Enhancing Teachers' Facilitation of STEM Learning through Afterschool Makerspaces

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ABSTRACT

We describe a maker-focused afterschool program which includes professional development of teachers as a central aim. The program serves New York City public school teachers and students. Teachers from multiple disciplines participate in the program; students are primarily 3rd - 7th graders attending Title I schools.

The use of a maker learning approach can develop teachers' skills and confidence while at the same time engaging students in student-centered STEM learning that builds life and career skills including problem solving, collaboration, persistence, and autonomy. Teacher-reported knowledge and confidence increased significantly, and the use of student-centered maker activities by teachers' during the school day increased. Students responded enthusiastically to the program and showed growth in targeted skills and dispositions.

Keywords

Maker Education; STEM Education; Professional Development; Computer Science; Engineering Design Cycle; Makerspace; Elementary Education; Afterschool; Informal learning

2. DESCRIPTION

2.1 Description of your setting

Our maker programs are implemented in the after school setting by New York City public school teachers who have received training from a national educational nonprofit that supports a network of schools, in partnership with a STEM curriculum developer and service provider. Two groups of learners build their knowledge and skills through the program: New York City public school teachers and public school students. The teachers in the program are elementary and middle school teachers from a variety of disciplines. Schools are invited to nominate up to two teachers to participate in the program. Teachers who express a commitment to the program expectations and the ability to facilitate an afterschool makerspace are eligible to take part in the program. Teachers come from schools in Brooklyn, the Bronx, Manhattan and Queens.

The students in the program range from 3rd grade to 7th grade, with a small number of 2nd and 8th graders also participating. All participating schools serve predominantly low-income students and students of color. A total of 105 students participated in the 2017-18 program. Participating students included English Language Learners and students with IEPs.

The two key partners have experience working with school leaders, teachers, and students, and have been partnering for several years. The school support organization has provided professional development to teachers and school leaders for a decade. The STEM provider has been running afterschool programs for six years, and recently began running teacher trainings, as well.

2.2 Description of the educational experience

During the 2017-18 school year, the school support organization partnered with a STEM curriculum developer to implement a year-long program for traditionally underserved students in grades 3 – 7. Training was conducted collaboratively by the two organizations. Nine teachers, representing two district and two charter schools, completed the full year program.

Through this program, the organizations trained and supported teachers to facilitate a weekly afterschool STEM "makerspace" using the program curriculum. Rather than permanent physical spaces, these makerspaces were student-centered, hands-on learning environments that relied on a maker approach and could be located in any available space within the school.

The program curriculum utilizes a maker approach to develop students' confidence as a maker, their interest in STEM disciplines, and skills of problem-solving, collaboration and persistence. Using a hands-on approach, students solve real world challenges and interact with engaging STEM content. Using an iterative cycle, students research and imagine solutions, design prototypes, and test their ideas, learning from their mistakes and peer feedback. This calls for persistence and a growth mindset.

Students began the year with an introduction to making, as well as to the Scratch programming language, which was the primary technological tool for the curriculum. They quickly moved into an extended project to design, program and test their own video games centered on the theme of the Hero's Journey. After coding a series of challenges for their Scratch heroes, students programmed a culminating encounter of the hero's journey. The year concluded with a unit in which students integrated a "movement art" (dance/hip hop, karate, parkour, or yoga) into a Scratch project using digital images of themselves.

While students built STEM interest and efficacy, participating teachers built the confidence and skills needed to facilitate maker activities. Teachers learned how to use the hands-on, interdisciplinary nature of maker activities to integrate computer science and computational thinking into the classroom. They also strengthened their STEM content knowledge, especially related to computer science.

Teachers were supported by three in-person trainings throughout the year. In addition, program staff visited the makerspaces regularly throughout the year; generally every 2 - 4 weeks. These visits served as opportunities to provide coaching and feedback to teachers, as well as to receive feedback and make observations regarding the successes and challenges in each makerspace. Staff interacted with teachers and students during these visits to learn as much as possible, and often debriefed with teachers following the visits.

The program was developed using a maker approach from the beginning. A central element of the maker approach involves learning how to solve problems using the iterative approach used in engineering. The program adapted the engineering design process and presented it as a three-step cycle of Research & Imagine, Design & Prototype, Playtest & Improve. The simplicity of this three-stage cycle belies its power as a framework for problem-solving. Each afterschool makerspace used this design cycle as a guiding framework for students' making. To facilitate this, small magnets with team names were used by students to visibly track their progress through the steps of the cycle.

The resources that support the program are aligned to the design cycle. These include lesson plans, videos, prototype builds, "challenge reports" (to be shared with families), and rubrics. Student makers in the program work in teams and collaboration is a central element of the program design. Not only do students collaborate within these teams, but collaboration is also encouraged within the makerspace. If one team has completed a stage of the design cycle, they are encouraged and expected to identify and assist other teams that may need support.

By its very structure, the design cycle provides a framework for developing problem-solving skills. In addition, teachers reminded students throughout the year that with this approach, failure is an opportunity to learn, not something to be afraid of. The iterative nature of the design cycle encouraged persistence. Finally, collaboration was essential and student-to- student support was strongly encouraged: students often worked in pairs or triads as they moved through the stages of the design cycle.
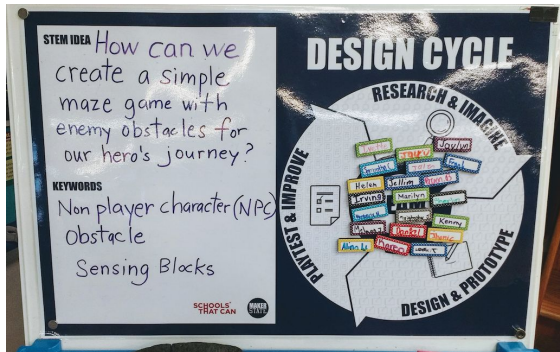

Photo. The Design Cycle in use.

Photo. Students track progress on a simplified Design Cycle.

The program was created to develop a model for engaging a larger number of students than through a direct-service afterschool model. Specifically, the program was designed to equip teachers with strategies and tools to facilitate an engaging STEM-focused afterschool makerspace. In the low-risk afterschool environment, program designers believed that teachers would have more freedom to try new techniques and build confidence with a maker learning approach and real-world STEM skills such as computer programming.

3. CONCLUSION

3.1 Results

Reflections by students at the end of the program indicated gains in several targeted areas. First, students' computer science skills and interest increased over the course of the year. Students who had begun the year with little computer programming experience completed the year confidently coding their own projects with little or no adult support. At the end of the year, 87% of students agreed or strongly agreed with the statement: "I am good at using Scratch"; and 83% agreed or strongly agreed with the statement "I can write a computer program that does something useful or fun." Students' high level of interest in programming with Scratch can be seen in the table below:

Table 1. End of Program Survey: Scratch programming.

Post-Program Question (Technology - Scratch)	Strongly Agree	Somewhat Agree + Strongly Agree

I enjoy using Scratch to design my own video game.	76%	100%
I work on my Scratch Makerspace project at home or during free periods.	33%	58%
I would like to become a better Scratch programmer.	65%	89%

Note: These questions were not asked in the pre-program survey. However, we know from teacher reporting that few participating students had any substantive experience coding with Scratch.

Students also developed a marked degree of autonomy in the makerspace over the course of the program. This is partially reflected in the confidence seen in the data above, and also in statements made by students in end-of-year interviews. Students remarked:

Table 2. Student qualitative feedback to end-of-year survey.

"The teachers give us freedom. I like because it makes me feel that there are no limits"

"I like that we could make our own design and not use the same background for the whole entire class in makerspace and doing our own design, characters, and saying."

"I like when we got to make whatever we wanted [in the later parts of the program] because there was tons of variety and we got to show lots of different skills."

Teachers also pointed out how the program had taught them lessons relating to student autonomy. Teachers had a tendency to maintain a high degree of control and structure early in the program, which they felt provided support to all learners as they became familiar with block-based programming. As the program progressed, teachers saw that some students were in need of greater challenges. In response, teachers began to encourage students to make the projects their own, customizing and adding more complex features. This quickly became a virtuous cycle, with student eagerness to build something awesome convincing teachers to encourage free-form innovation both within the program curriculum and beyond it.

At year-end, teacher survey responses conveyed their appreciation for the capacity of students to innovate:

Table 3. Teacher responses to end-of-year survey.

"I've learned that by letting go and allowing my students to take the lead on their projects they are capable of amazing things."

"This program has helped me facilitate a student-centered environment where students are in control of their learning and supportive of one another."

It was not only growth in student autonomy that teachers noticed. They also remarked on the community that was built within their makerspaces and how students treated each other. For example, one teacher said: "I learned how through challenges we can create a sense of community and empathy. Students learned from each other and provided each other feedback."

This type of feedback was useful in illustrating the ability of a maker-centered model of learning to foster essential life and career skills. The teacher response above points to the collaborative environment that was strongly encouraged throughout the program. Not only were students expected to work in teams, they soon learned that supporting each other was an effective and efficient way to move their coding skills forward. A positive consequence of this student-to-student support was that it freed teachers to be more strategic with their interventions, and to focus on occasional guidance for the entire makerspace, or targeted support for select students.

Being part of such a community of support is likely to support the persistence exhibited by students in the program makerspaces. One teacher noted this example of persistence: "One of our students struggles in most of his classes and gives up quickly when he is frustrated by a concept. Throughout the Maker program I have seen his ability to persist despite setbacks or frustration increase exponentially. He is very interested in making his projects in Scratch work so he is bound and determined to get through any challenging material."

These student outcomes were complemented by the growth we saw in participating teachers. An important goal of the program was for teachers to gain strategies, tools and skills to facilitate student-centered, project-based learning beyond the afterschool makerspace. The impact of this program in achieving that goal is demonstrated in the tables below.

Table 4. Knowledge of computer science and technology concepts.

Rate the statements below. How true are they for you?	Pre Mean	Post Mean	% increase in agreement
I understand computer science concepts well enough to teach them effectively.	2.00	1.44	28%

	1.55	1.22	21%
I can recognize and appreciate computer science and technology concepts in all subject areas.	1.55	1.22	21%

Scale: Extremely true-1, Somewhat true-2, Somewhat untrue-3, Not at all true-4

Table 5. Confidence in ability to plan, facilitate and teach STEM and project-based learning:

Indicate your agreement with the following statements:	Pre Mean	Post Mean	% increase in agreement
I am confident in my ability to teach STEM.	2.27	1.56	31%
I am confident in my ability to plan and facilitate project-based learning.	1.82	1.44	21%

Scale: Strongly Agree-1, Agree-2, Disagree-3, Strongly Disagree-4

Teacher-reported knowledge and confidence both increased significantly. The increase in teacher confidence in regards to the planning and facilitation of project-based learning (PBL) and the teaching of STEM in general and computer science in particular is essential to support the incorporation of these strategies and disciplines into the regular classroom.

Table 6. Ability to incorporate strategies, tools and skills into the classroom:

Indicate your agreement with the following statements:	Pre Mean	Post Mean	% increase in agreement
I can effectively incorporate computer science activities in my classroom	1.82	1.33	27%
I explicitly develop computational thinking in my classes	3.09	1.78	42%
I can assess student mastery of computer science concepts	2.00	1.33	34%
I incorporate student-centered maker activities into my classes	2.82	2.22	21%

Finally, at the conclusion of the program, teachers reported a 92.5% likelihood of incorporating the strategies, skills, and tools learned in the program into their classroom in the future.

This program has been a tremendous learning experience for the facilitators. Both teachers and students demonstrated growth in multiple areas as shown through qualitative and quantitative measures. While there were exciting successes, there were certainly areas for improvement. One example is curricular diversity. In last year's program, a strong focus on block-based programming supported the growth in student skills and confidence in this area. However, we also noted that students were eager for different challenges including more physical maker challenges; this year's program incorporates more of those types of challenges.

We also knew the program would benefit from using formative assessments more often. To accomplish that, the program facilitators have developed a rubric that is aligned to our maker approach (using the design cycle) and also encourages collaboration through the inclusion of a "guide" designation.

The broader impact on our school communities was felt through the integration of maker and STEM tools and strategies in teachers' classrooms. In addition to the results above, we learned of specific examples of this integration. One English teacher invited her students to write their own "last chapter" of a book they were reading using block-based programming and a creative maker approach. Another teacher challenged students to use programming and maker skills to create animated transportation machines that played a role in the early decades of U.S. history.

3.2 Broader Value

We believe that a maker approach provides an effective framework for the learning of STEM and 21st Century skills at the elementary and middle school level. Specifically, we would like to share how we have used such an approach to equip teachers with the tools they need to facilitate engaging, energizing afterschool makerspaces, and to take those same tools and strategies into their classrooms. With a focus on digital making and small-scale physical making, these makerspaces can happen in any available space.

By simplifying the engineering design process into a three-step cycle and aligning visual aids, rubrics and lesson plans with this cycle, teachers and students are guided and supported by a clear and powerful framework that encourages every person in the makerspace to think like an engineer. This design cycle / maker approach requires students to practice problem solving, collaboration, and persistence.

3.3   Relevance to Theme

Our maker approach to STEM learning is ideally suited to project-based learning. This year, teachers will be using our approach to challenge students to model aspects of the environment using block-based programming. Students will be taking the lead to construct their own digital simulations of earth and atmospheric phenomena. When students gain the tools to create their own models of weather, climate, physical processes, and ecosystems, we are supporting their engagement with fundamental aspects of scientific inquiry.

4.   BIOS

Roger Horton. As the Manager of Maker Programs for Schools That Can NYC, Roger is dedicated to empowering teachers and sparking students' passion for learning with real-world challenges. Roger was immersed in project-based learning as a teacher of Global History and Engineering Design at EPIC North High School in Queens. Roger has also managed youth and economic development programs in Uganda and Tajikistan for Mercy Corps, an international humanitarian organization. His earlier teaching experience includes two years in southern Bulgaria, and he has worked with internally-displaced and vulnerable youth in Kenya and Kosovo. Roger holds a BS in Civil Engineering from MIT and an MA/M.Ed in Social Studies and Interdisciplinary Studies from Teachers College, Columbia University.

Casey Lamb. Casey's passion for equity and quality in education developed during her pursuit of education policy at Pomona College, including completing her thesis on early education philosophies, and continued through her additional studies (M.Ed., Special Education). As a student, Casey honed her research skills and education experience working at think tanks, including Education Development Center (EDC) and Public Works, Inc. Following graduation, she joined Teach for America where she worked as a special education teacher at a traditional district middle school outside Atlanta. Casey then served as the founding special education teacher and Director of Student Support at an all-girls charter school in Norcross, GA. To be closer to family, Casey moved to New York, where she was the Learning Specialist Coordinator at an all-girls charter school on the Lower East Side before joining Schools That Can (STC) as the Founding Executive Director of the NYC region in 2013. Now, as the COO, she supports all aspects of STC's operations and growth.

Stephen Gilman. Stephen is the founder and executive director of MakerState. Stephen and his son Ben started MakerState because they wanted to bring fun STEAM building projects in robotics, coding, game design and more to all kids, schools and communities (STEAM: science, tech, engineering, arts, math). Stephen is a founding board member of the Urban Assembly Maker Academy, a founder of the Carnegie Learning Center, and founding teacher and dean of Bronx Expeditionary Learning High School (now Bronx Collegiate), a public school based in Outward Bound experiential learning. He is a founding board member of UlsterCorps, a volunteer network in New York, and is the author of Nightshade, an historical thriller set in 1702 about a conspiracy to control the Atlantic slave trade.