Expanding Informal Maker-Based Learning Programs for Urban Youth

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***Abstract*— This Research Full Paper contributes to research on creating maker-based learning experiences for youth in diverse informal learning settings. A key research question in this space is how to efficiently and effectively setup maker learning spaces and train educators to deliver high-quality maker curriculum in diverse sites. To study this question, we developed and deployed a multi-phase maker educator training program that included makerspace setup, educator training, and youth program deployment. We deployed three models of the program at three participating sites over roughly nine months. We analyzed data from educator pre- and post- interviews and found that the programs generated considerable interest in the youth and resulted in positive shifts in career aspirations and social and technical skills. Participants emphasized the importance of creating hybrid online and offline resources and training materials. Our participants also identified logistical challenges related to recruiting educators and youth attendance. Finally, participants described possibilities for content localization and the inclusion of participatory approaches to keep youth and educators engaged.**

***Keywords*— Maker learning, afterschool youth programs, urban settings, underrepresented minorities, sustainability**

I. Introduction

There is growing interest in understanding the possibilities of using maker learning programs in informal settings, such as afterschool programs and summer camps. These programs are shown to be effective in introducing and engaging youth in underserved populations to engineering and computer science topics and result in significant learning outcomes. Maker education programs provide multiple points of entry and pathways for youth to gain exposure, interest, and skill-building in high-growth technology skills [1]-[4]. Research has shown that maker-based programs delivered in informal settings can engage underrepresented audiences, including minorities and females, in technology career pathways [5]-[[7]. Additionally, setting up makerspaces in existing underutilized community centers, recreation spaces, and school libraries, as well as, working with community educators provide opportunities to make these programs more accessible and relevant for underserved populations.

Resources and guides on how to establish and run a makerspace are becoming increasingly available; however, more research is needed to understand the most effective ways to create these resources and support educators with different levels of experience teaching technical content to create and run maker learning programs for the first time. Additionally, it is unclear how maker learning programs can effectively and efficiently be set up in diverse settings.

In this paper, we address the research question of how to develop and conduct training programs to enable new maker educators to setup a technology learning space for the first time and deliver maker curriculum that covers topics in digital fabrication, coding and web development, among others. We have developed a holistic multi-phase maker technology educator training program, Rec-to-Tech, that includes makerspace setup, educator training, and youth program deployment. We designed three professional development models to train educators with no previous background in teaching technology-rich content to deliver a hands-on maker curriculum to diverse groups of youth.

Rec-to-Tech is developed based on our first-hand experience with transforming an existing underused recreational space in an urban setting into a thriving youth tech learning center in a large American city. The non-profit organization, Digital Harbor Foundation (DHF), has been providing out-of-school-time learning and training programs to youth and children (grades 1-12) in an American urban setting for the past seven years and has served more than 5000 participants. Given the success of the center, there has been growing demand on developing resources for sites in other neighborhoods and cities to create their own version of the programs delivered at DHF without compromising their quality or impact. To this end, DHF has been providing guidance and training to local community members and educators in a variety of technology and maker topics, such as 3D printing, programming and digital prototyping. DHF has also developed an introductory maker curriculum for youth to introduce them to hands-on self-directed maker activities. The curriculum and educator training models used in Rec-to-Tech are based on the material developed over several years at DHF.

We deployed Rec-to-Tech at three different sites over nine months, where we designed and setup a makerspace at each site, trained educators and supported them to deliver a maker curriculum to diverse youth cohorts. Using pre- and post-program interviews and site visits, we studied the perspectives of educators and administrators at the sites to understand the possibilities and challenges of expanding maker learning spaces and programs across diverse urban settings. In the next section, we summarize related research before describing the research project and its background. We next present our methodology,

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including information about research sites and participants. We describe our findings next, before discussing them and synthesizing them into lessons learned in the discussion section. Finally, we present concluding remarks and future directions.

II. Related Works

A. Making Supporting STEM Learning in Informal Settings

Making refers to a wide range of often-technical tinkering, customizing, designing, and fabricating activities that result in the creation of small-batch artifacts in self-directed projects [1]. In recent years, significant interest has developed in the role of making in learning [1][7]. Research has shown that participating in maker activities can positively impact self-efficacy [1], [8], technological awareness and confidence [9], and general and declarative knowledge of technical systems[4][10]. Researchers have identified a number of key effective elements in maker programs, such as self-directed learning, collaboration with others on group projects and the acceptance of failure as important for supporting learning, especially as related to Science, Technology, Engineering and Mathematics (STEM) topics [1], [2]. In a systematic review of research on the learning possibilities of maker programs, Papavlasopoulou et al. found that the number of empirical studies in this area has significantly increased in the last few years [4].

Afterschool programs focused on making introduce youth to engineering concepts and skills before college and provide opportunities to engage in hands-on projects that require creative problem solving, teamwork, and persistence [2], [3]. Additionally, these programs have been shown to strengthen job-readiness and can lead to careers in technical fields [1], [11], [12]. Many such programs are initiated as industry or government initiatives. Example programs include the Lab School that combines craft technologies with engineering and math education [13] and is built on the premise that students can learn through the design and fabrication process [14], or the FabLab@School worldwide network that engages children and youth in problem-solving activities using fabrication and rapid prototyping tools [15]. These project-based extracurricular programs can complement learning in the school classroom and introduce and engage youth participants in a variety of technical and non-technical topics [1]-[10].

Research has also identified challenges in designing and sustaining meaningful maker activities that support learning and engagement. For example, using observations from digital fabrication workshops with older students, Blikstein [16] identified a "keychain syndrome", where equipment is trivialized over time and students get stuck in fabricating a small number of designs (i.e., "keychains"). Similarly, Nemorin et al. described the challenges of using 3D printing in the classroom, where the pressure of achieving learning outcomes can take away from the enjoyment of creative exploration and that the experience of failure to effectively utilize digital technologies may lead to increased emotional labor for both students and teachers [17].

Given the diversity of settings in which maker programs are being offered and the range of projects, technologies, and approaches that they utilize, there is a need to understand how to support their growth by designing and validating effective strategies for setting them up and supporting their expansion into new diverse contexts. Additionally, research needs to investigate how to support the creation of meaningful and engaging maker activities for both youth and educators.

B. Supporting Maker Educators

While the majority of existing research on the learning outcomes of making is focused on the impact on children and youth, the importance of the role of maker educators in creating opportunities for learning and growth is previously recognized. Research has shown that the effectiveness of afterschool STEM programs to produce youth development outcomes is directly tied to the provider's expertise in both subject matter and youth education [3], [18], [19], and strong programmatic ownership by providers [20]-[[22]. Maker-based STEM professional development for out-of-school-time educators has shown early-stage, positive effects on educator skill development [23]-[25], youth outcomes [25][26], and program sustainability.

Despite these results, currently, STEM content in maker afterschool and out-of-schooltime programs is often delivered by staff with little subject expertise or confidence [27], [28]. Researchers are increasingly recognizing the importance of understanding and supporting the role of educators and teachers in informal learning contexts and critiquing the previous focus of maker narratives on the experience of individuals [29]. Therefore, research is needed to identify effective and efficient strategies and tools for training educators and providing them with the technical skills and confidence needed to design and deploy hands-on youth maker programs in diverse settings.

III. Expanding Afterschool Youth Tech Learning Programs

In this project, we developed and deployed a holistic, scaffolded approach for supporting the expansion of maker learning programs in informal afterschool settings. The goals of the project were to study what are the possibilities and challenges of expanding maker learning programs to diverse sites and developing effective and efficient training models for first-time maker educators. Our approach is based on our experience with designing, creating and deploying successful maker learning and training youth programs over several years at a youth maker learning center.

Following, we will first describe the educational and learning programs at the youth technology learning center, followed by details about the maker technology educator training program.

A. Digital Harbor Foundation (DHF): A Maker Technology Learning Center for Youth

Digital Harbor Foundation (DHF) is a non-profit organization that provides out-of-school-time maker technology learning and training programs for youth (grades 1-12). DHF is located in a large American city and serves youth from a wide range of socio-economic backgrounds. One of the main goals of DHF is to use technology and hands-on projects to engage inner-city youth in learning and creative activities.

To this end, it offers a wide range of Science, Technology, Engineering and Math (STEM)-based courses and workshops, including programs that focus on 3D printing and game design, on a pay-what-you-can basis. DHF was founded in 2012 and has since then served more than 5000 youth, of whom more than 70% identified as African American. Female participation at DHF is at an average of 40% per cohort.

DHF has experienced a surge in interest in its programs in the last few years, including interest from external sites in applying its model to the creation of localized programs that deliver similar content to youth. This interest has prompted the current effort to study how to effectively and efficiently support new sites and educators to setup their own localized makerspaces and tech-focused maker learning programs for youth.

Learning programs at DHF are offered as either courses or workshops. Workshops usually last from one to three days and are focused on specific topics. Courses take place over a period of 7-14 weeks, with classes usually meeting twice a week, and cover a range of topics and activities. Courses are structured to resemble a series of hands-on interactive workshops rather than traditional classroom lectures. DHF values self-directed learning, with youth participants being encouraged to explore online resources at home and continue exploration beyond face-to-face time. Once course material is covered through presentations by course instructors, participants work on team projects with creative freedom to either work on new ideas of their own or choose from a set of suggested projects. Teamwork is highly encouraged, and projects are often completed and presented by small teams (3-5 members). During design and fabrication times, senior staff are present in the space, but mainly help the youth with questions and locating online and offline resources rather than telling them what to do.

DHF requires all incoming youth to take an introductory course, Maker Foundations, that takes 14 weeks. This course introduces the youth to a wide variety of technology-focused maker-related topics, including 3D printing, coding, game design and physical computing. Youth who successfully complete the course can then choose from a variety of more advanced courses and workshops. Figure 1 shows a typical DHF course setting.

DHF operates on a trimester model, where programs are offered during the Fall, Spring and Summer terms. At the conclusion of each term, DHF organizes a showcase where the youth present their projects to community members, including parents, educators, and peers. Youth presentations often include descriptions of design processes and challenges that they faced and how they were overcome. The showcase is designed to supports youth's motivation, self-reflection, and presentation and communication skills. Fig. 2 shows a typical showcase setup.

Fig. 1: Typical setting for DHF's courses: The classes are held in one of several large spaces where participants work on shared tables and are surrounded by equipment such as 3D printers and laser cutters. They typically use their laptops or other digital or electrical tools when participating in the activities.

A key component of many courses at DHF, including Maker Foundations, is digital fabrication. These include the 3D modeling and printing of customized objects. Often, the resulting objects are combined with electronic components, such as sensors and microcontrollers to implement various digital functionality. A typical project can involve the design and 3D printing of a customized musical interface or controller that is then attached to a microcontroller or computer (e.g., using Makey Makey [30] or Raspberry Pi [31]) and used to control a musical application, an existing game or a new interactive game the participants have developed using an entry level coding platform, such as Scratch.

Fig. 2: At the DHF showcase youth show their final projects to visitors and explain their design and implementation process.

DHF also offers several technical employment training programs for youth in which youth who have completed a set of required learning programs gain real-world work experience in a professional setting. These programs include a youth-run 3D print shop that provides a range of 3D printing, 3D scanning, and 3D modeling services to community clients, as well as several national clients such as Nation of Makers [32] and CS4All [33]. Former projects include developing assistive devices for older adults, printing art assignments from younger youth, printing chess sets for local parks, and designing a case for scientific sensing equipment that will go in a volcano. The print shop employs youth who are eligible to work through a state government minor work permit and have completed an introductory course.

B. The Rec-to-Tech Project: Transforming Community Sites into Maker Learning Centers

Rec-to-Tech is a holistic, scaffolded approach for supporting the expansion of maker-based technology learning programs in informal afterschool settings. It is based on a process that led to the creation of DHF through transforming an underused recreational center into a dynamic and inclusive learning hub where urban youth participate in hands-on, technology-enhanced courses. Rec-to-Tech was developed in response to demand by community partners for a structured and scaffolded way to replicate this model of transformation in new sites and with educators who might not have prior experience in delivering maker content.

Rec-to-Tech integrates space design, hardware and software delivery, and professional development training, and curriculum design for K-12 educators and organizations to operate their own youth-focused makerspaces. We designed this approach based on principles of sustainable community youth programs as outlined by recent research [27], [34] that combine tech innovation, culturally responsive community youth programming, and skills-based educator professional development. Rec-to-Tech also innovates on traditional professional development models (e.g., the partnership, vendor, and insertion models [27], [35] - [37]) by providing a scaffolded approach to tech training for after-school educators with the goal of building their own skill competencies in high-growth technologies (i.e., web design, 3D design, game development, and electronics), and encouraging program ownership.

Rec-to-Tech comprises of three stages: 1) space design, 2) educator curriculum training, and 3) ongoing skills development and curricular supports for educators. Three variations of the educator curriculum training program were developed:

- *Home-site engagement:* The participating site sends at least 2 educators for 3 days of intensive training (8 hours per day) at DHF. The educators receive instruction on how to work with the tools in their makerspaces and deliver maker content based on the provided curriculum. Afterwards, educators deliver the program with online support and monthly phone meetings from DHF staff.
- *Satellite-site engagement:* DHF deploys a mentor to work side-by-side with at least two educators in their afterschool space for intensive in-person curriculum training over three days (8 hours per day).
- *Remote engagement:* In this model, all training and support takes place remotely. Participating educators receive asynchronous, step-by-step training in space design and the maker curriculum. Online training includes text- and photo-based task descriptions and session outcomes, with supplementary video demonstrations and talks of complex tasks and course subjects. Educators can request support from DHF staff via email, phone or video chat.

The DHF curriculum consists of the following modules:

- *Digital Literacy:* Strategies for Internet searches, web navigation, Google Drive applications, effective online communication, and computer use
- *Digital Design:* Fundamentals of graphic design, branding, and custom digital artwork
- *Digital Fabrication:* Creating 3D printed prototypes and designs, operating 3D printer hardware and software
- *Game Development:* Develop programming fundamentals through, block-based tools like Scratch; use these skills to create multi-level games
- *Web Development:* Develop a full-featured website with multiple pages using Wordpress
- *Circuitry & Electronics:* Introduction to circuits, electronics fundamentals, and microcontrollers such as Makey Makey

To evaluate the Rec-to-Tech approach and compare and contrast the three models of educator curriculum training, we deployed the program at three community sites, each using one of the three models described above. In all variations, space design and physical setup was conducted by in-person DHF staff at the sites (over a period of 8-12 hours). During the trainings, we worked with educators at each site who had not delivered a maker-based program to design their space, familiarize them with maker concepts and technologies, and train them in an established maker curriculum.

We next describe the participating sites, as well as, data collection and analysis methods.

IV. Methods

A. Settings and Site Selection

Three sites participated in the program; each going through three stages of preparation including the application of one of the three training models described above. The sites were selected from a pool of 15 applicants who responded to a call for participation. The applications were ranked based on a number of criteria, including the suitability of space they could allocate for the program, capacity to recruit youth from underrepresented minorities in STEM for participating in the program, and diversity of previous experience with delivering technical content. After an initial round of review, finalist sites were visited by DHF staff who narrowed down the list of participants to three sites.

Following the selection process, the process of transforming each site using the Rec-to-Tech approach was initiated. During the first stage, DHF consulted with participating sites to finalize the identification and preparation of a space suitable for the delivery of the program. The sites then received equipment, including 3D printers, laptop and desktop computers, and digital prototyping materials (1-2 months). DHF staff installed and tested the equipment at each site. Next, educators were

Table 1. Study participants' background information.

Participant ID	*Age Range*	*Gender*	*Role/Length of Experience/Training*	*Site/Training Mode*
Admin 1	50's	Female	Library Media Specialist/17 years/Library Science	Site 1/Home-site Engagement
Educator 1	50s	Female	Engineering Teacher/12 years/Electronics, System Engineering, Education	Site 1/Home-site Engagement
Educator 2	30s	Male	Math, Engineering, CS Teacher/13 years/Math, Teaching, CS	Site 1/Home-site Engagement
Educator 3	40's	Male	Math Teacher/3 years/Linguistic, English and Math	Site 1/Home-site Engagement
Admin 2	30s	Female	Director of Workforce Development and Social Enterprise/11 years/Visual Arts, Community Arts	Site 2/Satellite-site Engagement
Educator 4	20s	Female	Art Educator/2 years/Fine Art	Site 2/Satellite-site Engagement
Educator 5	20s	Female	Art Educator/1 year/Fine Art	Site 2/Satellite-site Engagement
Educator 6	30s	Male	Technology Educator/4 years/Engineering	Site 2/Satellite-site Engagement
Admin 3	30s	Female	Director of Programs and Operation/4 years/Social Work, Management of Human Services	Site 3/Remote-site Engagement
Admin 4	30s	Female	Education Programs Director/13 years/Public Administration	Site 3/Remote-site Engagement
Educator 7	18-20	Female	Tech Educator/1 year/Early Childhood Education	Site 3/Remote-site Engagement
Educator 8	20s	Male	Tech Educator/1 year/Film, Cinema, Video Studies	Site 3/Remote-site Engagement

trained using one of three training models as described below (1 months). Finally, the sites recruited 10-12 youth and conducted the maker training program for them with continued support and supervision by DHF trainers (5 months).

Site 1 is situated in a local high school which transformed one of its underused classrooms into a makerspace. Staff at site 1 were trained using the home-site engagement model. Site 2 is an organization that provides art-focused classes to youth and adult community members. Staff at Site 2 were trained using the satellite-site engagement model. Finally, Site 3 is an organization that provides drop-in afterschool programs to underserved youth in an urban setting. Staff at Site 3 were trained using the remote engagement model. Table 1 summarizes information about each sites and deployed training model, as well as, participants at each site.

B. *Study Participants*

At each site we recruited at least 2 adult educators and an administrator to participate in the study. Overall, 12 adult participants joined the study. Table 1 shows demographic information about the participants.

In addition to the adult participants, at each site, 10-12 youth also participated in the maker training program that was deployed following the educator training. While the adult participants provided us with observations about the youth, we did not directly collect data from them.

C. *Data Collection Procedures*

The study was approved by our Institutional Review Board (IRB) prior to data collection. The data collection consisted of pre- and post- interviews with all educators and administrators (n = 9) at the participating sites. Interviews lasted between 40-90 minutes and either conducted individually or with small groups of 2-3 participants. During the pre- interviews, we asked participants about their professional background and previous experience with teaching technology topics to youth. We also asked them about their experience with using digital fabrication tools and prototyping software. Example questions included: "*Do you have prior experience working with 3D printers?*" and "*What do you foresee as the main challenge in running the program?*". In the post- interviews, we asked them about their experience conducting the course, including successes and challenges, strategies that were effective in overcoming challenges and unexpected outcomes that they observed. Example questions included: *"What were some teaching strategies that worked during the program?*" and "*What parts of the curriculum did you see the youth being engaged with?"*.

The interviews were transcribed and analyzed using an inductive thematic analysis process by two researchers working independently.

V. Findings

Our analysis resulted in 4 themes and 7 subthemes within the themes that we will present next. These themes and subthemes are organized in corresponding subsections and subsubsections that follow.

A. *Educator Training and Program Support*

Our analysis of interview data showed that participants found the training and technical support from DHF crucial to creating maker learning spaces and delivering the programs at their sites. They described how the trainings provided them with technical skills and confidence, as well as, a reliable and trusted point of contact in DHF to consult with. With respect to the training models, the participants described hybrid models that combined in-person training with remote access to online resources (i.e., the home-site and satellite models) as more effective at brining participants up-to-speed than the remote-engagement model. Participants emphasized the importance of having on-going support from DHF after the trainings.

The participants emphasized the importance of training that brings educators with different levels of expertise and experiences to the same page with respect both the technical material that needs to be covered and also how to communicate the content to youth. For example, with respect to technical skills, Educator 7 stated, "before I even took the 3D printing training, I didn't know anything about a 3D printer, but when I had left the training…I had enough knowledge to go back and teach someone else how to use it." For teaching skills, Admin 4 stated, "we are not computer engineers so it's hard for us – to be able to translate that to little kids."

The participants emphasized the importance of having both face-to-face training and digital materials, describing the affordances of each mode. Specifically, participants described how having asynchronous access to digital resources is important. For example, Admin 2 said "I thought it was great that there was something that we could refer to the entire time… I also thought that was great that there were people that we could go to sort of the entire time during the project."

Participants further emphasized the importance of combining digital materials with in-person support: "What was good for us was that there were also people, real people, that we could talk to and troubleshoot with, but if this was curriculum that was just available to purchase or download or something like that, I'm not sure [if it was effective]." – Admin 3

Participants at the remote-training site (Site 3) stated that they would have preferred more in-person training. They also described how having a "support hotline" to call when technical problems arise during programs would be helpful.

All participating sites recognized the importance of training multiple individuals from each site and also involving administrators. They stated that this strategy would help with program resilience and sustainability. Site 2 and 3 had several educators who had participated in the initial training leave before the conclusion of the program and had to find replacements. The new educators had to be trained quickly and sometimes administrators had to temporarily take over instruction. In these instances, having multiple staff who completed the training was crucial to the successful continuation of the programs.

Additionally, training multiple staff helped with them building on each other's strengths and working as a team. Educators from Site 1 described how they each have experience in a different subtopic which was helpful to draw on during both training and program delivery. For example, Educator 2 said "I really appreciated having [Educator 1] to rely on. If something went wrong with 3D printer, I might not know how to solve that and, similarly, that I could help more with the coding side of things."

A surprising observation by Admin 4 at Site 3 about incoming instructors with limited technical background was that they shared the learning experience with the youth, potentially leading to increased empathy: "There are great benefits to having staff who are working to lead this curriculum who would not be coming from a tech background and are thinking more so about the way that you facilitate learning…. They just learned the concept the week before they're teaching it. That gives them a totally different perspective than somebody who might not be able to remember what it was like to not know how to do a certain concept."

All sites found the equipment provided by DHF adequate for conducting the programs and described how they would continue using them beyond the project. Participants at Sites 1 and 3 were particularly interested in setting up youth employment opportunities similar to the 3D print shop at DHF.

B. *Youth Engagement Strategies*

The educators and administrators identified a series of maker curriculum and program design elements, as well as, strategies that were effective at engaging the youth and providing them with valuable learning experiences. These included the customizability of program activities, the engaging nature of the included content, and the program's organized yet flexible and modular structure.

1) Customizability and Localization: The educators found that the curriculum provided the youth with the scaffolding and structure needed to get started learning new skills but that it also had built-in flexibility, in the form of self-directed projects, that could be used to customize the content to be relevant for the youth: "I think because we allowed them so much creativity and that's not just us, the curriculum, that they really got to do something of their own choosing." – Educator 2

The educators repeatedly described their approach to self-directed learning supported by the curriculum flexibility as important factors for engaging the youth. This characteristic was especially present in the design of the final capstone project: "I was surprised at how much they got into the capstone project…. With this group, they all really took ownership and got into it saying, 'Oh, how can I add another unit even beyond what my original plan was?'" – Educator 2

Educators at Site 2 described how they were able to customize some of the aesthetic components in the curriculum to be more art-oriented and suitable for the youth with a range of learning abilities attending their program. However, they described a need to have more flexibility with respect to "hands-on activities and things that were more tactile for a lot of learners who needed that attention." – Admin 2

Site 3 approached customization differently with a focus on customizing their design space to meet the learning needs of youth: "We've tried sort of different space configurations - either just kind of having it in the open and/or sort of closing it off…. We would block the room off for one side to do the [maker program] and the other side to do the regular after-school program, and it kind of created a kind of club feel to it that kind of made kids say, 'Oh, what's going on in there?'" – Educator 8

Site 2 had initial issues with "noise" which they alleviated using a combination of conducting program sessions in a larger space than initially envisioned and also playing ambient music during program sessions. Admin 2 described how they were able to customize the space configuration because of additional space they had in their building that may be available to everyone: "If we were in our former space, I think it'd be very difficult. We were in a space that was a third of this size."

2) Curriculum Content: With respect to the curriculum content, the youth were generally more engaged in the modules that produced tangible results. These included 3D printing and Makey Makey modules but not web development:

"I think having more of the ability to see [the Makey Makey] in action by another artist…really heightened their creativity and just their enjoyment of pursuing it. – Educator 6

"I think stuff like the 3D printing and the Makey Makeys have more of a practical feel to the kids." – Educator 8

Educators also found opportunities for the youth to combine skills from different modules useful. For example, at Site 1 Educator 2 described the youth's experience as "'Oh, I built a game in Scratch back here in this unit, and I made the Makey Makey circuit. So why don't I just wire those two together and have a Makey Makey controller for the game?'"

3) Program Structure and Scheduling: The participants at Site 1 found the program complementary to other school activities. For example, Educator 1 described how the "method we had the students follow when they did the capstone project, that aligns perfectly with our engineering design process". Additionally, Site 1 found the program easy to schedule the program sessions right after school time.

Participants at Site 1 also found the modular structure of the curriculum and how different elements came together in the capstone helpful: "The curriculum was great. It was easy to follow … I really liked the capstone piece, and I think the students did too, that they got to combine the different aspects or the different units into the final project." – Educator 1

Participants at Site 2 reported challenges with delivering the program over a small number of long sessions. They stated a wish for having a longer total program time spread over more days. "It was a lot of time in one day, but I felt like it wasn't enough for the week." – Educator 6

Site 3 adopted a drop in/drop out program to entice youth to attend their classes and to stay consist with their overall educational: "We like it that way because we want to give middle school kids … more independence as they're getting older." – Admin 4

However, this strategy proved challenging as youth who missed modules could not easily catch up later which might have contributed to a drop-in attendance later during the program.

C. Challenges and Strategies for Overcoming Them

1) Logistical Challenges: A key challenge at all sites was recruiting and keeping the youth engaged and motivated over time. Educators at all sites described how the youth have competing interests. Educator 1 described this dilemma as: "You have four things on your plate, how are you gonna get time?"

Educator 8 was specific in explaining how the additional makers class could be a burden on the youth. "They just got out of school. They got homework. They got all this. So, it's a lot for them to throw on them, like learning how to design a web." Unfortunately, Site 3 also saw a dramatic drop in attendance where they started with 15 or 16 youth, but they very quickly dropped out.

Educator 2 reported attendance problems due to conflicts with other school sports responsibilities. Many youth "…maybe had a Fall sport, so they wanted to come in and join after that, but they had already missed a few [modules], and other students had a winter sport."

Site 3 used incentives such as field trips or prizes for youth who completed the program. The educators found these incentives useful in motivating the youth: "So we had incentives that caught some our students' eyes, and it kind of pushed them to do it, but when they did it, they ended up liking it a lot and really pursued it. That was definitely a strength."

An interesting observation was made at Site 2: two youth who had low attendance in their school classes would consistently show up at the maker program and were engaged with the material. Admin 2 observed: "We're making an impact on these students, but there's something missing from the regular curriculum. So good for us, but what's going to bring them to school?"

Another challenge faced by Sites 2 and 3 was staff retention. At both sites, some of the educators who were trained to deliver the program left for other jobs. While this caused delays in program delivery, both sites were able to find and train new educators. A key factor in addressing this issue was that multiple participants, including administrators, were trained at both sites and could get the new staff started.

Another key challenge was the logistics of youth getting to program sites. Especially during the Winter months, with shorter days, it was more difficult for youth to stay for the programs due to concerns for safety when commuting back to home. All sites are located in urban centers with safety concerns which contributed to concerns about late afternoon programs for youth. Educators at Site 2 also described inconsistencies for youth arriving late and leaving early to meet their transportation, thus losing a part of the learning for the day.

2) Technical Challenges: While the majority of challenges were logistical in nature, participants at all sites also reported a range of minor technical difficulties. These included difficulties with loading filaments into 3D printers (Sites 1 and 3), difficulty with locating and accessing training videos (Site 2 and 3), downloading module contents due to bandwidth issues or broken links (Site 3).

Participants described how they used a combination of strategies, including contacting DHF for support, searching online for solutions, and brainstorming among themselves and with the youth to address technical challenges as effective ways to overcome issues.

D. Future Implementations

Participants made several suggestions for how future iterations on the training program can be improved. Many of the educators saw the biggest strength of the program in its flexibility as an alternative way for youth to gain skills and demonstrate their talents beyond school. For example, Educator 3 stated "What appeals to me [about the program] is its flexibility … high schools tend to have relatively rigid tracks… there's a good likelihood student[s] will find a niche that doesn't exist, but you know, is their own sort of original creative direction to go in."

Several participants described how they would customize program structure and content to be more suitable for their specific population. We will describe these suggestions next.

1) Changes in Program Structure: With respect to program structure several participants suggested breaking down long session (3-4 hours) into shorter session (1-2 hours) spread throughout the week. This was both to ensure the youth do not lose focus during a long session and that they retain what they learned between sessions.

All sites also expressed interest in having more time in the program, either through having it over multiple terms or with more frequent sessions during one term. Participants at Site 1 suggested to split the program into two terms as a way to get new youth or be able to make changes when the term changes: "…we could potentially do one Fall iteration of this, and then another spring iteration of it, and sort of get new recruits, new students." Additionally, they believed options could be explored to integrate the program more closely with formal school classes, as opposed to a separate after-school program.

Finally, Sites 2 and 3 expressed interest in having different classes for different age groups.

2) Changes in Program Content: Participants observed that the youth responded differently to various modules in the curriculum. Additionally, this response differed across sites. For example, at Site 1 the youth wanted to learn about more advanced techniques to assemble and solder custom electronic kits. Additionally, they were interested in having advanced game design and 3D modeling modules. Sites 2 and 3 wanted to expand on the activities with the Makey Makey to create more hands-on examples for the youth. They also both described how a customized web design module could work better for their sites. Specifically, the activities at Site 2 are specifically focused on visual arts and they recommended including more aesthetic elements in this module.

Participants at all sites described how different youth had varying degrees of previous knowledge with respect to different modules which sometimes made it difficult to engage everyone to the same degree. Educators recommended including optional advanced activities and topics in each module to both engage youth with more advanced skills and make it possible for motivated youths to go beyond the basics. For example, Educator 2 said "If you really know this unit already …test out of it or just go straight to the project without the learning piece." One of the educators at Site 2, Educator 6, completely modified the 3D modeling module based on his own previous experience with designing medical devices. He stated: "With the 3D printing, I did my own presentation because I used to work with 3D printing in my own engineering background."

Finally, in addition to advanced modules educators at Site 2 suggested having alternative modules for youth to complete if they are becoming frustrated by a specific one.

VI. Discussion and Future Work

Our findings show that hybrid training models, such as the Home-site and Satellite-site Engagements, that combine space setup, in-person meetings and asynchronous access to online resources, are effective and efficient ways to kickstart technology-rich maker programs in diverse settings and to increase educators' self-reported technology and teaching skills. These approaches can quickly provide educators who are unfamiliar with making with tools and skills needed to create engaging learning experiences for youth. While educators at all sites employed strategies to customize the content and structure of the program to best fit their needs, in the future more open-ended and customizable elements can be included in the curriculum and training to invite event more localization and inclusion of context-aware elements to engage youth.

Additionally, our findings underline the importance of supporting a maker learning ecosystem by training multiple educators and administrators from different sites and providing opportunities for them to meet and know each other. This approach can lead to increased resilience in the face of difficulties, such as staff turnover.

Moving forward, we plan to design and deploy a hybrid training model in new sites and compare outcomes with the current project. As part of the model, we will invite local educators to extend and customize the existing curriculum to reflect the particular cultural and community perspectives of the populations they serve. Studying the resulting curriculum and learning and engagement outcomes will inform the creation of future context-aware educator training programs.

Limitations of the current study included the small number of participants and its focused on the experience of educators and administrators. It is also important to study the experience of youth more directly. In the future, we plan to conduct youth focus groups before and after similar programs to better understand their perspectives and better incorporate it into future program design.

VII. Conclusion

As demand for out-of-school-time informal technology learning programs for youth grows, so does the need to design and study new approaches for supporting educators and administrators who lack experience delivering such programs. We presented a three-stage training program designed for setting up new maker learning programs in diverse settings. We deployed three variations of the program in three participating sites where educators and administrators learned to set up a maker learning space and deliver a modular technology-rich curriculum to youth. Using pre- and post-interviews, we found participating educators preferred a hybrid training model that combined in-person training and space setup with online resources that could be accessed any time. The participants also enjoyed having a curriculum to start with and expressed interest in customizing it to reflect specific youth interests and motivations in the future.

REFERENCES

[1] S. L. Chu, R. Schlegel, F. Quek, A. Christy, and K. Chen, "'I Make, Therefore I Am': The Effects of Curriculum-Aligned Making on Children's Self-Identity," in *Proc. of the 2017 CHI Conference on Human Factors in Computing Systems*, 2017, pp. 109–120.

[2] L. Martin, "The Promise of the Maker Movement for Education," *J. Pre-College Eng. Educ. Res.,* vol. 5, no. 1, Apr. 2015.

[3] P. Blikstein and D. Krannich, "The makers' movement and FabLabs in education: experiences, technologies, and research," in *Proc. of the 12th International Conference on Interaction Design and Children*, 2013, pp. 613–616.

[4] S. Papavlasopoulou, M. N. Giannakos, and L. Jaccheri, "Empirical studies on the Maker Movement, a promising approach to learning: A literature review," *Entertain. Comput*., vol. 18, pp. 57–78, 2017.

[5] K. Qiu, L. Buechley, E. Baafi, and W. Dubow, "A curriculum for teaching computer science through computational textiles," in *Proc. of the International Conference on Interaction Design and Children*, 2013, pp. 20–27.

[6] S. Jordan and M. Lande, "Might young makers be the engineers of the future?" in *Proc. of the Frontiers in Education Conference* (FIE), 2014 IEEE, 2014, pp. 1–4.

[7] C. H. Foster, A. Wigner, M. Lande, and S. Jordan. "Welcome to the Maker movement: parallel education pathways of adult Makers," in *Proc. of the American Society for Engineering Education (ASEE) Annual Conference and Exposition*, 2015, pp. 26-1716.

[8] P. Blikstein, S. L. Martinez, and H. A. Pang, *Meaningful Making: Projects and Inspirations for Fab Labs and Makerspaces*. Constructing Modern Knowledge Press, 2016.

[9] N. O. Ornelas, G. Calderon, and P. Blikstein, "Makers in Residence Mexico: Creating the Conditions for Invention," in *Proc. of the FabLearn Europe Conference,* 2014.

[10] E. Hamner, T. Lauwers, D. Bernstein, I. R. Nourbakhsh, and C. F. DiSalvo, "Robot Diaries: Broadening Participation in the Computer Science Pipeline through Social Technical Exploration.," in *AAAI spring symposium: using AI to motivate greater participation in computer science*, 2008, pp. 38–43.

[11] A. Hurst, S. Grimes, D. McCoy, N. Carter, W. Easley, F. Hamidi, and G. Salib. "Lessons Learned Creating Youth Jobs in an Afterschool Maker Space," in *Proc. of Conference for the American Society of Engineering Education (ASEE)*, 2017.

[12] W. Easley, F. Hamidi, W. Lutters, and A. Hurst, "Shifting Expectations: Understanding Youth Employees' Handoffs in a 3D Print Shop," in *Proc. of the ACM on Human-Computer Interaction*, 2018, Vol. 2, CSCW, Article 47.

[13] S. Reder, "*The lab school,*" *Focus on Basics* 8, no. A, 2005.

[14] Y. B. Kafai, E. Lee, K. Searle, D. Fields, E. Kaplan, and D. Lui, "A crafts-oriented approach to computing in high school: Introducing computational concepts, practices, and perspectives with electronic textiles," *ACM Transactions on Computing Education* (TOCE) 14, no. 1, 2014, pp. 1-20.

[15] M. Stacey, "The FAB LAB network: A global platform for digital invention, education and entrepreneurship," *Innovations: Technology, Governance, Globalization* 9, no. 1-2, 2014, pp. 221-238.

[16] P. Blikstein. "Digital fabrication and 'making'in education: The democratization of invention." *FabLabs: Of machines, makers and inventors*, 4(1), 2013, pp. 1-21.

[17] S. Nemorin, "A critical perspective on 'Making' in school: The implementation of 3D printing in high-school settings," in *Proc. of FabLearn Conference*, 2015.

[18] J. Freeman, R. Dorph, B. Chi, "Strengthening after-school STEM staff development," *Coalition for Science Afterschool*. Lawrence Hall of Science, University of California, Berkeley, 2009.

[19] G. Hall, L. Israel, and J. Shortt, "It's about time! A look at out-of-school time for urban teens," Wellesley, MA: National Institute on Out-of-School Time, 2004. Retrieved December 8, 2016, from http://files.eric.ed.gov/fulltext/ED518617.pdf

[20] D. Gottfredson, A. Cross, D. Wilson, M. Rorie, and N. Connell. "Effects of participation in after-school programs for middle school students: a randomized trial," *Journal of Research on Educational Effectiveness*. Vol. 3, Iss. 3, 2010.

[21] D. Sinisterra and S., Baker, "A System That Works: Highlights of Effective Intervention Strategies in a Quality Improvement System," *Afterschool Matters*. 12. 2010, pp. 37-44.

[22] G. G. Noam and J. R. Tillinger. "After-school as intermediary space: Theory and typology of partnerships." *New Directions for Youth Development*. 2004 (101), pp. 75-113.

[23] E. Buehler, S. Grimes, S. Grimes, and A. Hurst, "Investigating 3D printing education with youth designers and adult educators." *Fab Learn* (2015).

[24] A. Krishnamurthi, M. Ballard, G. Noam, "Examining the Impact of Afterschool STEM Programs," Noyce Foundation, 2014.

[25] B. Fishman, R. Marx, S. Best, R. Tal, "Linking teacher and student learning to improve professional development in systemic reform," *Teaching and Teacher Education*, 2003, 19, pp. 643-658.

[26] M. S. Garet, A. C. Porter, L. Desimone, B. F. Birman, and K. S. Yoon, "What makes professional development effective? Results from a national sample of teachers," *American educational research journal*, 2001, 38(4), pp. 915-945.

[27] T. Akiva, K. Povis, and A. Martinez, "Bringing in the tech: using outside expertise to enhance technology learning in youth programs," *Afterschool Matters*. 2015, pp. 45-53.

[28] D. Dougherty, "The maker mindset," *Design, make, play: Growing the Next Generation of STEM Innovators*, 2013, pp. 7-11.

[29] S. Vossoughi, P. Hooper, and M. Escudé, "Making through the lens of culture and power: Toward transformative visions for educational equity. Harvard Educational Review." 2016, 86(2), pp. 206–232.

[30] B. S. M. Collective and D. Shaw, "Makey Makey: improvising tangible and nature-based user interfaces," in *Proc. of the TE'12*, 2012, pp. 367-70.

[31] Raspberry Pi. (2019). Accessed: May 12, 2020. Available: https://www.raspberrypi.org/

[32] "Nation of Makers." [Online]. https://nationofmakers.us/. [Accessed: 31-Jan-2020].

[33] "CS4ALL." [Online]. https://www.csforall.org/. [Accessed: 31-Jan-2020].

[34] National Research Council. *Community programs to promote youth development.* National Academies Press. 2002

[35] M. Koch, T. Gorges, and R. Penuel, "Build IT: Scaling and Sustaining an Afterschool Computer Science Program for Girls." *Afterschool Matters* 16, 2012, pp. 58-66.

[36] D. Gottfredson, A. Cross, D. Wilson, M. Rorie, and N. Connell, "Effects of participation in after-school programs for middle school students: a randomized trial." *Journal of Research on Educational Effectiveness,* 3 (3), 2010, pp. 616-636.

[37] G. G. Noam, and J. R. Tillinger, "After-school as intermediary space: Theory and typology of partnerships." *New Directions for Youth Development,* 2004 (101), pp. 75-113.