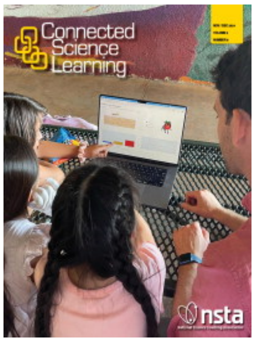

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RESEARCH ARTICLE

The Mobile Making Program: University Student Facilitation of Afterschool STEM Activities to Inspire the Next Generation of Scientists and Engineers

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ABSTRACT
This article describes the structure and outcomes of an afterschool Science, Technology, Engineering, and Mathematics (STEM) program called Mobile Making. Bridging formal higher education and informal K-12 education, university students visit school and community sites to facilitate engaging activities that afford youth participants (in grades 4–8) the opportunity to make playful and functional artifacts using STEM knowledge and skills. The program has been successfully running at one university for over a decade, but recently expanded to another three university campuses. This article describes the program's history, design principles, sample activities, collaborations, and positive implementation outcomes across all four universities to inspire others to create similar programs in their local communities. Recommendations for getting started are provided.

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KEYWORDS
STEM; afterschool; higher education; informal STEM education

Introduction

Guided by the "Maker Movement" in education (Bevan et al. 2015; Blikstein 2013; Halverson and Sheridan 2014; Martin 2015), the Mobile Making program aims to excite youth about the potential of Science, Technology, Engineering, and Mathematics (STEM) in their everyday lives by actively constructing playful, personally and socially meaningful artifacts anchored in real-world design challenges while using STEM knowledge and skills. Activities are facilitated by undergraduate students at local universities who bring the necessary tools, materials, and expertise to children (grades 4th to 8th), bridging formal higher education and informal K-12 spaces. Program activities have included a focus on robotics, coding, circuitry, pneumatics, and design; sample activities are included further below. The program started and has been successfully running for over a decade at California State University (CSU), San Marcos (CSUSM) and has recently expanded to three additional campuses: CSU Fresno (CSUF), CSU Long Beach (CSULB), and California Polytechnic State University in San Luis Obispo (Cal Poly SLO). This article describes the program, sample activities with instructional approaches, and documented benefits from program evaluation in hopes of inspiring others to foster such a program in their local communities.

Background

Humans are makers by nature. From functional tools to artistic expressions of dance or music, making is an innately human act. Throughout the last two decades, schools and educators have increasingly incorporated *Making* to support learning in educational settings due to in part the ubiquity of fabrication tools (e.g., 3D-printers, laser cutters) and digital tools (e.g., Scratch programming, TinkerCad) that allow for active construction. These tools provide a "low floor" and "high ceiling" for STEM; they are easy for beginners to use and provide increasingly complex functions for those ready for a challenge (Resnick and Silverman 2005). Moreover, making, creating, and building with both high-tech and low-tech (e.g., cardboard) tools often aligns with effective pedagogical practices such as project-based learning that educators are familiar with. Further, research investigating the impact of engaging youth in Making is overwhelmingly positive. Maker-based learning experiences

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increase youth interest and confidence in STEM (Bevan et al. 2015; Schlegel et al. 2019; Siyahhan, Price, and Marshall 2023). Making is also linked to learning gains in specific content areas, such as mathematics (Garneli et al. 2013), art (Peppler 2013), writing (Cantrill and Oh 2016), and computing (Papert 1980).

Mobile Making program: History and design principles

The Mobile Making program was originally developed at CSUSM as an afterschool program wherein racially and ethnically diverse undergraduate students facilitate maker-based STEM activities for upper elementary and middle school students at schools, libraries, and community sites. At most sites, the program also serves racially and ethnically diverse youth who are underrepresented in STEM. In many cases, the university students are originally from the communities in which they visit to facilitate sessions: we consider this a powerful component of the Mobile Making program. Program goals include promoting youth participants' self-efficacy, interest, and sense of the relevance of Making and STEM in their lives while making connections with college-going near-peers. The program started as a pilot program at one K-12 school in 2014 (Price et al. 2016) by dedicated university faculty and staff. Over the years, the program expanded to multiple schools, involved STEM university students and preservice teachers taking a service-learning course as facilitators of the activities, and offered the program in face-to-face, online, and hybrid modes (Siyahhan, Price, and Marshall 2023). For face-to-face sessions with youth, university students bring all materials and supplies to the community sites in their own vehicles, rather than using a large van or trailer like some other Making programs (e.g., Roden et al. 2018). This program and all associated research is approved by the Institutional Review Board (IRB) at CSUSM. Appropriate measures were taken to ensure privacy and respect of all human subject participants.

In Fall 2022, the program was expanded to CSU Fresno, CSU Long Beach, and Cal Poly SLO. At all four universities, the program is coordinated by dedicated university faculty in STEM and/or Education, with support of university staff. This expansion aimed to explore how the program can be implemented and adapted in different contexts while testing the six design principles that undergird the program. These design principles include: (1) establishing university-community partnerships, (2) leveraging undergraduate students as diverse near-peer facilitators, (3) providing access to resources by bringing materials, tools, and expertise to program sites, (4) employing authentic activities that connect to youth's everyday lives, (5) soliciting ongoing input from youth participants and undergraduate facilitators, and (6) establishing legitimacy within the community by embedding the program within the existing structures of the program sites and addressing local needs (see Price et al. 2023 for a detailed discussion of the design principles). In what follows, we share the experiences and program outcomes from all four campuses running the Mobile Making program.

Instruction and sample activities

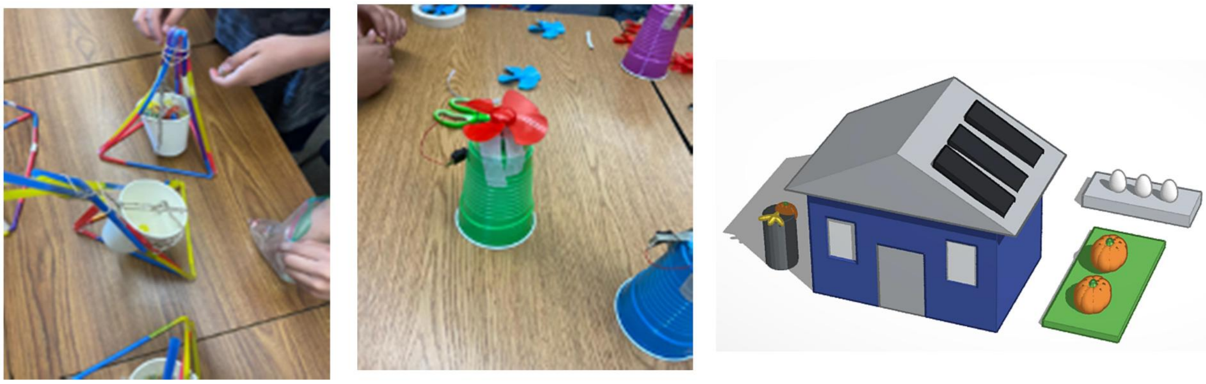
Our program offers youth the chance to dive into various hands-on projects that allow them to build and design with low-tech and high-tech tools. Each activity encourages students to use the provided tools and materials to create artifacts that address authentic design challenges. This immersive process fosters creativity and allows students to learn and apply essential STEM knowledge and skills. In general, activities are facilitated within 45 to 90-minute sessions, depending on the constraints of the partnering community sites. Facilitators begin each session with a short overview introducing the design challenge and briefly touch on any important STEM concepts that might emerge in the activity. However, very little direct instruction is intentionally given to youth participants. Instead, the majority of time in each session is dedicated towards youth playing, building, and testing their ideas in collaboration with other participants and facilitators. Below are examples of three sample activities.

Bucket tower

How might we design a water tower that can maintain stable pressure to store water safely for our town? Students were tasked with constructing a robust water tower (Figure 1) using only 20 straws and basic tools, ensuring the tower can hold 10 marbles without collapsing. This activity emphasized the engineering design process—identifying problems, developing solutions, and optimizing designs. By testing their models, students learned about structural stability and the iterative nature of engineering.

Portable fan

How might we create a portable cooling device for farmers working outdoors on hot summer days? To



Bucket Tower Portable Fan Sustainable Living

Figure 1. Sample activities using low-and-high tech tools.

tackle this design challenge, youth designed a solution: a lightweight, affordable, and safe portable fan. To complete this challenge, students used a 3 V motor, coin-cell battery, switch, and copper tape to construct an electric circuit powering the fan. For the hand grip, they repurposed a plastic cup and masking tape. This activity provided hands-on learning about energy conservation and transformation. Students were able to build, test, and redesign the fan.

Sustainable living

How might we design homes that support sustainable living? To tackle this design challenge, youth used the 3D-modeling tool TinkerCad to build homes that were energy-efficient and used environmentally friendly resources and practices. This activity provided an opportunity for students to research, discuss, and reflect on sustainable living in their everyday lives while engaging them in spatial reasoning, geometry, and scale.

Creating community partnerships

The Mobile Making program relies on community partnerships to be successful. While each community partnership is unique, we share some recommendations for creating these partnerships to help others begin similar programs.

For creating new partnerships with community sites, we found that personal communication, outreach, and networking were essential. In most cases, university faculty or staff approached potential partners near the university to ease transport and accessibility. For K-12 schools, this connection initially occurred via email to the principal and/or afterschool site coordinators. For libraries and community sites, initial contact was made to a director or other site leadership position. In these initial communications, we briefly described the program, its benefits, and past successes at other sites. We also emphasized that the program was free of cost, with all materials and supplies provided. In the event that no response was received, follow-up emails were sent. In some cases, in-person visits were also made to share promotional materials and introduce ourselves to key stakeholders at the sites. These in-person visits were often quite successful. In some cases, personal connections were also used to recruit sites. For example, some sites were secured through K-12 teachers or staff members who knew university staff or faculty involved in Mobile Making and advocated to their site leadership that this would be a beneficial program to add. In general, we found that many sites already had a strong interest in expanding STEM education opportunities for their youth, so the program aligned well with existing goals and was generally well received.

After a site expressed interest in participating, a university staff or faculty member would typically visit for an in-person meeting to discuss logistics and overall program design. These meetings were held at the community sites, serving as an opportunity to form relationships and review physical spacing (e.g., numbers of desks/tables, access to outlets or computers if needed) and potential constraints (e.g., lack of designated classroom). During these meetings, we made sure to share potential activities and get feedback on the overall program format (dates, length of sessions, rotation times) to ensure it aligned with the site's goals and structures. We also shared contact information and encouraged the site to reach out with any questions or concerns as the program began. It is important to note that communication was ongoing with site coordinators as the program ran, with university staff, faculty, and/or students checking in during each session to ensure the site felt supported and that the program was running smoothly.

In the Fall of 2023, the Mobile Making program expanded from one university to four universities. This expansion was done through securing additional funding through the National Science Foundation. Through this expansion, we were able to greatly increase the number of sites and types of community partnerships, ultimately increasing the number of youth served. See Table 1 for an overview of the various sites across universities, as well as the average duration of each session length. Note, at CSUF and Cal Poly SLO, the length of each session varied from the initial structure used by CSUSM to adapt to the context of the local partners (further described below in the "Implementation across Settings" section).

Youth participants

Across all four university campuses, the Mobile Making program targeted children in grades 4th to 8th across school, library, and community sites such as the Boys and Girls Club. At CSULB, the library site also included 3rd-grade students, siblings, and parents due to sessions that allowed anyone at the library to drop in without prior registration. In general, the Mobile Making program at all four universities primarily focused on reaching youth who are in underserved communities, the largest youth participant group being Latino. The program attracted boys and girls equally.

University student facilitators

We have recruited and prepared university student facilitators using two models. First, university students who are enrolled in a service-learning (SL) course can satisfy their service requirement as a facilitator in the Mobile Making program. SL courses are becoming increasingly common at universities, requiring students to complete service with a local organization or non-profit as part of their course requirements as an extension of their academic learning. We found that incorporating a required SL component into an existing course that is well aligned with the goals of the Mobile Making program rather than creating a brand-new SL course saves time and helps faculty jump-start the Mobile Making program. We have successfully run SL courses for Liberal Studies majors with plans to become future elementary teachers, and STEM majors with varied career aspirations. In this model, university students learn and practice the design challenges that they facilitate with youth during class time or during training sessions scheduled to prepare them for their SL experience. They also have explicit class sessions that discuss theories of teaching and learning, design thinking and engineering education, as well as classroom management.

Second, we have hired university students, mostly STEM majors, who serve as the facilitators of the design challenges with youth at various sites. In some cases, these students act as assistants who visit sites to observe the sessions and be additional support for SL student facilitators and youth. The training of this group of university students takes place during work hours and involves faculty carving out extra time for training and reflection. A challenge of this model is that continuous funding is needed to ensure a consistent supply of university facilitators, which is only sometimes possible. At Cal Poly SLO, university students took a SL course and were also paid to facilitate design challenges with youth at sites, a blend of two models.

In both models, our facilitators are often from the very communities in which they are working, and take the role of near-peer mentors. Many of the university students we have worked with are the first generation in their families to pursue higher education. As such, the university student facilitators are role models for youth participants and serve as a resource for them to learn more about the college experience.

Implementation across settings

Efforts to scale this program allowed expansion to new settings and participants. The number of university students and youth participants in each session does range based on university and community sites. In general, sessions serve 20–30 youth and are facilitated by 5–10 university students. In this section, we

Table 1. Number and types of sites served across universities.

University	# of School Sites	# of Libraries	# of Community Sites	Number of Sessions	Length of Each Session (minutes)
CSUSM	21	2	2	9	90
CSUF	6	0	0	5	45
Cal Poly SLO	1	0	0	5	60
CSULB	0	1	0	3	90

describe the various contexts in which the program has successfully operated with a focus on the benefits and limitations of each to inform others interested in initiating similar programs.

Afterschool programming at K-12 school sites

The Mobile Making program operates successfully within an existing afterschool programming structure at K-12 school sites where additional school staff operate the after-school hours of 2:30–6:00 PM at the school. The afterschool programming often has specified time for homework, outdoor recreation, snacks, and enrichment activities. We found that the Mobile Making program can be offered as one of the "enrichment" activities. This setup affords the benefit of ensuring youth are present to participate in the activities. However, attendance can fluctuate and decline over the afternoon as more parents pick up children at some sites. Because the afterschool programming structure often has strict rotation times, the implementation of the Mobile Making activities must fit within the time allocated by the afterschool staff. For example, we had to modify the Mobile Making program in one district so that each session ran for 45 minutes rather than 90 minutes. We had to simplify the activities to ensure youth were able to complete design challenges in less time than originally intended. Additionally, we found that space can be a constraint in this context. We were not always afforded a designated classroom and sometimes facilitated in less ideal settings, such as in a loud cafeteria.

Afterschool programming at community settings

We have also engaged local youth across community settings such as Boys and Girls Clubs (BGCs) and public libraries. We found that BGCs are similar to afterschool programs at school sites; however, they serve different audiences and can offer more flexibility than school-based programs. BGCs also serve students year-round, providing fertile ground for new programming initiatives, especially during the summer months when K-12 schools are typically closed.

Collaboration with local libraries also provided an avenue for engaging with youth. Over the past decade, libraries have become more interested in STEM-based programming. Libraries provide free weekend and summer activities for all children including those from underserved communities. Libraries also provide a unique opportunity for multi-generational engagement in Making and STEM among elementary-aged youth and their parents or guardians. Yet the openness of these sites brought challenges. For example, there is usually no guaranteed audience for the Mobile Making program at a library because families choose whether to attend each session and drop out at any time. Attendance may vary widely, meaning some sessions might overflow with eager participants, while others are nearly empty. Participants may also drop in after the program has started, requiring additional support to engage in the activity. In some cases, recruitment was necessary to develop an audience, using resources and connections of the library and university to recruit interested participants.

Program outcomes and evaluation

In the expansion of the Mobile Making program from one university to four, we observed positive program outcomes previously noted elsewhere (see Price et al. 2016, 2023; Siyahhan, Price, and Marshall 2023). University student facilitators administered a feedback form for all youth participants at the end of each session across all K-12 school and community implementation sites, and a retrospective post survey at the end of the Mobile Making program at all implementation sites except CSULB due to the fluctuation in youth participation at the library. Additionally, we have regular, informal conversations with site partners to ensure the program is operating well logistically and meeting their site goals.

Program evaluation findings from Fall 2023 suggest the majority of youth participants enjoyed the maker-based STEM projects with:

- 71% of participants at CSUSM ($n = 1223$)
- 76% at university CSUF ($n = 753$)
- 95% at university Cal Poly SLO ($n = 44$)
- 94% at university CSULB ($n = 34$)

indicating that they enjoyed the program, defined as responding 4 or 5 where 1 = Not at all, 3 = It was OK, 5 = Really enjoyed it. Additionally, the level of rigor in projects was generally right for youth participants, with only 10% of participants at CSUSM, 8% at CSUF, 5% at Cal Poly SLO, and 3% at CSULB responding with a 1 when asked how difficult the project was (where 1 = Very Difficult, 3 = Neither difficult nor easy, and 5 = Very Easy). Finally, the results suggest that many youth participants felt successful in completing the design challenges and learned new things about engineering, science, and technology. See Table 2 for the percentage of

Table 2. Youth affirmative responses (choosing 3 = Yes on a 3-point scale) on the feedback forms collected across four universities after each session.

Feedback Form Items	CSUSM (*n* = 1223) (%)	CSUF (*n* = 753) (%)	Cal Poly SLO (*n* = 44) (%)	CSULB (*n* = 34) (%)
I made some mistakes during the project but figured out how to fix them.	45.4	47.7	73.8	73.5
I felt successful after doing this project.	47.3	54.2	61.9	70.6
The project helped me understand how I can create with things in my everyday life.	37	40.4	69	48.4
I learned something new.	42.6	51.5	80.5	66.7
The project kept me interested.	59	61.2	81	82.4
The project helped me learn something I will use in school.	29.5	32	52.5	50
The project helped me learn something about math.	19.7	16.1	26.2	24.2
The project helped me learn something about engineering.	46.6	45.1	52.4	63.6
The project helped me learn something about technology.	40.7	37.3	57.1	61.8
The project helped me learn something about science.	31.4	44.9	56.1	64.7

participants who responded with a 3 on a 3-point scale to the questions shown (1 = No, 2 = Somewhat, 3 = Yes).

The percentages for many of the items on the feedback survey is higher for Cal Poly SLO and CSULB. This could be due to sample size differences with those universities having significantly lower sample sizes compared to CSUSM and CSUF. Further, CSUSM and CSUF are similar and distinct from Cal Poly SLO and CSULB with respect to their implementation structure. CSUSM and CSUF both used SL college facilitators who received course credit for facilitation (rather than payment) and served a higher number of total sites. In contrast, Cal Poly SLO and CSULB each worked with just one site and paid their college student facilitators.

The findings from the retrospective post-survey suggest that youth participants' interest and confidence in STEM and Making mostly increased. Since our design challenges primarily focus on science, technology, and engineering, it is reasonable that fewer youth participants reported an increase in their interest and confidence in mathematics (see Table 3) (defined as responding, 1 = My interest/confidence decreased, 2 = My interest/confidence stayed the same, 3 = My interest/confidence increased). Further, 81.5% of youth participants at CSUF, 87.5% at Cal Poly SLO, and 60.8% at CSUSM reported interest in participating in our program in the future (1 = No, 2 = Maybe, 3 = Yes). CSULB did not administer a post-survey due to the drop in nature of the sessions, and therefore were not included in the analysis.

In addition to evaluating youth outcomes via surveys, we also ensure to meet with site coordinators at each site at the end of the program. While this is done informally, we typically ask for their impressions of the program, thank them for allowing us to partner and serve their students, as well as discuss the possibility of returning again. These conversations have resulted in small tweaks to the program (e.g., length

Table 3. Percentages of youth participants' reporting increased interest and confidence in STEM and Making across three universities, based on retrospective post-surveys.

	CSUSM (*n* = 230) (%)	CSUF (*n* = 213) (%)	Cal Poly SLO (*n* = 16) (%)
Interest in Science	47.2	56.5	73.3
Confidence in Science	43.1	51.6	61.5
Interest in Technology	55.5	50.3	66.7
Confidence in Technology	51.2	46.5	61.5
Interest in Engineering	51.8	44.3	64.3
Confidence in Engineering	50.9	45.6	72.7
Interest in Mathematics	27.8	35.9	55.6
Confidence in Mathematics	32.2	38.1	45.5
Interest in Making	60.4	55.6	76.9
Confidence in Making	51.5	51.3	71.4

of sessions, location of sessions) to ensure the program runs smoothly and the site is able to continue offering the program. We also typically share youth survey results once they are analyzed with site leadership and sometimes photo highlights of student projects to help with communication and to strengthen the partnership.

Further, we receive feedback about the program from our college student facilitators. They are in a unique position to provide input about how the program is running as they work directly with youth. The format of this feedback varies based on the university. At most universities, college student facilitators share regular reflections during their designated class time: they complete field notes after each site visit which provide input on specific activities and sessions, as well as complete a final portfolio and presentation about their learning over the course of the semester. At Cal Poly SLO and CSULB, college student facilitators outside of regularly occurring classes frequently meet with program leadership to share how the program is running across sites. Across all universities, these conversations and reflections often result in changes to activity design, materials, or facilitation strategies to better support future youth participants. At Cal Poly SLO, specifically, one major change that resulted from these interactions was the creation of a "Maker Journal" that youth could continuously return to each site visit to document their design ideas and creations, as well as record ideas about their experiences of engaging in STEM-rich making.

Recommendations

Below, we provide several recommendations for others interested in starting similar programs in their community.

- Start small. Just one school or community site is enough to get the program started and make an impact on youth.
- Consider low-tech activities first. You do not need a 3D printer or laser cutter to engage youth in meaningful making. Sometimes every day and recycled objects work just as well (and are more affordable). Cardboard, tape, scissors, and a creative design challenge can go a long way in engaging youth in active construction.
- Identify a program champion at each site. We found that having a dedicated teacher or staff member who was responsible for helping coordinate logistics and recruitment was essential. This person can serve as an advocate and ensure program continuity if space, schedules, staff, or resources change.
- Listen to program participants and make changes as needed. Feedback from youth participants and facilitators is key to ensuring a successful program. We found that incorporating ideas from college student facilitators was empowering to them and improved the overall experience for youth participants. We suggest providing ongoing opportunities for all participants to give feedback on activities through short reflections after each session.

Conclusion

Through integrating real-world design challenges and hands-on activities facilitated by undergraduate students, the Mobile Making program engages upper elementary and middle school students in STEM and Making across various educational settings. The design of the program is flexible enough to be adapted to different environments such as afterschool programs at school sites, Boys and Girls Club, and libraries, each presenting unique benefits and challenges. The success of the program is evident in the high levels of enjoyment and learning reported by the youth participants, as well as their increased interest and confidence in STEM and Making. Educators and researchers who wish to start the program in their local context should consider starting small and with low-tech activities, identifying program champions at their implementation sites, and maintaining a feedback loop with participants to ensure ongoing improvement.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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