Capturing the spark: Using choice-based assessment to measure the impact of *making*

Chin, D.B., Conlin, L.D., Blair, K.P., & Schwartz, D.L. (2018, April). Presented at the 2018 Annual Meeting of the American Educational Research Association, New York City, NY.

ABSTRACT

Many institutions of learning, both formal and informal, embrace *making* as an engaging way to learn. We measure the proximal impact of *making*, by examining what children choose to learn after a period of *making*. A cross-over design used two activities with 9-13 year olds learning about spinning tops. One was to build a top. The other was a video-based activity in which children chose which clips to watch about tops-related science. The study was replicated under controlled classroom conditions (N1=73, N2=48), as well as a free-choice, informal learning setting (N=114). Analyses found site differences, but more importantly, found that *making* can trigger increased exploration of learning resources. This "spark of curiosity" can lead to improved performance on learning measures and has Implications on children's future learning and interest development.

INTRODUCTION

Designers of informal, "free-choice" learning experiences aim to put individuals on a trajectory of lifelong learning that includes developing skills, fostering interests, and changing behaviors (Falk & Dierking, 2002; Friedman, 2008; NRC, 2009). A challenge exists in measuring these outcomes. Surveys, interviews, and tests disrupt and alter the nature of informal experiences (Michalchik & Gallagher, 2010), and children are freer to refuse. This makes it difficult to track effects beyond observing the learning experience, e.g. later interest development (Renninger & Bachrach, 2015).

Maker activities are quintessential, free-choice, hands-on experiences. They are a staple of informal learning (Honey & Kantner, 2013). Martin (2015) defines *making* as *"activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful end, oriented toward making a "product" of some sort..."* Visit any science center, and one is likely to encounter a table spread with building materials and surrounded by visitors industriously designing their own marble ramps or paper circuits.

Making is increasingly penetrating formal education (Dougherty, 2012; Halverson & Sheridan, 2014), whether in the arena of project-based learning (Barron et al., 1998; Bell 2010) or as an entrée into learning scientific and engineering principles (Crismond, 2001; Puntambekar & Kolodner, 2005; Peppler 2013; Conlin & Chin, 2016). On the spectrum of hands-on activities, *making* contrasts with more traditional school activities with respect to goals and constraints. Science experiments, for example, are usually quite rigidly defined. Students follow explicit protocols with the goal of gathering data to prove pre-determined scientific principles. In contrast, *making* is open-ended and often encourages individual trajectories of exploration and learning. Makers frequently set out with similar goals, but "bump into" different phenomena and surmount different challenges along the way. Thus they may be doing, becoming curious about, and learning different things. This makes it difficult to measure the impact of maker activities and other informal learning experiences (Friedman, 2008; NRC, 2009).

The current research assesses the impact of *making* through the use of a choice-based assessment (CBA). CBAs are interactive, computer-based technologies, frequently game-based, that present learners with a challenge and learning resources, and then track how learners go about solving the challenge (Schwartz & Arena, 2013). They shift assessment from traditional tests of *knowledge* to focus on dynamic measures of *learning processes* and *behaviors* (Shute et al., 2009; Conlin et al., 2015; Cutumisu, Blair, Chin, & Schwartz, 2015; Chin, Blair, & Schwartz, 2016). Presumably, a major goal of *making* experiences, stated broadly, is to influence the kinds of choices that children will make regarding their future learning. A CBA is more tightly aligned with the goals of *making* compared to a test of factual or procedural knowledge outcomes, which likely vary across children, given their individualized trajectories.

STUDY DESIGN & METHODS

We examined two learning experiences: a maker activity, build a spinning top, and a video-based experience, à la YouTube, in which learners have an assortment of short, tops-related science videos which they can choose to view (or not). The YouTube-like experience was chosen for its ecological familiarity to students as a learning resource (Duffy, 2008; Bonk 2011; Lee & Lehto 2013).

A cross-over design used two treatment conditions (Fig.1). The "Build-first" condition started with the maker activity, then they shifted to the video-based activity. The "Video-first" condition was the reverse. The design tests the hypothesis that building a top *first* would affect children's choices of videos (choice-based assessment). Does *making* spark increased interest in learning?

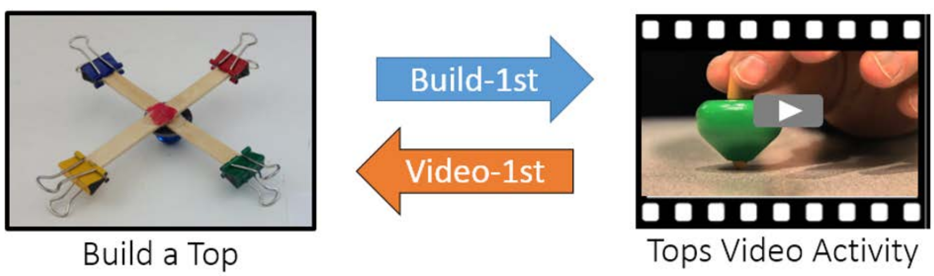

Figure 1. Cross-over design of research study

Activities

<u>Build a Top</u>

The activity came from a science museum, and the goal was simple: build a top that spins. There were no other constraints beyond the materials, which included cardboard, craft sticks, paper plates, marbles, golf tees, dowels, binder clips, hot glue, etc. Facilitation was minimal, consisting of an introduction to the goal and a presentation of the materials and various examples. Help was provided mainly as an extra pair of hands or the safe use of tools (e.g., glue guns).

<u>Video-based Learning Activity</u>

Fig. 2 shows the flow of the assessment and its learning resources (a combination of videos, text, and images).

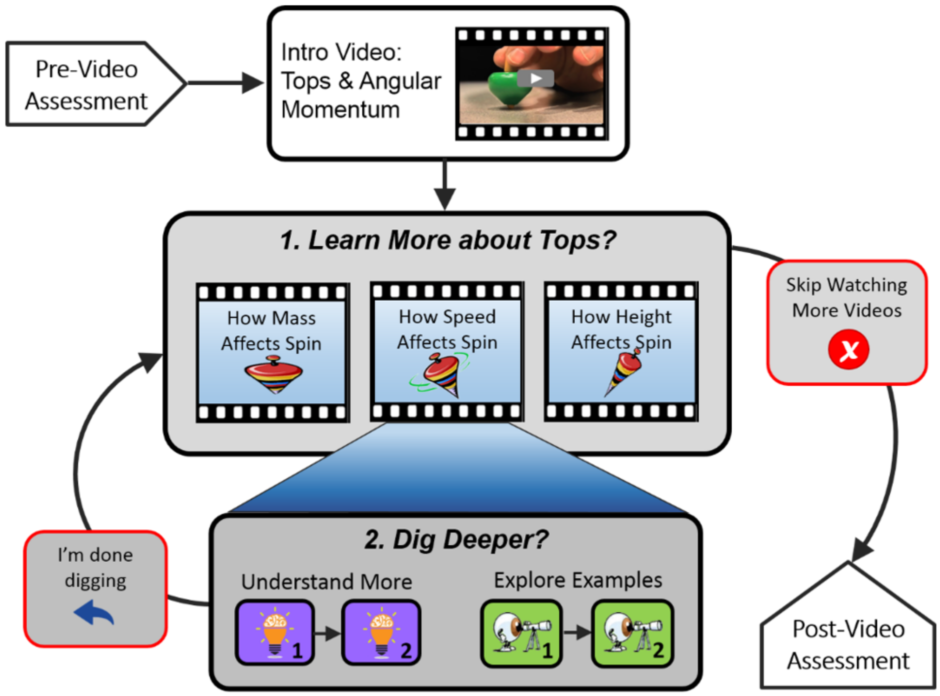

Figure 2. Flowchart for video-based learning activity.
White-filled shapes indicate mandatory steps which all learners experience. Light and dark gray-filled shapes indicate optional learning steps. Red outlined objects indicate explicit choices to "opt out." Learners were allowed a maximum of two *Learn More about Tops* videos (choice level 1) and eight *Dig Deeper* pages at choice level 2 (4 per video).

The activity begins with a "pre-video" assessment, then children watch a 2-minute video discussing tops and related physics concepts, e.g. angular momentum. At the video's conclusion, children go to the "*Learn More about Tops?*" page (choice level 1). They can click on any of three additional short videos focusing on how mass, speed, or height affect a top's spin. The page also offers the option of skipping additional videos. If children choose to view a *LearnMore* video, they may choose to "dig deeper" at the video's conclusion or to opt out by clicking "I'm done." Each *LearnMore* video has its own set of *DigDeeper* options, called *Understand More* and *Explore Examples.* Both options consist of two pages of text and images. *Understand* pages focus on abstract, scientific explanations for spinning tops, and *Examples* pages show concrete examples of other tops, highlighting differences in mass, speed, or height. Children have the choice of viewing one or both pages within each *DigDeeper* option before they are returned to the *Learn More about Tops?* page. To reduce overall time, children can choose a maximum of two *LearnMore* videos and accompanying *DigDeepers* (making for a range of {0-2} videos and {0-8} *DigDeeper* clicks). After reaching their limit of learning choices (or opting out), the software sends children to a post-video assessment.

Participant and Procedures

This basic study design was tested in classrooms for better control of environmental conditions, then on a museum floor.

<u>Formal Settings: Schools 1 and 2</u>

A total of five 4th grade classrooms participated. School 1 had three regular classrooms (N=73; 1.3% African American, 11.6% Asian/Filipino, 85.9% Hispanic/Latino, 1% White, 0.2% Other; 95.8% socioeconomically disadvantaged; 44.2% English learners). School 2 contributed two design-focused, elective classes (N=48; 0.6% African American, 8.4% Asian/Filipino, 13.4% Hispanic/Latino, 66.1% White, 11.6% Other; 3.6% socioeconomically disadvantaged; 5.1% English learners).

Randomization of children to either the Build-first condition or Video-first condition occurred within each class. At the beginning of a 50 min period, children were told that they would be doing two different activities, one with iPads. Children were unaware they would be building tops, thus the Video-first children provide baseline data for click rates through the learning resources. After the introduction, half of the children were sent to a separate room to build their tops, while the other half remained at their desks to complete the video-based activity. Children worked individually for ~20 minutes before switching rooms.

<u>Informal Setting: Museum Floor</u>

Site 3 was the makerspace in a science museum. The study was conducted on six weekdays spanning three weeks. Participants were visitors, aged 9-13, recruited from a mix of family groups on spring break and schoolchildren on field trips (N=114). Museum policy required that both activities be explained to visitors before gaining informed consent from parents or chaperones. Visitors were alternately assigned to either build first in the makerspace or taken to an adjacent room, separate from the floor, for the video-based activity (constrained by seat availability in either space). Both activities were open-ended; visitors were allowed to linger however long they wanted.

The activities across all sites were as closely matched as possible. Facilitation methods for the *making* were the same, and though there were minor differences in the video activity across sites, the space of choices was identical for all groups (two videos and eight *DigDeepers*).

Measures

Log data. We compiled children's pre- and post-video item responses and "learning choices" (number, order, and total time of the videos viewed from the *LearnMore* page, as well as the number, order, and time spent for each of the *Understand* and *Examples* options).

Learning assessment. At the two school sites, we examined children's science learning using a post-test that consisted of multiple-choice questions, each contrasting two tops that varied on key structural features (e.g. top height or mass distribution). Children were asked which top would spin better or if they would spin the same. Questions were graded 0/1 and a cumulative score tallied (scores {0 – 6}).

Top Design. We scored children's tops separately on the structural features of mass distribution {0-2} and height {0-2}, then added them for a combined total top structural score {0-4}.

Research Questions:

- How does *making* affect children's choices to view science-related learning resources? Does site make a difference?
- How does making affect children's science learning?

RESULTS

There were no age effects on children's choice behaviors in the museum, thus the full range of visitors was included in the analyses.

Table 1. Sample sizes by site and condition

		Condition		
		Video	*Build*	Total
Site	*School 1*	36	37	73
	School 2	23	25	48
	Museum	60	54	114
	Total	119	116	235

To most efficiently analyze the data, the three populations were examined together. We first conducted analyses on *VideosViewed* and *DigDeeper*s in separate 3x2 ANOVAs using the between-subjects factors of Site (School1 vs. School2 vs. Museum) and Condition (Build-first vs. Video-first).

Making **can spark children to view more science-related learning resources**

On choice level 1, the ANOVA on *VideosViewed* indicates a significant main effect for Condition, $F_{(1,229)}$=5.01, p=.026, as well as a significant Site*Condition interaction, $F_{(2,229)}$=3.72, p=.026. Building *first* seemed to trigger viewing more videos, but only for the school sites (Fig. 3A).

On *DigDeepers* (choice level 2), there was a significant main effect for Site, $F_{(2,229)}$=9.1, p=.000, driven by School1, and importantly, a main effect for Condition, $F_{(1,229)}$=10.57, p=.001, indicating that, overall, the Build children chose to view more *DigDeeper* resources (M=3.12, SE=0.22) than their Video-1st counterparts (M=2.10, SE=0.23). There was also a Site*Condition interaction effect, $F_{(2,229)}$=3.15, p=.045, due to the museum children showing no condition differences (Fig. 3B).

The CBA was designed such that children could only access the *DigDeeper* resources if they clicked on a video. Thus, the condition differences in *DigDeepers* could be driven by the top level video choices. (Build kids watched more videos and thus had more *DigDeeper* opportunities.) To address this, the average number of *DigDeepers* chosen *per video* was calculated. A simple t-test showed the Build condition had a larger ratio of *DigDeeperClicks/Video* than the Video condition, t(220)=2.97, p=.003.

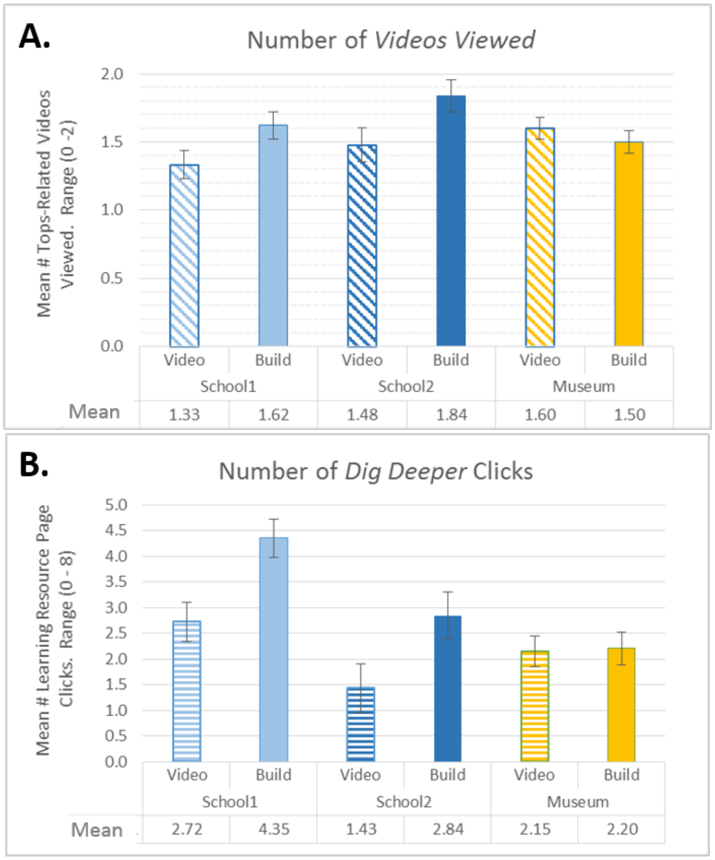

Fig. 3. Learning Choices by Site and Condition.

A. Number of Videos Viewed. Mean number of videos children *chose* to view. Learners were permitted a maximum of two videos. Error bars indicate SE. ANOVA indicates a significant main effect for Condition (p=.026) and a significant Site*Condition interaction effect (p=.026). There was no main effect for Site (p=.256).

B. Number of Dig Deeper Clicks. Mean number of Dig Deeper learning resource pages children *chose* to view. Learners were permitted a maximum of 8 clicks (4 per video). Error bars indicate SE. ANOVA indicates significant main effects for both Site (p=.000) and Condition (p=.001), as well as Site*Condition interaction effect (p=.045).

We also separated the *DigDeeper* choices into the *UnderstandMore* and *ExploreExamples* choices. A repeated-measures analysis examined the within-subjects factor of Type (science-focused *UnderstandMore* vs. concrete *ExploreExamples*), using the same 3x2 (Site x Condition) factors as before. The analysis showed no difference between Resource Types, $F_{(1,229)}=2.80$, $p=.096$ (Fig. 4). Additionally, there were no significant interactions of Type with either Site or Condition. By implication, children who choose to learn more, regardless of site or condition, choose equally to see more examples and to understand the physics.

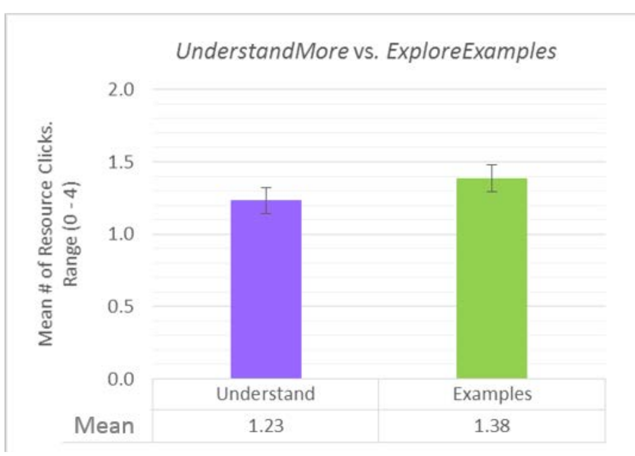

Figure 4. Clicks on Understand More and Explore Examples.
Learners were permitted a maximum of 4 for each type of learning resource.

***Making* can lead to better science learning**

At the two school sites, we examined children's science learning using a post-test that consisted of multiple-choice questions, each contrasting two tops that varied on key structural features (e.g. top height or mass distribution). Children were asked which top would spin better or if they would spin the same (Figure 5).

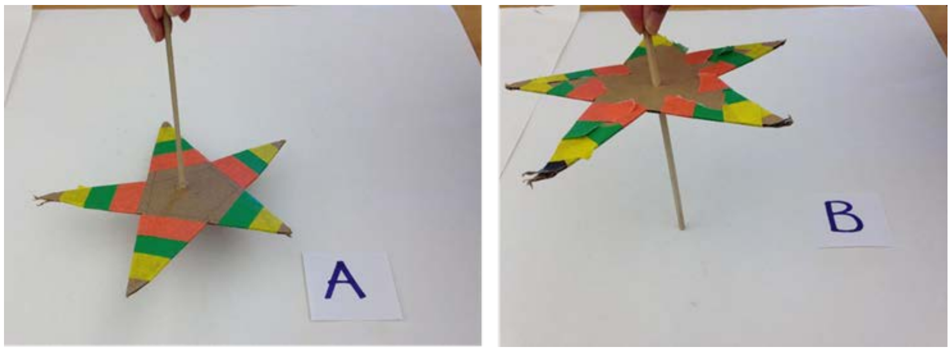

Figure 5. Example of a contrasting case used in post-test.
The two tops pictured contrast on the key feature of height.

Questions were graded 0/1 and a cumulative score tallied (scores {0 – 6}). We also scored children's tops on their structural features of mass distribution and height (scores {0-2}). We analyzed post-test scores in a 2x3x3 ANOVA, using *Condition*, *Videos Viewed*, and *Top Score* (see Figure 6). Results indicate that Build children displayed slightly better science understanding ($F_{(1,72)} = 4.26$, p=.043). There were also significant main effects for *Videos Viewed* ($F_{(2,72)}$= 6.61, p=.002) and *Top Score* ($F_{(2,72)}$= 4.29, p=.017), as well as a significant interaction effect *Condition*TopScore* ($F_{(2,72)}$= 4.42, p=.015). The interaction effect was driven by the Video children's higher top scores, as would be expected, given that they had viewed the videos before building.

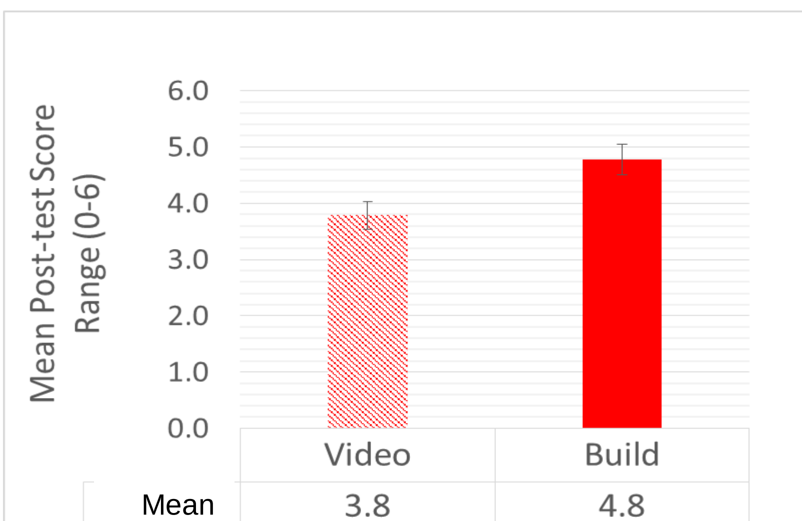

Figure 6. Post-test Scores by Condition.
Students in the Build condition outperformed their peers in the Video condition.

CONCLUSION

The study assessed the impact of *making* through children's learning choices. Site differences were expected. School1 used normal, homeroom classes. School2 kids were tested in their Design class, an elective period focused on a succession of *maker* projects, typically 2-3 days in length, in an informal atmosphere. And of course, the museum environment is a cornucopia of sensory and cognitive stimuli.

Of more interest were condition differences. In both schools, the children who built *first* consistently chose to view more learning resources (videos *and* deeper content pages) than their peers who had not yet built. In contrast, museum visitors were more similar across the two treatment groups. It could be that the recruitment process, in which visitors were told the nature of both activities, triggered an increased desire to learn more about tops before actually building one, or that after making their top, visitors were more interested in seeing the rest of the museum than viewing videos.

Prior research has shown that integrating scientific concepts into design and making activities can be problematic. Children frequently focus more on the particulars of *building* and do not naturally reflect on the STEM principles that educators attempt to integrate into these activities (Crismond, 2001; Puntambekar & Kolodner, 2005). The results here show that making shows promise in sparking curiosity, triggering more exploration of learning resources, and leading to better science learning. This is relevant for both formal and informal educators debating whether to integrate *making* into their programs and curriculum.

Finally, this model of assessing the impact of *making* (and perhaps other informal experiences) on learning behaviors shows potential and is relatively simple to execute in multiple settings. Videos of phenomena and underlying scientific explanations are legion, and deployment of tablets easy.

REFERENCES

- Barron, B. J., Schwartz, D. L., Vye, N. J., Moore, A., Petrosino, A., Zech, L., & Bransford, J. D. (1998). Doing with understanding: Lessons from research on problem-and project-based learning. *Journal of the Learning Sciences*, *7*(3-4), 271-311.
- Bell, S. (2010). Project-based learning for the 21st century: Skills for the future. *The Clearing House*, *83*(2), 39-43.
- Bonk, C. J. (2011). YouTube anchors and enders: The use of shared online video content as a macrocontext for learning. In *American Educational Research Association (AERA)(annual meeting), New York*.
- Chin, D.B., Blair, K.P., & Schwartz, D.L. (2016). Got game? A choice-based learning assessment of data literacy and visualization skills. *Technology, Knowledge, and Learning, 21(2)*: 195-210. doi: 10.1007/s10758-016-9279-7
- Conlin, L.D., Chin, D.B., Blair, K.P., Cutumisu, M., & Schwartz, D.L. (2015, June). Guardian angels of our better nature: Finding evidence of the benefits of design thinking. *Proceedings of the 2015 Meeting of the American Society of Engineering Education*, Seattle, WA.
- Conlin, L. & Chin, D.B. (2016, June). Can tinkering prepare students to learn physics concepts? *Proceedings of the 2016 Meeting of the American Society of Engineering Education*, New Orleans, LA.

- Crismond, D. (2001). Learning and using science ideas when doing investigate-and-redesign tasks, *Journal of Research in Science Teaching, 38*, 791-820.
- Cutumisu, M, Blair, K.P., Chin, D.B., & Schwartz, D.L. (2015). Posterlet: A game-based assessment of children's choices to seek feedback and to revise. *Journal of Learning Analytics, 2(1):* 49-71.
- Dougherty, D. (2012). The maker movement. *Innovations*, *7*(3), 11-14.
- Duffy, P. (2008). Engaging the YouTube Google-eyed generation: Strategies for using Web 2.0 in teaching and learning. *The Electronic Journal of e-Learning*, *6*(2), 119-130.
- Falk, J. J. H., & Dierking, L. L. D. (2002). *Lessons without limit: How free-choice learning is transforming education*. New York: Rowmand & Littlefield.
- Friedman, A. (Ed). (2008). *Framework for evaluating impacts of informal science education projects.* Arlington, VA: National Science Foundation. (Available at: http://caise.insci.org/uploads/docs/Eval_Framework.pdf)
- Halverson, E. R., & Sheridan, K. (2014). The maker movement in education. *Harvard Educational Review*, *84*(4), 495-504.
- Honey, M., & Kanter, D. E. (Eds.). (2013). *Design, make, play: Growing the next generation of STEM innovators*. Routledge.
- Lee, D. Y., & Lehto, M. R. (2013). User acceptance of YouTube for procedural learning: An extension of the Technology Acceptance Model. *Computers & Education*, *61*, 193-208.
- Martin, L. (2015). The promise of the Maker Movement for education. Journal of Pre-College Engineering Education Research (J-PEER), 5(1), 30-39. http://dx.doi.org/10.7771/2157-9288.1099
- Michalchik, V., & Gallagher, L. (2010). Naturalizing assessment. *Curator: The Museum Journal*, *53*(2), 209-219.
- National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits.* Committee on Learning Science in Informal Environments. Philip Bell, Bruce Lewenstein, Andrew W. Shouse, & Michael A. Feder, Eds. Board on Science Education, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, D.C.: The National Academies Press.
- Peppler, K., & Glosson, D. (2013). Stitching circuits: Learning about circuitry through e-textile materials. *Journal of Science Education and Technology*,*22*(5), 751-763.
- Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science by design. *Journal of Research in Science Teaching, 42*, 185–217.
- Renninger, K.A. & Bachrach, J.E. (2015). Studying triggers for interest and engagement using observational methods. *Educational Psychologist, 50*(1), 58-69. DOI: 10.1080/00461520.2014.999920
- Schwartz, D.L. & Arena, D. (2013). *Measuring what matters most: Choice-based assessments for the digital age.* Cambridge, MA: MIT Press.
- Shute, V. J., Ventura, M., Bauer, M. I., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning: Flow and grow. In Ritterfeld,

U., Cody, M., & Vorderer, P. (Eds.). *Serious games: Mechanisms and effects*, (pp. 295–321). New York: Routledge.

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation, the MacArthur Foundation, and the Moore Foundation. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the granting agencies. The authors would like to thank the staff at our local science museum.