Investigating a Museum-Based Pop-Up Science Program as a "Learner Centric Ecology of Resources"

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Abstract: As informal learning environments, museums encourage social, interest-driven learning among visitors. Pop-up programs are a kind of museum-based experience that include learning goals, yet offer flexibility based on visitors' interests and prior knowledge. To evaluate the design of a pop-up science program, we used the Learner Centric Ecology of Resources (LCEoR) model to frame our investigation of learners' interactions with supportive resources. We used sociocultural discourse analysis and association analysis to identify learners and useful resources, then qualitatively examined how learners related to the intended learning goals of the program (i.e., Knowledge/Curriculum) based on characteristics of their museum visit (i.e., Environment/Organization). As expected from prior research, parents and children acted as learners and resources. However, families' experiences revealed more agency over Knowledge and Environment than indicated in the original LCEoR model. We modified our representation of the model to illustrate how museum studies can extend this learning sciences framework.

Introduction

Museums, as informal learning environments, foster "free choice" learning, meaning that learning is driven by visitors' interests and agendas (Allen, 2004; Dierking & Falk, 1994). As visitors move through exhibits, they have choice over the content, depth, and timing of their learning. Yoon, Elinich, Wang, Steinmeier, and Tucker (2012) summarized informal learning as "fluid, sporadic, social, and participant driven—characteristics that contrast with the highly structured formal classroom experience" (p. 521), which indicates that a special kind of learner-centric experience occurs in informal learning contexts.

To support learning in museums, we can integrate a wide variety of resources (e.g., objects, texts, phenomena, activities, tools, and technologies) into the design of exhibits (Allen, 2004; Yoon et al., 2012). Also, exhibit design is often intended to encourage social interactions, thus promoting the role of visitors as resources. Visitors can explain phenomena (Crowley et al., 2001), investigate shared questions (Allen & Gutwill, 2009; Yoon et al., 2012), and observe others' problem-solving processes (Tissenbaum, Berland, & Lyons, 2017). Both adults and children can interchangeably move between teaching and learning roles by collaboratively generating questions, exchanging information, and negotiating goals (Allen & Gutwill, 2009; Crowley et al., 2001; Mai & Ash, 2012; Zimmerman, Reeve, & Bell, 2008). From a distributed scaffolding lens, the combination of social and material resources can deepen visitors' conceptual understanding when the purpose of each resource is clear (Allen, 2004; Puntambekar & Kolodner, 2005; Tabak, 2004; Yoon, Anderson, Park, Elinich, & Lin, 2018).

While many museum exhibits and programs are designed to support learning, visitors may use resources in unanticipated ways, especially because learning is voluntary and interactions are brief (Allen, 2004; Block et al., 2015; Lyons, 2018). Young children, in particular, may need guidance from adults or older children when making sense of exhibits (Crowley et al., 2001; Falk & Dierking, 2000). We cannot assume that all visitors, as diverse as they are, will readily perceive the intended affordances of each resource, but we can still identify design principles for resources that support visitors' learning (Block et al., 2015; Borun, 2008; Crowley et al., 2001; Lyons, 2018; Yoon et al., 2018).

Evaluation frameworks such as Luckin's (2008) Learner Centric Ecology of Resources (LCEoR) can help us examine how learners interact with available resources (and especially technology) at timely moments in their learning. Luckin (2008) termed available resources as the *Zone of Available Assistance* (ZAA), and described the *Zone of Proximal Adjustment* (ZPA) as the implementation of appropriate resources at timely moments. The LCEoR framework situates the *Learner* at the center of the learning context. The framework also identifies several key elements of the learning context, such as the kinds of *Knowledge* learners are expected to learn; the *Curriculum* that reflects social and cultural capital of this knowledge; the *Resources* provided to support learning; and the *Administration* that presents these resources. The LCEoR framework also identifies the *Environment* in which learning occurs, as well as structures of the Environment that impact how learners interact (i.e., the *Organization*). To connect these elements, the LCEoR framework considers how each element interacts with others. In particular, Luckin (2008) noted that the learner has limited control over specific elements, as indicated in the following quote:

> … a learner's activity has little impact upon the nature of knowledge and curricula, likewise they often have little impact upon the organisation of their Environment. Hence in Fig. 2, which illustrates this Ecology of Resources approach there are bi-directional arrows linking Knowledge, Resources and Environment, and linking Curriculum, Administration and Organisation. However, the arrows between a learner and her Environment and between a Learner and the Knowledge she seeks are uni-directional. (p. 453)

By identifying these elements in a museum context, and especially investigating how and when resources are leveraged at specific points to support learning, we can improve how we incorporate resources into the design of museum exhibits and programs while revealing museum-specific characteristics of learning.

In this study, we used the LCEoR framework to evaluate the design of a museum-based pop-up program. Pop-up programs are often intended to reach audiences beyond the museum walls (Feinstein & Meshoulam, 2014; Grant, 2015). However, in this study, the pop-up program was an extension of a middle-school life sciences curriculum that was hosted in two science museums, with the intention of understanding how visitors interacted with resources to understand science topics. We investigated how the pop-up program represented a Learner Centric Ecology of Resources with the purpose of redesigning the program to better support learning. In particular, we considered how the voluntary, interest-driven, and often brief nature of a museum visit impacted relationships among learners (i.e., visitors) and elements of the LCEoR framework. We used an interdisciplinary approach that combined principles from the learning sciences with prior literature about family learning in museums. Our research questions were: (1) How was each element of the LCEoR framework represented in this pop-up program? (2) What were the relationships among these elements, including learners? and (3) How might we adapt or extend the LCEoR framework to reflect the nature of learning in museums? By investigating these questions, we can engage in reciprocal theory building across formal and informal learning contexts (Paris & Ash, 2000) while gaining practical insights into the design of museum programs.

Methods

Design of the pop-up program and facilitation procedure

The pop-up program was developed as an extension of a middle-school life sciences curriculum in which students designed their own compost bio-reactors (Dornfeld Tissenbaum & Puntambekar, 2018). The design-based curriculum focused on science topics such as matter, energy, ecosystems, and interdependent relationships among organisms. Students learned about these topics and other variables related to compost (e.g., materials, moisture, and particle size) as they worked on their designs over eight weeks.

As a museum-based extension, the pop-up program featured two activities: (i) a sorting activity in which families sorted disposable items into landfill, recycling, and compost, and (ii) a simulation activity in which families simulated building a compost heap. Considering that families with children comprise a significant base of museum visitors (Borun, 2008), and that many of these children would be of preschool to elementary age, we modified the activities to highlight the impact of human activity on waste management. The Next Generation Science Standard K-ESS3-3 (communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment) summarizes expected learning outcomes of the modified activities in the pop-up program.

When designing the program, we used a distributed scaffolding lens (Puntambekar & Kolodner, 2005; Tabak, 2004; Yoon et al., 2018) to purposefully integrate a variety of resources into the program, with the goal of examining how visitors interacted with these resources as scaffolds (Dornfeld Tissenbaum, 2018). Table 1 (below) lists the included social and material scaffolds, which describe the *Zone of Available Assistance* in the pop-up program. To understand how social and material scaffolds supported learning, we implemented the pop-up program at two science museums (a natural history museum and a science center) in a mid-sized U.S. Midwestern city. The first author facilitated the program as a participant-observer. She used a script (Table 2, below) when interacting with visitors. She modified the script as needed to align with visitors' ages, interests, and time constraints, and to build rapport with participants (Falk, Moussouri, & Coulson, 1998; Grenier, 2009; Sword, 1999).

Table 1: Social and material scaffolds in the pop-up program

Social Scaffolds	Material Scaffolds in Sorting Activity	Material Scaffolds in Simulation Activity
Parents Children Facilitator	Ideal Compost Guide Real-Life Decomposition Model "Greens" Model "Browns" Model Sorting Items Sorting Bins	Ideal Compost Guide Virtual Compost Bin Materials Menu/Information Compost Mixture Data Simulation Output Simulation Comments

Table 2: Facilitator script for interactions

Purpose	Script
Identify motivation for visit	What brings you to the museum today?
Assess prior knowledge	So, what do you know about compost? I have some materials here that I need to throw out, and I'd like you to help me sort them into the correct containers. Can you help me? Where do you think this item goes? Can you tell me why you put *[item]* there *[into compost/trash/recycling*]?
Facilitate observations in sorting activity	What do you notice about the real-life compost? What's an example of a green material? What's an example of a brown material?
Facilitation observations in simulation activity	Would you like to try making your own compost? I have a simulation of a compost on this laptop. You can make as many as you'd like. You can pick what materials you want here [indicates Materials button]. Just shake the shaker to add materials. You can change the materials whenever you want. When the simulate button lights up, you can press it. *As visitors are working:* What are you adding to your compost? Why are you including [material]? *If visitors use a trial-and-error approach:* Here's an example of what a "perfect" compost looks like *[indicating Ideal Compost Guide].* Do you think you can make the perfect compost?
Assess new knowledge	Now that you know about compost, would you like to show me how you'd sort the materials again? What goes where? Why? What about the brown paper bag? What do you think - does it go in recycling or compost?

Participants and data sources

Over the course of five weekend afternoons (approximately 22 hours), the first author facilitated the pop-up program at the museums. Participating families were recruited using an active consent and assent process. Twenty-five families (defined as at least one adult and one child/teen who were related) consented to participation, consisting of 36 adults and 36 children.

The first author collected video data of families' interactions with the pop-up program. Two cameras were angled to capture gestures as families participated in the sorting and simulation activities. Due to considerable background noise, two audio recorders were placed to supplement sound recorded by cameras. Screen capture software (Screencastify) was used to record families' actions in the simulation.

We transcribed families' conversations with the facilitator and included gestures that indicated use of resources and/or bids for joint attention (e.g., pointing). Data for two families could not be transcribed due to excessive background noise, which resulted in a final sample of 23 families (34 adults, 33 children). Seventeen families completed both the sorting and simulating activities, while six families with very young children completed the sorting activity but not the simulation. The 23 transcripts included 3,701 turns of talk, with an average of 161 turns of talk per family. On average, families spent over nine minutes at the pop-up program, which is longer than the average dwell time at an exhibit (Block et al., 2015; Hornecker & Stifter, 2006).

Data analyses

Our goals were to identify the elements of the LCEoR framework as represented in this pop-up program, as well as the relationships among them, and to consider how we might adapt or extend the LCEoR framework to reflect the nature of learning in museums. As such, we used sociocultural discourse analysis (Mercer, 2004) to identify who the learners were in each family and how family members acted as resources for each other. To identify learners, we coded talk that indicated a need for support (e.g., not understanding, help-seeking) based on research about responsive support by Koole and Elbers (2014). We also coded talk that indicated understanding or learning (e.g., identifying and describing, interpreting and applying) based on research about family learning in museums by Borun, Chambers, and Cleghorn (1996). Wood, Bruner, and Ross's (1976) description of scaffolding provided a base for coding kinds of support (e.g., recruiting interest, maintaining direction, reducing degrees of freedom, marking critical features, managing frustration, and demonstrating). We added two emergent codes for support based on qualitative examinations of the data: revoicing (Tabak & Baumgartner, 2004) and making connections (Mai & Ash, 2012). The first author coded 20% of the data (763 turns) with an external coder and achieved a global Cohen's kappa score of .892 on that subset. All Cohen's kappa values for individual codes ranged from substantial to almost perfect (Dornfeld Tissenbaum, 2018).

To understand how resources were used in the pop-up program, we used association analysis (Tan, Steinbach, Karpatne, & Kumar, 2019) to identify when resources were included in social support. Association analysis identifies when two variables co-occur. In this case, the first variable indicated social support, and the second variable indicated material support (i.e., the physical or digital resource used). Association analysis calculates the *support* for each variable, which is found by dividing the frequency of a variable (or co-occurring variables) by total occurrences (i.e., turns of talk). We used an open-source machine learning tool (Orange3) and the *apriori* algorithm to identify code co-occurrences with at least 1.0% support (i.e., social support plus material support co-occurring in at least 37 turns of 3701 total turns).

After qualitatively and quantitively comparing how families participated in learning and providing support, we reflected on our design and facilitation of the pop-up program, then mapped our reflection to the LCEoR framework. Knowledge, Curriculum, Resources, and Administration were already integrated in the design of the pop-up program. The Environment and Organization emerged from qualitative reflection on the intended and actual experiences with facilitating the pop-up program. We also reflected on the relationships among these elements and identified gaps where the LCEoR framework seemed to miss critical aspects of this museum-based experience.

Findings

Family members as learners and resources

The LCEoR framework centralizes learners in a particular learning context. We found that both parents and children acted as learners in this pop-up program. Parents demonstrated learning talk (as demonstrating need for support or as learning) in 32.5% of 784 total codes. This was demonstrated as help-seeking (8.7%), indicating confusion (3.4%), interpreting and applying program topics (18.1%), and identifying and describing (2.3%). Children also demonstrated learning talk in 88.9% of 888 total codes. This was demonstrated as indicating confusion (18.5%), help-seeking (17.6%), interpreting and applying program topics (37.6%), and identifying and describing (15.2%). Together, these findings indicate that parents participated as learners at least some of the time, while children participated as learners the majority of the time.

Parents and children also acted as resources for each other in the pop-up program, although children provided support less often than parents. Parents provided support in the majority of their talk (529 of 784 turns, 67.5%). In contrast, children's support was relatively infrequent (99 of 888 codes, 11.1%). Table 3 (below) shows parents' and children's support as individual kinds of support. Most support provided by children (97 codes) was provided from one child to other children in the family. From qualitative observations, we noted that instances of children's support generally required the presence of a sibling, with support being provided from an older sibling to a younger sibling. For example, in a family with a father and two children, the father first helped the older brother to participate in activities as the younger brother watched. When the father and facilitator began a discussion about compost, the older brother helped his younger brother to participate in the same activities. Only 2 codes indicated that a child provided support to a parent. In families with single children, parents often acted as co-facilitators of their child's learning.

Together, these findings indicated that parents and children interchangeably took on roles as learners and resources in the pop-up program, which we expected from prior research (e.g., Mai & Ash, 2012). However, parents were more likely to provide support compared to children, and children were more likely to demonstrate

a need for support or evidence of learning than parents. With respect to the LCEoR framework, we considered both parents and children as Learners, and parents and siblings as Resources.

Table 3: Percentage of codes indicating forms of support for parents and children

Support Code	% of Parents' Total Codes	% of Children's Total Codes
Recruiting interest	0.51	0.11
Maintaining direction	2.17	0.11
Reducing degrees of freedom	37.24	8.33
Marking critical features	9.57	1.58
Managing frustration	0.38	0.11
Demonstrating	0.64	0.56
Revoicing	10.08	0.34
Making connections	6.89	0.00

Key resources in the pop-up program

In addition to integrating family members as resources, we integrated a variety of material resources (see Table 1) to support learning in the sorting and simulating activities. The association analysis revealed several rare but important interactions between social and material resources in the pop-up program, as indicated by the code co-occurrences within the same turn of talk. First, the facilitator combined verbal support with sorting items (support = 2.007%) and the real-life decomposition models (support = 1.154%). Qualitatively, the facilitator used sorting items and real-life models to facilitate joint activity among family members. Sorting items were intended to promote discussion among visitors, especially around items that were not easily sorted (e.g., a disposable coffee cup with a plastic lid and a cardboard sleeve). The real-life models (which consisted of decomposing flowers, vegetable peels, and shredded newspaper) were used to show the importance of including a variety of materials when building a compost heap. The sorting items and real-life models provided support as expected, with the added bonus of serving as a reference for families who participated in the simulation activity.

Another important interaction occurred when children used sorting items to demonstrate a need for support (support = 1.154%). Qualitatively, children could easily pick up sorting items and show them to parents and the facilitator as they asked for help. Children often asked what certain items were, such as the disposable coffee cup. Because there were multiple sorting items that could be easily moved, children could readily ask for help with sorting, which encouraged joint activity among family members – an unexpected but positive outcome. Based on these interactions, we can identify the sorting items and real-life models as key Resources in the LCEoR framework for this pop-up program.

The pop-up program as a learner centric ecology of resources

To map the pop-up program context to the LCEoR framework, we qualitatively reflected on families' experiences with the program as well as the facilitation experience. In comparing the original design and actual experiences, the first author noted that she often went "off script" to account for families' interests and prior knowledge. For example, several families asked for practical advice in building (or rebuilding) a backyard compost heap. Another family asked whether carrot peels should go in the waste bin or the garbage disposal when compost was not an option. In reality, a three-year-old girl new to sorting waste requires a different kind of interaction than a thirty-year-old man who leads a composting program at work. These off-script moments show real-world connections to Knowledge and Curriculum, and indicate the need for flexibility when facilitating pop-up programs for diverse audiences.

We also reflected on how the voluntary nature of the families' visits gave visitors control over the days they visited the museum, the duration of their visit, and their ability to walk away from activities that were not interesting or relevant to them. Three important factors emerged from this: (1) six families did walk away after the sorting activity, stating that their children were too young to participate in the simulation activity; (2) this demonstrates how visitors influence the Environment and Organization of museum visits; and (2) this study sample is likely limited to visitors with interest in compost and/or educational programs.

The actual outcomes of this pop-up program indicated a need to modify the LCEoR framework in two ways. As quoted earlier, Luckin (2008) stated, "…the arrows between a learner and her Environment and between a Learner and the Knowledge she seeks are uni-directional." (p. 453). However, in the context of this pop-up program, we find that bi-directional arrows are needed between the Learner and Knowledge/Curriculum and between the Learner and the Environment/Organization (see red arrows in Figure 1 below). This modification

reflects the free-choice, interest-driven experience of the museum visit, as well as modifications to the pop-up program that fit the Learner's interests, questions, prior knowledge, and time constraints. Facilitation was focused on negotiating, rather than imposing, learning in this context.

In summary, we found that both parents and children acted as Learners in the pop-up program. Parents acted as Resources, as did some children when siblings were present. Other key Resources included the sorting items and the real-life models of decomposition. After reflecting on families' experiences and the facilitation experience, we found that Learners had considerable agency over Knowledge/Curriculum and Environment/ Organization due to location of the pop-up program in museums that foster interest-driven learning. This is reflected in the modified LCEoR model in Figure 1.

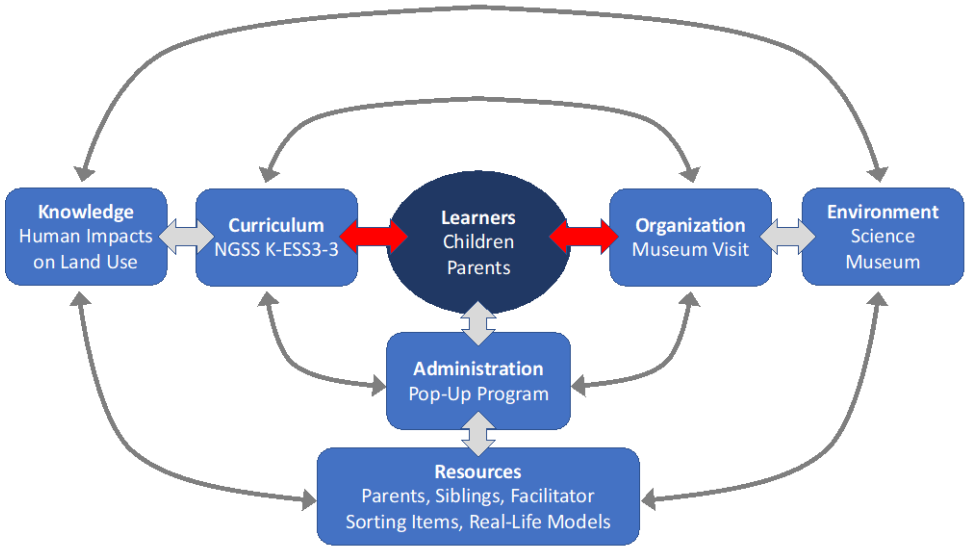

Figure 1. The modified LCEoR model for the pop-up program, based on Figure 2 from Luckin (2008).

Discussion and conclusions

In this study, we aimed to answer the following research questions: (1) How was each element of the LCEoR framework represented in this pop-up program? (2) What were the relationships among these elements, including learners? and (3) How might we adapt or extend the LCEoR framework to reflect the nature of learning in museums? To answer Questions 1 and 2, we represented each element and its relationship to other elements in Figure 1. We noted two differences in our representation based on the voluntary, interest-driven nature of a museum visit. Because visitors chose to participate in the activities and could leave at any time, visitors had greater agency over the Environment and Organization than indicated in the original LCEoR framework. Also, visitors could express their own interests as questions about compost and disposable items, and visitors shared different levels of prior knowledge about compost. Rather than ignore these questions and differences in prior knowledge, the facilitator modified her interaction script, thus negotiating the learning goals of the program. To show this, we added bidirectional arrows between the Learner and Knowledge/Curriculum, and between the Learner and Environment/Organization, which answers Question 3.

In our qualitative examination of the data, we found that both parents and children acted as learners and resources for learning, which we expected based on prior literature (e.g., Mai & Ash, 2012; Zimmerman, Reeve, & Bell, 2008). However, children acted as resources most often when a sibling was present. The presence of other children, and especially younger children, created opportunities for children to provide support. In contrast, instances of children providing support to parents were exceedingly rare. For the one family in which this occurred, the child had experience with composting at school. This opens new questions for investigation around collaboration among family members, and for different kinds of families.

We also identified key interactions between social and material resources for supporting learning. The sorting items and real-life decomposition models enhanced social support from family members and the facilitator. The sorting items were used to demonstrate need for support and to provide support, as each participant could easily pick up sorting items and show them to others. This finding echoes earlier studies of multi-user museum experiences as being more family-friendly (Borun, 2008). Also, the real-life models helped visitors to see decomposition in action, making the program more multi-modal while making the idea of compost more tangible (Borun, 2008). The ways in which these resources were used indicated families' *Zone of Proximal Adjustment*, in

which available resources were used at timely moments in learning (Luckin, 2008). This kind of evaluation offers practical guidance by identifying which resources are critical for learning and how they provide support (e.g., Yoon et al., 2018).

We used the Learner Centric Ecology of Resources framework (Luckin, 2008) because of its alignment with distributed scaffolding (Puntambekar & Kolodner, 2005; Tabak, 2004; Yoon et al., 2018), the lens used to design the pop-up program. We found that Knowledge, Curriculum, Administration, and Resources were described in the program design, but characteristics of the Environment, including its Organization, were less known. After qualitatively examining the data, we found that the interest-driven nature of a museum visit (in which the pop-up program was situated) impacted how Learners related to other elements in the LCEoR framework, namely Knowledge and Environment/Organization. Visitors had relatively high agency in this pop-up program, allowing them to negotiate the content, timing, and overall facilitation of their interactions.

This pop-up program represents an intermediate step between the LCEoR examples and the Learner Generated Contexts described by Luckin (2008). This program had intended learning goals, but the goals were negotiable in light of museum-specific factors. In general, we can consider the facilitated pop-up program to be more "responsive" to visitors' interests, questions, prior knowledge, and time constraints than formal learning environments, given the priority on learners' choices in museums (Falk & Dierking, 2000; Falk et al., 1998; Grenier, 2009; Koole & Elbers, 2014). Future investigation of facilitation, especially "off script" moments, can reveal best practices for support, especially for responsiveness to diverse audiences and dialogic interactions (Grenier, 2009; Koole & Elbers, 2014; Puntambekar & Kolodner, 2005). Additional studies of non-facilitated programs and exhibits can further reveal nuances of museum learning as represented in the LCEoR model.

In conclusion, the Learner Centric Ecology of Resources framework is useful for identifying learners' interactions with key resources in a supportive learning context, such as a pop-up program in a science museum. However, the unique characteristics of the learning context can promote unexpected interactions among learners and elements of that context. Based on our investigation of families' interactions in a pop-up science program, we found that the interest-driven, voluntary nature of a museum visit required a modified representation of the LCEoR model to reflect visitors' considerable agency in museum contexts. Design evaluation helps to understand how resources effectively support social interaction and learning among museum visitors, as intended or not (e.g., Yoon et al., 2012).

While the findings are not entirely surprising, this study illustrates how the extension and application of an existing framework to a museum-based context can provide insight into informal learning processes, especially in how the design of pop-up program supported learning in actuality. This study is limited by the small sample of participating families (who were likely interested in composting and/or pop-up programs), and we plan to study families' learning in more depth based on explanations of science in museums (Crowley et al., 2001) and mechanistic reasoning (Russ, Coffey, Hammer, & Hutchinson, 2009). Yet, the interdisciplinary nature of this study shows how a learning sciences framework was productively applied to a museum context, despite the seeming disconnect between the learning sciences and museum studies, can seem disconnected–and demonstrated museum-based studies can inform and extend our understanding of supportive learning processes (Paris & Ash, 2000). Further interdisciplinary studies can support evidence-based decisions for exhibit and program design while building deeper understandings of the ways people pursue and participate in informal learning.

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