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Planting Seeds: Implementing Maker-Based Learning Programs for Urban Youth (Evaluation)

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1. Introduction

Research has long recognized the educational value of technology-rich maker activities for engaging youth and adults in self-directed STEM learning activities. Making refers to hands-on design, prototyping, and fabrication activities conducted by amateur technologists, designers, and artists using consumer-grade technologies, such as 3D printers and low-cost microcomputers and microcontrollers [1 - 4]. Many aspects of making echo key principles in engineering education as recently articulated in the Framework for P-12 Engineering Learning [5], and which include recommendations to "leverage making as a form of active learning," and to "connect with student interests, culture, and experiences." With increasing interest in creating and scaling maker-based informal learning experiences, there is a need to study how to design efficient and effective ways to expand these programs to diverse settings and to engage educators and youth who are historically underserved in this space. Furthermore, it is important to find effective ways to evaluate the impact of such programs on all participants. In this paper, we present findings on educator and administrator's observations on the impact of maker-based learning experiences set up in three diverse informal learning settings for urban youth. We focus on the perspectives of educators and administrators who conducted the programs towards observed youth learning outcomes and identify possibilities and challenges for the future implementation of similar programs.

Over the past three years, we have designed, developed, and deployed a multi-phase maker-based training program that includes makerspace setup, educator training, and youth program deployment. The program gradually introduces youth to increasingly complex topics in digital fabrication, programming, design, and web development. The educator training is designed for individuals with little or no prior experience with making and can be conducted either in person, virtually, or in a hybrid mode combing both. These educators would then be in an ideal position to serve youth in diverse settings that are spread out across the urban landscape, each serving the particular population surrounding them. After training the educators, we implemented the program at three sites for approximately nine months.

We found that participants observed considerable interest in the youth and positive shifts in their career aspirations as well as social and technical skills. Educators emphasized the importance of connecting curriculum to youth's specific interests, for example as it relates to the entrepreneurial possibilities of digital design and fabrication. They also observed challenges with youth attitudes towards program assessments and suggested ways forward for developing alternative ways to evaluate youth experiences and provide feedback.

Next, we present a literature review, before describing our methods, including the training program, participants, sites, and data collection and analysis in detail. We then present our qualitative findings, followed by a discussion of the lesson learned, and the study limitations and future directions, before concluding.

2. Literature Review

Previous research has shown that engaging in hands-on, self-directed technology-rich making activities can both engage diverse populations, and result in positive gains in technical and social skills [1 - 4]. While there are ongoing efforts to bring in making tools and activities in formal learning contexts (e.g., [1 - 4, 5]), such as schools, colleges, and universities, the majority of maker programs are currently in informal learning settings (e.g., afterschool programs, summer camps, libraries, etc.) [3, 4]. While these informal learning settings provide opportunities for creating customized and diverse programs that are appealing to learners of all ages, this diversity results in a challenge on how to ensure maker programs consistently result in positive gains, are sustainable and can be offered to communities who may be spread across urban or rural geographical areas [7, 8].

Additionally, while the majority of research has focused on developing activities and tools for participants in maker programs, there is a smaller number of efforts that focus on how to provide professional development and support for educators and administrators that deliver them. Existing research has shown that youth learning outcomes are directly tied to educators' expertise in both subject matter and youth education [3, 7-9]. Additionally, strong programmatic ownership by providers can result in more effective and sustainable programs [10-12]. Maker-based STEM professional development for educators in informal learning contexts has shown positive effects on their skill development [13-15], and subsequent youth outcomes [15, 16]. Despite these results, further research is needed to identify the impact of maker professional development programs on both educators and youth and provide insight into how to design such programs to be relevant to the values and interests of diverse communities. Furthermore, research is needed on how to support educators and administrators in designing programs and assessing outcomes using participatory and contextually relevant approaches. The current research aims to address this gap.

3. Methods

3.1. Program Description and Educator Training

Our research was conducted to assess the efficacy of a holistic, scaffolded program for supporting the expansion of technology-rich maker learning programs in informal afterschool settings. The Rec-to-Tech program is developed by the Digital Harbor Foundation (DHF), a non-profit organization with more than 7 years of experience in providing out-of-school-time learning programs to more than 5,000 youth in Baltimore City in the Eastern United States. DHF was founded by transforming an underused recreational center in an urban setting into an inclusive and dynamic maker learning hub where youth from different areas of the city can participate in hands-on, technology-rich courses and activities. Rec-to-Tech was developed by DHF 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 with limited prior experience in delivering maker content.

Over the years, DHF has developed an introductory youth maker curriculum, Maker Foundations, that covers key topics such as digital fabrication, programming, and web development. In addition to providing learning experiences for youth, DHF also operates a youth-staffed 3D print shop that offers technical employment training opportunities for youth. DHF has also developed a series of educator training programs and workshops.

Rec-to-Tech builds on DHF's previous work and is comprised of three stages: 1) space design, 2) curriculum training, and 3) ongoing skills development and curricular supports for educators. During the first stage, DHF staff work with participating sites to identify spaces suitable for equipment set up and program delivery. The sites then receive equipment, including 3D printers, laptop and desktop computers, and digital prototyping materials. DHF staff install and test the equipment at each site. Next, educators and administrators from each site are trained using one of three training models: a home-site engagement model where educators attend training at DHF; a satellite-site engagement model, where educators are provided with hybrid online and offline training; and, finally, a remote engagement model, where educators receive all training remotely through online resources. Finally, the sites would recruit local youth and conduct the maker training program for them with continued DHF support and supervision.

3.2.Sites and Participants

Three sites participated in the program, each going through three stages of preparation as described above. Site 1 is situated in a local high school which transformed one of its underused classrooms into a maker space. Site 2 is an organization that provides art-focused classes to youth and adult community members. Finally, site 3 is an organization that provides drop-in afterschool programs to underserved youth in an urban setting. Staff at site 1 were trained using the home-site engagement model, staff at site 2 were trained using the satellite-site engagement model, and staff at site 3 were trained using the remote engagement model.

Table 1. This table provides information about the 9 adult participants. IDs with an "E" prefix refer to Educators, and an "A" prefix refer to Administrators.

ID	***Age Range***	***Gender***	***Role/Length of Experience/Training***	***Site***
A1	50's	Female	Library Media Specialist/17 years/Library Science	Site 1
E1	50s	Female	Engineering Teacher/12 years/Electronics, System Engineering, Education	Site 1
E2	30s	Male	Math, Engineering, CS Teacher/13 years/Math, Teaching, CS	Site 1
E3	40's	Male	Math Teacher/3 years/Linguistic, English and Math	Site 1
A2	30s	Female	Director of Workforce Development and Social Enterprise/11 years/Visual Arts, Community Arts	Site 2
E4	20s	Female	Art Educator/2 years/Fine Art	Site 2
E5	20s	Female	Art Educator/1 year/Fine Art	Site 2
E6	30s	Male	Technology Educator/4 years/Engineering	Site 2
A3	30s	Female	Director of Programs and Operation/4 years/Social Work, Management of Human Services	Site 3
A4	30s	Female	Education Programs Director/13 years/Public Administration	Site 3
E7	18-20	Female	Tech Educator/1 year/Early Childhood Education	Site 3
E8	20s	Male	Tech Educator/1 year/Film, Cinema, Video Studies	Site 3

After the training, each site recruited 10-12 youth and conducted the maker training program for them with continued support and supervision by DHF trainers. We analyzed interview data from 9 educators and administrators (see Table 1).

3.3.Data Collection and Analysis

We conducted interviews following the completion of the program with all educators and administrators (n = 9) at the participating sites. We chose this approach to understand participants' perspectives on administering the programs since this was the first time, they delivered a maker curriculum. We also conducted two focus groups where participants met and discussed their experiences with DHF staff and each other. Finally, for the duration of the program setup and administration (roughly 9 months), we organized monthly group phone calls in which participants raised any questions they had about the program and commented on their experience. In the interviews and focus groups, we asked participants about their observations when administrating the programs and any challenges or possibilities they may have encountered. We also asked them about their observations of participating youth's technical and social learning. All interviews, focus group discussions and check-in calls were audio-recorded, transcribed, and analyzed using an inductive thematic analysis method [17] where we systematically identified, compared and contrasted, and synthesized main themes and subthemes. For this paper, we will focus on themes that are specifically related to youth program outcomes and present findings on the impact of the program on educators elsewhere [18].

4. Findings on Youth Program Outcomes

At all sites, educators observed positive outcomes for the participating youth for both technical and social skills, as well as confidence and career aspirations.

4.1.Impact on Technical and Social Skills

All sites reported observing improvements in youth technical and social skills over the course of the programs. At Sites 1 and 2 educators described how some of the youth were curious about more advanced topics and wanted to go beyond the modules in the curriculum. The educators were impressed with how much technical skills the youth were getting familiar within each module: "I saw great growth just even over the …three weeks we spent on each unit." -E2

Several of the youth took leadership roles and helped others with technical or design challenges. For example, E7 observed that "one [youth], she actually taught [the other youth] a bit …. because she knew about it previously… It gave her the opportunity to sort of show her expertise and be a leader in that space because she was so successful at it."

E5 specifically identified how the program design supported self-directed learning and resourcefulness: "…learning how to be resourceful since they didn't know that everything was new to them…since we let them be a little more independent."

A3 described positive shifts in one of their youth's social skills and role in the program: "She's a student who, I think, is a little bit more timid in the way that she is interacting with her peers and even with staff. But she was having a lot of success personally in each of the different modules, and she would move more quickly through it than, I think, both staff and other youth...so she was able to then serve in a leadership role helping her peers to get through pieces of the curriculum."

This process was mirrored by observations about another youth at Site 2: "At first, he didn't really enjoy the class, but then he became more engaged in it…. And then his attitude towards how he was presenting stuff and his outlooks on what he wants to do with the future [changed] … It was that kind of thing, having someone change their mind about that." -E6

4.2.Impact on Confidence and Career Aspirations

Educators at all sites described how the youth became more confident in their technical skills over time and took an active role in solving problems and addressing challenges.

For example, E6 described how many of the youth in the program would research answers to questions themselves and sometimes help the instructors: “So they had to just maybe research things on certain websites that we gave them…instead of telling them what to do.” E2 stated, “They were all super proud to show that off and we had the visitors.”

Following the program, many of the youth described how they planned to pursue technical and entrepreneurial careers in the future: "A lot of them do have interest in pursuing technology and to do arts and engineering….and the class really influenced that." –E6

At both Site 1 and 2, educators observed several youths who were low-performing in their school becoming very engaged with the program and demonstrating a high level of technical skills and talent: "A student doesn't attend school, but attends [Site 2] for the [program name] and is actually a very talented, skilled student." – A2

4.3.Challenges with Youth Attitudes

Participants at all sites reported difficulties arising from youth’s attitudes towards learning assessments and to a lesser degree some of the program content. The program required the administration of short surveys, as well as the creation of online documentation in the form of blog posts and portfolios by youth. Participants encountered challenges with both of these methods.

For the surveys, all sites reported that youth displayed negative attitudes due to difficulty seeing the surveys’ relevance to their learning and described how they were similar to school exams. This was particularly present at Site 3. As A4 put it "The thing about school in general for kids this age is like, ‘What does this have to do with my life?’" These issues were especially present at the beginning of the program where the new material was not yet introduced: "We hadn't started the program material yet, so we couldn't contrast it with the program material. Kids were like…’what is this, what are we doing this for?’" -E8

The youth at all sites also showed resistance to maintaining portfolios and blogs. At Site 1 a key question was how much documentation is necessary. Youth were initially asked to keep and update an engineering journal, a maker notebook, and a summary online portfolio of what they learned. However, this became too much work over the course of the program and the educators only asked the youth to keep the notebook. E1 described how “I see the value in doing both to plan, having something to sketch is a lot easier than trying to do something on a Google Drive, and then a portfolio is something you can show people when you’re live; but, I do think that that maybe was too much documentation, that might have…taken away from the time that they could be learning new concepts.”

At all sites, participants recommended providing more transparent reasons for why assessments are important for youth learning to make them more relevant to them.

Sites 2 and 3 also reported observing signs of frustration or being overwhelmed in some of the youth during the program. E5 observed that sometimes youth would be flustered when "we introduced something new and they didn't either understand it or just assumed they won't be interested so they just wouldn't listen…or they would listen and wouldn't even try." In one case, the educators gave an alternative activity outside of the curriculum to one of the youths who was becoming frustrated by not being able to complete a program module. At Site 3, the participants described that negative attitudes may arise in youth who had missed a session and had difficulty catching up. One strategy was to provide them with additional time or access to some of the material at home to catch up.

5. Discussion

Our findings show that educators and administrators generally shared positive observations on how the programs engaged participating youth and provided them with opportunities to learn technical and social skills, necessary to navigate STEM topics. While educators also reported on challenges, they emphasized several key strengths of the program. These included providing opportunities for youth to take leadership and mentorship roles, using concrete hands-on exercises and activities to strengthen skills, and engaging students who might otherwise be struggling in school in technology-rich learning activities. In alignment with previous research (e.g., [19, 20]), our findings also show that educators being exposed to technical skills and activities may have motivated youth to consider future technology-oriented careers. Finally, educators and administrators viewed the open-ended approach to self-directed learning and exploration of topics beyond classroom time, which is built into the curriculum as a motivator for many youths to independently search online for solutions, advanced technical topics, and resources beyond the ones included in the curriculum. These observations align with several Engineering Habits of Mind, including persistence, collaboration, and creativity as identified in the P12 Engineering Education Framework [5].

In addition to strengths, participants also described challenges that they observed youth facing when taking part in the program. These included youth demonstrating a negative attitude towards assessments and being frustrated in case some of the presented materials are challenging or some portion of instructions were missed because of being absent. The presence of negative attitudes towards assessment in maker contexts aligns with previous research in this space [17, 19]. Participants had several insights on how to keep youth engaged despite these challenges, including providing detailed information on why assessments were important and providing options for them to complete alternative activities and access to materials at home to catch up if a lesson was missed. These directions point to opportunities for making the programs more participatory and self-directed for youth by engaging them in conversations about how to make assessments more meaningful for them, and how to support their agency in selecting topics in the curriculum and in accessing them at a pace that works for them. While these possibilities may add some logistical complexity to program design, they may help with increased engagement and agency in youth participants.

6. Limitations and Future Work

A limitation of the current paper is that we did not collect youth perspectives directly and relied on educator and administrator observations. In the future, we plan to conduct interviews and focus groups with youth to ask about their experiences and feedback on how to improve the program in the future. Additionally, a co-design session could better inform us as to how to design and conduct assessments that are more meaningful for youth. In the current project, participants delivered a curriculum that was previously designed and identified possibilities where youth could look up additional activities online and provide feedback on what to cover in the program. We plan to deploy an open-ended version of the curriculum that allows participants to localize and customize it to better fit the needs of the youth they are serving. We would then study the level of engagement of educators and youth in this setting to better inform how to support their engagement and agency.

7. Conclusion

Flexible learning programs that engage diverse youth in a range of settings in technology-rich maker activities can result in positive technical and social learning outcomes and lead to increased interest in STEM career paths. Despite their potential, logistical and cultural barriers still exist that prevent underrepresented youth to participate in maker activities. Specifically, it is unclear how to efficiently and effectively provide resources and professional training to educators and administrators to equip them to deliver maker content effectively to the populations they serve. In this study, we investigated the perspectives of educators and administrators of new maker programs delivered by first-time maker educators to youth in 3 urban settings. Participants reported that youth showed a high degree of engagement and interest in the programs and demonstrated both technical (i.e., problem-solving) and social (i.e., leadership) skills as a result of participating in the programs. Participants also observed negative attitudes in the youth towards completing program assessments and when unable to follow particular topics in the curriculum. These findings are promising and also point to areas that future efforts can improve.

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