EXAMINING THE DEVELOPMENT OF SCIENTIFIC REASONING IN CONTEXT

A Museum and Laboratory Partnership

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The Team

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The Museum Setting

The educational mission of the Thinkery (formerly the Austin Children's Museum) is to create innovative learning experiences for children and families to equip and inspire the next generation of creative problem solvers. The Thinkery is a foundation for learning and exploration. Galleries such as Innovator's Workshop and Kitchen Lab emphasize skill development and creative problem solving, while also bringing "STEAM" subjects (science, technology, engineering, art, and math) to life for visitors. The emphasis of all educational programming at the Thinkery is on facilitation and inquiry-based learning. The Thinkery is committed to ensuring that each visit includes a meaningful interaction with educators and staff. This commitment has established the Thinkery as an authority on family education throughout Central Texas.

In this chapter, we describe the collaboration between the Cognition, Culture, and Development Lab (CCD Lab) at the University of Texas at Austin and the Thinkery in Austin, TX. As institutions with distinct missions—one to engage in empirical research with the goal of advancing our understanding of the development of scientific reasoning, and the other to create an inclusive and innovative learning environment where children and their families can play while engaging with science—the collaboration between these two institutions has been a dynamic process that has grown and evolved over the last 5 years. First, we will describe the history of the partnership between the CCD Lab and the Thinkery. Next, we will describe the research that has resulted from this collaboration. Finally, we will discuss the goals of the partnership between the CCD Lab and the Thinkery, provide researcher and practitioner perspectives on the partnership, and discuss mutual benefits and challenges.

History of the Partnership Between the CCD Lab and the Thinkery

The late Becky Jones, director of education at the Austin Children's Museum (ACM) for nearly 30 years, had a passion for educational research and for building university–museum partnerships. Cristine Legare and Becky Jones began working together in 2009 to increase the involvement of the ACM in educational research on children's learning. The partnership began with researchers from the CCD Lab engaging museum visitors as participants in research on the development of children's causal explanations and exploratory behavior. Children's museums provide a venue for collecting data, which contribute to our understanding of early science learning with the added benefits of allowing researchers to sample from a population that is larger and potentially more diverse than the population typically attracted to the university lab setting. This fruitful partnership allowed for the collection of data, which has resulted in more than 10 empirical papers published in top-tier cognitive and developmental journals, including Child Development, Child Development Perspectives, Cognition, and The Journal of Experimental Child Psychology. The collaboration with the Thinkery has been instrumental to the production of this line of empirical research on early science learning. This partnership has also recently resulted in a collaborative grant funded by the National Science Foundation to Maureen Callanan at UCSC, Cristine Legare at UT Austin, David Sobel at Breeze University, and museum partners at the San Jose Children's Museum, the
Thinker, and the Providence Children’s Museum to examine cultural diversity in parent–child explanation and exploration.

Research Conducted at the Thinker in Eastern Europe

Curiosity is characteristic of early childhood; there is evidence that both infants (Stahl & Feigenson, 2015) and young children (Legare, Gelman, & Wellman, 2010; Legare & Gelman, 2014) are more motivated to explain unexpected outcomes and engage in causal learning through exploration (Schulz & Borowicz, 2007). Our collaborative research at the Thinker is based on research demonstrating that explaining and exploring work in tandem to drive the scientific reason- ing process in early childhood. Our long-term objective is to apply our understanding of early scientific reasoning to improve early science education (Gelman, Brenner, Macdonald, & Roman, 2010).

There is growing evidence from research in developmental psychology that children’s explanations and exploration benefit learning (Austerliz & Wellman, 2006; Crowley & Siegler, 1999; Nicolopoulou, 2010; Rittle-Johnson, Saylor, & Swygert, 2008; Siegler, 1995; Singer, Golinkoff, & Hirsh-Pasek, 2006). Experimental evidence indicates that generating explanations benefits both causal learning and the capacity to engage in generalization (Lombrizo, 2006; Wellman, 2013). Children’s exploratory behavior has also been linked to positive learning outcomes (Baldwin, Markman, & Melartin, 1993; Borowicz, van Schijndel, Friel, & Schult, 2012). For example, there is evidence that even young children can disambiguate causal variables by exploring relevant evidence (Cook, Goodman, & Schulz, 2011; Schulz, Borowicz, & Griffiths, 2007). Research examining the kinds of outcomes children are most motivated to explain and explore has demonstrated that explaining inconsecutive outcomes may be especially useful in guiding and directing exploratory behavior in the service of learning (Legare, 2012).

Much of the research conducted by the CCD Lab at the Thinker has exam- ined the relations between explanation, exploration, and scientific reasoning. One of our research projects has examined how self-explanation may uniquely and selectively benefit causal learning. Although there is some evidence that explana- tion may benefit learning more than comparison activities in older children (McElloon, Durkin, & Rittle-Johnson, 2013; Rittle-Johnson et al., 2008), little is known about the process underlying these effects in early childhood. There are a number of ways that explanation may benefit learning. For example, explanation may selectively focus children on identifying unobserved causes, internal mechanisms, causal functions, and causal mechanisms (Kurl, 2006; Legare, 2012; Legare, Wellman, & Gelman, 2009; Walker, Lombrizo, Legare, & Gopnik, 2014), and on making generalizations (Walker, Williams, Lombrizo, & Gopnik, 2012; Williams & Lombrizo, 2010).

One series of studies conducted at the Thinker (Legare & Lombrizo, 2014) examined how and why explanation influences learning in young children. In these studies we examined the unique and selective effects of explanation compared to other tasks that require equivalent cognitive engagement. In two studies, we compared children’s performance on measures of causal and noncausal learning based on whether they were asked to explain or observe (Study 1) and explain or describe (Study 2).

First, we gave 3- to 6-year-old children a novel mechanical toy with visible interlocking gears. When the gears are connected in the correct way, a crank operates the machine and makes a fan turn. The three middle gears have peripheral pieces attached to them that are used to differentially assess children’s memory versus their understanding of the functional mechanism underlying the machine. Children participate in one of two conditions: an observation condition in which children attend to the machine but do not explain or explore (observe condition), and an explanation condition in which children were asked to explain how the machine works without exploring it (explain condition).

Following the experimental manipulation, children participated in three additional tasks. Two of the tasks are learning measures (presented first) followed by one procedural knowledge measure in which children are asked to reconstruct the machine. In each of the learning tasks, the intact machine is presented to the child with one gear missing. In the memory learning task, another five candidate para- meters are presented to the child to assess the child’s memory for the exact missing piece. All five pieces are the correct size and shape, but only one is the same color as the missing piece. In the mechanism learning task, five candidate parts are presented to the child, none of which are identical to the missing part. The choices are: a part of the correct size and shape but different color, a part of the correct size but incorrect shape, a part of the correct size and incorrect shape, a peripheral piece they have seen before but which is not the correct shape, and a distracter part. In each task the child is asked to select the part that will make the machine work. After completion of the learning tasks the machine is taken apart. All of the gears are removed from the base, and the peripheral parts are removed from the three middle gears. Participants are asked to reconstruct the machine in exactly the same way they saw it before and make it work in the reconstruction task.

Data from this experimental study provide evidence that the benefits of explana- tion are selective: children who explain learn more about the causal mechani- sms in the machine and less about noncausal information (i.e., memory for causally irrelevant, peripheral details such as color). This suggests that explanation may be especially beneficial for causal learning. In our next study, we compared how explanation versus description impact causal and noncausal learning to control for effects of verbalization.

Children were introduced to the same machine as in the previous study, and asked either to describe the machine but not explore it (describe condition) or to explain how the machine works without exploring it (explain condition). Using the same measures as the previous study, we assessed learning as a function of the type of verbal response, with children’s spontaneous utterances coded for the presence of explanations. We also presented children with a generalization task to examine children’s ability to recreate the causal mechanical function of the gear machine.
We examined the extent to which children understood the machine's functional-mechanical relations, remembered perceptual features of the machine, successfully reconstructed the machine, and generalized the function of the machine in constructing a novel machine. Our findings replicated and extended key findings from the first study. First, we found reliable effects of explanation when comparing the context of children's responses rather than the experimental prompt that they received (i.e., to describe versus explain the machine). Children who explained outperformed non-explainers on measures of causal learning, but not on measures of non-causal learning. This result is important in establishing that effects of explanation do not derive solely from the use of language, as all children produced verbal responses. The effects of explanation were not eliminated when compared with alternative kinds of verbalization is especially striking in the context of our two studies given that the noncausal properties that we tested (e.g., color) were, if anything, easier to express linguistically than the causal properties (e.g., gear shape).

Across two studies, children who provide an explanation performed better on measures of causal than non-causal learning. In our study comparing explanation to description, we found evidence that children who explained also engaged in more generalization. Thus, the effects of explanation are both selective in that they benefit causal more than noncausal learning and unique from other kinds of engagement, such as observation or verbal description. These results also indicate that self-explanation can benefit young children's learning, even in the absence of feedback from others.

In other lines of research, members of the CCD Lab have demonstrated that explaining and exploring are not mutually exclusive in spontaneous conversation and play, but instead may operate in tandem (Legare, 2012, 2014). Explanation allows children to generate, construe, and evaluate hypotheses. Explanation allows children to test hypotheses. Explanation and exploration are thus connected in the context of causal learning and allow children to move beyond concrete appearance to reason about abstract causal structure. We have also demonstrated that explaining inconsistency guides exploratory behavior. For example, the kind of explaining children generate for inconsistent outcomes differentially predicts (a) the kind of exploratory behavior children engage in, (b) the amount of hypothesis-testing exploratory behavior they engage in, and (c) the extent to which they modify their hypotheses when confronted with disconfirming evidence.

Museum Practitioners' and Researchers' Perspectives on the Partnership

In constructing the partnership, researchers at the CCD Lab and practitioners at the Thinkery constructed a set of objectives for the partnership. We endeavor to more effectively deliver activities and exhibits that promote science learning to the Thinkery, based on cutting edge research on children's learning. This learning can best occur when we engage museum staff in the research process in order to build a better understanding of the research process, what learning research looks like, and how to incorporate it into the museum environment. In doing so, we promote broad thinking from many different perspectives, which informs how to apply insights about parent-child learning to the wide variety of activities, spaces, and educational programs. We also aim to demonstrate the "nature of science" to staff, visitors, and program participants. Public outreach serves to inform the community about learning research by making the research visible and accessible to the public.

Researcher Perspective on Collaborating With Practitioners

The partnership with the Thinkery provides a variety of unique opportunities to enrich the research conducted in the CCD Lab. For example, working in the Thinkery allows us to examine learning in context; examining parent-child interaction in the context of meaningful science learning experiences would not be possible inside the walls of the laboratory. Collaborating with the Thinkery also provides us with the challenge of translating our data about causal reasoning and scientific reasoning in early childhood into information that science practitioners can use to inform and improve museum visitors' learning experiences. Another advantage of working with museum practitioners at the Thinkery is to learn more about how to modify the design of our research to provide insight into questions about learning in context.

The CCD Lab has also assisted the Thinkery with a visitor research project that informed the development of the Thinkery's new early learners' programs. Research assistants have worked with staff to develop formative evaluation surveys, collect and analyze data, and make programmatic suggestions. This increased the Thinkery's capacity immensely in this area and guided decision-making around core programming before the museum transitioned into the new space. This is not a project that the staff would have had the capacity to accomplish without assistance from the CCD Lab. The commitment of time and expertise was key in enabling the museum to approach the project with a more research-based strategy.

In the new Thinkery facility, the CCD Lab has continued their work of collecting data on early science learning. As this partnership has matured, great improvements have been made in the presentations and professionalism on both the part of the Thinkery and the CCD Lab staff. Museum visitors are becoming more accustomed to participating in research during their visit to the museum. Museum staff at all levels have also bought into this partnership, with the result that staff are more receptive to visitor feedback and using data to inform decisions. Moving forward, this partnership has great potential to become a true collaboration. Funders are increasingly holding informal learning institutions more accountable in terms of impact on visitors and educational outcomes.
Designing the new facility for the Thinkery afforded museum staff the opportunity to rethink the visitor experience in terms of exhibits, programs, and staff interactions. With this fresh perspective, the Thinkery staff have been able to draw from experience and research to design new exhibits that not only engage visitors in STEAM learning, but also provide flexibility for open-ended use. This flexible “platform approach” allows museum staff to quickly and easily switch out exhibit components so that visitors might have new experiences with each subsequent visit. This fluidity also supports an attitude of ongoing refinement, with the ability to modify exhibits and experiences without incurring huge costs, the museum can be receptive to feedback from visitors and input from researchers.

The studies conducted by the CCD Lab provide insight into how parent interaction affects children’s causal learning and scientific reasoning; although the museum cannot control parent interaction, museums can provide guidance for parents in the form of verbal suggestions, signage, handouts, and modeling best practices during staff-led programs. Thinkery staff will incorporate findings from these studies into staff training sessions on effective facilitation and program development. Furthermore, as the Thinkery continues to refine existing exhibit experiences and design new components, findings from these studies will inform the style and purpose of exhibit text. This research partnership between the Thinkery and the CCD Lab will not only yield empirical evidence to support program, exhibit, and staff development but will also increase the credibility of the museum in the field of informal education.

Discussion of Mutual Benefit

The spirit of the Thinkery is one of adaptability, flexibility, and responsiveness. The staff prides itself, and the facility, on its ability to reflect on successes and challenges and to quickly make changes for improvement. With this attitude, Thinkery staff welcome feedback from guests to improve the visitor experience, from suggestions to offer sensory-friendly hours for children on the autism spectrum to providing waterproof smocks for the water exhibits. The findings from the proposed research projects will provide information that can immediately benefit the programs and the staff who deliver them. As the CCD Lab shares its data analysis with the museum, the staff will be able to make adjustments to program facilitation and program content that incorporate the suggestions from the research. The CCD Lab research will provide a critical step in the feedback loop for exhibit and program refinement at the Thinkery.

Challenges of Partnerships Between Museum Practitioners and Researchers

There are a number of challenges associated with this partnership. The foremost of these challenges is the pace with which each entity can conduct and achieve their
stated goals. The Thinkery prides itself on being a nimble and fast-paced organization that can respond quickly to the desires of its members. This means that when new ideas, concepts, or ways to improve the museum are developed, they can be implemented quickly. The scientific research process, on the other hand, is much more methodical and time consuming. The CCD Lab strives to conduct cutting-edge research that is informed by theory and utilizes rigorous and creative methodologies, a process that by its nature takes time. Thus, both partners in this collaboration must acknowledge the pace at which the other entity can operate and must work to find a common ground upon which new strategies can be implemented in the museum without compromising the integrity of the research. New researcher-practitioner partnerships will benefit from close collaboration and frequent communication to ensure that both parties construct shared goals and maximize mutual benefits.

Another challenge to the partnership has been integrating the participation in CCD Lab studies into the overall museum experience. One of the goals in this partnership has been to make science accessible to museum visitors, not only through exhibits, but through participation in ongoing empirical research being conducted through the CCD Lab. When researchers from the CCD Lab approach families about participating in a study, we do not want them to feel as though we are pulling them away from the fun of the exhibits, rather that we are providing an additional, exciting opportunity to engage with science. We think this can be better achieved by fully integrating information about the CCD Lab into museum literature and promotions.

Conclusion

The CCD Lab and the Thinkery’s overlapping and overarching goals are to better understand how science learning happens in the informal learning setting so that we can more effectively impact our visitors and community. We also intend to integrate the findings of the research into the museum programs and staff trainings through communication with learners, teachers, and parents. We aim to communicate this research to parents in order to engage them more effectively in their children’s learning. We also intend to use the research from this partnership as a case study for how to best effectively develop family and adult/child learning environments. We are well on our way to achieving these goals and are eager to strengthen our ongoing collaborative partnership.

References


SECTION 2

Discussion of Partnerships