1) introduction to PlushPal and AI, (2) storytelling activity with PlushPal, and (3) lesson design activity. For Part 1, we gave a presentation that provided a beginner-friendly introduction to ML. During Part 2, educators were asked to bring a plush toy to life using PlushPal in groups of two to three. A Google Slides template was provided to help them brainstorm a story and the gestures associated with it. During the activity, each group created a demo video and shared it on the video-sharing platform FlipGrid. Using virtual post-it notes on Jamboard, educators then reflected on what the experience made them think, wonder, and want to explore. For Part 3, the educators formed larger groups and created a lesson idea using a template that contained specific components of a lesson (such as objectives, activity prompts, reflection prompts, troubleshooting ideas, etc.). At the end of the workshop, participants again took time to reflect on opportunities, questions, and challenges in implementing activities like the ones they designed.

Data and analysis

The data we collected include demo video recordings of the storytelling project and brainstorming notes; digital post-it notes of reflections; the lesson plans generated in Part 3; and observation notes and debrief meeting notes documented by the facilitators. Two team members of the study, including the primary facilitator of the workshop, closely read the data separately and identified themes; they then met to discuss the themes until they reached an agreement for all the themes being identified.

Findings

RQ1: What are the ways the ML-supported tool contributes to storytelling?

To explore this question, we first looked at the storytelling projects created by the participating educators. In total, the groups of educators produced 14 short demos (from 30 seconds to 1 minute) videos recorded using PlushPal and a variety of plush toys that they owned. The demo videos presented various project ideas that educators explored with the platform.

Overall, we identified five types of stories (Table 1), including *narrated stories* like the project in Figure 3a, *conversational stories* like the project in Figure 3b, and *collaborative stories* like the project in Figure 3c. Other types of stories include *explanatory stories*, where an educator explains each movement ("This is a jumping gesture.") and demonstrates the movement and sound played by PlushPal, and *performative stories*, where an educator fully narrates *as* the character ("What a long day. Good night!") while playing other types of sound.

Table 1. Types of storytelling.

[Table 1 goes here]

[Figure 3 goes here]

Figure 3. Examples of educators' demo Videos: (a) narrated, (b) conversational, and (c) collaborative storytelling.

Figure 3a shows an example of a *narrated* story, which was a story of a baseball-loving sloth who goes to a baseball field, tries to catch a foul ball but falls asleep on the way. An educator narrated the story ("A day in the life at work of [DL] sloth. He loves going to the zoological baseball field") while PlushPal played sounds of walking, reaching out for the ball, and sleeping based on each of these distinct gestures.

On the other hand, the project shown in Figure 3b shows an example of a *conversational* story, where one of the educators in the group appears in the frame as an actor in the story having a conversation with a dog, as the dog goes about his morning routine sipping a cup of coffee. In this project, PlushPal was used to voice the dog's reactions to the educator, also recorded by the same educator:

> Educator: I'm here joined by my friend Percival Pascal. This dog got so much attitude (…) He likes to start out for the day with a cup of cappuccino so got some of that for him right here. (helps the dog drink from a cup) See how he likes it.
>
> Dog: (makes slurp sound) Whew! Yeah, yeah yeah. That's the stuff, right there, right? Cappuccino.
>
> Educator: That was good?
>
> Dog: My goodness gracious, that's pretty good stuff right there. I'm ready for the day now. (slurps more)
>
> Educator: No more, you need no more (…) (Dog starts to jitter intensely) Oh-oh. He had too much caffeine already. Here we go again.
>
> Dog: Oh my god, what did they put in this cup?
>
> Educator: It's caffeine, man.

Dog: I mean, I know it's caffeine, but what kind of caffeine?

Educator: Regular caffeine?

Dog: I know, but look… Whatever, I'm taking off to running.

Educator: Oh my goodness gracious (…) (Dog still speaking in the background) Look, are you still talking? Be quiet! (…) Is there anything you want to tell the people before we go? Hmm?

Dog: I don't know why you guys let this guy… (inaudible).

Educator: Wow, wow, take it easy!

Dog: No. No, let me talk before you finish. You asked me a question, I would like to reply.

Educator: You're being rude.

Dog: Anyway, I have no idea what he's talking about. You can't put me away.

Educator: No forget it. Be quiet. (to the audience) Sorry guys, you guys have a good day.

By skillfully improvising to the timing that PlushPal plays different remarks of the dog, who speaks like an adult human, the educator successfully presented a comedic skit between the educator and a dog that became jittery from drinking a cup of cappuccino.

Figure 3c is an example of a *collaborative* story, where three educators worked together using the group remote conferencing tool to present a conversation between three characters performed synchronously from each site. They used the same background to set the story in a tundra, where one of the characters' lives and one of the characters tries to convince the other two to come to live with her (which the other two refuse because it is too cold). Each educator used PlushPal to play sounds associated with their characters (one character makes the sound of shivering and the other character says "no thank you").

Each group's video was situated in a different context, from an amusement park to an enchanted forest. We asked educators to create three gestures during the brainstorming time, so most projects included three to four gestures such as *eating*, *greeting*, and *flying*. We also noticed several video-making techniques, including using a hand-held recording device (such as a phone) and recording in Zoom with virtual backgrounds.

We observed that PlushPal was used in several different ways in those projects, including (1) to make a sound that a character makes, (2) to voice what a character says, (3) to add narration, and (4) to play background music/sound and a combination of several of those. Some of the sounds were using the pre-recorded sound available by default in the PlushPal platform or uploaded from educators' computers, while others recorded their voices or used the text-to-speech function to create their original sounds.

RQ2: How may storytelling with ML support learning in classroom settings?

To examine this question, we looked at the documentation of educators' reflections as well as observation and debrief notes taken during and after the workshop. About a third of the educators mentioned that storytelling could be a way for their students to engage with specific domain ideas or build vocabularies for the fields like mathematics and computer science. One educator described the idea of having students role-play a math educator to engage in math ideas. Another educator talked about an application for young students to create a biography to help them understand history. Language arts, which is learning how to listen, speak, and write, were also mentioned as an educational goal; for example, an educator described, "[I would] bring story elements, dialogue, and all parts of writing to life after S[tudent]s create it on paper. Then practice speaking, listening, reading, and writing for all, especially ELLs (English language learners)," emphasizing the possibility of using PlushPal to bridge different skills in language arts.

Another popular idea mentioned by educators was to incorporate the tool to support collaboration and social-emotional learning (SEL). For example, several educators mentioned the idea of bringing younger and older students together to work on a project collaboratively, where older students help younger students turn their imagination into a project with PlushPal. For SEL, a group designed an activity to have students explore emotions by programming certain movements to have sounds associated with each emotion. Some other educators described students creating stories about themselves using PlushPal to explore their own emotions, identity, and characters.

Five educators discussed ideas to raise awareness about physical movements and gestures. For instance, one group created a lesson idea that focused on an activity that aims to engage students in thinking about different ways body languages (such as nodding and crossing arms) are interpreted by having them look up and represent them in PlushPal. Two of them even proposed the idea of attaching a micro:bit directly on a human or animal to more directly address the issue. Educators also wanted to connect multiple micro:bits and other sensor tools to different types of outputs to enhance data collection, implying that many educators had access to a larger inventory of technologies that can enhance physical learning experiences in their schools.

Finally, educators discussed how PlushPal could create opportunities for students to learn how ML works, and how they are being used in real life. One educator mentioned that this activity would not only engage students to help them learn about AI but also encourage them to use their creativity to work with AI. Others also talked about engagement with the PlushPal platform can allow students to analyze graphs and understand the system through problem-solving when something does not work. A number of educators described a problem-solving experience with PlushPal where they had to fail and figure out how to fix it. One educator commented directly on this experience, "Thank you so much for allowing us space to fail and then succeed and finally have fun! All part of the process."

One of the most common concerns mentioned by educators about implementing PlushPal in classrooms was troubleshooting. It is likely that these claims resulted from many troubleshooting educators needed to do during the workshop, as misrecognition is common for ML, especially until one understands how pattern recognition works. One educator described that they are worried that teaching activity with PlushPal would be chaotic and would require a lot of practice and patience for students. Other educators mentioned the lack of resources and expertise in supporting students to troubleshoot. While some educators proposed ways to support troubleshooting, such as having students make videos of successful troubleshooting and assigning "expert" roles to students who mastered the tool to help other students, or pre-recording sound snippets and sentence stems so that students can focus on other things, it emerged as an important topic to further explore.

As a technical concern, some other educators also indicated that access to infrastructure and hardware remains a top concern for them. Internet and Bluetooth connectivity were not stably available in all school environments. While the educators at the workshop were provided with a micro:bit, they indicated that preparing it for a class was not necessarily an option for everyone. They also identified challenges around saving and working on the projects across multiple periods of sessions. PlushPal platform allows users to export recorded gesture samples but does not allow exporting sound files and programmed projects to protect the privacy of children using the platform. However, this was a challenge for many educators who expected that students would work on projects over many sessions.

Discussion

Through a 4-hour professional development workshop with 39 educators using PlushPal, we discovered that PlushPal was able to support and enhance storytelling for learning. The ideas expressed by the educators highlighted the creative possibilities of integrating storytelling with ML in classroom settings. The various ways educators envisioned storytelling through the projects they created with PlushPal, from explanatory videos to role-playing to collaborative storytelling, demonstrated the variety of ideas that can be explored with students in classroom settings. It also indicated that the tool provided a fair amount of open-ended play possibilities that enabled participants to explore ML with their own ideas, which has been considered important in some literature (Kahn & Winters, 2021; Touretzky et al., 2019; Vartiainen, et al., 2020). In the projects created by the educators, ML played a role in opening up the possibility of types of sound and gestures that can be used to create the projects. This helped some participants tell stories that are highly contextualized in their own environments, which is another indication that there was enough flexibility and openness for participants to personalize their stories.

While we started this project with the question of how to engage children with AI through the constructionist, exploratory learning approach (Harel & Papert, 1991), educators pointed out a variety of other learning outcomes that they think can be achieved through the storytelling activities using PlushPal. From language arts to math, science, and physical movements, the projects created by educators illustrated how storytelling is a tool that can be applied to various different domains, and how ML may help engage students by allowing them to connect those topics to their own contexts.

The projects created by educators also demonstrated a variety of ways learners can collaborate on creating projects through storytelling with PlushPal. Despite the fact that PlushPal was designed primarily for individual use, the educators enjoyed and were inspired by the collaborative activities they experienced during the workshop and saw it as a possibility for their classrooms. The ways educators collaborated during the workshop, from brainstorming together and one educator recording the whole project, to each educator creating a project and playing it together as one story, showed diverse ways students can work together with this ML tool. This might be an interesting direction to explore as many AI-driven tools such as voice assistants are tailored to individual use and not designed to be used by a group of people.

Many educators discussed that troubleshooting was their concern in incorporating PlushPal into their classrooms. Educators described that being able to resolve troubles in a timely manner is crucial to keep student engagement high in classrooms. On the other hand, educators were learning about ML by trying to solve problems when things were not working. Some educators even mentioned that troubleshooting itself, analyzing and solving the problems, could be a valuable learning experience for their students. Another study by our team with younger children using the same storytelling tool also showed that troubleshooting can be an opportunity where participants gain a deeper understanding of how ML works (Tseng, et al., 2021). This may imply that while more resources for educators to support students in troubleshooting are needed, there is also an important opportunity to explore the role of troubleshooting in learning for students. Since the workshop needed to be held entirely remotely, we could not closely observe how data visualization functions of PlushPal were utilized for troubleshooting by the educators. The future study should explore how the capacity to see the decision-making process of ML may contribute to learners' understanding of ML and the comfort of working with it as a creative tool.

Lastly, the fact that many educators requested the function to save student project data raises the question of how educators should teach students about ethical problems of data handling in AI and how to protect them from potential harm. In addition, it is increasingly recognized that children themselves need to learn the potential ethical issues surrounding AI (Akgun & Greenhow, 2021). Though it was out of the scope of this study, creative storytelling like the one we examined engages students in direct and exploratory interaction with AI and has the potential to provide students with an opportunity to reflect on those issues based on their first-hand experiences. Future studies should explore how constructionist learning with AI can contribute to this field.

Conclusion

Through introducing an ML-supported construction tool in a remote educator professional development workshop for 39 educators, we explored how educators envision the role of ML-supported storytelling in their classrooms and challenges as well as opportunities for such activities. Our analysis showed early evidence that ML can invite learners to construct a wide variety of stories by incorporating objects and environments around them, along with the ways ML can be used for storytelling. Based on the experience engaging with PlushPal, the educators also suggested many applications of ML-supported storytelling activities into their classrooms, as well as potential challenges. Future studies should explore how troubleshooting could be supported and how it may contribute to users' learning process.

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11. Building a "Home-Place" in STEM

Leveraging Race, Resistance, and Cultural Wealth to Foster STEM Counterspaces for Youth of Color

TIERA TANKSLEY

Abstract: This paper examines the power and potentiality of STEM (science, technology, engineering, and mathematics) homeplaces as places of refuge, spaces of healing, and sides of radical possibility for Students of Color. Qualitative interviews with two Women of Color educators ground this study, and provide insight into the programmatic features, including cultural norms, policies and practices, that fostered feelings of safety, love, healing, and empowerment for Youth of Color in an otherwise toxic and exclusionary STEM field.

Introduction

> Historically, African American people believed that the construction of a homeplace, however fragile and tenuous…had a radical political dimension. Despite the brutal reality of racial aparthied, of domination, one's homeplace was the one site where one could feely confront the issue of humanization, where one could resist. (hooks 2014)

In her seminal piece "Homeplace (A Site of Resistance)," hooks describes the sociopolitical power and potentiality of culturally situated and race-conscious "homeplaces" for People of Color. Definitively, a homeplace is a space of refuge that fosters a culture of love, support, humanization, nurturance, and restoration for People of Color. Crafted by Women of Color, homeplaces play an indispensable role in the survivance of marginalized people namely because they "include caring for one another, for children…in ways that elevated our spirits, that kept us from despair, [and] that taught some of us to be revolutionaries able to struggle for freedom." This latter piece is crucial, and illuminates the indispensable connection between homeplaces as sites of *care, love, and hope*, and homeplaces as sites of resistance, transformation, and radical possibility.

Although hooks' (1990) original notion of homeplace was situated in a private, family home – a location *outside* of physical spaces that reinforced racial oppression – Kelly (2020) reminds us that homeplaces can also exist *within* oppressive spaces, such as schools and classrooms (p. 451). Serrano's (2020) work on academic homeplaces further illuminates how Students of Color construct racially affirming homeplaces in order to transformatively resist hostile racial climates on campus. In addition to sustaining a community of love, resistance, and healing, academic homeplaces foster "a sense of family and home for students who must navigate the daily challenges of racism in institutions of higher education and beyond" (Serrano, 2020, p. 14). They are also spaces that offer culturally sustaining pedagogies, mentorship, and support, and increase students' access to Mentors of Color who can draw upon shared experiences with racial domination to inspire, support, and meaningfully connect with their students. In these ways, academic homeplaces prepare Students of Color to survive and resist "the daily reminders that these institutions were not built for the students who now occupy their seats" (p.14).

In the context of STEM, where racist and sexist cultures consistently mediate the experiences of marginalized students, academic homeplaces can prove to be beneficial for educators interested in fostering more supportive and racially healing learning environments. Though there is a growing body of scholarship documenting the educational and sociopolitical benefits of academic homeplaces, there remains a critical dearth in scholarship detailing the practical steps and pedagogical strategies that educators can leverage to create and sustain homeplaces in the racially fraught discipline of STEM. To address this gap, this paper explores how two Women of Color educators created race-conscious and culturally sustaining homeplaces for Students of Color in STEM. The following research questions ground this study:

1. What programmatic features foster educational resilience in general, and STEM resilience in particular, for Students of Color?
2. How do educators leverage their sociopolitical identities and or minoritized funds of knowledge to create and sustain such programmatic safe spaces?

In the following section, I detail the permanence and pervasiveness of intersectional oppression in STEM for marginalized youth, and the power and potentiality of academic homeplaces as sites of resistance, retention, and radical possibility.

Literature Review

Extant literature reveals that Students of Color consistently endure inequitable, dehumanizing, and racially hostile conditions as they traverse the STEM education pipeline (Collins et al., 2020; Ireland et al., 2018; King & Pringle, 2019). In general, Students of Color are more likely to attend schools that are underfunded, dilapidated, and racially segregated; have high rates of teacher and principal turnover; and lack high-quality learning resources, such as digital technology, lab space, and up-to-date text books. The schools that serve the highest rates of Black and Brown students are simultaneously less likely to have gifted and talented (GATE) programs, advanced placement (AP) classes and academically rigorous extracurriculars, like coding or robotics, that adequately prepare students for STEM careers and college pathways. Alternatively, when STEM-rich learning resources are available, Students of Color are rarely identified as gifted, talented, or eligible for high-performing learning tracks (Collins et al., 2020; Evans-Winters, 2014). Instead, they are disproportionately tracked into remedial and low-performing pathways regardless of their interests, engagement, or achievement in STEM. Such systematic barriers quietly funnel Black and Brown youth out of STEM college and career pathways.

Unfortunately, even when Students of Color are enrolled in well-funded schools with adequate STEM facilities and learning resources, they still experience challenges with achievement, engagement, and retention (Davis, 2020). Studies have identified a multitude of factors behind these dismal outcomes, including culturally irrelevant curricula, lack of diverse representation, limited access to Peers and Mentors of Color, and the ubiquity of racial and gendered microaggressions. Cumulatively, these factors foster racially hostile learning environments for marginalized students, and have been identified as some of the primary causes of their eventual disengagement from and disinterest in STEM.

Despite the ubiquity of racial hostility in STEM, educators have worked diligently to foster racially affirming and culturally situated “safe spaces” that can foster resistance, resilience, and retention for marginalized students (Serrano, 2020). Because they directly challenge the racially oppressive STEM status quo, these identity-centered spaces are considered to be STEM counterspaces, and have a profound impact on the educational experiences of Youth of Color (King & Pringle, 2019; Lee et al., 2015; Sandoval, 2013; Scott, 2009; Scott & Garcia, 2016; Scott & White, 2013; Scott et al., 2015;). As defined in the literature, counterspaces are academic and social spaces that allow Students of Color “to promote their own learning and experiences, facilitate discussions on experiences of overt racism, and promote a positive racial climate” (Serrano, 2020, p. 5). They can be physical, digital, verbal or spiritual spaces that provide a protective barrier against racial assaults, and in doing so offer opportunities to heal and, subsequently, “fight back” against oppressive conditions (Serrano, 2020; Solorzano, 2022). Unlike traditional STEM spaces that operate from culturally deficit and racially hostile frameworks, academic homeplaces maintain an asset-based view of Students of Color, and place their cultural identities and racialized experiences at the center of learning rather than on the margins. They simultaneously provide invaluable access to Peers and Mentors of Color – and research has consistently linked sustained access to mentors from similar backgrounds as a crucial component of retention and success in STEM (Dickens et al, 2021; Griffin et al., 2010; Kricorian et al., 2020).

Importantly, counterspaces embrace alternative approaches to STEM teaching, learning, and mentoring that center, rather than obscure, the cultural and racial wealth of marginalized communities (Serrano, 2020). Yosso (2005) defines community cultural wealth as "an array of knowledges, skills, abilities, and contacts possessed and used by Communities of Color to survive and resist racism and other forms of oppression" (p. 154). By validating students' cultural, racial, and ethnic identities, and meaningfully incorporating their community cultural wealth into the space, STEM counterspaces not only increase Students' of Color achievement, interest, and persistence in critical science, but also improve their overall sense of STEM self-concept, critical science agency, and interest in pursuing STEM college and career pathways (Calabrese & Tan, 2019; Sandoval, 2013; Scott & Garcia, 2016; Scott & Zhang, 2014; Scott et al., 2017; Searle & Kafai, 2015). In addition to educational benefits, culturally situated counterspaces simultaneously foster student agency and activism that positively impacts students' lives beyond the contours of the classroom. In many instances, the sense of agency and empowerment gained from participation in culturally responsive STEM programs empower students to transformatively resist systems of domination in every facet of their lives and schooling experiences.

While critical race theory's (CRT) counterspace framework can illuminate how STEM counterspaces foster resistance and critical consciousness, hooks' notion of homeplace can shed light on the indispensable, yet largely overlooked socioemotional benefits of these fugitive spaces. Though they are a type of counterspace, homeplaces are distinct from traditional counterspaces in that they unapologetically center hope, healing, and humanization as key determinants of survival and resistance. In homeplaces, the focus is on love and nurturing; they are about healing the soul, and giving Students of Color a chance to relax, let their guard down, and breathe. Crafted by Women of Color, homeplaces are spaces of refuge where People of Color can validate and care for one another; name, process, and heal from the atrocities of everyday racism; and be humanized in ways that prepare them to fight back and resist against racist domination.

Given their multifaceted benefits, I believe that homeplaces could be revolutionary for Students of Color in STEM. However, there is a significant dearth in scholarship documenting the power and potentiality of homeplaces in STEM. More research must be done to understand the norms, policies, and practices of educators that successfully construct STEM homeplaces for historically marginalized students. Without this essential insight, the field lacks practice-oriented means of replicating and scaling these invaluable learning spaces.

Study

This research is part of the All Together Now study, funded by the NSF Advancing Informal STEM Learning (AISL) program. The study investigates how informal STEM learning (ISL) programs can broaden participation in STEM by building STEM-relevant social capital and cultural connection for underrepresented and historically marginalized youth. The research team conducted observations and interviews at three ISL programs in Southern California with varied approaches and organizational contexts, serving predominantly Latinx youth. The organizations were selected because they are focused on achieving STEM equity for historically marginalized youth, and they also embody key elements of connected learning, including project-based and interest-driven programming, a safe and socially supportive environment, and culturally responsive approaches. While data collection for the larger study consisted of regular program observations to observe unique program features of each organization, youth interviews, and educator interviews, this paper analyzes a subset of data focusing solely on Women of Color educators. The next section centers the voices, experience, and pedagogical insights of two WOC educators, Linda and Evelyn (all names have been anonymized).

Findings

A rigorous thematic analysis of educator interviews revealed three main findings about STEM homeplaces: 1) they provide students with frequent opportunities to discuss, process, and heal from everyday racism; 2) they actively protect students from racist domination in school, in society, and in STEM; and 3) they catalyze students' ability to survive and resist racism in school and society.

Homeplaces provide students with opportunities to discuss, process, and heal from racism.

One of the main features of the subset of programs for this study was a staunch commitment to seeing, supporting, and listening to Students of Color in ways that were atypical in traditional STEM settings. Evelyn captures this loving approach to STEM mentorship:

> There's been several times, it probably happens once a week, where they don't even work on anything. They just sit, and we just talk about everything…They like to talk to me a lot. That's how I feel like I connect with them. I build my relationship with them, and I make time for them. If they just want to talk, let's just talk.

Evelyn's willingness to hold space for and talk with students is radically different from their traditional STEM experiences, where the students are often ignored, overlooked, and talked over. Because Evelyn intentionally fosters a community of support, sharing, and open dialogue, the students regularly open up to her about the racial discrimination experience in school. For instance, Evelyn recalls a time she helped students' process and heal from a racist incident at school:

> Then when one of them shares a story about what happens in school, especially with the whole Trump thing, … how because they're darker skinned how people were judging them, and people were calling them names, and they were being racist… They would come in here, and they would be down. I'm like, guys, you're going to get people like that everywhere you go. I would tell them about my brother. I say my brother works for Northrop. … and you should see how these white engineers that are probably 10 years older than him, or some of them 25 years older than him are like, "He's going to give us the presentation? This little Mexican boy?" They put him down, but you know what? He did it.

Importantly, Evelyn does more than listen to and hold space for her students – she actively seeks out ways to support and inspire them. After discussing the racist incident, Evelyn tapped into her extensive community networks to find other Latinx people who experienced racism in STEM and found ways to navigate and survive it. In this specific case, she reached out to her brother and asked him to share his stories of survival and resistance with the students. "I would Facetime Peter, and I'd be like, do you have time? Can we Facetime you? So, then I'll just put the TV on the thing, and I'll just be like, Peter, can you tell them about your story? Kids are going through people being racist and stuff like that."

For Evelyn, showcasing how everyday people not only survived, but thrived in racially hostile STEM environments is an indispensable part of her mentorship model.

> I try to bring people… I know a lot of people…even people in my family, I bring them in to kind of help give the kids examples. Look, this Latino boy did it. You can do it too. Like, he is going through racism. Look how he's approaching it. Look how he's treating it and coping with things and doing things. You guys can do it too. It helps them a lot, just seeing someone that's just like them or reflects them, you know?

Ultimately, by holding space for students to discuss and process racist harm, Evelyn cultivates a STEM homeplace that protects Students of Color from the dehumanization and oppression that pervades traditional schools and classrooms.

Homeplaces actively protect students from racist harm and educational pushout.

In addition to providing spaces where students could discuss, process, and eventually heal from racism, the educators in this study took it upon themselves to actively protect their students from racist harm that occured in their schools and classrooms. For instance, Evelyn describes a time she leverages her experiential knowledge, academic capital, and critical consciousness to challenge racist domination in the form of educational pushout. After explaining how she supported Ernie, a "very, very shy student" through his adolescent and early teenage years, Evelyn shares a powerful story about how she continued to protect him from racial inequity in his college years:

> He wants to be a doctor. He wants to do medicine, and he's a DACA. You don't know how much I helped him. The school was trying to charge him international fees because he was a DACA. I said, no, he is not. So I called, and I pretended I was the mom, and I said, look, my son has been living in California for several years, since he was two. He's not an international student. He's just a DACA student. I know there's a law. I'm going to call my lawyer.... So, they transferred me to the dean, and the mom was here [with me]. I was just pretending I was her. When she told me, I was like, "Do you know that they fixed it? and he gets like two or three thousand dollars every semester because of the grants and everything he's getting, because he gets straight As." The mom was crying. The lady still calls me. She still sends me messages. She still comes. She's so grateful. She's like, "If it wasn't for you, I was already thinking, like how am I going to pay $8,000 in a year." It was intense, but people take advantage of [Latinx and undocumented people], and that's why we're here. We're here for all that. It's just not one thing. It's so many things.

For Evelyn, protecting students and their families is a crucial part of fostering educational resilience and STEM persistence for marginalized students. Her love for students is palpable, and she admits, "I could almost put my hands in fire" to ensure that they get an equitable education.

This example is important because it demonstrates that homeplaces are not passive spaces where students simply escape or find respite from racial hostility; they are radical, action-oriented spaces that readily challenge racist structures that threaten the lives, well-being, and academic successes of Students of Color.

Homeplaces catalyze students' ability to transformatively resist racism in school and society.

In addition to protecting, affirming and supporting Students of Color, the WOC educators in this study simultaneously prepared them to transformatively resist oppressive conditions that existed within and beyond the school context. To do this, they were intentional about fostering students' critical consciousness through critical education. For Linda, who wants the students "to care about the environment…to be concerned about their community," critical consciousness and civic service was ingrained into each and every project she taught.

For instance, following the rise of COVID-19 and the shift to distance learning, Linda had the students study the filter mechanisms of face masks. Rather than simply understand the mechanics and importance of filtering systems, Linda had the students consider dis/ability justice and whether or not their prototypes were accessible to folx with physical disabilities. She remembers telling her students, "I want you guys to make your own safe masks, but … I want you to also think about people that wear glasses…what about people who can't tie behind their back or what if the person doesn't have an arm, how are they going to put a face mask on?..How can we make things easier for people who could use that?"

She also had the students do projects about environmental justice in their local community. For instance, Linda had the students conduct a civil engineering research project on water waste and pollution in the resort district of Anaheim. The students, whose parents and family members worked in resorts, immediately noticed the environmental inequities that pervaded these billion-dollar tourism corporations. After interviewing loved ones and doing their own research, the students realized that hotels were creating an exorbitant amount of pollution from single-use plastic toiletries. From there, Linda led her students through a process of grassroots activism in hopes of improving the environmental injustices that permeated the local community:

> They wrote to the hotels, they wrote to the city. The city had them come, they went with the mayor and the main council members. They went to talk to the mayor and they explained their project, why they were concerned. And then what they did was they addressed it and they had the head of the hotels of Anaheim come and listen to what our kids tried to say. And I think what, my thing is, I want them to also have a voice in their world and I want them to understand that.

Importantly, Linda's incorporation of critical consciousness, activism, and agency were strategic, and went beyond superficial interests in making STEM more relevant or engaging content. She is clear that her choice to transform MESA into a civil service learning space was to empower students to make tangible change to the oppressive conditions that mediate their lives and schooling experiences.

Discussion

The findings from this study provide preliminary insights into the programmatic features, pedagogies, and mindsets that foster resilience and retention for Students of Color in STEM. Specifically, STEM homeplaces are spaces where marginalized students can name, process, and cope with the trauma of everyday racism; be lovingly and vigorously protected from educational pushout and racist microaggressions; and gain the critical consciousness and transformative agency to not only survive oppressive conditions, but also to actively transform them.

To foster this space, the Women of Color educators readily leverage culturally situated and identity-specific pedagogies – or "homeplace pedagogies" – as a way to increase students' feelings of safety, nurturance, and validation in the program. These homeplace pedagogies purposefully promote feelings of safety, healing, agency, and critical consciousness for Students of Color, who in turn leverage the empowerment they gain from these racially affirming and radically loving spaces to transform the oppression conditions that permeate their lives and schooling experiences. The Women of Color educators in these spaces were committed to protecting and uplifting their students, and readily leveraged community cultural wealth – including social connections, financial resources, familial networks, and linguistic skills – to challenge and transform the matrices of domination that threaten to harm their students both within and beyond the STEM learning environment.

As a result of these homeplace pedagogies, the programs maintained significantly high rates of engagement, retention, and achievement in STEM for minoritized students. These results were not just contained to the local STEM program – in fact, Students of Color that participated in these programs had long-lasting success in college and career STEM pathways long after their time in the program ended.

Conclusion

The STEM homeplaces that were examined in this study served as a protective barrier against racist oppression and

STEM pushout. The educators in these spaces leveraged homeplace pedagogies that included caring for and nurturing students; providing opportunities for students to discuss, process, and heal from racism; teaching students how to challenge and interrogate racist structures; fostering students' critical consciousness and activist potential; and making meaningful connections between STEM and students' everyday lives and cultural experiences.

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12. Social Media to Streets

Brazilian Youth Movements, Political Affinities, and Connected Learning

ALICE TAYLOR

Abstract: This paper examines the relationship between the digital and the street in youth-driven collective action. It draws from a multi-sited ethnographic study of youth movements that emerged just over a decade ago throughout Brazil. I conceptualize them as "hybrid" movements, finding that they activate digital spaces as well as in-person ones in ways that are interconnected and often simultaneous rather than operating in separate spheres. This approach understands movements as emerging from powerful collective action in the streets, and gradually mediated by and combined with the proliferation of digital technology and social media.

Hybrid forms of activism did not begin with the pandemic; youth activists began experimenting with such approaches over a decade earlier, and they shifted over time. This paper identifies and discusses forms of hybrid connections such as in building a movement and mentoring new activists, defending public education, and through youth movement extensions into electoral politics. Brazilian youth movements are critical spaces for raising new questions and implications for connected learning, affinities, and digital civic engagement. They also shape our understanding of new collective constructions of democracy at a time of deep political polarizations.[1]

A bicycle rally ends in a long grassy, palm-tree lined park. The bikers arrange themselves in the shape of a political candidate's ballot number. Yellow ribbons are tied to taxis and bikes. A flash mob. The Rio de Janeiro sky fills with kites. It was 2012, and youth activists working on the campaign of a progressive political candidate began to invite their peers to these creative calls to action on Facebook. They photographed the actions and re-posted photos of them. The momentum continued: Facebook invitations multiplied, each action growing larger than the last. In a final rally, almost 5,000 youth filled a plaza with a sound car in tow, surprising even the organizers who wondered if they would fill a 300-person auditorium initially planned for the rally. – Fieldnote from interview, November 2021, Rio de Janeiro

These memories belong to Leo[2], a co-founder of a youth movement. They echo many Rio de Janeiro-based youth activist and politicians' underscoring this 2012 campaign as pivotal to their lives and the lives of movements in which they would engage. These collective actions were part of a campaign called "Social Media and Streets," *Redes e Ruas* in Portuguese, and a municipal political campaign for a progressive candidate. They foregrounded an on-going intertwining of formal politics with youth movements I study, an intertwining that shapes the landscape across which youth activists learn. This paper focuses on another foundational aspect of this period: youth activists' early experiments with digital tools in ways that would shift over the next decade in relation to the street.

Brazilian Youth Movements in a Digital Age

In 2008, the global economic crisis set off a series of protests referred to as the "2008 to 2013 wave." From the Occupy movements in the U.S. and Turkey, to *Indignados* in Spain, and the Arab Spring, young activists led struggles against precarity. Inspired by the 2008 to 2013 wave, protests erupted in cities across Brazil in 2013, with over a million in the streets in some cases. The 2013 protests in particular gave rise to and fortified a novel set of Brazilian youth movements that began to act in this context. Youth movements continued to fight student struggles present since the dictatorship era: bus fare, near-free student meals twice per day (the bandeijão), and other conditions that make it possible for low-income students to not only access, but also remain in universities. They protested a steady stream of public education budget cuts and efforts toward privatization that began before but were intensified in the Bolsonaro administration.

Youth movements also shook student governance and took on a new kind of project: activists sought to articulate multiple, intersectional struggles of anti-racism, feminism and ecosocialism. From defending working class struggles and public universities, to defining a feminism for the 99% and denouncing racist violence, they respond to multiple issues of pressing contemporary concern. Youth movements are active in nearly every state and consist of thousands of activists from high school ages (16-18), to university students (through their 20s), and up to age 30, the age to which the category "youth" extends according to Brazilian legislation.

Critical to the history of Brazilian youth movements, and what I argue, is that they emerged from powerful collective action in the streets, and alongside the rise of the internet and proliferation of social media in Brazil. (Figure 1) traces these simultaneous histories. Between 2005 and 2014, Brazil moved from tenth to fourth among countries with the most internet users in the world (BBC, 2014). The largest jump in internet use occurred from 2015 (57.8%) to 2016 (64.7%), which is most likely attributable to the proliferation of smartphone 3G technology during this time. Brazilians spend an average of ten hours per day on the internet, about half that time on cellular phones, and just over three hours of time on social media (DataReportal, 2021). Social media use has increased notably: Brazil has the third highest number of Whatsapp users worldwide, after India and the U.S.. Instagram is especially widespread among young users (16-29).[3]

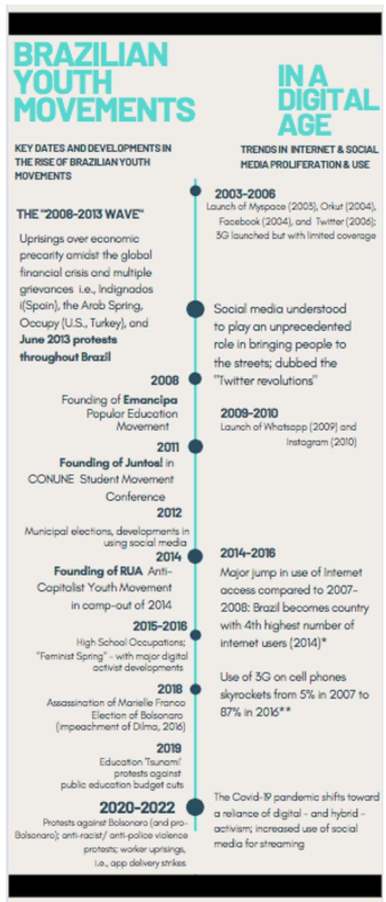

Figure 1. Brazilian Youth Movements in a Digital Age

These data are essential for understanding youth learning and education, and the conditions in which youth movements emerged. Youth activists' use of social media continued as they developed street actions: they organized street protests, teach-ins, and marches with chants and speeches, prolific forms of political education on Youtube, social media, and in community centers alike. While scholarship has increasingly attended to the *digital* in activism and ethnographies (Postil & Pink, 2012; Bonilla & Rosa, 2015), it has paid less attention to the interconnections among digital and in-person spaces, especially in the street.

This paper asks how, as activists dedicated themselves to being together in the streets, they experimented with ways to be and act collectively online. Youth movements used social media for nearly a decade before the pandemic began, but were called to (re)occupy, (re)navigate, and (re)invent themselves and their ways of being collective and political in public space. I found that this relational, interconnected history of youth activists' hybrid practices is central to how activists make meaning in and through movements. Affinities and collective practices create belonging and sustain movements, and they shape possibilities for learning.

This paper draws from my broader dissertation research, a hybrid, multi-sited (Vossoughi & Gutiérrez, 2015) ethnographic study carried out from 2018 to 2022. I conducted over 100 interviews with youth activists, politicians, and others engaged with youth activism, and carried out discursive analytic approaches to examine social media artifacts, speeches, chants, protests, public hearings, and political and popular education courses on- and off-line. RUA ("Street") Anti-Capitalist Youth Movement and Juntos! ("Together") (and a related popular education movement, Emancipa and Juntas! feminist movement), are the principal movements of focus in my research. Each engages in student activism and is anti-capitalist, with Black, feminist, LGBTQ, and ecosocialist branches. They are therefore highly plural movements rather than ones that struggle toward a more singular cause. Fieldwork primarily took place in Rio de Janeiro and briefly in São Paulo (cities critical to the founding and contemporary activism of the movements), and in digital – and hybrid – spaces in nearly equal proportion. The inclusion of hybrid spaces meant that events and interviews could involve activists based in several Brazilian regions.

Learning as Sociocultural and Connected

Both learning and civic engagement in digital spaces are deeply social processes. This study draws from constructs of sociocultural learning theory, focusing on connected learning and affinity networks in digital spaces. Learning, according to Lave's (1996) foundational sociocultural theorization, is participation in shifting communities of practice. It is "deeply embedded in the joint work of individuals as they negotiate and manage their participation, and the participation of others, in and across cultural practices" (Nasir & Hand, 2006, p. 467). The notion of *learning as movement* is relevant for conceptualizing practices and cultural repertoires co-constituted and leveraged across multiple spaces and time scales (Gutiérrez, 2008; Vossoughi & Gutierrez, 2015). Importantly, by virtue of being on and offline, and from reading circles to streets, social movements entail participation across a complex set of sites. Across these sites, joint learning processes encompasses language and literacy practices as well.

In alignment with sociocultural theories, connected learning grew out of evidence that learning is resilient and meaningful when it is tied to social relationships and cultural identities, and when it spans in-school and out-of-school settings (Hull & Shultz, 2001; Ito et al., 2018). A strand of connected learning research recently investigated the role of affinity networks. It draws from Gee's (2005) notion of "affinity spaces" that refer to online spaces in which people interact, learn, and develop language around common passions or interests. Like the affinity networks Ito and colleagues (2018) describe, youth movement affinities are youth-driven and based on intentional communities of shared interests and collective action, rather than according to instrumental goals. They have strong shared sets of youth movement cultures, values, and practices. They share these characteristics of meaningful, socially supportive relationships linked to deep interests.

Scholarship on affinity and connected learning has focused on youth engagement in online groups according to interests such as fanfiction, art practices, or gaming. Underlying this work is the notion that youth can mobilize cultural interests to pursue civic and political action (Ito et al., 2015; Ito et al., 2018; Jenkins et al., 2016). In different ways, this work has raised critical questions of what counts as civic participation in public life, and has challenged dominant narratives of disengaged youth. Youths' "social and cultural activities" tend to be conceptualized as *potentially* connected to, but initially separate from "civic and political practices" that from the start are not typically understood as sources of interest or affinity for youth.

Studying Brazilian youth movements, however, shifts the starting point. Youth activists come together with deeply political interests and affinities. Non-white youth (i.e., mixed race, Afro-Brazilian youth) highlight their process of reflection and critical consciousness about race or oppression in this process, from an early experience about hair, to discrimination in school, to coming to identify as "Black" (Paschel, 2016). Their sociopolitical learning, language, and literacies is grounded in their (already always) politicized and intersectional identities.

I draw from notions of civic engagement and political action across multiple sites and platforms, in ways that are held together by joint interests, affinities, and identities (Ito et al., 2015). Youth digital activism is also aligned with the notion of affinities in that it promotes dialogue and critical counter-narratives on issues the group define as important (Stornaiuolo & Thomas, 2017). By sharing affinities around a more equitable vision for society, youth movements embody participatory practices (Kahne et al., 2014) and offer an explicit link to digital forms of civic engagement (Garcia et al., 2021). In the rest of this paper, I examine relationships among the street and the digital, and the role of political affinities and learning across these sites.

Social Media and Streets

In the Social Media and Streets campaign, youth activists largely used social media to "call people to the streets." Scholarship on the so-called "Twitter revolutions" of this same period – the 2008-2013 wave of protests amidst the global economic crisis – similarly emphasized the central role of digital tools in social movements, examining, for example, patterns of digital use and its relationship to democracy and governance regimes (Howard & Hussain, 2013; Tufekci, 2017), and the role of youth activism and digital media as youth learn citizenship (Herrera, 2012). The internet was conceptualized primarily for its role in "mobilizing and diffusing" (Gerbaudo, 2012), for quickly connecting users to other, separate, and "more important" or more in-person spaces like plazas and streets

Brazilian youth movements (that largely grew after 2013) wanted to enable protests through digital platforms, but they also organize as social movements over time and between protests to build deeper, collective ties of responsibility. Digital and face-to-face protests build upon one another (Postill & Pink, 2012), and they increasingly must be conceptualized according to the collective and hybrid ways in which youth engage, and according to how they can reflect or magnify sociabilities, experiences, and identities (Bonilla & Rosa, 2015)

Digital practices therefore matter to youth activism beyond a generalized 'networked' sense in social movements (Castells, 2012), in terms of how "crowds" are produced (Bennett, Segerber, & Walker, 2013), or as "feeds" separate from offline activity (Lane, 2019). Rather, the digital can be used to reinterpret and contest meanings (Bonilla & Rosa, 2015). Social media can reveal characteristics of a social group and what that group chooses or values. It is users' choices about how to use platforms, not the social tool itself, that generates social movements (Tufekci, 2017). Digital and face-to-face protests ultimately build upon one another (Postill & Pink, 2012) and challenge our notions of how youth activists make their voices heard collectively. Brazilian youth construct civic and political identities as they develop these discourses on and offline. Youth movements complicate dichotomous conceptions of resistance on the street *versus* digital activism, showing instead continuities and interconnections among 'digital' and 'in-person' sites that are experienced often fluidly and indistinctly. In a similar way, they disrupt compartmentalized notions of digital or in-person learning, and expand conceptions of what constitutes civic engagement and where it takes place.

These changes underscore youth activists' shifting participation with relation to social media and the streets, and they signal learning of the movement as a whole. Youth continued experimenting with social media in ways that suggested a more complicated relationship of the street to social media. Rather than one diffusing to the other, interactions, identities, and meanings happen in hybrid ways through both. Youth do not just consume media but learn to "produce, remix, and expand on it" and "archive, annotate, appropriate, and recirculate media content *in powerful new ways*" (Jenkins, 2006, italics added). As activists become authors and listeners across multimodal contexts, i.e., on cell phones, computers, and in streets (Hull, Stornaiuolo, & Sterponi, 2013) – and in political campaigns and a broad array of movement activities – it further amplifies the ecologies in which they learn and become civic actors.

Together, these influences gave rise to what I call a "youth turn" and the birth in the early 2010s, of the main youth movements of focus in my study. My broader dissertation project conceptualizes the category "youth," situating it in youth activism and movement literature. "Social media to streets," and the other youth movement events and practices I analyze, were also grounded in these histories. In the 2012 Social Media to Streets event itself, in-person actions were similarly captured, replicated, and disseminated throughout social media (primarily Facebook at the time). These hybrid strategies began to stir something of a "youth spirit" – a culture of youth politics, a youth political culture – that grew and propelled youth toward the plaza. I continue to trace these feelings and effects of being together, "*wanting to be there*," that continue over the years as youth activists continue to act off and online; and the kinds of learning and civic engagement taking place.

A "Movement Feeling": Cultivating Affinities, Complicating Hybrid Activism

I identified three ways in which interactions between social media and streets took place: through recruiting activists to build a movement and sustaining those movements through intergenerational mentorship among youth; through actions to defend public education such as protests and simultaneously co-authoring chants on and offline; and by engaging in political campaigns as extensions of youth movement activity. The remainder of this short paper briefly discusses the final two aspects (all three were the subject of my CLS talk and expanded upon in recently published (Taylor, 2022) and forthcoming work). Affinities and forms of learning connect and animate these hybrid interactions, reshaping the civic landscape.

Similar to their involvement in the 2012 campaign, youth activists continued to work on political campaigns and run for office themselves alongside their movement activism. The campaigns became sites for continued experimentation with social media and streets. The 2020 city election season, which took place during the pandemic, illustrates ways in which they brought a sense of the streets and being together to social media platforms. Bia, a coordinator of Emancipa, a popular education movement, ran a fellow youth popular educator Luana Alves's campaign for city council in São Paulo. She explained how activists worked together to leverage hybrid spaces, depending more than ever on Whatsapp given the constraints of the pandemic: "We asked her [the candidate running for office] to record audio [messages]. She'd say 'electing me is possible,' and 'turn the votes!' as a challenge [to the organizers working on her campaign]." Bia also described how the campaign volunteers, many of which were activists, responded: "There were 1,000 messages per day! And people responded: 'I turned X many votes!' and 'I turned 3 more votes!'"

She referred to the strategy as "pedagogizing politics", in which "we learn in the movement *to construct, to dialogue* together. We formulate, [we] don't see [politics] as fixed." The volume of messages constituted a dialogue among the candidate and activists who volunteered to run her campaign, and brought a fast-paced energy and dialectic listening and responding that fueled the campaign. Bia added, "And this – people multiplying these things […] the communication was fundamental to create that *climate of a movement itself*, of overflowing, of involving people."

Luana's campaign illustrates affinities cultivated on and offline, and how they can generate a sensation of being together, again linking the digital back to the experience of being on the street. Each "vote turned" represented a vital interaction in which a social movement activist engaged on Whatsapp, in person, or otherwise, with a neighbor, family member, or friend as a possible voter. This engagement with voters was central to the collective nature of how youth activists constructed campaigns. It also challenges the notion of the digital as disengaged, and in-person as more authentic or engaged. It is the people "turning the votes" and dedicated to engaging with one another that fosters this "movement climate," a *movement-feeling*. Like the calls to the streets in the 2012 campaign, they created a "wanting-to-be-there" (in person) sensation. This time, the place they wanted to be was in-person at times (i.e., a political rally or pamphleting in the streets during the pandemic) but also to be part of the group constituted through the Whatsapp exchanges.

Another activist who co-founded RUA, Laura, pointed to the role of the street as a "school" that educated them but that also created a feeling that they are "bigger" than the oppressions they confront. This concept of strength in numbers can generate a sense of collective efficacy (Kirshner, 2007), and it echoed throughout on and offline actions. It again suggests a shift in participation and learning: together in movements, youth feel they can accomplish more than they can alone. Laura explained,

> "We're in a period of blow after blow, with a fascist government in the middle of a pandemic and in a political, economic, and environmental crisis. Imagine – you enter the movement and want to confront all of that – [in a] protest, a "Tsunami" – you look around and feel a million people around and say, 'man that's it! *We're bigger*.'"

In 2019, I attended the "Tsunami" protest she refers to, in which youth activists created classes on the streets and protested severe budget cuts in public education in the far-right Bolsonaro government. Again and again, they demonstrated "strength in numbers" and experimented how to do this online. For example, through a series of hybrid actions at a university in Rio de Janeiro in late 2021, activists from RUA, Juntos!, and other youth movements that comprised student governance along with university staff, protested the privatizing of a public university hospital. A Juntos! activist declared, "I am not alone!" after using his cell phone to pan out to a packed room filled with protestors, signs, and banners. They had gathered in the dean's office at the university campus itself, to debate with administrators and thousands of listeners who joined the hearing online.

Youth activists continuously sought to bring collective attributes generated in streets, to guide their digital engagement. Laura made a distinction between online posting and activism: "I think *what makes it activism is if you do it collectively*. If you're doing it [posting a comment or tweet] alone, you're expressing what you think, but it's not activism. Activism presupposes tactics and strategies."

Being, organizing actions, and learning *collectively* is so significant that it is what defines activism itself. Political affinities brought youth activists together, and they generated momentum, the feeling of being in a movement similar to the "feeling of" being in the street that the RUA co-founders pointed to a decade earlier. For others who joined the Whatsapp mobilizing during the campaign during the pandemic in 2020, their relationships were built and sustained online – and always connected to historical offline relationships. It was common for youth activists to describe entering a movement for one struggle or cause and becoming engaged in multiple other ones.

Discussion: Connected Learning, Affinities, and Civic Engagement

Brazilian youth movements offer insights into theoretically and empirically understanding the relationship of the digital with the street. Each activist, event, and type of struggle was uniquely positioned to off and online sites and contributes to rethinking notions of the digital according to hybrid continuities and interconnections that are experienced fluidly and often indistinctly. Youth activist learning is deeply embedded in the social practices of movements and can be understood through the shifts in which they engaged over time. If initially they used social media to "call to the streets," the pandemic heightened youth activists' need to reinvent digital forms of activism.

Brazilian youth movements offer insights for educators who are "rethink[ing] what it means to educate for digital citizenship" (Garcia et al., 2021, p. 320). I found that youth movements practice the very kinds of skills and dispositions that educators seek to foster – and reimagine – in civic reasoning and discourse curricula. This finding underscores an argument I make in my work more broadly, that educators can and should learn from social movements as they design civic education in schools. With current crises of the climate, pandemic, on-going systemic racism and gender discrimination, the time could not be more imperative for educators and researchers to learn from youth who will continue to act together in movements in the streets and online. Learning shifts as the hybrid and pandemic landscape shift, and with shifting struggles. Affinities shape and connect learning, and they may contribute to shifting civic engagement, toward civic and affective commitments.

Endnotes

- (1) This paper was submitted to and presented in the July 2022 Connected Learning Summit. It has since been edited and expanded upon for a forthcoming paper. Special thanks are owed to a RUA youth movement co-founder (anonymous in this paper) for his read and feedback and to youth movement participants in each of the movements. Thank you to Mimi Ito, Glynda Hull, Tiera Tanksley, Claudia Castro, Michael Dezuanni, and Hyeon-Seon Jeong for their facilitation, comments, and questions; and to participants of the CLS Inclusive and Community-Driven Research and Design Pre-Conference Meetup.
- (2) Pseudonyms are used except for the case of public political figures. This categorization is complex and imperfect; I aimed for a consistent approach to protect anonymity of activists.
- (3) PNAD Contínua, yearly reports for data on 2011-2015; 2019 report for data on 2016-2019. For 2020, data from Pesquisa TIC 2021. Access has not been evenly distributed across regions of the country and in rural compared to urban areas, although it is generally high for poor and working class Brazilians.

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13. Taking Advice From a Virtual Agent

Usability of an Artificially Intelligent Smart Speaker App for Parent and Child Storybook Reading

MEREDITH THOMPSON; GRACE C. LIN; ILANA SCHOENFELD; CIGDEM UZ-BILGIN; AND KATHRYN LEECH

Abstract: Parent and child interactions form the foundation for children's language development. These interactions can be mediated through digital media in a way that can scaffold positive reading practices. We have designed an Artificial Intelligent Smart Speaker App that listens in to parent and child conversations and provides questions at specific points in a storybook. The goal of the app is to support parents' use of dialogic reading strategies during story time. We examine the usability of this app during an initial introduction to the app session, a four-week at-home trial period with the app, and a second feedback session about the app. Results suggest that parents find the app easy to navigate and use during story time, but some encounter timing issues with the question-asking feature. Parents demonstrate different patterns of use at home that are not directly related to their perceptions of usability. Parents report that the app has helped increase interaction, question asking, and engagement of their child during reading time. This study suggests that parents can learn and practice positive reading strategies by taking the advice from an artificially intelligent virtual agent.

Introduction

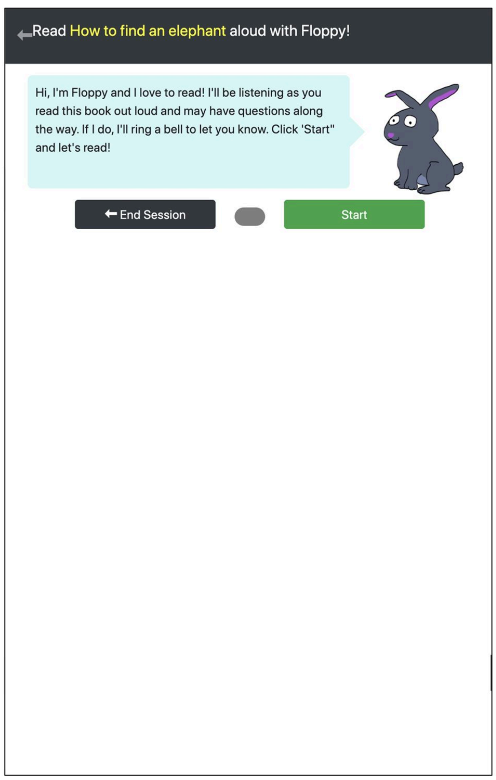
Interactions, particularly with caregivers, are essential for children's early language and word development (e.g., Bornstein et al., 2008; Tamis-LeMonda et al., 2014). In recent years, developmental scientists have conducted studies to encourage conversations between caregivers and children, as back-and-forth conversations are the foundation and "gold mine" of language development (Hirsh-Pasek & Golinkoff, 2019; Romeo et al., 2018). Signs in supermarkets to spur conversations, strategies to encourage talks at mealtimes, hidden figures or puzzles at bus stops to challenge children, or even life-size board games to stimulate STEM talks and learning have all demonstrated positive effects not only on caregiver attitudes toward playful learning, but also impacts on children's development (e.g., Bustamante et al., 2020; Hadani et al., 2021; Leech & Rowe, 2021).

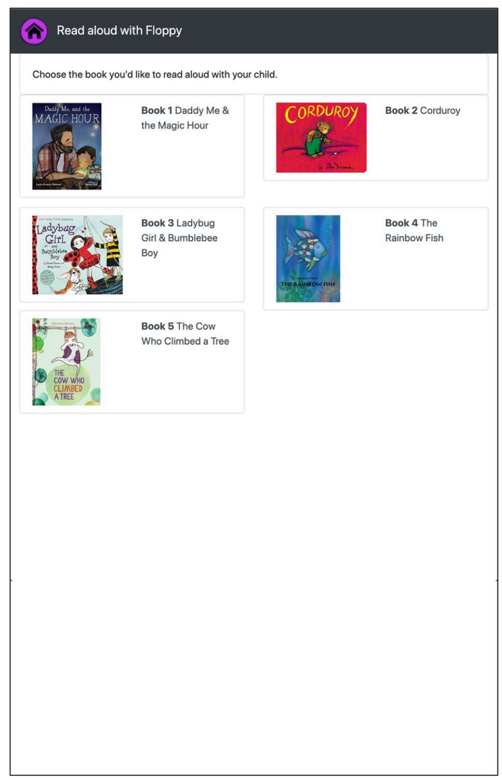
The trend extends into the digital media world as well. With the affordances and the engagement of children with digital media such as tablets, researchers have developed games that promote collaborative construction between caregivers and children, and the effects of such apps have been promising. After using apps designed to promote caregiver-child interactions, study dyads have richer conversations and children's language complexity also increased (Rowe et al., 2021). Furthermore, dialogic reading practices meant to elicit back-and-forth conversations between reading partners have been shown to be beneficial for children's story comprehension and retention of story contents (Xu et al., 2021).

Digital apps have great potential in helping foster positive interactions between parents and children. We developed an app and supporting videos to help parents learn and practice dialogic reading approaches to reading during storytime. This paper reports our findings from a usability study designed to understand how parents perceive the app and videos in terms of usability, their perceptions of the effectiveness of the app, and their patterns of use of the app at home between the first and second study session.

Description of the R.E.A.D.Y. Strategies and Smart Speaker App (Floppy)

The project team designed the Smart Speaker app to promote dialogic reading strategies (Leech et al., 2021; Leech et al., 2018). The first part of the app contains video resources introducing users to the R.E.A.D.Y. strategies: R stands for "Recall the Past" (e.g., Can you remember a time when you shared something with a friend? What was it?), E stands for "Explain New Words or Ideas" (e.g., What is a vegetarian?), A stands for "Ask Questions" (e.g., Where is the octopus hiding?), D stands for "Discuss the Future" (e.g., What would you do if you caught a firefly?), and Y stands for "You Can Do It!" (Y is included as a message to increase efficacy and motivate parents to incorporate R.E.A.D.Y. conversations into their daily interactions with children). This study focuses on the second part of the app, a reading companion that features a virtual agent named Floppy, as shown in (Figure 1). Floppy is an artificially intelligent virtual agent who is preprogrammed to ask questions to model dialogic R.E.A.D.Y. reading strategies at specific timepoints in each of the books available on the app. Floppy "listens in" as the caregiver-child dyads read each physical storybook aloud and the app transcribes the spoken interaction of the dyads. Every time the app detects one of the unique word combinations that serve as markers, spoken prompts are activated and Floppy interjects the read-aloud with a pre-determined question written by the researchers. The app is designed to be a companion to reading and not the focal point, so the user interface of the app is purposefully simple, straightforward, and easy to navigate.





Figures 1-3. Floppy, the virtual agent, on left, and two sample screenshots (center and right)

Research Questions

In order to gauge the usability of the app, we asked the following three research questions:

1. How usable is the Virtual Agent (Floppy) application according to parents? Which parts of the application work well? What aspects need to be changed?

2. What patterns of use emerge in parents when they use the Floppy app at home in between the first and second study sessions? How do parents' views of usability change after at home use?
3. What are parents' perceptions of the impact of Floppy on their reading habits?

Methods Research Participants

Twenty parent-child dyads recruited from across the United States participated in the study. In the first session conducted via Zoom, the participants were introduced to the Smart Speaker app; they watched the video resources and went through one reading session using the app. The researchers then interviewed the caregiver for their impression of the app; participants also filled out a separate survey following the interview. After three to six weeks, during which participants were instructed to read three books with the app when they saw fit, they joined another Zoom session where they again read a book with the app, answered interview questions, and filled out another survey regarding their experience with and perception of the app.

The sample was designed to be diverse geographically, socioeconomically, and in race and ethnicity. Eighteen of the adult participants were mothers and two were fathers. Eight adult participants identified their race as white, five as African American, three as Native American, two as Asian, and one as Middle Eastern. Four identified their ethnicity as Hispanic. Eight parents had graduated from college, eight had some college, two had a high school diploma, and two had some high school, but did not graduate. The adults were between the ages of 20 and 50, with eight between 20 and 30, ten between 31 and 40, and two between 41 and 50. There were ten girls and ten boys in the study; seven of the children were between three and four years old, eight were between four and five years old, and five were between five and six years old.

Survey and Interview Development

Survey questions were developed by the research team and also gathered from existing sources. The First Session Survey (FSS) and Second Session Survey (SSS) both included the System Usability Scale, a ten-question survey commonly used in usability studies (Brooke, 1996). The SUS includes both positively and negatively scored items and asks participants to give a rating between 1 (strongly disagree) and 5 (strongly agree), and is scored out of 100 points (Lewis, 2018). The FSS and SSS included questions about future use, enjoyment, and whether the parent would recommend the app to other parents. The SSS also included questions about the support videos that accompanied the app. Participants also participated in a First Session Interview (FSI) and a Second Session Interview (SSI). The interview questions were developed by the research team, and gathered feedback about parents' normal reading habits (1st session survey), their impressions of the R.E.A.D.Y. Smart Speaker App (containing Floppy), the introductory video, and the supporting videos that accompanied the app. In this study, we focus on the survey questions and interview questions about the R.E.A.D.Y. Smart Speaker application where Floppy would interject with questions during caregiver/child reading sessions.

Analysis

All surveys were conducted online using Qualtrics, and responses were downloaded into spreadsheet form. Two researchers reviewed the responses and generated a coding scheme, then independently coded the responses. The researchers met to review all discrepancies until 100% agreement was reached. Two researchers observed each session

(Session 1 and Session 2), and one researcher took detailed notes during the interview. One researcher coded one- or two-word responses (e.g., “It was easy to use”). For the longer responses, one researcher developed an inductive coding scheme (Miles & Huberman, 1994). The researcher divided each response into units of meaning as described in Strijbos et al. (2006). The researcher shared the units of meaning and set of inductive codes with a second researcher, who coded them independently. The researchers met to discuss any disagreements until 100% agreement was reached. For RQ2, a researcher gathered the meta data from the audio recordings of participants’ home reading sessions with the Smart Speaker app: the date, duration of reading session, and selected book. After converting the dates of reading to the number of days after their first session, the researcher conducted hierarchical clustering of the data (Wards, k-means, and k-medians). Two researchers discussed the resulting clusters to identify the patterns.

Results

RQ1: Usability of the App

Parents completed the System Usability Scale (SUS) at the first session and again at the second session of the study. Participants gave the app high scores for the first session (87.7/100 points, SD 9.58) and the second session (average of 88.6/ 100, SD 7.44). The perceived usability of the app was surprisingly consistent between the two sessions. Only three participants’ scores changed, and all three increased. Furthermore, all scores even during the first session were in the acceptable range with all but one scoring above “excellent” (Bangor et al., 2008). The FSIs were completed directly after the parents’ first session. During the FSI, 19 of the 20 caregivers responded to the first and the last session. One caregiver did not complete the first session due to technical issues. In the FSI, 18 of the 19 parents responded that the app was easy to use. Parents described it as “super simple” “easy”, “straightforward” and “smooth”. Only one parent had difficulty with the video, explaining that “If the video had uploaded like they’re supposed to, it should be easy”.

Parents were asked for their first impressions of the app during the FSI, and 13 of the parents were positive. Eight parents liked that the app would intervene with questions (mentioned eight times), and five mentioned that they liked having a chime preempt the questions. One parent commented that the app “doesn’t distract from the story itself, which is good. The questions are just enough to get the context of the story, instead of distracting him into 400 other questions” (1815). Six parents had mixed feelings about the app, two mentioned the timing of the questions, two mentioned that the volume was too low, one mentioned clunky animation, and one said they could not comment due to a lack of experience using the app.

Visual Features

Participants were asked to comment on the visual and audio features of the app. Twelve participants thought the visual interface of the app was good, describing the app as “simple”, “straightforward”, “easy to use” and “easy to navigate”. One parent explained “I like the layout the books are [in]. It’s easy to find the book”. In fact, the app was so user friendly that one participant had their child use the app on their own. The participant described the app as “Very easy to decipher what’s start, stop, and when it’s recording”. Later, the same parent continued “Once I showed him the first time, he (child) navigated it by himself”. While this is not the intended use for the app, it does indicate that the app is easy to use. Five participants suggested some type of change to the visuals. Two participants thought the app should have more colorful images, one thought the Floppy Virtual Agent should be even more present on the phone, and one parent suggested that the question text appear on the phone as well as audio. These suggestions could potentially shift the focus towards the phone, which is not the goal for the app. The app is designed to remain unobtrusive, 'listening in' and interjecting with questions in the background.

Audio Features

Participants were asked for feedback on the audio prompts (e.g., questions asked by the app's Floppy character). Nine participants reported that the questions were timed well. One parent commented that the questions were "at a good break or stopping point. It's asking questions on a certain aspect without fully losing the immersion in the story itself" (1510). Three mentioned the prompts came late, and two mentioned the prompts came early. Four of the five participants who mentioned timing issues wondered if it was their fault. One participant said, "I don't know if I'm reading too fast" and another said, "I tried to slow my pace a little". Another parent wondered "did Floppy ask questions too fast, but thought maybe I was reading a little too slow" (2510). Five parents commented on the chime. Three mentioned that the chime was effective in getting their attention, explaining that the ringing was "long enough that you know the question is coming" and that the chime "gets attention". One parent described the chime as "a little light", while another described it as "annoying" and "repetitive" and suggested a different sound.

RQ2: Patterns of Home Use and Perceptions of the App After Home Use

Our second research question focuses on the patterns of home use of the app that occurred between the first and the second reading sessions. Each time the participants used the app, it provided a record of when they were reading and the book they chose to read. We examined these metadata and identified four main usage patterns: there were four avid user 'fans' who have used the app more than once a day for multiple days in between their two test sessions, seven 'pacers' who spread out their usage of the app, six 'procrastinators' who used the app the day before or on the day of the final session, and two parents who wanted to Get It Over With (GIOW) and used the app to read the assigned books the day after the first session. One participant was non-compliant and only opened the app for a total of one minute. The three participants whose SUS scores changed were from different usage pattern groups, and all except one father scored usability as "excellent" in the first session.

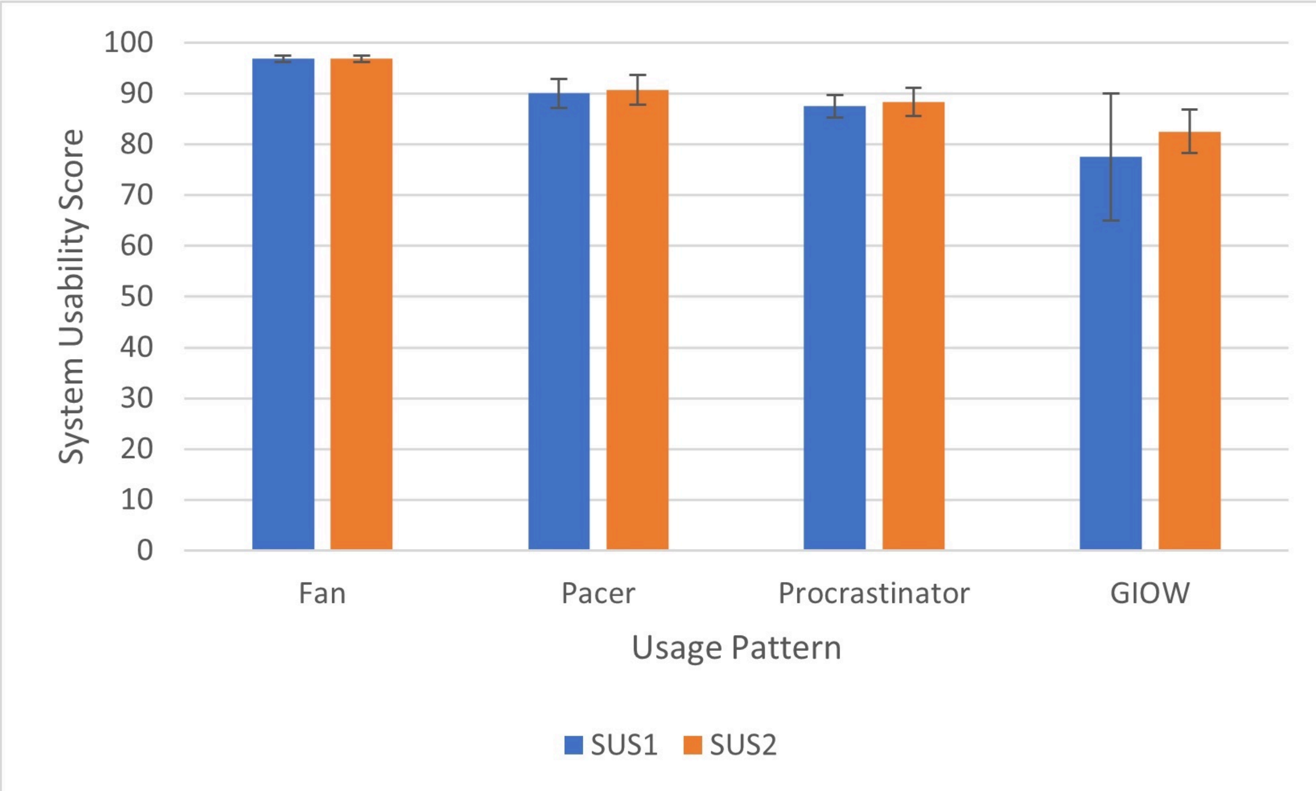


Figure 4. System Usability Score (SUS) for the first and second session by usage pattern

In the SSI, parents were asked if their impressions of the app changed after using the app at home. Thirteen parents had the same impression of the app during the FSI and SSI; 11 stayed positive and two had mixed feelings about the app both times. The two parents who gave mixed reviews remembered being hesitant at first. One parent explained, “The first time I used it, I didn’t like it as much at first. Cause I gotta get used to it and everything. Once I did, I started liking it more” (2415). The second mixed parent stated, “I thought it worked fine the 2nd time. I like it when the bell chimes. But when it chimes in, if it could adapt that. Or if the questions change” (2410).

Five parents changed their views. Three became more positive about the app; two mentioned low volume as an issue at the FSI but didn’t mention it at the SSI (1810, 2210), and one initially mentioned a timing issue but didn’t mention it during the SSI (1815). The parents who changed from positive to mixed brought up not knowing when the next question would be asked (1915) and having some issues with the app. In the SSI, the parent explained that their child was initially distracted by the app but got used to it over time.

RQ3: Perception of the Impact of Floppy on Reading Habits

Survey results suggested a high level of satisfaction with the Floppy app; 19 out of 20 parents would read with Floppy in the future, and all 20 parents stated they would recommend the app to their friends and that they enjoyed using the app.

Impact on reading habits. We asked parents for their ideas about how the application impacted their reading habits. A few themes emerged in the questions about the app in both the survey and the interviews. First, the application helped parents by giving them *ideas for questions to ask their children* during reading (mentioned by six parents during the interviews (I) and the survey (S). Parents described how the app “gave prompts I would not necessarily have thought of myself" and "Helped us have good questions." During the interview, parents' comments mentioned that Floppy *increased the number of questions* they asked during storytime (I=9 times S=2 times). One parent explained that the app "helped me ask more questions even when I wasn't using Floppy" (1710), another commented "I did find myself adding in more questions on my own without having the program" (1510). Although self-reported, this suggests that the app may help build parents' capacity for future reading without the application, which is one of the goals of the app.

The parents were positive about the app on the final survey; only one parent mentioned that they "would use it, but not very often." Their responses were more varied during the interview. For example, five parents responded that the app did not affect their reading habits. Parents explained that they already asked questions during reading sessions, explaining that "it doesn't change much in terms of us talking about the stories" and that "we know how to prompt them," and that "we already read a lot."

Interaction during storytime. In the interviews, parents were asked how Floppy affected their interactions with their child. Six parents mentioned that there was more interaction between them and their child as a result of using the app. One parent explained, "Yes, it's a big change. It's not just me talking. It's us interacting. The interaction with me using the Floppy. They were different than just me doing the reading" (2610). The survey results also showed the parents felt the app *increased interaction between the parent and the child* during story time. The questions that Floppy shared enabled parents to engage in conversations with their child about the book. Parents explained how the app prompted "little mini discussions," "sparked conversation" with their child, "helped us have dialogue" and made it easier to "open up conversations about the book."

The app helped *keep the child focused on the story* (S=5 times, I=2 times). In the survey, a parent described how the "program kept my daughter focused on the story we were reading more than when we tried to read a story without using the app." Parents described how the app was an "excellent way to keep your child entertained," that the app made "my child a little more involved" in the story. Floppy helped the children by making the child an active part of the reading process. One parent described how her daughter was "excited to hear Floppy's next question so she can answer them." In the interview, one parent explained, "She seems engaged. Listening to all of those. But engaged in terms of really understanding what's going on, paying attention," adding that "she's more like paying attention because she knows she will be listening to and answering questions" (2510).

In addition to keeping the child focused, the app also helped with *reading comprehension* by developing critical thinking skills through asking engaging questions and prompting discussions about the story. Parents mentioned how the app helped the child understand particular words in the story and "cemented knowledge" about the book. One parent explained how "I would recommend the app to friends because it encourages quality time spent thinking about details of the story that may not otherwise be considered" (2615). In the interviews, five parents mentioned that the app prompted deeper reasoning about the story, and that using the app was "encouraging us to have a bigger discussion" (2410). Another parent thought the questions from the app helped the child connect the book with his own experiences. "He's not really done that with other books before, so I gotta attribute that to Floppy" (1815).

Although the parents all reported that they would use the application in the future and would recommend it to others on the survey, four parents reported that the app had no impact on their reading habits during the interviews. Two parents explained that they already read every night, that they were already incorporating the ideas into their reading. Another parent felt the app "required more attention from me so I was trying to hear it more. And I was keeping track of the question" (2210).

Discussion

Overall, participants gave the app high SUS ratings and found the Floppy app to be easy to use. By sharing questions at key points in the study, Floppy modeled dialogic reading strategies for the parents in real time. This experience gave the parents ideas for questions and also reminded them to ask questions during reading. Increasing parents' responsiveness to their children is an important factor in building children's language skills (Tamis-LeMonda et al., 2014). Other studies have found that conversational agents can help children improve their reading (Xu et al., 2021); this study suggests that parents can also improve their reading through interaction with an intelligent virtual agent. The timing of when questions were fired was the most challenging aspect of the app; a few parents found the app to be either too fast or too slow. Parents tended to blame their reading pace, rather than the app, for timing issues.

Parents had different ways of using the app during the at home sessions: fans, who used the app more than once a day for multiple days, pacers, who spread out their use of the app over time, procrastinators, who used the app right before the second session, and parents who used the app immediately after the first session in order to Get It Over With (GIOW). While we did not find any relationship between SUS scores and patterns of app use, these patterns of use are of interest as frequency and the timing of reading books has implications in the efficacy of the app and in the development of positive reading practices. To address this in future studies, we plan to send a weekly text reminding parents to read with their children throughout the course of the study.

After using the app, parents reported both an increase in interaction as well as a more focused attention to the activity of reading and deeper engagement with the topics in the book, which can lay the groundwork for their child's language development (Hirsh-Pasek & Golinkoff, 2019). Just as games can improve interaction and engagement (Bustamante et al., 2020), embedding the Floppy Virtual Agent made reading sessions more engaging for the children and parents. This initial usability study suggests that an intelligent virtual agent can provide guidance to parents during storybook reading; our future research will explore the impact of the Floppy app on reading strategies when compared to a control group.

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14. Investigating How Teacher Educators Implement and Preservice Teachers' Respond to Online Simulations on Argumentation-Focused Discussions

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Abstract: Argumentation has been identified as an essential practice in both mathematics and science education. As a result, it is important for preservice teachers (PSTs) to become proficient in facilitating discussions that engage K-12 students in mathematical or scientific argumentation. Simulations are one way to develop proficiency in teaching and are increasingly used to help PSTs learn new skills. In this study, we examined how teacher educators (TEs) used and how PSTs responded to a simulation designed to help PSTs learn how to facilitate argumentation-focused discussions (AFDs); this simulation was implemented in four secondary methods classes. Results show that TEs framed the simulation with either a focus on Talk Moves or Argumentation Scaffolds. We saw similar patterns of PST enactment regardless of instructional focus, which suggests that there are multiple productive approaches for integrating the simulation into methods classes. Some PSTs expressed reservations about asking students to critique one another's ideas during the simulation, signaling an important instructional aspect that would be fruitful to address in future methods classes. This online simulation enabled us to examine patterns in PSTs' simulated teaching behaviors, which can be useful in helping inform instruction in teacher education classes.

Introduction

Engaging students in productive argumentation is viewed as one of the critical practices that support student sensemaking within the content areas (Henderson et al., 2018; Staples & Newton, 2016). Productive argumentation typically involves opportunities for students to construct and justify viable arguments, offer rebuttals and counterexamples, compare and critique others' reasoning, and persuade others to modify their initial arguments (Connor et al., 2014; McNeill et al., 2017). Preservice teachers (PSTs) need structured opportunities to learn how to facilitate argumentation with their future students (Osborne et al., 2019). One viable approach for providing such opportunities is the use of online simulations where teachers can try out and practice discrete skills. We developed a series of simulations to help PSTs practice facilitating argumentation-focused discussions (AFDs) as part of a larger multiyear National Science Foundation-funded project. This paper focuses on one type of simulation – the Teacher Moments simulation – that was implemented by four teacher educators (TEs) at four different universities in science and mathematics classes during the project's pilot phase. Our goal in this analysis is to learn more about how TEs implement and how PSTs respond to two versions of the Teacher Moments simulations.

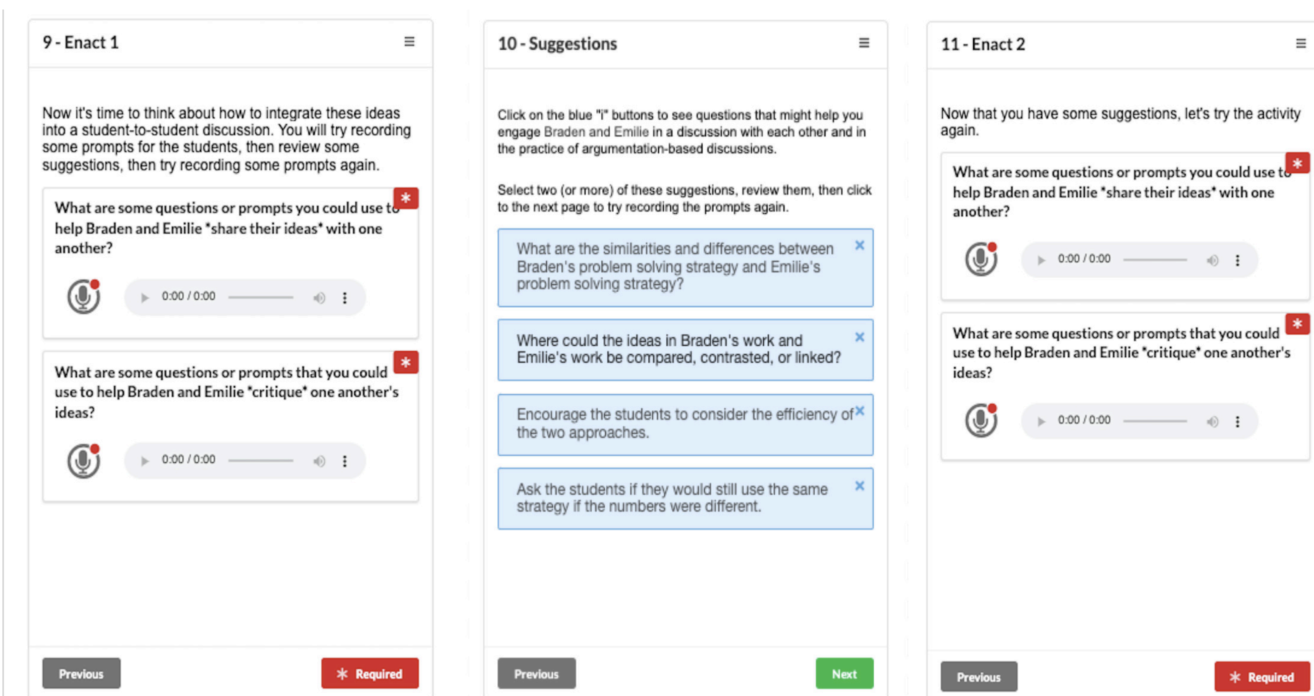
Teacher Moments

The simulations discussed in this paper are located in an online platform designed to host simulations that help preservice and in-service teachers develop and practice key skills in teaching (www.teachermoments.mit.edu). This study examines two Teacher Moments single-user simulations, *The Keeping the Heat Discussion Task* and *Facilitating*

Student-to-Student Discussions on the Rate of Strawberry Picking that are intended to help PSTs facilitate AFDs in a middle-school science and middle-school mathematics context, respectively.

Both scenarios have the same premise: the PST takes on the role of a teacher who assigned a problem (in mathematics) or a question about an investigation (in science) to a class of fictitious students and asked the students to explain their thinking. In both scenarios, the PST is given the written work of two hypothetical students. Each fictitious student's profile is designed to approach the problem or investigation in a different way. The profiles also show how the virtual students disagree with their partner's thinking. The simulations are designed to enable the PST to prompt the students to both compare and critique each other's thinking – even though both students may arrive at the correct answer or have the correct conception, they still disagree on the process they used to arrive at the solution or the evidence and reasoning they used to justify their claim. The PST is then prompted "What are some questions or prompts you could use to help *Student* A and *Student* B 'share their ideas' with one another?" and "What are some questions or prompts that you could use to help *Student* A and *Student* B 'critique' one another's ideas?" We chose to analyze how the PSTs structure their AFD-related responses to the "critique" question. While we also analyzed the data from the "compare" questions, those results will be discussed in a separate report.

The data collection process began with an analysis of how the PST responds to the question by generating prompts they would use to set up an AFD for the two students by viewing prepopulated suggestions (see Figure 1 for screenshots from the mathematics simulation). They're then asked to repeat generating prompts for an AFD by responding to the same questions again. The reason for two rounds of response is to allow the PST to view suggestions and to consider whether they want to change or augment their response by using those ideas. We did not see a discernible difference between the response to the critique question in "Enact 1" and "Enact 2", so we analyzed both of each PST's responses as one full dataset (rather than two separate sets). The data were collected in the form of transcriptions of PSTs' audio responses from the second question on both of the "Enact" pages, as shown in Figure 1.



Research Questions

This is an exploratory study to investigate how TEs implement these simulations and the features of Argumentation or Talk Moves that are present in PSTs' responses to the simulation. In this paper, we consider the following research questions:

In their methods class, how do TEs introduce and frame a simulation designed to help PSTs facilitate AFDs?

1. To what extent did the PSTs use specific Talk Moves in their Teacher Moments simulation responses? In what ways, if at all, did the frequency of the specific Talk Moves the PSTs used differ by the way the TE framed the nature of the Teacher Moments simulation (Talk Moves vs. Argumentation Scaffolds framing) or by content area (mathematics vs. science)?
2. To what extent did the PSTs use specific Argumentation Scaffolds in their Teacher Moments simulation responses?
3. In what ways, if at all, did the frequency of the specific Argumentation Scaffolds the PSTs used differ by the way the TE framed the nature of the Teacher Moments simulation (Talk Moves vs. Argumentation Scaffolds framing) or by content area (mathematics vs. science)?

Background

Argumentation-Focused Discussions (AFDs)

One widely leveraged approach that teachers use to provide opportunities for students to engage in argumentation is the use of small and whole class discussions (Association of Mathematics Teacher Educators, 2017; National Science Teaching Association, 2013). When facilitating AFDs, teachers need to learn how to prompt students to share, justify, compare, and critique ideas, as well as encourage students to interact directly with each other. Facilitating AFDs is a complex teaching practice. For example, students often struggle to engage in critique (Henderson, 2015), which is an important aspect of AFDs (Gonzalez-Howard et al., 2019).

Use of Simulations in Teacher Education Courses

Simulations are beneficial tools because they can narrow the complex task of teaching into more focused activities – what Grossman et al. (2009) describe as "approximations of practice. These approximations allow PSTs to focus on specific skills, receive feedback on their performance during the approximation, and then practice those new skills. Furthermore, simulations allow TEs to observe multiple PSTs enacting their ideas about teaching during the simulation. Normally, observing PSTs "in action" occurs when a TE observes the PST teaching in a K-12 classroom. Simulations allow TEs to observe and assess many PSTs' skills in a more efficient way, saving time and resources.

Facilitating Discussions through General Talk Moves and Argumentation-Specific Scaffolds

PSTs learn how to start and sustain productive discussions in their classrooms by using techniques such as Talk Moves and frameworks for class discussions. Talk Moves include questioning strategies such as probing student ideas, pressing for examples, revoicing a part of a students' idea, encouraging peer to peer interaction, or focusing on a specific aspect of a complex task (Harlen, 2015; Michaels & O'Connor, 2015; Windschitl et al., 2018). Note that Talk Moves can also be used to support argumentation; in this study we classify any Talk Move that includes argumentation language specifically as argumentation. Facilitating class discussions requires teachers to incorporate Talk Moves into the framework of a larger class discussion that engages all of the students. Smith and Stein (2018) propose five ways to orchestrate mathematics discussions: anticipating students' ideas, monitoring students in class, selecting approaches and students to share them, sequencing students' presentations purposefully, and connecting students' approaches and the underlying concepts. Both Talk Moves and strategies for orchestrating discussions are useful tools to help PSTs become better facilitators of AFDs.

Both science and mathematics standards identify argumentation as a key goal: the Next Generation Science Standards (NGSS) include "engaging in argument from evidence" as one of the eight practices essential to science and engineering (NGSS Lead States, 2013), and the Common Core Math Standards suggest students should be able to "construct viable arguments and critique the reasoning of others" (National Governors Association, 2010). To support argumentation, the "claims, evidence, reasoning" (CER) framework is commonly used in science contexts (McNeill et al., 2016), while mathematics educators draw from a slightly different scaffold: "conjecture, justification, conclusion" (Knudsen et al., 2014). Both scaffolds follow a similar pattern and are useful to help students learn the language and strategies to successfully engage in AFDs.

Method

Sample

Four secondary TEs participated in the pilot study: two were mathematics educators teaching mathematics methods class (we will call them MTE1 and MTE2), and two were science educators teaching science methods class (we will call them STE1 and STE2). Two TEs identified as male and two identified as female; three identified as White and one identified as Hispanic. The four institutions were all public universities located in the Midwest (2) and in the Northeast (2) in the United States. The TEs had a range of two to three years of experience teaching methods classes. The simulation was done in the beginning of the semester, after AFDs had just been introduced in each class.

Of the 38 total PSTs who consented to participate in the study, 25 PSTs were enrolled in a mathematics methods class and the other 13 PSTs were enrolled in a science methods class. Overall, 97% of the PSTs identified as White, 5% as Asian or Asian American, 5% as Hispanic, and 3% as Black; 68% of the PSTs identified as female, and the remaining 32% identified as male.

Data Collection

TEs were introduced to the Teacher Moments simulation in the semester before they implemented it in class and were given access to a wide range of resource materials they could use to support teaching PSTs about AFDs. For example, TEs were given practitioner-based articles about argumentation in the classroom (e.g., Knudsen et al., 2014) and about how to incorporate Talk Moves as pedagogical strategies (e.g., Harlen, 2015; Michaels & O'Connor, 2012). TEs also had access to slide decks and assignments that other TEs utilized when they taught about AFDs. Each TE had autonomy over how they incorporated the simulation into their class. Each class instance that included a focus on AFDs was observed by a researcher, which allowed us to know how each TE introduced AFDs and how they introduced classroom discourse moves. During each observation, the researcher took detailed field notes and gathered classroom artifacts (slides, handouts, etc.) and the PSTs' written assignments. All assignments were deidentified. Three TEs assigned the simulation as homework, and one TE had their PSTs complete the simulation during class time. When generating prompts for student discussion, PSTs spoke their responses into their computer microphone. Audio responses were transcribed automatically and then researchers reviewed and edited transcriptions for accuracy.

Coding System

Our coding system was based on an existing rubric developed by other members of the research team for a prior existing project that identified five dimensions of AFDs: (1) Attending to Student Ideas, (2) Facilitating a Coherent and Connected Discussion, (3) Encouraging Student-to-Student Interactions, (4) Developing Students' Conceptual Understanding, and (5) Engaging Students in Argumentation (Go Discuss Project, 2021). The adapted rubric includes nine codes that are numbered with the associated argumentation dimension (Table 1). We omitted the fourth dimension about conceptual understanding because the simulation was focused on facilitating AFDs rather than developing content knowledge; in the simulation instructions, PSTs were specifically instructed: "You don't need to check if students are using these [content-specific] skills correctly—you want to focus on how to engage the students in discussion with one another and in the practice of argumentation."

We grouped the codes into two categories: Talk Moves/Facilitating Discussions (codes linked to dimensions 1-3) and Argumentation Scaffolds (codes linked to dimension 5). The first four codes are connected to Talk Moves and focus on how the teacher addresses the students, brings in the topic area, and encourages interaction among the students. The second set of codes (codes linked to dimension 5) focuses on features of argumentation – whether the PSTs incorporate argumentation-based language and prompt students to engage in persuasion, justification, and critique. The final code was designed to track a particular type of PST response where some PSTs encouraged their students to "use ideas from others," whether it was trying out the other student's mathematics problem-solving technique or their scientific reasoning. While this code was designed by the researchers for this study, it still fell under dimension 5 of Engaging Students in Argumentation in the rubric.

Two researchers coded the PSTs' responses in the form of the transcribed audio from their spoken responses to the question shown in both Enact 1 and Enact 2 of the Teacher Moments simulation about what questions or prompts they could use to have the students critique each other's ideas. Their responses were coded for the presence or absence of each of the nine codes shown in Table 1. If the code was present in either the PST's first or second responses, the PST received a "1" in that category. We checked reliability with Gwet's AC, an alternative reliability measure to Cohen's Kappa that follows the same scale (0-1, with 0.7 and above being desirable) (Landis et al., 1977; Zec et al., 2017). For the two codes that fell below 0.6, we revised the codebook, recoded the data set, and reconciled all codes until we reached 100% agreement between researchers.

Code	Rubric Dimension	Description
Talk Moves/ Facilitating Discussion Codes		
Specific Topic	1	Mention a concept or detail specific to the content of the simulation
Use Names	1	Explicitly address both students by name
Connect Ideas	2	Ask students to compare/contrast ideas or think about how their responses fit together on a common topic
Peer Interaction	3	Questions/prompts require students to talk to each other and/or work together
Argumentation Codes		
Argumentation language	5	Explicitly use terms such as claim, evidence, reasoning, critique, justification, consensus, conjecture, or conclusion
Persuasion	5	Ask students to find advantages of their claim, strategy, or evidence-based reasoning over the other's
Justification	5	Ask students to explain or reflect on their reasoning, thought process, or approach
Critique	5	Ask students to point out flaws in the other person's ideas or to bring up feedback from the students' written responses to each other's claim, strategy, or evidence-based reasoning
Use Others' Ideas	5	Asks the students to explain or use the other student's claim, strategy, or evidence-based reasoning without evaluation or critique

Table 1. A summary of the Talk Moves (dimensions 1-3) and Argumentation Scaffolds (dimension 5) codes.

Results and Discussion

Some audio responses from one or both Teacher Moments attempts were missing, so there are 12 responses from science PSTs and 24 responses from mathematics PSTs. In total there are 36 PST responses to the prompt on how to critique ideas.

Research Question 1

We reviewed the observation notes, slides, and readings to characterize how the Teacher Moments simulation was introduced in each of the four classes. All four TEs introduced specific AFDs (Argumentation Scaffolds) and questioning and discourse strategies (Talk Moves/ Facilitating Discussion)in their classes; however, we observed that TEs framed the Teacher Moments simulation differently than others. While all TEs used both Argumentation and Talk Moves/ Facilitating Discussion in their classes, in this paper we focus on the specific framing the TE emphasized directly before introducing the Teacher Moments Simulation. MTE1 and STE1 both framed the introduction to Teacher Moments in terms of argumentation. In MTE1's class, for homework the PSTs read an article by Knudsen et al. (xxxx) titled "Advice for Mathematical Argumentation", and MTE1 introduced the simulation with a discussion on "What is mathematical argumentation?". Similarly, STE1 used "Claims, Evidence, and Reasoning" (CER) as a scaffold for introducing argumentation, and referenced CER twice on the slides. In contrast, MTE2 framed the introduction to the Teacher Moments simulation in terms of Talk Moves. MTE2's PSTs read an excerpt from the book 5 *Practices for Orchestrating Productive Mathematics Discussions* (Smith & Stein, 2018), and the class learning objective from the slides was to "learn strategies for orchestrating math discussion in math class." STE2's class also focused on identifying effective Talk Moves;

STE2 included a list of productive Talk Moves and citations from the literature directly on the slides in the class when the Teacher Moments simulation was introduced (Harlen, 2015; Windschitl et al., 2008). We will refer to the classes as "Argumentation Scaffolds" and "Talk Moves" to reflect the framing for the simulation.

Research Question 2

In Research Question 2, we examined the presence of Talk Moves in the PST responses (Figure 2). We found that the science classes have a higher occurrence of all the Talk Moves codes than the mathematics classes. One might expect the PSTs in both of the Talk Moves classes would have a higher presence of the Talk Moves/Facilitating Discussions codes than the PSTs in the Argumentation Scaffold classes; however, when we reviewed the data with the classes grouped by framing, there did not appear to be a pattern.

Overall, PSTs showed lower frequency rates of asking students to connect ideas or to directly interact with each other compared to the frequency rates of addressing the topic and/or students specifically. This indicates that PSTs could be better supported in facilitating clear and connected discussions and in encouraging student-to-student interaction. As an example, a prompt that would demonstrate both connecting ideas and peer interaction is to ask the students, "Can you two work together to find similarities and

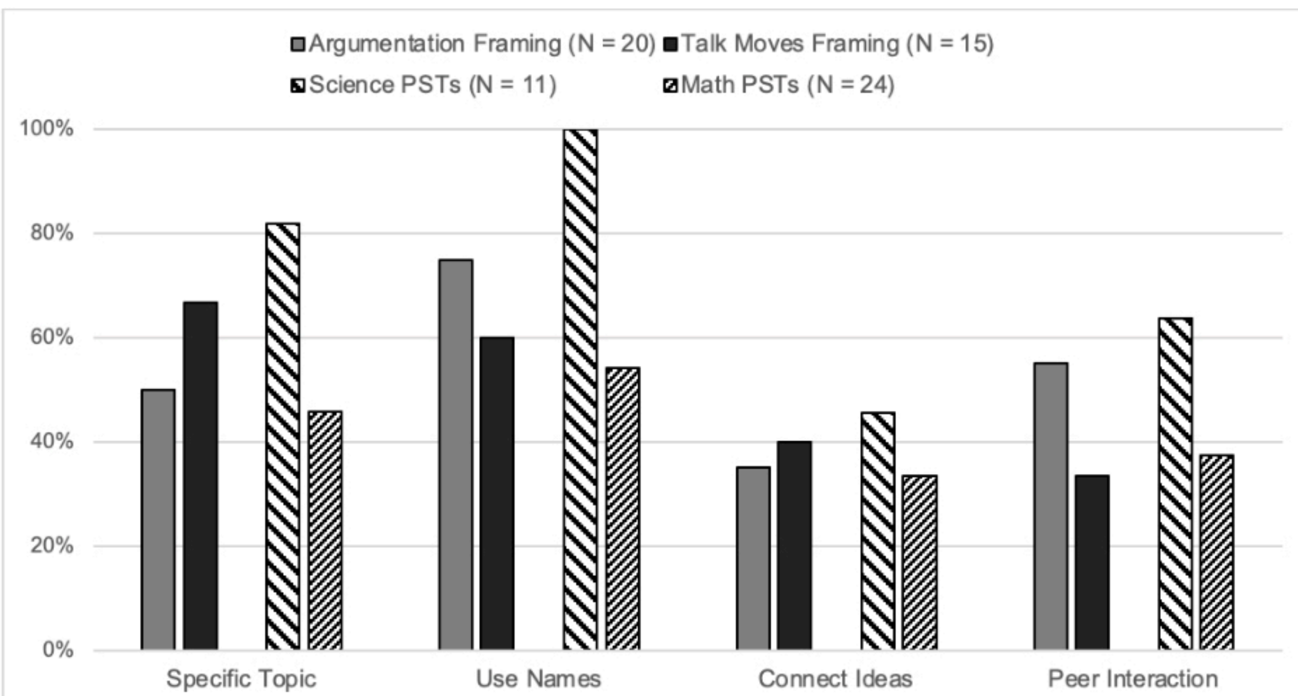


Figure 2. Frequency bar chart for Talk Moves codes, grouped by activity framing and content area.

Research Question 3

In Research Question 3, we examined the presence of Argumentation Scaffolds in the PST responses (Figure 3). Once again, the framing of the Teacher Moments simulation did not appear to influence the PSTs' responses; we did not see more argumentation codes for the classes that were framed with the specific Argumentation Scaffolds when compared to the more general Talk Moves/Facilitating Discussions framing. Only four mathematics PSTs (17%) and no science PSTs used persuasion in their responses. Mathematics PSTs were also less likely to use argumentation language than science PSTs. Since the CER framework is a popular framework in science (Windschtil et al., 2008), this could explain the more prominent use of argumentation language by the science PSTs. Integrating the more familiar language of CER into the curriculum may help mathematics PSTs include argumentation language when leading discussions.

Many of the PST responses for prompting critique asked the students to justify their answers. This suggests that PSTs associate argumentation with justification of students' ideas. While findings showed that many of the PSTs' responses included evidence of critique, some PSTs were hesitant to ask students to critique one another's ideas directly. For example, one PST noted that they "would definitely make sure that the critique is wholesome and they're not like doing things that will possibly harm another student." Another PST expressed concern that "if [the students] critique [each other's ideas], then they're just looking at what they don't like about the solution." This PST contended that asking students to consider the perspective of the other student would help them better understand and analyze the problem than prompting the students to directly critique the student's ideas. We found more than half of the science PSTs (55%) and 21% of the mathematics PSTs suggested that students use the other students' rationale or problem-solving method, without instructing them to evaluate their peers' response. While the majority of PSTs did use critique in their response, this suggests that a subset of PSTs may feel uncomfortable leading discussions that include critique and may need additional support in incorporating critique in their own teaching.

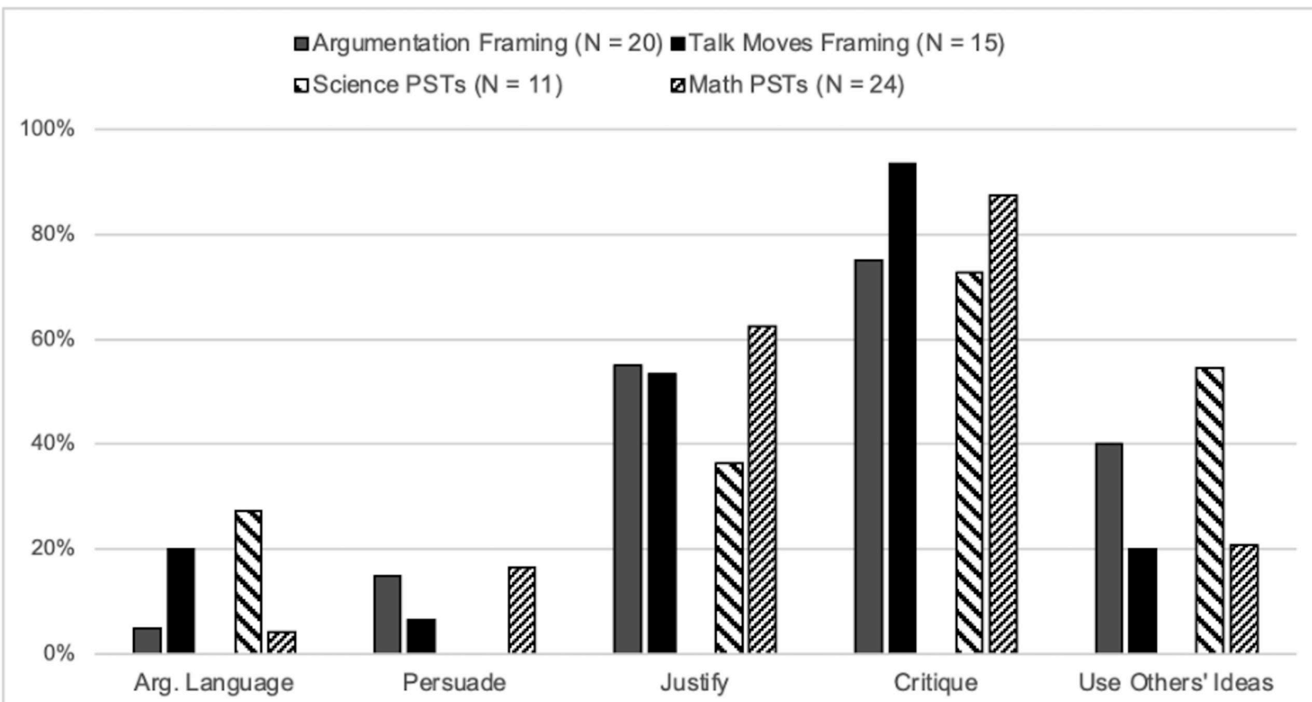


Figure 3. Frequency bar chart for Argumentation codes and Talk Moves/Facilitating Discussion, grouped by activity framing and content area.

Conclusion

Preparing PSTs to facilitate AFDs requires the ability to assess PST's current skills, and the ability to help PSTs develop new skills through practice and feedback. TEs are often limited to assessing PST's skills one PST at a time, either through practice lessons or by observing PSTs in the field. These are time- and resource-intensive activities. The results of this study indicate that simulations can serve as approximations of practice, enabling PSTs to learn and demonstrate their skills in facilitating AFDs. We learned that PSTs do utilize Talk Moves and Argumentation Scaffolds in their simulations, but that certain aspects of argumentation, specifically persuasion and the use of specific argumentation language, could be improved. Gathering this type of evidence through practice teaching and one-on-one observations usually takes a lot of time. The Teacher Moments simulation allows us to capture how PSTs could respond to a situation more efficiently, provide PSTs feedback, and then allow them to practice those new skills.

The simulation was conducted at the beginning of the semester, which could indicate that PSTs have strong incoming beliefs and habits around what constitutes an effective AFD. In future studies, we will examine how PSTs' performance changes after additional instruction and simulations about facilitating AFDs.

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15. Across the Digital Divide

Parents' Use of Technology for Supporting Their Children in School

ZHEXUN XIN; DAMIAN BEBELL; GARETH CLEVELAND; AND MICHAEL RUSSELL

Abstract: This study explores the results of a May 2021 parent survey regarding their use of digital technology in their household. As part of a larger longitudinal impact evaluation of a free community broadband initiative in Chattanooga, Tennessee, a telephone parent survey was conducted with a random sample of 416 households stratified across their broadband connectivity/access. Results provide a summary of parents' use of technology to connect with their children's teachers, accessing lessons and assignments, and school information. Respondents' demographic information provides additional context to the results, supporting exploration of how the provision of broadband to households addressed inequities that otherwise existed. Results suggest that households participating in the community broadband initiative had a small, but statistically significant impact on parent practices. Moreover, the impacts from broadband participation were similar across households regardless of racialized groups, suggesting that household participation in the broadband program could be beginning to correct for racial inequities in parents' access and use that are the product of racial oppression.

Introduction

> [S]tudents whose parents are involved in their schooling are more likely to have higher grades and test scores, attend school regularly, have better social skills, show improved behavior, and adapt well to school.(Henderson and Mapp, 2002)

Parent/guardian involvement in a students' educational experience plays an important role in supporting positive educational outcomes (McNeal, 2014). As education has increasingly embraced digital technologies to support learning and communication with parents, home broadband access plays an increasingly important role in supporting parents and guardians' involvement in their children's education. Unfortunately, home broadband subscription rates and mobile access rank as the least equitable utility/resource in the United States today. The gap between people who have the functional accessibility to digital devices and broadband connectivity from those who do not is referred to as the digital divide, an extension of the nation's economic disparities and racial inequities.

The 2019 U.S. Department of Commerce's National Telecommunications and Information Administration's survey indicates that Families with income less than $25,000 used the internet from home much less than families with income more than $100,000 (NTIA, 2019). The lack of accessible and affordable access to the internet in the home disproportionately affects racial and ethnic minorities (Galperin et al., 2020). Inequitable access to home broadband results, in large part, may be due to the history of racial oppression that has segregated communities and provided fewer economic opportunities for racialized communities, particularly those membered Black and Latine. A 2015 study reports that approximately 84% of White K-12 students have broadband connectivity at home while only 68% Hispanic students, 66% Black students, and 56% Native American students have broadband connectivity at home (KewalRamani et al., 2019).

Beginning in March 2020, the COVID-19 pandemic led to unprecedented school closures that placed an estimated 1.5 billion students into an educational limbo. Instead of traditional in-person classrooms, students across the nation were provided with a hodgepodge of home-based lessons, stopgap educational technology, remote learning efforts, and in some cases, nothing at all (Katz & Rideout, 2021). In this new educational paradigm, long-standing inequities have been exacerbated by the sudden challenge of educating children with limited or no access to in-person classrooms (Galperin et al., 2020; Gan & Sun, 2021).

Given the immediacy of the pandemic, governments and organizations quickly sought to address the digital equity gap by providing free or reduced-price broadband services, technology devices, or technology training services. For example, in Michigan, $25 million was invested to support distance learning (Kelley & Sisneros, 2020). As one of the U.S.'s largest and most far-reaching community broadband initiatives, HCS EdConnect provided free 100Mbps symmetrical internet to more than 15,000 students and their families, which is over one-third of the entire Hamilton County school district. Launched at the height of the pandemic in July 2020, this initiative provided an estimated 25,000 Chattanooga residents with current internet access. While 98% of enrolled families receive fiber connectivity, approximately 500 families who live beyond service areas or do not have a permanent residence receive a 4G LTE mobile hotspot with unlimited data.

Despite that access to technology isan important predictor of student outcomes, research on parents' use of it to support their children's school is largely out-of-date or less applicable to post-COVID conditions. In 2012, a nationally representative survey found 69% of parents believed "digital devices have educational content to teach" (Wartella et al., 2013). More recently, a nationwide parent study found technology use and attitudes were strongly correlated with their children's technology habits and attitudes, even after researchers controlled for technology access (Lauricella & Cingel, 2020). Similar studies have found parental attitudes and practices influence children's academic achievements, non academic interests, self-efficacy, and use of technology across school and household settings (McNeal, 2014).

Despite these examples, there remains little empirical research documenting the impacts and roles of parents in a modern educational landscape, or in the context of community broadband initiatives. In January 2021, an independent equity evaluation study was launched to examine whether and how household usage enabled by universal broadband access could mitigate long-term racial, economic, educational, and social inequities across this diverse community.This paper explores partial results from a May 2021 phone survey of 416 randomly sampled Grade-8 parents from across a school district and aims to document their experience and practices of using technology to support their children and school.

Theoretical Framework and Research Questions

The current study adopted a culturally responsive evaluation (CRE) framework that prioritizes equity and power balance when working in diverse cultural contexts and focuses attention on historically marginalized groups (Hood et al., 2015). By engaging with a diverse and representative group of stakeholders, including those who were directly and indirectly impacted by the program, the research team continually sought to "create accurate, valid, and culturally-grounded understanding of the evaluand" (Hood et al., 2015). Guided by CRE theory, our study explores if and how the provision of free community broadband access increased equity with respect to parents' frequency of support for their students' K-12 education. We raise the following three research questions:

1. How frequently do parents actively use technology to access/communicate with their children's school?
2. What is the relationship between free, equitable community broadband access and parents' use of technology for supporting K-12 education?
3. To what extent does the provision of technology to households result in equitable parent/guardian use of technology to support K-12 education?

Methodology

As part of a larger research and evaluation study, a telephone parent survey was conducted with a random sample of 416 Hamilton County School (HCS) district households in Chattanooga, Tennessee, in May 2021. HCS represents a 576-square mile region including urban, suburban, and rural settings across 78 PreK-12, public schools.

Using a district-supplied list of all eligible households containing Grades 5-8 students, households were stratified into four groups based on their level of connectivity (EPB status) and then randomly sampled to approximate the overall program participation rates across the county. In addition to broadband connectivity status, household race/ ethnicity and number of children in the household were collected to provide a greater context to the results and allow richer exploration of the research questions. Given the complexity of race and ethnicity variables including that some households contained different ethnicities or multiracial children, we created three dichotomous variables indicating households with at least one child who identifies as Black, at least one child who identifies as Hispanic/Latine, or a household containing only children who identify as White. Using these distinctions, we summarized the overall distribution of participants' broadband connectivity status across the sample (Table 1).

	Connectivity Status		
	EPB Active	Not EPB Active	Total
At least One Child Identified Black	59.0% (102)	41.0% (71)	100% (173)
At Least One Child Identified Hispanic	51.4% (37)	48.6% (35)	100% (72)
All Children Identified White	31.7% (45)	68.3% (97)	100% (142)
Total	46.6% (190)	53.4% (218)	100% (408)

Table 1. Broadband program participation/connectivity status by household race (n = 408).

The parent survey instrument was developed with local stakeholders and a Community Advisory Board to efficiently measure parents' frequency of using digital devices for personal purposes, for interacting with their children's school, as well as their beliefs and attitudes related to educational technology. In this paper, we focus on parents' *experience* and *practices* using technology to support their children's education.

Data Analysis

The 416 survey responses were cleaned, coded, and analyzed using SPSS v. 27 and R v. 4.1.2 to explore and report patterns and trends across broadband connectivity status and household ethnicity/race. Descriptive statistics were calculated to summarize the data while a series of ordinary least squares linear regression models examined the impact of connectivity status and impacts across racialized categories specific to parents' experience and use of technology.

Results

First, looking across the diverse sample of households, parents generally reported a high frequency of technology and digital device use for interacting with their children's schools. Table 2 provides a summary of the frequency of the parent's self-reported use of technology over a one-month period.

During the past month, about how often have you used technology in your home to:	Never	Once or twice	Several times
Access information about your child's grades or performance.	14%	13%	73%
Get information about your child's homework or assignments.	16%	15%	69%
Communicate with your child's teacher or school.	12%	22%	66%
Get information about a school event or schedule.	14%	24%	62%

Table 2. Summary of parent's frequency of technology use related to their child's school (n = 416).

Overall, parents generally reported at least some use of technology over the past month related to their child's school experience. "Accessing information about their child's grades or performance in school" was the most frequently reported use, while more active communication with their child's teacher or "getting information about a school event or schedule" occurred somewhat less frequently. To provide a richer quantitative lens to parent voice, we summed individual survey responses into an aggregate measure of parents' use of technology for interacting with schools (Figure 1).

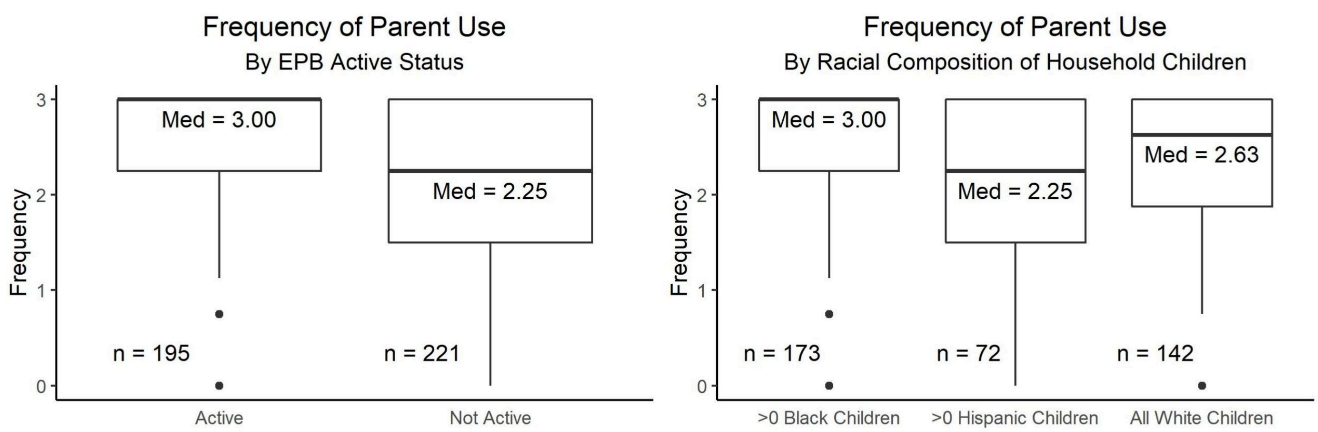

Figure 1. Frequency of parent technology use for supporting school by connectivity (EPB) status and household race.

Comparing the distributions of active users and not active users of the community broadband program, we observed a higher median frequency of parents using technology to interact with schools for program users than nonactive households. The differential pattern of parent technology use across the racialized/ethnic composition of households was also noted, with the highest median use observed for those households reporting at least one child who is identified as Black (Figure).

To better explore the potential differences in the use of school-related technology practices for connected versus nonconnected parents, as well as across the racialized and ethnic groups, we created and compared two multiple linear regression models using the aggregated measure of parents' use (Table 3).

	Household Race	Household Race + EPB Connectivity
R Square	.048	.110
Adjusted R Square	.043	.103
F	10.19	16.58
F-Significance	*<.001*	*<.001*
Unstandardized Coefficient	Black: .294	Black: .175
	Hispanic/Latinx: -.229	Hispanic/Latinx: -.309
	-	EPB Connectivity: .455

Table 3. Comparison of regression results for parent technology use

Given the longstanding racial inequities in the community, the first regression model (household racialized identity) explores how the household background variables "having at least one child identified as Black" and "having at least one child identified as Hispanic" relate to the overall variance in parents' technology use. The second regression model (household race + EPB connectivity) includes the additional variable, EPB, representing the households' participation in the community broadband program. Although there was relatively little variance accounted for by the model, as indicated by the modest R square values in both models, we found the dichotomous measure of EPB status and the two household variables significantly related to parent use. However, by adding EPB status to the second model, the adjusted R square increased from .043 to .103, indicating that we observed a statistically significant impact for households' broadband connectivity, in addition to the households' racialized/ethnic background. In other words, parents' frequency of online interaction with their child's school varied across household backgrounds, but the relationship between program connectivity and parent use was greater and accounted for a greater proportion of the overall variance in parent practices.

Discussion

The critical role that parents and guardians play in supporting their children's education is well documented. However, few published accounts have explored the experience and practices of parents in the context of pandemic-era remote home learning, particularly through the lens of a community-wide broadband initiative directly aimed at equity. Overall, this study begins to update the parent-school literature and document the frequency parents connected with and supported their children's schools by addressing three related research questions.

Addressing our first research question, *how frequently do parents actively use technology to access/communicate with their children's school*, we found the vast majority of surveyed households (including both participants and non-participants of the broadband program) reported using technology to access information and communicate with the child's school. Across the entire sample, more than two- thirds of responding parents reported regularly using technology to access school-related information or communicate with their child's teacher and school during Spring 2021. Compared to prior studies and nationally normed data sets (Wartella et al., 2013), the HCS households generally reported more frequent access and communication to their child's school and teacher (as well as more positive beliefs towards the role and impacts of educational technology for their child).

Looking more deeply, the study results also provide opportunities to address and explore actual household participation in the broadband initiative (research question 2) and whether broadband access increased equity of use across racialized/ethnic households (research question 3).

Addressing the second research question, the relationship between households' EdConnect broadband participation (EPB status) and parents' use of technology to connect and support their child's school, we encountered a limitation due to the relatively small degree of variance across household practices. Because so many of our surveyed parents reported such a high frequency for connecting and supporting their child's school, there was less opportunity to examine differences. Despite this overall limitation, we found that a household's broadband connectivity status was our strongest single predictor of parent use. In other words, households participating in the EdConnect program at the time of the survey reported significantly more frequent use of technology for supporting/connecting with their child's school than those households who were eligible but not actively participating.

Examining the potential relationship and differences in the frequency and patterns of parent use across the major historical racialized/ethnic groups in the community, we explored race and ethnicity by examining three categories of households: households with at least one student identified as Black (42% of all study households), households with at least one student identified as Hispanic/Latine (17%), and households in which all children identified as White (34%). Results showed notable differences in the frequency and patterns of use across the three household groups, with those households reporting at least one child identified as Black exhibiting the most frequent practices and those households reporting at least one child identified as Hispanic/Latine reporting lower use. As such, the household background variables exhibited a statistically significant relationship with patterns of household use, but the overall regression results found relatively small degrees of variance accounted for. This means the racialized identity of the household was related to patterns in parents' use of technology for supporting/connecting with their child's school, but only a small portion of the overall differences among households could be explained by these traditional race/ethnicity variables.

When examined collectively (both household racialized/ethnic identity and EPB status), we found the positive impacts of broadband participation on parent use were similar across households regardless of the racialized identity of students in the household. Despite examining only the first year of program implementation, these results hold an optimistic promise that household participation in the broadband program may be beginning to correct for racial inequities in parents' access and use, and in which themselves are a product of racial oppression.

Given the long and difficult history, we have little expectation that the pervasive inequality across different racial and ethnic households can be quickly or easily addressed by providing equitable internet access. Nonetheless, these results offer a promising glimpse into how equitable public resources may serve to mitigate historic inequities. As such, in our next stages of research and evaluation, we will continue annual household surveys to explore if the variance accounted for by program participation continues to eclipse the differences reported across racial groups. In addition, recognizing the limits of a solely quantitative approach described here, we are conducting in-depth interviews across a range of EdConnect households to better detail *how* parents are using technology and other resources to communicate and support their children in school.

Although brief, our study provides an updated context and results concerning the important and ever-evolving relationship between parents and schools. As educational technology and community broadband initiatives continue to proliferate, it is increasingly important to examine the role internet access plays in parents' use of technology to interact and support their child's education. As such, these results not only begin to address the reality of parent-school relationships in a modern educational landscape,but set the stage for a deeper examination of how opportunities and resources like universal broadband may shift and evolve parent practices across all facets of a community over time.

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