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


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?

Activities

Build a Top

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).

Video-based Learning Activity

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

Formal Settings: Schools 1 and 2
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.

Informal Setting: Museum Floor

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

<table>
<thead>
<tr>
<th>Site</th>
<th>Video</th>
<th>Build</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>School 1</td>
<td>36</td>
<td>37</td>
<td>73</td>
</tr>
<tr>
<td>School 2</td>
<td>23</td>
<td>25</td>
<td>48</td>
</tr>
<tr>
<td>Museum</td>
<td>60</td>
<td>54</td>
<td>114</td>
</tr>
<tr>
<td>Total</td>
<td>119</td>
<td>116</td>
<td>235</td>
</tr>
</tbody>
</table>

To most efficiently analyze the data, the three populations were examined together. We first conducted analyses on VideosViewed and DigDeepers 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, $t(220)=2.97, p=.003$. 


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.
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).

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

![Figure 6. Post-test Scores by Condition.](image)
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


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