Program Evaluation - STEAM Trunks: Enhancing K-8 Project-Based Learning through Mobile Makerspaces

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STEAM Trunks: Enhancing K-8 Project-Based Learning through Mobile Makerspaces

Abstract

This study describes the development, initial implementation, and preliminary findings from the evaluation of one school’s grant-funded effort to use mobile makerspaces to enhance project-based learning in STEAM (Science, Technology, Engineering, Arts, and Mathematics) disciplines. With the goal of integrating makerspace resources into its existing project-based learning (PBL) instructional model, the school has designed, built, and deployed nine STEAM Trunks, each featuring materials and tools aligned to specific themes including “Arts & Crafts”, “Construction”, “Electronics”, and “3-D printing”. Following professional development sessions that introduced the STEAM Trunks and facilitated initial project planning, K-8 teachers began incorporating STEAM Trunks into PBL during the 2015-16 school year.

Utilizing a transformative mixed-methods approach, this case study uses observation, survey, and document data to address the question, “to what extent and in what ways are mobile makerspaces being integrated into project-based learning at each grade level?” Observations are being conducted as STEAM Trunks are utilized for projects planned by teachers at each grade level, both in classrooms during the regular school day and at special school events where students showcase their projects. Using a semi-structured observation protocol, researchers focus classroom observations on student engagement with STEAM Trunk materials in order to determine whether and in what ways making using the STEAM Trunks may foster the essential elements of project-based learning. An online survey administered at the end of each semester is being used to gather teacher perspectives on the STEAM Trunk initiative. This survey asks K-8 teachers to share examples of how they have used the STEAM Trunks, to reflect on whether and how the STEAM Trunks have enhanced project-based learning in their classroom, and to provide suggestions for additional materials or improvements to the STEAM Trunks. Finally, a variety of documents including photographs, meeting agendas and notes, implementation calendars, school websites, promotional materials, and communications (flyers, emails, etc.) are being analyzed as a secondary data source detailing the STEAM Trunk development and implementation process. Preliminary results suggest both challenges and benefits related to STEAM Trunk implementation. Challenges include aligning STEAM Trunk materials with project-specific needs and logistics (scheduling, arranging secure and convenient storage, monitoring and replenishing STEAM Trunk supplies and equipment). Observation and survey data indicate a high level of adoption and satisfaction among K-8 teachers. Additionally, observations document numerous examples of students utilizing STEAM Trunk tools and materials to meaningfully engage in the engineering design process.
Introduction

“I am calling on people across the country to join us in sparking creativity and encouraging invention in their communities. Today, let us continue on the path of discovery, experimentation, and innovation that has been the hallmark not only of human progress, but also of our Nation’s progress. Together, let us unleash the imagination of our people, affirm that we are a Nation of makers, and ensure that the next great technological revolution happens right here in America”.

President Barack Obama, 2014 White House Maker Faire

Schools across the country are taking up the challenge issued by President Barack Obama at the first ever White House Maker Faire. Encouraged by the prominence of engineering within the Next Generation Science Standards (NGSS) and the rise of the ‘maker’ movement, schools are experimenting with various approaches to infusing making into K-12 teaching and learning (Foster, Dickens, Jordan, Lande, 2015; Halverson, 2014; Martin, 2015). Many schools have forged partnerships with community-based makerspaces, repurposed their own libraries or classrooms as dedicated makerspaces, and invested in new technologies (e.g. 3D printers and design software) that allow students think and create in new ways.

Although maker education has its philosophical roots in the rich traditions of constructionism and constructivism (Donaldson, 2014), little research has examined efforts to establish makerspaces and create a culture of making within modern K-12 schools (Hira, Joslyn, Hines, 2014). In spite of recent support for maker education at the national level, schools continue to experience pressures, such as an emphasis on high stakes standardized tests, that would seem to be incompatible with the exploratory, student-centered mode of learning envisioned by maker education. Similarly, practical limitations on time, space, and resources pose real challenges for schools that are interested in creating functional makerspaces. How does making fit within already taxed schedules? How do makerspaces fit within the physical boundaries of over-crowded schools? Thus, there is a real need for research that documents innovative approaches to incorporating makerspaces into unique K-12 education settings.

This study describes the development, initial implementation, and preliminary findings from the evaluation of one school’s grant-funded effort to use mobile makerspaces to enhance project-based learning in STEAM (Science, Technology, Engineering, Arts, and Mathematics) disciplines. The study is guided by the following evaluation questions:

1) To what extent and in what ways do teachers utilize mobile makerspaces to enhance project-based learning in their classrooms?
2) What are teacher’s perceptions of mobile makerspaces?
3) What factors influenced the implementation of mobile makerspaces?
Framework

Although the evaluation of the STEAM Trunk program is not intended as a formal assessment of fidelity of implementation (FOI), the study of STEAM Trunk utilization was informed by Century and colleagues' Innovation Implementation Framework (Century & Cassata, 2014; Century, Cassata, Freeman, & Rudnick, 2012). In particular, Century et al. define an array of individual, organizational, and contextual factors that may influence whether individual users (e.g. teachers) decide to adopt and continue to utilize an intervention. These factors include characteristics of the innovation, such as its complexity, duration, and scope; characteristics of individual users such as motivation, self-efficacy, attitudes toward the innovation and users perceptions of the ease of using the innovation; and organizational characteristics at the school level including shared beliefs and values, resources, and instructional leadership. An in depth exploration of all of the factors influencing STEAM Trunk utilization is beyond the scope of this paper; however, this framework provided a useful lens for considering potential factors that may have shaped whether and how teachers utilized this new mobile makerspace resource.

School Context

This program evaluation research was conducted at a charter school located in a large metropolitan area in the Southeastern United States. STEAM Charter School (a pseudonym) served over 1800 students in Pre-K through 12th grade during the 2015-16 school year. Although significant community revitalization has occurred in recent years, the school community remains predominantly low-income with the majority of students qualifying for free or reduced-price. Over the course of its 16-year history, STEAM Charter School has developed a well-regarded academic program and is currently recognized as one of the highest performing schools in its district and a top charter school in the State.

For the previous five academic years, the school has employed a model wherein project-based learning (PBL) serves as the primary vehicle for instruction in STEAM (Science, Technology, Engineering Arts, Mathematics) disciplines. The school is divided by grade level into Elementary (K-5), Junior (6-8), and Senior Academies (9-12th grade). This evaluation research focuses on a program implemented at the Elementary and Junior Academies (K-8th grade). In addition to classroom instruction in core disciplines, Elementary Academy students participate in a rotating schedule of daily enrichment courses in a variety of STEAM disciplines including: engineering design, robotics, technology, visual and performing arts, and environmental science. Electives in many of these disciplines are offered at the 6th-8th grade levels. Teachers at all grade levels continuously engage in professional development in project-based learning and a variety of topics related to integrated STEAM teaching and learning. Teachers at each grade level collaborate to design project-based learning experiences integrating STEAM disciplines and students regularly present their project work to the school community at quarterly PBL Showcase Events.
The STEAM Trunk Program

The STEAM Trunk initiative was launched as part of a larger grant-supported effort to enhance project-based learning through makerspaces. As part of this grant, the school had outfitted engineering classrooms at each of its two campuses (K-5th grade and 6-12th grade) as makerspaces. These makerspaces have been utilized for school wide Maker Night events and are accessible to students and their families during dedicated makerspace hours after school and on the weekends. Although these makerspaces have been well-received and frequently utilized, because the classrooms serving as makerspaces were reserved for the school’s engineering design courses during the school day, they did not necessarily suit the needs of teachers interested in integrating makerspace resources into their project-based learning instruction in core classes. Anticipating this need, the school decided to develop a fleet of mobile makerspaces they called STEAM Trunks to provide additional maker resources to K-8 students and teachers.

A total of 9 STEAM Trunks were developed for implementation in Kindergarten through 8th grade classrooms during the 2016-17 school year. Although the STEAM Trunks vary somewhat in size and configuration, each is approximately 4’ x 4’ x 2’ and constructed of wood with four wheels and various compartments and storage features (e.g.: hooks, drawers, peg boards, shelves) containing materials and tools. Each STEAM Trunk focuses on a specific strand of making: arts and crafts, construction, electronics, or 3D printing. Middle-school engineering design students were enlisted to develop the initial design of Arts and Crafts, Construction, and 3D printing STEAM Trunks and the Electronics trunk was designed and sponsored through a school partnership with RadioShack. Although the school had hoped to involve students in the construction of the trunks, due to time constraints and the level of carpentry required, professional carpenters and members of the school community with carpentry experience were contracted to complete the actual construction of each of the STEAM trunks. A tenth Fun & Games STEAM Trunk to include games, puzzles, gadgets (e.g. Dash + Dot Robots), Legos, and gears is currently under development. The specific contents of each STEAM Trunk were determined by a school leader who had previously served as the school’s engineering design teacher, with suggestions from teachers responding to a brief needs assessment survey conducted at the beginning of the grant. Photographs, associated tools and materials, and approximate initial costs for each STEAM Trunk are listed in Table 1 below. Initial costs include materials used to build the actual trunks, one-time investments in tools and equipment (e.g. 3D printers), and an initial supply of consumable materials intended to last at least one school year (e.g. filament for 3D printers). Note that the estimate for the 3D printing STEAM Trunk does not include the cost of 4 laptop computers as the school was able to utilize decommissioned laptop computers they had on hand. The additional cost for 4 basic laptop computers capable of running 3D printing software would be approximately $1200. Additionally, estimates do not include the cost of construction labor to build the trunks.
**Table 1.**
STEAM Trunks and Associated Tools and Materials

<table>
<thead>
<tr>
<th>STEAM Trunk (Number of Trunks)</th>
<th>Tools and Materials</th>
<th>Approximate Initial Cost Per Trunk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arts + Crafts Trunk (3)</td>
<td>Crayons, colored pencils, markers, tempura paint, Glue sticks, Washable School Glue, various tapes (duct, masking, electrical, double-sided), various brushes (chip, easel, foam), aluminum foil, plastic wrap, cutting mats, recycled materials (cardboard, magazines, etc.), poster board, foam board, butcher paper, aprons, old t-shirts, box cutters, glue guns, x-acto knife set, tap measures, wooden rulers, construction paper, tissue paper, plastic string, yarn.</td>
<td>$500</td>
</tr>
<tr>
<td>Construction Trunk (2)</td>
<td>Drills, 24in. box frame level, metal rulers, carpenter angle square, metal squares, Japanese saw, hand saws with miter boxes, washers, wingnuts, nuts and bolts, wood craft sticks, corner braces, fluted dowel pins, screwdrivers, hex wrenches, drill bits, hammers, hack saws, trigger clamps (large), trigger clamps (small), ratchet, post + level set, sanding sponges, tape measures, heavy duty staple gun and staples, wood glue, high temperature glue gun and glue, screws, nails, dust masks, safety goggles, wood.</td>
<td>$900</td>
</tr>
<tr>
<td>3D Printing (2)</td>
<td>Printrbot 3D Printers (4), laptop computers (4), laptop chargers, extension cord, power strips, USB cables, extra printer filament rolls, printer tape, ruler, tools for scraping filament or sculpting printed products (scissors, x-acto knife, metal spatula, flathead screwdriver, needle nose pliers, wire cutters), calibration spacer, spare 3D printer parts.</td>
<td>$3500</td>
</tr>
<tr>
<td>Electronics (2)</td>
<td>Digital multi-meter with probes, alligator clips, dual wire stripper and cutter, battery charger, screwdriver set, soldering irons, desoldering irons, soldering supplies (solder, clamps, solder sucker, brass sponge, desoldering braid, tips, fan fume absorber), snap circuits, Energy Project kit, Little Bits Premium Kit, electrical tape (various colors), wire connector assortment, Build-it Kit: Sound to Light Device kit, Build it Kit: Electronic Mesmerizer, Built-it Kit: Water Alarm, extension cord, electronics vocab flash cards, dual printed circuit boards, batteries (C,D,AA,AAA, 9V, Button Cell), LED Lights, paper clips, jumper wire, assorted switches.</td>
<td>$900</td>
</tr>
</tbody>
</table>
Prior to STEAM Trunk implementation, the school developed a number of procedures and systems including an online calendar and forms for reserving STEAM Trunks, safety rules and procedures, and professional development sessions introducing the trunks to teachers and providing instructions and practice using various tools and materials. The school partnered with Maker Ed’s Maker VISTA program to host two Maker VISTA members for a yearlong appointment at the school. These Maker VISTA members assumed much of the responsibility of managing the school’s STEAM Trunk initiative, including conducting and maintaining inventory, coordinating STEAM Trunk reservations and storage, assisting with professional development related to the STEAM Trunks, documenting teachers’ usage of STEAM Trunks, and maintaining the STEAM Trunk calendar.

**STEAM Trunk Implementation Data Sources**

Observation, survey, and document data were triangulated to describe STEAM Trunk implementation in K-8th grade. Each of these data sources is detailed below.

**Observations**

Observation data included both classroom observations and informal observations conducted at school events showcasing students’ project work. For classroom observation visits and school events, observation data were recorded using a semi-structured protocol created to document connections to project-based learning, illustrative quotations from teachers and students, and ratings of student engagement with STEAM Trunks recorded over the course of each session observed. Regarding the ratings of student engagement, the protocol asked the researcher to rate the overall level of student engagement with STEAM Trunk materials every five minutes on a scale of 1 to 4, where 1 signifies a complete lack of engagement with STEAM Trunk usage and 4 indicates that all students in the classroom were actively utilizing STEAM Trunk materials. Classroom observations were scheduled by referencing an online school calendar indicating the time and classroom locations for STEAM Trunks reservations. Prior to classroom observations commencing, all K-8 teachers were notified that an evaluation researcher may visit their classrooms to observe implementation of STEAM Trunks. A total of eight classroom observations were conducted over the course of a 4-month period. Each observation visit lasted the duration of a class period (approximately 1 hour). In order to observe both a breadth of project-based learning activities and use of the trunks for an extended project, three observation visits were devoted to observing one day of project work in classrooms at different grade levels (K, 3rd, and 7th grade), two observation visits were devoted to observing in a 4th/5th grade robotics class, and the remaining three visits were devoted to observing over the course of a multi-week project implemented in one 5th grade science classroom. Informal observations were conducted at three school events during the same semester: a school-wide PBL Showcase Night, 5th Grade Project Science and Engineering Fair Presentation Day, and the school Science and Engineering Fair.
Surveys

An online Teacher Survey was conducted at the end of the first full semester in which teachers had access to the STEAM Trunks. The survey, which was conducted as part of a larger grant evaluation, was intended to gather additional documentation of STEAM Trunk utilization and teacher feedback regarding the STEAM Trunks and associated professional development opportunities. The survey asked teachers to indicate their current level of experience with and participation in professional development related to Maker Spaces and to rate their interest in incorporating Maker Space resources, such as the STEAM Trunks, in their classrooms. Finally, teachers were asked to complete an open-ended item in which they were asked to share any examples of how they utilized STEAM Trunks to support project-based learning in their classroom. A total of 31 K-8th grade teachers responded to the survey.

Documents

A variety of documents were compiled and reviewed as additional evidence of STEAM Trunk implementation. These documents include: implementation calendars and reports on STEAM Trunk usage provided by the school, grant meeting agendas and notes, flyers and announcements of relevant school events, the school’s website featuring descriptions of projects and photographs of STEAM Trunks in use, and the school’s social media (e.g. Facebook group) where examples of STEAM Trunk usage were shared with the school community.

Findings

STEAM Trunk Utilization for Project-based Learning

Documents, observation, and survey data provides clear evidence that teachers have begun to utilize STEAM trunks to enhance project-based learning in their classrooms. Utilization of the STEAM Trunks has been most evident in the school’s Elementary Academy (K-5), where trunks were checked out for use a total of 98 times by 24 teachers during the first semester in which they were available. The vast majority of these reservations (84%) occurred when teachers utilized carts for project-based learning activities. Although STEAM Trunk usage was not as frequent or widespread in the Junior Academy (6-8th grade) due to delays in Trunk construction, there were also promising examples of middle school teachers utilizing the STEAM Trunks. Table 2 below presents illustrative examples of projects utilizing each of the STEAM Trunks.
Table 2.
Illustrative Examples of STEAM Trunk Utilization

<table>
<thead>
<tr>
<th>STEAM Trunk</th>
<th>Grade Level(s)</th>
<th>Project Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Printing</td>
<td>5&lt;sup&gt;th&lt;/sup&gt; Grade</td>
<td>As part of the school's Science and Engineering Fair, students designed and prototyped original innovations to solve real world problems.</td>
</tr>
<tr>
<td></td>
<td>8&lt;sup&gt;th&lt;/sup&gt; Grade</td>
<td>Student's design and prototype helmets that would more effectively protect against injury in a variety of contact sports.</td>
</tr>
<tr>
<td>Electronics</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;/5&lt;sup&gt;th&lt;/sup&gt; Grade</td>
<td>In their Robotics enrichment class, students use various electronics tools and materials to build underwater robots.</td>
</tr>
<tr>
<td>Construction</td>
<td>3-5&lt;sup&gt;th&lt;/sup&gt; grade</td>
<td>In their environmental science and visual arts enrichment courses, students build a weather station and a scarecrow for the school's Tinker Yard.</td>
</tr>
<tr>
<td></td>
<td>6-8&lt;sup&gt;th&lt;/sup&gt; grade</td>
<td>In their engineering enrichment class, students design and build a new raised bed garden for the school.</td>
</tr>
<tr>
<td>Arts and Crafts</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; Grade</td>
<td>Students learn about the life cycle of different animals by creating artistic representations with supplies from the trunk.</td>
</tr>
<tr>
<td></td>
<td>3&lt;sup&gt;rd&lt;/sup&gt; Grade</td>
<td>Students design and build solar ovens out of cardboard, aluminum, plastic wrap, and other materials.</td>
</tr>
<tr>
<td></td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; – 3&lt;sup&gt;rd&lt;/sup&gt; Grade</td>
<td>In their Spanish class, students created puppets for a project that incorporated puppetry and digital storytelling to enhance students' language learning.</td>
</tr>
<tr>
<td></td>
<td>1&lt;sup&gt;st&lt;/sup&gt; Grade</td>
<td>Students created marketing materials for a Fall Farmer's Market where they sold produce they grew themselves.</td>
</tr>
</tbody>
</table>

Classroom observations revealed a high level of student engagement and frequent opportunities for students to practice critical 21<sup>st</sup> Century Skills and engage in the engineering design process. During the approximately 10 hours of STEAM Trunk implementation observed, ratings of student engagement indicate that during 63% of available class time either a majority or all of the students in the classroom were observed utilizing STEAM Trunk materials. Instances when fewer students were engaged with STEAM Trunk materials most often occurred during the first or last 10 minutes of class sessions or when the teacher was modeling use of STEAM Trunk materials. For example, in one session observed in the Robotics classroom, the majority of the class period was devoted to the teacher modeling and working with individual students to learn how to use the soldering iron and related materials on the Electronics Cart. In addition to ratings of the proportion of students utilizing STEAM Trunk materials, field notes provide numerous examples of students’ expressing their excitement about the opportunity to work with the STEAM Trunks. Many students were visibly excited as they entered the classroom to see the STEAM Trunks - saying "yes!", chatting with friends or the teacher about what they would be doing with STEAM Trunks, talking about how they had used
other STEAM Trunks in other classes. Similarly, as class sessions ended, students commonly asked teachers whether they would get to use the STEAM Trunks again the next day.

Field notes collected in the 5th grade classroom implementing the innovation project are particularly illustrative of the ways in which STEAM Trunks were used to engage students in the engineering design process. As students worked on their designs, the teacher capably and, it seems, rather intentionally, prompted students to engage in design thinking and an iterative design process that included identifying a problem, researching and designing potential solutions, developing and testing prototypes, and sharing designs with the school community. For example, when she noticed that some students had begun to discard early design renderings or “misprints” (3D printed designs that did not work), she told students, “if you make a prototype that doesn’t work, keep it to show your process.”

As students described their inventions, it became apparent that the majority of students sought to create innovations addressing real-world problems that they or their family or community members had experienced personally. As depicted in the photograph below (Figure 1), students were observed utilizing laptops and design software (Tinkercad) furnished by the 3D printing trunk to create renderings of their prototypes.

![Figure 1. 5th grade student uses Tinkercad to render their design.](image)

Students then worked together to create physical models and could choose to use either the 3D printing STEAM Trunk or other materials. The teacher estimated that just over half of the students had opted to utilize the 3D printing STEAM trunk for their projects. A number of these students were able to design working prototypes using the 3D printing STEAM Trunk. For example, one student successfully designed and printed a 3D prototype of a “cord protector” – a small
attachment that was precisely measured to fit over iPhone charging cords to prevent them from fraying (Figure 2).

![Cord Protector Invention Created Using 3D Printing STEAM Trunk](image)

**Figure 2. Cord Protector Invention Created Using 3D Printing STEAM Trunk**

In addition to documenting they ways in which STEAM Trunks were utilized, observations confirmed the support offered to teachers to effectively use STEAM Trunks to facilitate project-based learning in their classrooms. During observations of the 5th grade invention project, one of the school's Maker VISTA members was present to assist the teacher as she facilitated the 3D printing of students’ designs. This assistance became critical when it came to troubleshooting minor technical glitches. For example, when one 3D printer didn’t work as expected, the Maker VISTA member was able to determine that the wrong type of filament had been loaded into the printer. He was then able to change the filament and get printing back online while the teacher continued to circulate and engage with her students about their design process. In addition to this “real time” support, the Maker VISTA member confirmed that the teacher had participated in a 45-minute training before checking out the STEAM Trunk.

Field notes taken at grant meetings and the program-sponsored events captured additional documentation of STEAM Trunk utilization. Among the many projects showcased at the Elementary Academy was the digital storytelling project facilitated by the elementary Spanish teacher in collaboration with an artist-in-residence at the school. In this project, students used both the Arts and Crafts STEAM Trunk and digital storytelling applications to create original puppetry shows to demonstrate their developing Spanish language skills.

**Teacher Perceptions of STEAM Trunks**

Survey and document data provide preliminary evidence that teachers at each grade level have embraced the STEAM Trunks as a method for enhancing project-based learning in their classrooms. Several teachers expressed their gratitude for the STEAM Trunks, noting that they had been a valuable resource for planning and implementing projects. For example, the environmental science
teacher shared her gratitude for the STEAM Trunks in a post on the school’s Facebook group:

“First grade is gearing up for their fresh fall market! So thankful for the STEAM trunks that have made so much of our project work so much easier this quarter. We’re using the Arts & Crafts trunk to make banners....Hope to see you at the market!”

Teachers’ survey responses also suggest a high degree of satisfaction with the training they’ve received as part of the STEAM Trunk initiative. For example, one teacher noted, “The STEAM PD’s have been very helpful. She has explained how we can use some of the STEAM carts, what and how the makerspaces work, and how we can incorporate more STEAM into our PBL units.” Similarly, one 3rd grade teacher described the professional learning sessions, stating, “P.D. about makerspaces explained how to check them out and gave examples of how they could fit in with our lessons. For example, we used a makers cart to engineer solar ovens.”

**Factors Influencing STEAM Trunk Implementation**

A number of factors enabled the initial development and implementation of the STEAM Trunk program. Through its grant funding, the school had sufficient resources to equip the STEAM Trunks with materials and tools that often exceeded what teachers generally had access to in their classrooms. The school’s instructional model in which STEAM disciplines are integrated through project-based learning and its recent efforts to foster a “maker culture” at the school made the STEAM Trunks a resource that was generally compatible with teachers’ existing practices and shared beliefs about teaching and learning. For example, because students have been exposed to 3D printing and a number of tools included in the STEAM Trunks in their engineering design enrichment course, the idea that such tools could be used in the service of learning was not unfamiliar to students or teachers. Similarly, the school has a relatively experienced faculty with low rates of teacher turnover. As the school has invested several years in building teachers’ capacity for planning and facilitating project-based learning, many teachers have developed the requisite instructional planning and classroom management skills to effectively utilize the STEAM Trunks. Teachers received ample support for their utilization of STEAM trunks including encouragement from school leadership, ongoing professional development, technical assistance during STEAM Trunk use, systems for efficiently reserving STEAM Trunks, and recognition when students’ projects completed using the STEAM Trunks are showcased at school events and on the school website. Much of this support was made possible by the school’s partnership with the Maker VISTA program, which placed two full-time Maker VISTA members at the school with the explicit goal of building the school’s capacity for making.

These enabling factors notwithstanding, the school did encounter a number of practical challenges as they developed and implemented the STEAM Trunks. The most significant challenge was limited capacity for the actual construction of the STEAM Trunks. Identifying skilled carpenters willing to build the STEAM Trunks customized to the school’s specifications within the grant’s budget proved to be more difficult than expected and resulted in delayed implementation, particularly at the school’s Junior Academy. Additionally, with limited physical space available,
finding a convenient, secure space to store the fleet of STEAM Trunks when they were not in use posed another challenge. Finally, although the school has made significant investment in supplies for the STEAM Trunk and hopes to continue its partnership with Maker VISTA, additional investments will likely be necessary in order to sustain the program long-term.

While the current study highlights some of the promising elements of this innovative program, there are certain aspects of makerspaces that were undoubtedly compromised by the mobile makerspace approach. The STEAM Trunks were generally temporary fixtures in classrooms that must be reserved for a finite time period in order to complete a certain project-based learning activity. Although students often had opportunities to utilize tools and materials in creative ways within the context of project-based learning, tinkering, free exploration, and play may be more limited than in a typical makerspace environment. Similarly, because each STEAM Trunk focused on a specific strand of making, students did not have access to the vast array of tools and materials that may be available in a makerspace. These concerns are mitigated by the fact that the school developed the STEAM Trunks to supplement its two makerspaces, which are available to students and their families afterschool and on weekends.

**Conclusion**

This study provides insight into one school's efforts to enhance project-based learning through an innovative mobile makerspace program. Overall, preliminary implementation data suggest the STEAM Trunk program as an efficient and relatively cost-effective approach to integrating making in K-12 classrooms. Across grade levels, teachers have utilized the STEAM Trunks to infuse project-based learning with a variety of making activities, from arts and crafts to 3D printing to construction. In some cases, the STEAM Trunks were used for projects that meaningfully engaged students in the engineering design process. Future research should include studies exploring potential relationships between making and both academic and affective outcomes, such as the development of various 21st Century Skills (e.g. problem solving, creativity, collaboration). Additionally, more in-depth ethnographic work could examine how makerspaces of various forms function within diverse school contexts to create or sustain communities of practice.
References


