Information and Learning Scie

"I played a song with the help of a magic banana": Assessing Short-term Making Events

Journal:	*Information and Learning Sciences*
Manuscript ID	ILS-08-2020-0184
Manuscript Type:	Article
Keywords:	Makerspace, STEM, Assessment, Informal learning, Design, Short-term learning

"I played a song with the help of a magic banana":

Assessing Short-term Making Events

Abstract

Purpose

Designers of learning experiences are concerned with how people learn across a range of timescales from a semester to a single moment in time. And just as designing experiences at different timescales requires unique goals, tools, and processes, measuring what people learn from their interactions is also timescale-specific. The aim of our work is twofold: 1) To understand how learners describe their experiences with short-term, introductory maker experiences and; 2) To test a method for assessing learners' experiences authentic to short-term learning.

Design

We collected written responses from participants at a two-day event, STEM Center Learning Days. Through an analysis of 707 unique instances of learner responses to participation in drop-in maker activities, we examined how participants describe their short-term learning experiences.

Findings

We found a connection between specific making activities and descriptions of passive and active learning; and that some learners described themselves as working in tandem with tools to create something work and other learners viewed the tools as working autonomously. We found that as our assessment method allowed us to gain an understanding of how learners describe their experiences offering important implications for understanding short-term learning events.

Originality/ Implications

Our findings provide important implications for those who design and study short-term learning experiences as well as for those who wish to promote STEM pathways and identities.

Keywords

Makerspaces, STEM, assessment

"I played a song with the help of a magic banana": Assessing Short-term Making Events

Makerspaces provide visitors a kaleidoscope of moments filled with new experiences and magical wonders they've not previously encountered. These small moments--such as playing Jingle Bells on a banana or powering a light using Play-Doh--are difficult to assess as they are over almost as quickly as they begin. Although designers of makerspaces recognize these moments as important to an individual's learning trajectory, we lack the appropriate assessment tools to determine their impact in a way that values learners' experiences. To this end, this article unpacks how participants describe what they learned from a series of drop-in maker activities and offers a method for assessing short-term making events.

Designers of learning experiences are concerned with how people learn across a range of timescales from a semester to a weekend to a single moment in time. And just as designing experiences at different timescales requires unique goals, tools, and processes, measuring what people learn from their interactions is also timescale-specific (Pelligrino, 2010). "Small moments" contribute to an individual's learning trajectory over time differently than more extended and recursive trajectories (Lemke, 2000); therefore designing for people to learn in small moments requires more robust means of assessment than we currently have. While researchers have assessed short-term learning events in informal learning settings using methods such as surveys, observations, and pre- and post-tests, those methods only tell us about the activity itself or the learner's inert, pre- and post-knowledge of a particular activity with little insight into learners' experiences. To assess short-term learning events in situ, we need a method that mirrors the learning experience itself. This article documents how learners described their experiences with short-term, introductory making experiences by asking the following questions:

- How do participants describe their experiences with short-term learning events?
- How do we assess these learning experiences?

Through the creation and implementation of the Bricolage Artifact Response Board (BARB), a method to collect participants' responses and reflections on their experience with a range of short-term activities, our research provides unique insights into the small moments of learning that take place during making experiences. We used BARB to collect and analyze responses from 707 young makers; we found that there was a connection between particular making activities and the extent to which learners viewed their experience as passive or active learning. While some learners described themselves as working in tandem with tools to create and/or make something work, other learners viewed the tools as working autonomously without their assistance. Our findings provide important implications for those who design and study short-term learning experiences. Recognizing that STEM learning occurs across spaces and timescales, educational designers can design experiences that allow learners to build upon the many connections between learning episodes.

Small Moments of Learning

Out of school spaces--from after school programs to museums--specialize in small moments of activity that occur within short-term learning. Lemke (2000) calls these short-term learning moments "episodes," events often designed for large numbers of participants in open-ended spaces. In this context, learning may not mean the kind of breakthrough moments or fundamental changes in identity, attitudes, or reasoning that we often set as our goal; rather, it acknowledges that when people engage in designed activities, *something interesting is* *happening* (Lemke, 2000). Learning is fundamentally tied to growth and change which is difficult to assess in short-term episodes; however, through small moments, learners are engaging with materials and ways of thinking that have connections to other aspects of their lives. These somethings accumulate over time so that eventually, what occurs during short-term learning episodes does result in substantive identity and behavior changes (Bricker and Bell, 2014; Samuelson and Horst, 2008). A brief episode can amplify a much longer event just as much as a longer episode can impact a short-term event (Lemke, 2000). While it is difficult to measure learning in terms of growth for short-term events, we *can* understand more about how learners experience these moments.

Small Moments of Learning in Informal Spaces

Designers of short-term learning experiences design with flexibility and interactivity in mind. Makerspaces in particular are purposefully designed to enable learners to move freely across place and time (Author B, 2014). As a result, informal learning spaces are designed to meet the needs of the ever changing and broad audience of learners. A challenge, though, is for short-term experiences to go beyond the acquisition of facts and content knowledge and extend into more procedural or cause and effect learning (Puchner *et al*., 2001; Andre *et al.*, 2017). Museum exhibit designers use the following design principles to achieve these ends: 1) build opportunities for learner interactivity; 2) create clear scaffolding and; 3) provide limited choice (Andre *et al.*, 2017; Crowley *et al.*, 2001; Cheng *et al*., 2011; Falk and Storksdieck, 2005). Across all of these design principles, just as classroom learning relies on a teacher, informal learning also relies on guidance from an adult or more experienced mentor.

Assessing Small Moments of Learning

The increase of makerspaces in libraries, museums, after-school settings, and schools, has increased the need for assessments. As the editors of this special issue argue, “educators need assessment to provide meaningful feedback to learners, to justify programs and curricula, to make claims about learning and engagement, and to support educator reflection to shift instructional practice and design” (Wardrip *et al*., 2020). Through examining short term learning moments, we recognized the need to assess the design and instructional practices taking place in a non-standardized way that centered learners’ experiences. The emerging significance highlights the need for new and dynamic modes of assessment that help us understand what is taken away by learners in these environments.

The Need for A New Assessment Method

Agreeing to focus on the small moments of learning requires that we reorient our methods of studying learning and assessments. We do not expect big cognitive or sociocultural shifts to happen within a 5-15 minute experience, so our methods cannot require such a shift to take place in order to assess learning. Additionally, small moments of learning often occur in places where there are large numbers of learners moving in and out of the experience. These large numbers of people, moving relatively quickly through an experience presents multiple challenges, including: acquiring participants’ informed consent, accounting for a wide variety of activities, a lack of available demographic information due to participants’ short amount of time spent in the space, and, most importantly, temporal constraints.

Museum studies have found that researchers must choose between studying visitor behavior across settings and visitor behavior at a detailed level (Van Schijndel *et al*., 2010). For this reason, studies have focused on either visitor actions or larger exhibit-specific research including researching visitor behavior at the exhibitor level (e.g., Boisvert and Slez, 1995; Brody *et al.*, 2008; McManus, 1987; Sandifer 1997, 2003); visitor behaviors (Boisvert and Slez, 1994); and visitor agendas (Dierking and Falk, 1994). Across these approaches, researchers have used a variety of quantitative, qualitative, mixed methods, and design experiment approaches.

Tracking visitor behaviors at scale

Quantitative measures allow for researchers to track visitor behaviors such as the amount of time visitors spend at exhibits, the percentage of learners that stop at exhibits, the time learners talk to each other at exhibits, the time they interact or play with exhibits, and the time they spend reading at exhibits (Van Schijndel *et al*., 2010). This data can be helpful for interactivity, which increases visitor's ability to recall information (Allen, 2004; Van Schijndel *et al*., 2010). Researchers have used pre-existing tools such as free choice survey items to determine the categories of use of adults engaging in science activities (Brody *et al*., 2008, p. 8); pre and post tests (Lebeau *et al*., 2001); and surveys (Falk *et al*., 2001). Quantitative measures, such as holding times and interactions can provide a comparison between exhibits, but do not tell us how visitors experience an exhibit (Van Schijndel *et al.*, 2010). Although it may seem that holding times correspond with more opportunities for learning, this is not always the case especially for young learners (Van Schijndel *et al*., 2010; Ramey-Gassert *et al*., 1994; Schauble, 1996).

How people experience museum exhibits

Qualitative approaches recognize lived experiences and offer the opportunity to understand visitors' individual experiences and behaviors as qualitative researchers analyze visitors' talk to each other at exhibits and visitors' interaction with exhibits (Van Schijndel *et al*., 2010). Common methodological approaches in museum exhibits and makerspaces include: observation (Brody *et al*., 2008); video-based field notes (Dillon, 2007); case studies (Anderson *et al*., 2000; Sheridan *et al.*, 2014); learner-generated diaries (Leinhardt *et al*., 2000); Activity theory (Rahm, 2012; Ash, 2014); and design experiments (Author B, 2018; Litts, 2015).

Qualitative research brings its own complications. During short-term learning experiences collecting data is often difficult as participants do not necessarily want to spend their time in interviews or taking pre- and post- tests. More importantly, while interview questions or surveys may ask about the experience taking place in situ, it is difficult to attribute learning to a specific activity or experience (Brody *et al*., 2008).

Researchers identify the limitations of a single method approach to short-term learning. For example, Van Schijndel *et al*. (2010) admit that their own study lacked understanding of the human experience. Brody *et al.* (2008) identify the value of a mixed methods approach to studying informal learning environments in order to capture both the depth and breadth of the experiences.

As we developed our line of inquiry to understand how participants describe their experiences with short-term learning events, we realized that the available assessment methods were not ideal for assessing the unique moments we hoped to learn about. Surveys, pre- and post- interviews, or field notes would not help us make sense of individuals' experiences (Denzin and Lincoln, 2011) in a way that was unobtrusive and that mirrored the learning experience itself. As a result, we created a data collection method that matched the unique short-term moments we sought to understand.

[Project name blinded for review] and the exploration of short-term learning

This article describes one study that is part of a larger effort to integrate making experiences into rural communities. [Project name] is a collaboration between researchers from a land grant, flagship public university and a technical college located in the same Midwestern state. The overall project is focused in designing maker experiences, training local high school students as maker-mentors for the community, developing partnerships with area community-based organizations, and researching what participants learn about STEM and computational thinking.

[Project name]-sponsored events took place onsite at the technical college's STEM Center, at local community-based partnership sites such as Boys & Girls clubs, public libraries, Boy Scout troops, and at large-scale community events including parades, county fairs, and a Hmong heritage festival. The events all featured maker experiences designed over the course of the project. These designed experiences were divided into three types: short *exposure* activities (5-15 minutes), extended *skill building activities* (90 minutes), and long-term, community-driven *maker activities* (weeks-long).

In this article, we focus on exposure activities. These drop-in making experiences were staffed by trained, high school-aged maker-mentors and designed for communities who lack regular access to innovative STEM practices. Table 1 summarizes the full range of exposure activities.

<Insert Table 1 about here>

The focus of this manuscript is to understand a) what people learned as a result of their participation in exposure activities and; b) whether our method for assessing learning in short-term learning events seems appropriate to this inquiry. We begin by describing the data collection method we developed and then describe the specific context in which we collected data.

The Bricolage Artifact Response Board

Given the challenges associated with capturing short-term moments with both depth and scale, we saw the need for a new way to address what people learn during drop-in learning events. Lemke (2000) identifies "semiotic artifacts" as a bridge across timescales for learners. He provides evidence of learning at the episodic level that can then be taken up as part of learning at the curricular level and then later leveraged as part of a student's identity. We saw the creation of a semiotic artifact as an opportunity for learner reflection and (therefore) for data collection. We adopted the metaphor of "bricoleur" as an opportunity for data collection, "deploying whatever strategies, methods, or empirical materials are at hand" (Denzin and Lincoln, 1999, p. 4). We created the Bricolage Artifact Response Board (BARB), as a method to collect participants' responses and reflections on their experience with a range of short-term, introductory maker activities.

[Project name] Short-term Learning Events

We collected data at a two-day event, STEM Center Learning Days, hosted at the technical college in their STEM Center. As part of this larger event, the [Project name] set up its mobile maker trailer with five different exposure activity maker stations: 1) four 3D printers, 2) Fruit Piano, 3) Makey Makey Whack-a-mole, 4) Play-doh Super Mario Brothers, and 5) squishy circuits. [Project name] maker-mentors, high school students trained in maker facilitation, served as guides for participants, providing insight about how various aspects of the activities worked and answering learners questions. We positioned BARB just outside the trailer, inviting learners to create written responses to the prompt, "What did you do today?" Throughout the two day event, participants created and shared 707 unique responses. Figure 1 shows BARB at the STEM Center Learning Days event.

<Insert Figure 1 about here>

The participants who created BARB responses represent a wide variety of demographics and have varying levels of experience with making activities. For example, some could name the company "Makey Makey" when writing about their experiences and others were seeing a 3D printer for the first time. To value this range of personal histories, we respected each experience equally. We aimed to allow participants' words and experiences to serve as the foundation of discovery. In so doing, we recognize that individual experiences can be used to describe a larger, universal experience (Creswell, 2013) or "grasp the very nature of the thing" (van Manen, 1990, p. 177). Individuals experience phenomenon differently depending on their background and the time, place, and perspective from which they experience an event (Moustakas, 1994). The short-term learning activity merges with the individual's consciousness and meaning is created as a relationship between their previous knowledge and new experiences.

Before we describe our analytic process, a brief word about our research participants. An important key feature of this study is that we have no information about our study participants. We see this feature as a feature and not a bug. Typically, qualitative studies of learning experiences rely on demographic information as a mechanism for drawing inferences about peoples' behavior: Families working on a task behaved this way, boys who identify as Hmong behaved that way. We do not deny the utility of "knowing something" about research participants; if this was a case study we would likely be much more interested in who these learners are. Here, we were interested in developing a reasonable and scalable mechanism for assessing learners' experiences. We wanted our data on learners' reflections to mirror the ways in which designers and facilitators' experiences with visitors at scale. In this way, we intended to see learners' experiences through their collective eyes.

Analyzing BARB Data

We began our analysis of the 707 written responses with in vivo coding which allowed us to prioritize and honor participants' voices (Miles *et al*., 2014). After initial coding, we used pattern coding to break our codes into four initial categories as we recognized that the majority of responses fell into one or more of the following constructs: verb use, pronoun use, activities referenced, and science talk. Table 2 summarizes learner's responses. For our full coding scheme see Appendix A.

<Insert Table 2 about here>

Across these four categories, we created a series of content-analytic summary tables to identify patterns across and between categories (Miles *et al*., 2014). The tables represent the intersection of activity and: agency (Table 3); verb use (Table 4); and emotional response (Table 5). Using the tables, we were able to analyze the large data set and scan for trends, verify findings, draw conclusions, and reflect (Miles *et al*., 2014).

<Insert Table 3 about here>

<Insert Table 4 about here>

<Insert Table 5 about here>

Findings

In total, we collected and analyzed 707 individual notes which included 788 responses. We counted each instance of naming an activity as a separate response. Table 6 represents the number of responses for each activity.

<Insert Table 6 about here>

While responses ranged from brief mentions of particular activities to more in depth explanations of what the participant learned or made, responses most often pointed to one activity rather than naming multiple activities. Responses described the activities in a range of ways:

- Stating the name or description of the activity if they did not know the technical name (for example, "fruit music" to stand in for the Makey Makey fruit piano);
- Providing an emotional response or affinity with a specific activity;
- Describing the activity and how they interacted with the objects and/or;
- Describing what they were able to achieve when they worked with the object.

Maker Activities

Learners mentioned specific activities in 62% of their responses. While there were four different maker activities available during our data collection time, the 3D printer and the Fruit Piano received the majority of BARB mentions (265 and 278 respectively for a total of 548 out of 788) (see Table 6).

Emotional Responses

Many learners shared emotional responses while mentioning specific activities. Emotional responses were always positive and fell into the following categories: mentioning their favorite part or their favorite activity, expressions about activities that were "really cool" or that they "really loved" and several learners used smiley faces combined with text to express emotion such as "3D printers :)"

Surprisingly, the majority of emotional responses (33 of 62) came from comments about passively watching the 3D printer. One learner described: "So the 3D printer was so cool, I learned that the stuff that's made from a 3D printer is plastic!" While we have little evidence of constructive or interactive behaviors in learners' responses, we do have some evidence that learners are taking some agency in these experiences and that they make some emotional connection to the activities and tools.

Tool as autonomous agent

Many participants described their activities as if their being present had little to do with how each activity functioned (see Table 3). They positioned themselves as outside of the action: "Fruit piano. We saw how fruit plugged into a computer makes music" and, "my fav. thing was seeing what the 3D printer was making". The majority of descriptions of the tool acting autonomously involved the 3D printer. After all, 3D printing is a time intensive process that does not mirror short-term learning design. When learners arrived, the 3D printing was already underway. Additionally, because the 3D printer can work on its own for hours, there was not always a mentor located at the station to assist in visitor's experience, to answer questions, or to engage learners in the process. Learner descriptions match this reality. In fact, many learners described watching the 3D printer rather than making something with the 3D printer. Comments such as "The printers use plastic wires and turn it into things," and "Three de printers can make a lot of things",[1] placed the tool into the position of the actor. In a few cases, the 3D printer was anthropomorphized, as in, "I watched a 3d printer create something."

Participants also treated the Makey Makey piano and Whack A Mole activities as autonomous tools. The Makey Makey piano cannot work without learners being physically attached via metal alligator clip serving as the conductor. Yet, several mentions of the Makey Makey piano also place the activity or the components of the activity working without the help of the visitor. Examples include "Fruit piano we saw how fruit plugged into a computer makes

[1] All learner comments are printed verbatim, not corrected for spelling or grammar

music" and "I learned that fruit, vegetables, and play do can make electricity and 3d printers can make anything you want."

Person and tool working in tandem

Other learner descriptions reflected a feeling of working with the tools to produce something (see Table 3). Most often, this meant creating music with bananas and pianos. Learners described their interaction with tools in three ways: 1) The learner acting as the primary actor using the tool to accomplish a task; 2) The tool working as the primary actor using the visitor to accomplish a task or; 3) An equal partnership between visitor and tool to achieve a task. Comments such as, "I made some Beats on The Banana," recognize the banana as something the visitor used to create music, while not fully describing how the two work together. However, in comments like, "The banana sends electricity through your body," the tool is given much more agency than the learner gives themselves. Examples like, "I participated in the banana piano. When I didn't had the banana it wouldn't play because it wasn't complete," demonstrate an understanding of the relationship between the banana and the visitor as both being necessary components in creating sound.

Verb Use

In response to our prompt, "What did you do today?" learners used verbs to describe their experiences 32% of the time. The four most popular verbs represented one passive act - to see or watch - and three active verbs - to play, to make, and to do (see Table 4).

The most commonly used verb, "saw" or "watched," was most often used in conjunction with the 3D printer. The verb "saw" reflects the nature of the 3D printer as an activity in a makerspace; for short-term learning experiences, learners are rarely actively involved in the action. They do not get to touch, play with, or tinker around with the materials at all. However, the verb "saw" was also used for other activities such as the Makey Makey piano and Whack A Mole, which require learner participation.The use of passive verbs for these activities conflicts with the nature of the activity itself, but suggests learners saw the exhibit from afar, saw other learners playing with the activity, or felt their actions were somewhat removed from the activity.

Learners used a variety of at least 13 other verbs, most of which suggested active participation. Play and make, the second and third most used verb, match the goal of makerspace experiences. These events are made to spark learners' interest, to allow for purposeful play and inquiry through hands-on experiences. The verb "play" which was most often used in connection with the Makey Makey piano and "make" which was most often used with the 3D printer, suggest a feeling of engagement with the materials and tools in the space. The two verbs also point to learners' feelings of being part of the production process as it suggests their part in creating a product. For the Makey Makey piano, this was the creation of music. For the 3D printer, some learners felt they were part of the process of making a 3D printed object, even if they were not present for the entirety of its production.

Intersection of Activity and Verb

Of the total learner responses (788 responses), 294 responses included a verb. Of these responses, a majority of learner responses (63%) used a passive verb suggesting a passive experience for learners (see Table 4). Many responses only listed an activity (ie. "piano fruit," "Playdough circuit thingymibopper") and many used passive verbs to describe their experiences.

To augment descriptive data in Table 4, we used Chi-Square and Cramer's V to understand the association between verb use relative to different objects. Crossing "see" with piano and printer $\chi^2 = 0.838$, $p = .360$, Cramer's V = 0.076, $p = 0.360$; "make" with piano and printer $\chi^2 = 0.368$, $p = .544$, Cramer's V = 0.051, $p = .544$; and "do" with piano and printer $\chi^2 =$

0.552, $p = .457$, Cramer's V = 0.062, $p = .457$ suggests that different verbs were used across different objects. For example, the verb, "play" could not be crossed with piano and printer because the verb "play" was never used to describe the printer. The findings demonstrate a lack of strong association for verbs across different objects, which suggests that learners used different verbs to describe different objects. One possible explanation for these findings is that learners understood the object (e.g., printer) as doing the making.

Pronoun Use

Although many learners used passive verbs to describe their actions, passive learning is not the whole story. Learners used pronouns in 28% of their responses; the majority of these were the first person pronouns "I" or "we" (79%), indicating that this subset of learners positioned themselves as active agents (Table 7). An overwhelming number of learners (115) used the singular pronoun "I" in their response, whereas 35 used "we" and 35 used the object itself (such as the fruit piano) as the main actor in their response. In a few instances, learners used the second person pronoun, you, to describe the experience in terms of what people, in general, might do or learn in such a space. When learners used "we" it was often to describe a simultaneous experience between the visitor and someone else. Comments such as "we played piano using fruit" may serve as a response for several members of a group who moved through the exhibits collectively.

<Insert Table 7 about here>

Discourse Related to Science

6% of the total responses contained what we identified as "science talk"; direct references to the words "science", "conductivity", and/or "electricity", or a description of a scientific process (see Table 8). Although the majority of the science exploration was related to activities that required active engagement, learners most often combined science comments with the verbs “watch” or “saw” rather than more active verbs. “Learn” was the third most used verb used to share comments about science learning.

<Insert Table 8 about here>

While the 3D printer proved to be less of an active experience for learners, there were several examples where learners tried to make sense of how it worked, breaking down the printer into smaller, more manageable parts. The comments, “I learned that the stuff thats made from a 3D printer is plastic" and “The 3D printing dinosaurs look metallic, but feel stringy” show visitor’s attempts to explain how the 3D printer works.

In two instances, the learner tried to make sense of, or recognize their part in, making. From “I made a light turn on,” to “Make a stegasorus we learned how to make a stegasorous,” learners saw their part in the creation. Yet, often understanding how science works meant talking about the objects as making something such as “I learned that fruit, vegetables, and play do can make Electricity and 3d printers can make anything you want.” The 3D printer was often described in terms of making something from a fully 3D printed item to the 3D printer making objects change color.

While the science vocabulary varied, learners used their available language to describe what they understood to be happening. The example, “I participated in the banana piano. When I didn’t had the banana it wouldnt play because it wast complete,” shows this maker trying to explain their knowledge of basic circuitry. The most used science vocabulary terms were electricity and conductivity. When learners used these terms they were always in reference to the piano, Whack A Mole, or squishy circuits.

In the three instances when learners used the term conductivity, they used various verbs and descriptors. All three of the instances were in connection with the banana piano. The first instance, “that bananas can make music with conductile,” is similar to the response, “I learned that fruit can conduce electricity to play a piano”. Both verbs used -- make and play -- are verbs often used to describe music production. In two instances, the verb “can conduct”, provided agency to the inanimate object. “The fruit can conduct,” and, “fruit can conduce electricity,” appear as instances of exploration of how things work and who is active in making it work. It also reflects a surprising realization that a common, everyday item like a banana holds scientific properties.

Electricity was used in conjunction with conductivity as a means to explain the outcome or purpose of conductivity. Examples include comments such as, “My favorite thing was the fruit piano because I like electricity and its cool how the fruits can conduct.” The phrase, “I learned that,” was used in conjunction with discussion of electricity and combined talk of what they learned with how they learned this information. Even the statement, “I learned that you can create light wihtout electricity,” suggests the learner either saw this act taking place or participated in creating light themselves. Responses such as “elextrisity thru playdo” and “The banana sends the electricity through your body” tie their learning to one of the specific activities available in the learning space.

Discussion

For this study, we set out to: 1) Catalogue the ways learners describe their experiences as short-term learning events and; 2) Determine the value of as assessment method that matched this unique learning experience. Through the close analysis of learner-created responses, we have seen that short responses written immediately following their activities provide insight into how people learn in such brief learning moments and the range of active and passive learning moments occurring in this setting.

Everyday Items as Entry Point To Learning Experiences

When learners enter a short-term learning event they are rarely told what they will experience, what they will learn, or how to approach the experience. Yet, we know that it is difficult for people to learn new content when they are unable to pair their prior knowledge with new information. Constructionists argue that learning can be realized through the creation of external artifacts. This does not mean that mentors and teachers do not aid in the building of knowledge; indeed, they are a necessary component in learning (Kafai, 2006). Because the kind of sustained engagement offered by a teacher in a classroom is not possible in short-term learning experiences and learners' prior knowledge varies drastically, short-term learning experiences must quickly meet learners across very broad zones of proximal development. The maker activities we studied here made this possible by using recognizable, everyday items that allowed learners to make connections between their prior experiences and new experiences in a short amount of time.

Everyday items, such as the banana and Play-Doh, were among the most mentioned tools in participants' descriptions. Part of this draw might be the contrast between what one expects to see in a science environment and the everyday. The contrast creates intrigue while learners' prior experiences with fruit creates a bridge between what one knows of the world and what one does not yet know through the use of a recognizable item. Not all learners described their experience with the banana or Play-doh beyond mentioning the activity. Many learners simply mentioned the item "the magic banana thing," or described the outcome, "We played piano using fruit," but some learners were able to move beyond description to share the new understanding of science, electricity, or conductivity they were able to gain from the experience. In the example, "The banana sends electricity through your body," we can start to see how learners are connecting a very common object to a statement of gained knowledge.

Experiences like the [Project name] at the STEM Center Learning Days learning event are, in part, exciting for learners because they are different than the everyday learning experience, especially for rural communities that are likely to have less regular access to STEM learning experiences (Authors, 2019, under review). They spark curiosity and promote exploration and are highly novel experiences (Cors *et al.*, 2017). While there are competing philosophies about whether novelty is helpful or detrimental in learning (Cors *et al.*, 2017; Falk *et al.*, 1978), novelty is often appealing and attractive to learners (Anderson and Lucas, 1997). In interest based learning, we recognize that learners are more motivated to learn when they have an invested interest in the content. For this reason, it is helpful to understand learners' initial connections with the exhibits in such spaces.

Although learner interest may change or fade within months of the short-term learning event (Cors *et al.*, 2017; Barmby *et al.*, 2005; Dowell, 2011), short-term learning moments allow for individual exploration and individual goals. As learners create individual paths, they can spend more time engaging with activities that spark a positive emotion which may therefore lead to learners expanding their new knowledge into a new interest-driven pursuit.

Even though not all learners shared the new knowledge or discoveries made, their descriptions provide important implications for designing short-term learning experiences. The more opportunities to bridge a wide range of learners' prior experience to new knowledge will provide further opportunities for learning in such brief encounters. Furthermore, for an activity like the 3D printer, which is less active for learners and most likely has less familiar components for learners, additional mentors or guides may be positioned near the printers to help learners bridge this gap and learn about how 3D printers are being used in meaningful ways in science, engineering, and artistic endeavors.

Active and Passive Learning

Researchers have demonstrated repeatedly that learners are more successful in gaining new knowledge when they actively engage with their environment. While our assessment method did not allow us to gain an understanding of learners' behaviors, their non-prompted, self-report descriptions suggest an overwhelmingly passive experience.

Chi and Wylie (2014) describe four modes of learning activities: "Interactive mode of engagement achieves the greatest level of learning, greater than the Constructive mode, which is greater than the Active mode, which in turn is greater than the Passive mode (I>C>A>P)" (p. 220). Different people can engage in activities in the same mode or in altogether different modes. For example, an activity such as the Makey Makey banana piano may be very passive for some learners if they only watch from a distance. Likewise, for an activity like the 3D printer, which is less active for learners and most likely has less familiar components for learners, additional mentors or guides may be positioned near the printers to help learners bridge this gap and learn about how 3D printers are being used in meaningful ways in science, engineering, and artistic endeavors.

Recognizing that Chi and Wylie's (2014) framework for analyzing active learning focused on overt behaviors, we adapted their work to analyze learners' descriptions. Table 9 reflects Chi & Wylie's four modes of learning and our adapted descriptions.

<Insert Table 9 about here>

Using this adapted framework, we found that 567 responses, the majority of comments, reflected a passive experience for learners. From simply mentioning an activity to detailing the act of watching or looking at an activity, learners answered the question, “What did you do today?” with a response suggesting passive learning.

While passive learning is not the desirable outcome of such an event, it is worth noting the majority of the emotional responses from learners came from comments about passively watching the 3D printer. The lack of agency or participation did not take away from their pure enjoyment and intrigue in the tool. Emotional responses ranged from “my favoratite part was watching the mechine print” to “I look at all the 3d printer now I want one I think I am going to get one.”

While we coded each comment that simply mentioned a device as passive, this also does not necessarily mean that they did not interact with the tools in some way. While BARB allowed us to capture learners' experiences immediately after, we do not know if their responses match their overt behaviors.

In addition to passive responses, we coded 87 active responses. The majority of the active responses were either about playing or “doing” the banana piano, and several others about playing Whack a Mole or “doing” the 3D printer. Learners also used active verbs, in some cases, to describe a fairly passive learning experience. The comment, “I spent 1 hour and 18 minutes making a Cat,” uses the active verb making, while we can assume that most of this time the learner was passively watching the 3D printer.

While more difficult to assess based on comments, we coded 9 responses that suggested constructive behaviors (Chi and Wylie, 2014). In these instances, when learners mentioned the output of their time (i.e., made music, created a working circuit) they did not always mention what tools they worked with to create an output. For example, when a participant notes, "I made a light turn on," we can assume they used the squishy circuits to create this output, though the tool itself is not mentioned. In other instances such as, "I created a working circuit to power a fan with playdoe," there is a direct connection between person, tool, and output. While there were only a few responses that suggested constructive behaviors, we can see how short-term events can allow enough time and space to move beyond passive experiences. Just as mentors may assist in building a bridge between old and new knowledge, so too may they serve as guides in building knowledge through creating more opportunities for constructive behaviors.

Use of Science Vocabulary

When learners described science or how things worked, they used the language available to them. There were many mentions of circuits, electricity, and conductors. But even when this vocabulary was not available to them or part of their current repertoire, they could still explain scientific concepts using their everyday language. While young people may not yet have the vocabulary to describe their learning experience, they are often able to report content of new information before being able to explain what they have learned (Esbensen *et al*., 1997; Gopnik and Graf, 1988; O'Neill *et al*., 1992). Using available language, they are able to construct a complex understanding of the way each activity works.

Conclusions

BARB allowed us to gain an understanding of how learners describe their experiences in short-term learning events offering important implications for designing short-term learning events. BARB allows researchers to study learning in its natural setting, releasing learners to describe and make sense of their individual experience (Denzin and Lincoln, 2011). It also affords the chance to capture learners' experience in situ while they are engrossed in the learning space itself. The resulting comments are as closely situated in time as possible to the experience.

Designers of short-term learning experiences who find current methods do not accurately reflect user experiences may use a research method like BARB to assess their own environment. Just as we learned that we can improve several activities by creating more opportunities for active learning and that several activities could benefit from using a guide to scaffold new information, designers of other short-term learning experiences may use BARB to understand more about their unique activities in order to improve small learning moments.

Limitations and Future Directions

As a data collection method, BARB allowed us to gather learner reflections during small moments of learning. However, we recognize that to fully understand one's learning requires evidence of change. As many researchers before have concluded, tracking learning at short-term experiences is particularly difficult for this reason. Although methodological approaches like BARB, interviews, or surveys help us understand how learners describe their experiences, it is difficult to attribute learning to a specific activity or experience (Brody *et al*., 2008).

While our research showed that many learners described their experience using passive language, we do not know if their description reflects their own actions or are reflections of watching others participate in an activity. To more fully understand these experiences, researchers must also track learners' overt behaviors. Ideally, comparing learner responses with observed behaviors would provide a more comprehensive understanding of how learners experience these small moments.

The overwhelming number of responses that suggest passive learning provides evidence that we may find new ways to engage learners actively throughout short-term experiences.

However, it also raises important questions about how a passive activity, like watching a 3D printer, may be memorable enough or exciting enough to pique visitor interest that they may explore further in the future. That a significant chunk of responses weren't passive demonstrates the capacity for short-term learning environments to be more than passive suggests there's potential for more learners to be engaged more deeply. Understanding how to bridge that gap may be the work of further investigations.

References

Allen, S. (2004), “Designs for learning: Studying science museum exhibits that do more than entertain”, *Science Education*, Vol. 88 No 1, pp.17-33.

Anderson, D., and Lucas, K. (1997), “The effectiveness of orienting students to the physical features of a science museum prior to visitation”, *Research in Science Education*, Vol. 27 No. 4, pp.485-495.

Anderson, D., Lucas, K.B., Ginns, I.S., and Dierking, L.D. (2000), “Development of knowledge about electricity and magnetism during a visit to a science museum and related post-visit activities”, *Science Education*, Vol. 84 No 5, pp.658-79.

Andre, L., Durksen, T., and Volman, M. (2017), “Museums as avenues of learning for children: A decade of research”, *Learning Environments Research,* Vol. 20, pp.47-76.

Ash, D. (2014), “Positioning informal learning research in museums within activity theory: From theory to practice and back again”, *Curator: The Museum Journal*, Vol. 57 No. 1, pp.107-118.

Barmby, P., Kind, P. M., Jones, K., and Bush, N. (2005), Evaluation of lab in a Lorry (Vol. Final Report): CEM Center and School of Education, Durham University.

Barron, B. (2006), “Interest and self-sustained learning as catalysts of development: A learning ecology perspective”, *Human Development*, Vol. 49, pp.193-224

Boisvert, D. L., and Slez, B. J. (1995), “The relationship between exhibit characteristics and learning-associated behaviors in a science museum discovery space”, *Science Education*, Vol. 78, pp.137-148.

Brandes, A. A. (1996), “Elementary school children's images of Science”, Kafai, Y. and

Resnick, M. (Eds.), *Constructionism in Practice: Designing, thinking and learning in a digital world* (pp. 37-69). Lawrence Erlbaum Assoc., Mahwah, NJ.

Bricker, L. and Bell, P. (2014), "What comes to mind when you think of science? The perfumery!" Documenting science-related cultural learning pathways across contexts and timescales. *Journal of Research in Science Teaching*, Vol. 51 No. 3, pp.260-285.

Brody, M., Bangert, A., and Dillon, J. (2008), "Assessing learning in informal science contexts", Commissioned paper by the National Research Council for Science Learning in Informal Environments Committee.

Callanan, M. (2012), "Conducting cognitive developmental research in museums: Theoretical issues and practical considerations", *Journal of Cognition and Development*, Vol. 13 No. 2, pp.137-151.

Cheng, M., Annetta, L., Folta, E., and Holmes, S. Y. (2011), "Drugs and the brain: Learning the impact of methamphetamine abuse on the brain through a virtual brain exhibit in the museum", *International Journal of Science Education*, Vol. 33 No. 2, pp.299-319. doi:10.1080/09500693.2010.482571.

Chi, T. and Wylie, R. (2014), "The ICAP framework: Linking cognitive engagement to active learning outcomes", *Educational Psychologist*, Vol. 49 No. 4, pp.219-243.

Clarke, A. C. (1973), *Profiles of the Future: An Inquiry Into the Limits of the Possible, Revised Edition,* Harper & Row, Publishers, Inc., New York, NY.

Cors, R., Muller, A., Robin, N., and Kunz, P. (2017), "Toward a more comprehensive framework for investigating novelty at out-of-school learning places for science and technology learning", *Progress in Science Education,* CERN.

Creswell, J. (2013), *Qualitative inquiry & research design: Choosing among five approaches*

(3rd ed.). Sage, Los Angeles, CA.

Crowley, K., Callanan, M., Jipson, J., Galco, J., Topping, K., & Shrager, J. (2001), "Shared scientific thinking in everyday parent–child activity", *Science Education*, Vol. 85, pp.712-732.

Denzin, N. K., and Lincoln, Y. S. (2011), *The SAGE handbook of qualitative research* (4th ed.). Sage Publications, Thousand Oaks, CA.

Denzin, N. K., and Lincoln, Y. S. (Eds.), (1999). *The SAGE handbook of qualitative research* (3rd ed.), Sage Publications, Thousand Oaks, CA.

Dierking, L. D., and Falk, J. H. (1994), "Family behavior and learning in informal science settings: A review of the research", *Science Education*, Vol. 78 No. 1, pp.57-72.

Dillon, J. (2007), "Participation at exhibits: Creating engagement with new technologies in science centres", *International Journal of Science Education*, Taylor Francis (Routledge), Vol. 29 No. 12, pp.1531-1555.

Dowell, K. (2011), 2010-2011 Evaluation of the MdBioLab Program. In EvalSolutions (Ed.), (pp. 33): Prepared for: MdBio Foundation, Rockville, Maryland.

Engeness, I. (2019), "Teacher facilitating of group learning in science with digital technology and insights into students' agency in learning to learn", *Research in Science & Technological Education*, DOI: 10.1080/02635143.2019.1576604.

Esbensen, B. M., Taylor, M., and Stoess, C. (1997), "Children's behavioral understanding of knowledge formation in themselves and others", *Cognitive Development*, Vol. 12, pp.53-84.

Falk, J. H., Brooks, P., and Amin, R. (2001), "Investigating the long-term impact of a science center on its community: The California Science Center L.A.S.E.R. Project", In J. Falk (Ed.), *Free-choice science education: How we learn science outside of school* (pp. 115-132), Teachers College Press, New York, NY.

Falk, J.H., Martin, W.M., and Balling, J.D. (1978), "The Novel Field-Trip Phenomenon: Adjustment to Novel Settings Interferes with Task Learning", *Journal of Research in Science Teaching*, Vol. 15 No. 2, pp.127-134.

Falk, J. H., and Storksdieck, M. (2005), "Learning science from museums", *Histo´ria, Cieˆncias, Sau´de-Manguinhos*, Vol. 12, pp.117-143.

Frank, M., Vul, E., and Saxe, R. (2011), "Measuring the development of social attention using free viewing", *Infancy*, Vol. 110, pp.1-21.

Gopnik, A., and Graf, P. (1988), "Knowing how you know: Young children's ability to identify and remember the sources of their beliefs", *Child Development*, Vol. 59, pp.1366-1371.

Kafai, Y. B. (2006), Constructionism. Sawyer, K. (Ed.), *Cambridge handbook of the learning Sciences*, Cambridge University Press, Cambridge, MA.

Lebeau, R.B., Gyamfi, P., Wizevich, K., and Koster, E.H. (2001), "Supporting and documenting choice in free-choice science learning environments", Falk, J. (Ed.), *Free-choice science education: How we learn outside of school* (pp. 133-48), Teachers College Press, New York, NY.

Leinhardt, G., Tittle, C., and Knutson, K. (2000), Talking to Oneself: Diaries of Museum Visits. Retrieved December 29, 2006 from http://mlc.lrdc.pitt.edu/mlc

Lemke, J. (2000), "Across the scales of time: Artifacts, activities, and meanings in ecosocial systems", *Mind, Culture, & Activity*, Vol. 7 No. 4, pp.273-290.

Litts, B. (2015), "Making learning: Makerspaces as learning environments" (Doctoral dissertation). Retrieved from Proquest. (UMI 3672348)

McManus, P. M. (1987), “It’s the company you keep. . . The social determination of Learning-related behavior in a science museum”, *International Journal of Museum Management and Curatorship*, Vol. 6, pp.263-270.

Miles, M., Huberman, M., and Saldaña, J. (2014), *Qualitative data analysis: A methods Sourcebook* (3rd ed.), Sage, Los Angeles, CA.

Moustakas, C. (1994), *Phenomenological research methods*, Sage, Thousand Oaks, CA..

Nasir, N.S., Rosebery, A.S., Warren, B., and Lee, C. D. (2006), Learning as a cultural process: Achieving equity through diversity. R.K. (Ed.) *The Cambridge handbook of the learning sciences* (pp.489–504), Cambridge University Press, Cambridge, UK.

O’Neill, D. K., Astington, J. W., and Flavell, J. H. (1992), “Young children’s understanding of the role that sensory experiences play in knowledge acquisition”, *Child Development*, Vol. 63, pp.474-490.

Pelligrino, J. (2010), The Design of an Assessment System for the Race to the Top: A Learning Sciences Perspective on Issues of Growth and Measurement. Educational Testing Service: http://www.ets.org/Media/Research/pdf/PellegrinoPresenterSession1.pdf

Puchner, L., Rapoport, R., and Gaskins, S. (2001), “Learning in children’s museums: Is it really happening?”, *Curator: The Museum Journal*, Vol. 44 No. 3, pp.237-259

Rahm, J. (2004), “Multiple modes of meaning-making in a science center”, *Science Education*, Vol. 88, pp.223-247.

Ramey-Gassert, L., Walberg, H. J., III, and Walberg, H. J. (1994), “Reexamining connections: Museums as science learning environments”, *Science Education*, Vol. 78 No. 4, pp.345-363.

Samuelson, L. and Horst, J. (2008), "Confronting complexity: Insights from the details of behavior over multiple timescales", *Developmental Science*, Vol. 11 No. 2, pp.209-215.

Sandifer, C. (1997), "Time-based behaviors at an interactive science museum: Exploring the differences between weekday/weekend and family/non-family visitors", *Science Education*, Vol. 81, pp.689-701.

Sandifer, C. (2003), "Technological novelty and open-endedness: Two characteristics of interactive exhibits that contribute to the holding of visitor attention in a science museum", *Journal of Research in Science Teaching*, Vol. 40 No. 2, pp.121-137.

Sheridan, K. M., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., and Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. *Harvard Educational Review,* Vol. 84 No. 4, pp.505-531.

Schauble, L. (1996), "The development of scientific reasoning in knowledge-rich contexts", *Developmental Psychology*, Vol. 32, pp.102-119.

van Manen, M. (1990), *Researching lived experience: Human science for an action sensitive Pedagogy*, Althouse Press, London, ON, Canada.

Van Schijndel, T. J. P., Franse, R. K., and Raijmakers, M. E. J. (2010), "The exploratory behavior scale: Assessing young visitors' hands-on behavior in science museums", *Science Education*, Vol. 94, pp.794–809.

Tables and Figures

Exposure Activity	Description
Fruit Piano/ Makey Makey*	Makey Makey circuits are connected to fruits that, when touched by a participant, make sounds like a piano.
3D Printer*	3D printers on display printing numerous 3D items including 3D cats.
Whack-a-mole*	Makey Makey circuits are connected to multiple pieces of Play-Doh. Participants play a game where moles that pop up on the screen correspond to different pieces of Play-Doh. "Hitting" the Play-Doh acts as the control mechanic to hitting the moles on screen in the game.
Mario*	Mario, a classic Nintendo video game, is played using Makey Makey as the controller, where circuits are connected to Play-Doh.
Squishy Circuits	Any number of activities that allow users to create electronic circuits using conductive and insulating Play-Doh.
Sphero	A programmable robot controlled by a phone or tablets
Ozobot	A robot that uses basic programming concepts and can follow lines, colors, and codes on physical surfaces.
Vegetable & Fruit Conductivity	Makey makey circuits and an LED are connected to fruit or potato to demonstrate conductivity and electricity
"Walk on Water"	Using oobleck--water and cornstarch--to introduce the basic concept of dilatant fluids and how they change with and without force.
Self Inflating Balloons	Using balloons filled with baking soda into a water bottle with vinegar to expose young learners to solid, liquid; gas properties by expanding a solids volume with a gas caused by a chemical reaction
Augmented Reality Sandbox	An AR sandbox that allows learners to shape sand which is augmented by an elevation map that simulates mountains and water. The visual is then represented in real time on a television monitor.

Table 1. Summary and Description of Exposure Activities (those marked with an asterisk were available for this study).

Category	Number of responses
Mentions of a specific maker activity the learner participated in	788 (100%)
Verb use to describe participation	249 (32%)
Pronoun use to describe participation	211 (26%)
Discourse related to science	26 (03%)

Table 2. Summary of responses by coded categories

Activities	Learner Relationship with Activity	
	Tools and learner	Autonomous tools
3D Printer	3	15
Fruit Piano	24	6
Squishy Circuits	1	2
Makey Makey	0	0
Whack-A-Mole	4	1
Mario	0	0
Unspecified	0	0
Total	32	24

Table 3. Cross-reference of Activity and Agency

	See	Play	Make	Do	
3D Printer	60	2	19	5	
Fruit Piano	11	52	9	21	
Total Responses	71	54	28	26	179

Table 4. Cross-reference of activities and verbs use in learner responses

Activities	Emotional responses

3D Printer	33
Fruit Piano	15
Squishy Circuits	2
Makey Makey	1
Whack-A-Mole	1
Mario	2
Unspecified	8
Total	62

Table 5. Cross-reference of activity and emotional language in learner responses

Activities	Total Number of Responses
3D Printer	265
Fruit Piano	278
Squishy Circuits	66
Makey Makey	18
Whack-A-Mole	59
Mario	28
Unspecified	74
Total	788

Table 6. Activities Mentioned in Learner Responses

Activities	Pronoun			
	I	we	you	object/it
3D Printer	44	20	0	18
Fruit Piano	47	14	4	14
Squishy Circuits	11	2	0	3
Makey Makey	3	0	0	0
Whack-A-Mole	12	1	1	2
Mario	2	0	0	0

Unspecified	14	3	1	2
Total	133	40	6	39

Table 7. Cross reference of activities and pronouns in learner responses

Science		Total
Science	Magic	
10	0	
9	4	
6	0	
0	0	
1	0	
0	0	
6	0	
32	4	36

Table 8. Science Talk in Learner Responses

	Interactive Mode	Constructive Behavior	Active Mode	Passive Mode
Chi & Wylie's description of overt behaviors (2014)	Learners interact with a device, a learning environment where both partners' utterances are primarily constructive, and there is a sufficient degree of turn taking	Learners generate or produce outputs or products beyond what was provided in the learning materials. The outputs of generative behaviors should contain new ideas that go beyond the information given	Some sort of motor action or physical manipulation is undertaken (Examples can include rotating objects, inspecting parts)	Learners receive information without overtly doing anything related to learning

Revised framework to analyze responses	Descriptions that suggest interaction with others (two peers), knowledge gained through dialogue with others where each person's ideas are mutually considered	Descriptions that include the output of their work with the tools or activity to create new knowledge	Descriptions that include mention of physical manipulation of objects	Descriptions of seeing or learning something with no mention of doing something

Table 9. Comparison of Chi & Wylie's (2014) four modes of learning and adapted descriptions

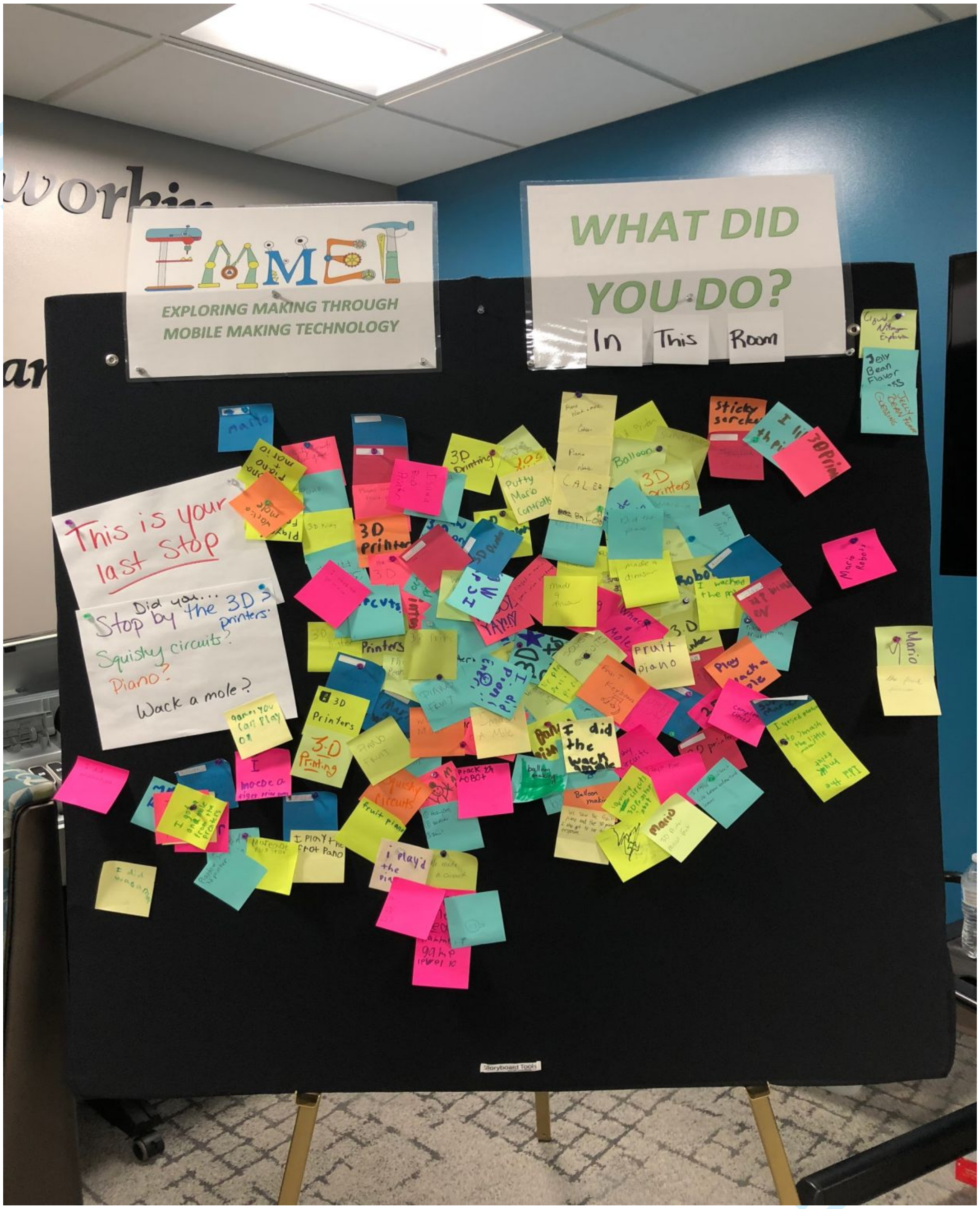

Figure 1: Bricolage Artifact Response Board (BARB) at the STEM Center Learning Days

Appendix A
Full Coding Scheme

Activities	Total # of mentions	Emotional responses	Verb													Pronoun				science				actor	
			participate	create	went	saw	use	print	got	do/did	send	play	make	learn	other	I	we	you	object/it	science	magic	conductivity	electricity	autonomous tools	tools and actor
3D Printer	265	33	0	2	1	60	3	7	2	5	0	2	19	6	4	44	20	0	18	10	0	0	0	15	3
Fruit Piano	278	15	2	1	0	11	3	0	2	21	1	52	9	4	2	47	14	4	14	9	4	4	2	6	24
Squishy Circuits	66	2	0	2	0	4	1	0	0	3	0	3	4	2	1	11	2	0	3	6	0	1	3	2	1
Makey Makey	18	1	0	0	0	1	0	0	0	2	0	2	0	0	1	3	0	0	0	0	0	0	0	0	0
Whack-A-Mole	59	1	1	0	0	2	1	0	0	5	0	8	0	2	1	12	1	1	2	1	0	0	0	1	4
Mario	28	2	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0
Unspecified	74	8	0	0	1	7	1	0	0	2	0	2	10	3	0	14	3	1	2	6	0	0	0	0	0
Total	788	62	3	5	2	85	9	7	4	38	1	72	42	17	9	133	40	6	39	32	4	5	5	24	32