

Making the Engineering Design Process Visible: Effects of Interventions on Caregiver-Child Interactions

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Biographical Notes

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Adult caregivers play a critical role in shaping children's learning during STEM activities in museum settings. However, many caregivers disengage or struggle to engage due to discomfort with engineering concepts. This study aimed to evaluate the impact of an intervention designed to make the engineering design process (EDP)—create, test, improve—more explicit during a design challenge activity. Three interventions were implemented: (a) an introductory explanation of the EDP, (b) hanging signs marking EDP steps, and (c) a tabletop sign illustrating the EDP. Findings indicated a noticeable increase in the number of caregivers referencing the EDP after the interventions, with the "test" phase being the most commonly mentioned. Caregivers also demonstrated a slight increase in referencing phases focused on iteration and improvement. Educator reflections indicated that the hanging signage was particularly effective in prompting EDP language, while the introduction received mixed responses. These findings suggest that simple, low-cost design changes can enhance caregiver engagement and language around iterative engineering processes. Future research should explore how such interventions influence long-term caregiver and child STEM learning behaviors in informal environments.

Keywords: adult-child interactions, engineering design process, failure, language use, signage

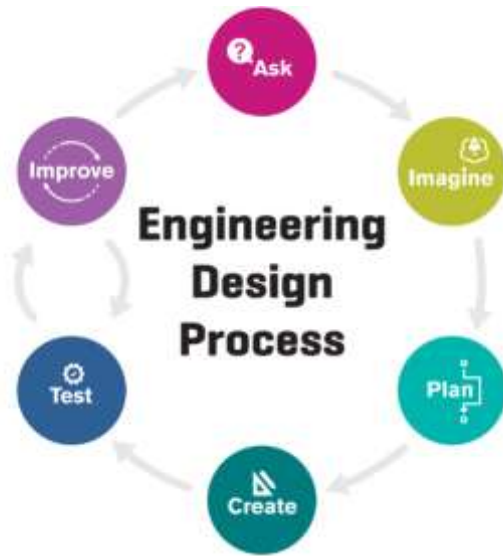
Introduction

Adult caregivers play a vital role in children's learning experiences when engaging in activities within a museum setting¹. For example, Degotardi et al.² observed sustained shared thinking and co-construction of knowledge between adult caregivers and children through four approaches from the caregivers: (a) establishing shared attention based on a child's interest, (b) asking purposeful questions, (c) using descriptive vocabulary and precise technical words, and (d) connecting new information with a child's existing knowledge base. Adult caregivers may also disengage from interacting with their child(ren) as a way to provide agency and space for their child(ren), as well as

other children, for purposes of free exploration³. Within museums focused on engaging children and families in science, technology, engineering, and mathematics (STEM) concepts and practices, adult caregivers may disengage from the process due to their discomfort and misconceptions of STEM topics⁴.

The purpose of the study was to evaluate the impact of making the engineering design process (EDP) more prevalent for caregivers during design challenges (see Figure 1), particularly steps framed around moments of failure - create, test, and improve. Based on prior studies⁵, we hypothesized that caregivers might be more supportive of the process, and less focused on a successful product, if they were made more aware that this was the goal of the activity. We did this through implementing three interventions: (a) a new introduction, approximately 5-15 seconds longer in length, describing three steps of the engineering design process (i.e., create, test, improve) before introducing the specific engineering challenge, with the delivery format varying based on crowd size—given as a large announcement on busy days when many visitors gather in front of the counter, or individually to visitor groups arriving sporadically on quieter days; (b) hung signs from the ceiling to indicate where each step of the engineering design process took place in the space (see Figure 1B); and (c) the addition of a tabletop sign depicting the process to the same area where caregivers heard the introduction and grabbed materials. After conducting a baseline evaluation, we observed 28% of adult caregivers reference the EDP when engaging with their child. Given the relatively small sample size ($n=46$), our goal was to increase the baseline to 41% through our interventions. This is a percent increase of about 46% of caregivers referencing the EDP through the intervention.

Figure 1
Engineering design cycle



Methods

This study took place during one design challenge within the Engineering Design Workshop, Soaring Satellites (see Figure 2A). This is the only design challenge in the Workshop that does not include a leader board, a visible board that displays visitors' quantitative results and serves as a measurable goal for them to aim for. We wanted to see what impact our interventions might have when experiencing failure, but without the complication of people referencing the leader board.

Figure 2
Image of Soaring Satellites exhibit and new signs embedded as part of the intervention



The data for this study was collected through observations and educator reflections. The observation form was developed through an iterative process. The final form focused on observations of whether caregivers used three phases of the EDP - create, test, improve - to encourage their children when experiencing failure while participating in the design challenge (see Figure 3). The focus was on one caregiver and all the interactions they had with their child(ren) while testing whether their satellite prototype would float for five seconds between the colored lines (see Figure 2A). If they used one of the words or a similar word (e.g., test, try out, fix), then the sentence that the word was used was recorded verbatim. “Go *change* your design” was an example documented for the improve stage of the engineering design process. Visitors were made aware of the data collection process through a sign that stated the following: “To help better serve our visitors, this area is being observed ending at (insert time).” Further, visitors were offered an informational sheet regarding the purpose of the research study. Observational data was collected during a “busy” weekday (average of 166 visitors) from each of the three educators once a week for 30-minutes over a four-week period. Similar to the baseline data, forty-six caregiver-child interactions were recorded during the intervention. Based on observational data, children were between the ages of 2 and 14. Analysis included comparing and contrasting frequency counts between the baseline data and the intervention data.

Figure 3
Observation Protocol

Start time: _____ End time: _____ Testing area observed: _____
 Total # of visitors at EDW Design Challenges during data collection period: _____

RQ: Do the changes that we have made lead caregivers to more frequently reference the Engineering Design Process when supporting their children?

Group #	Description (observed age, gender, and adult's shirt color e.g. GF, M9 blue)	Focus Person	Create (alternative language: make, build, construct, design)	Test (alternative language: try/try out, experiment, evaluate)	Improve (alternative language: redesign, tweak, make better, remake, change)	Additional notes (anything that might be relevant to the RQ)

Reflections from three educators were also utilized to supplement observations. The reflection included two questions and were included once a week for the four-week period of observational data: (a) What did you notice? and (b) Did you hear visitors reference the EDP? If so, when/where? The three educators had between 3.5-6 years of experience in informal learning, and between 2-3 years experience at our museum. Two of the educators were part-time program presenters; the other was a full-time education associate.

Results

From the research, we learned that the hung signs and revised introduction seem to make a positive impact. While the interventions did not lead to a dramatic increase in adults referencing the EDP when supporting their children, there was still some change. First, did the changes we made lead to caregivers more frequently referencing the Engineering Design Process when supporting their children? Yes, there was about a 17.5% increase, from 28% to 45.65%, in the number of adult caregivers who referenced the engineering design cycle during the Soaring Satellite activity. This is approximately a 4% increase above our goal of 41%. Test was the most referenced engineering design phase in both the baseline (79%) and intervention data (68%). “Try” was the most common term used by adult caregivers within the testing phase. Examples include: (a) “Let's try it upside down and put it in the red one [tube].”; (b) “Try that again” (to child after child made adjustments to their satellite).; and (c) “You wanna try going the other way [flipping the satellite around]?” There was only one instance in which a caregiver did not use “try,” but the word “test.” During the intervention, we also observed a small increase in the number statements within the improve phase of the engineering design process, from 17% to 24%. Examples include: (a) “What do you want to change about it [the satellite]?” and (b) “Alright, do you want to go back to the table and try to fix it?”

Second, did the changes we made lead to a difference in how many steps of the

engineering design process caregivers referenced? Yes, there was a 6.5% increase in caregivers using more than one of the EDP terms when supporting their child.

From the educators' reflections, there were a couple of instances in which they heard visitors reference the engineering design process. For example, Kamila noted the following: "In particular, a few groups of elementary-aged students with a camp chaperone were using "redesign" and "improved from my last test" a lot in between interactions at testing to make their satellite successful." Katy too "heard a couple of adults tell children that redesigning was part of the challenge."

In addition, the educators shared insights into the three interventions with the introduction being received with mix feelings. As described by Kamila, "The intro is longer in length with the added design process. The combination of this and the busy environment today often prompted two results: folks either listened very diligently and were excited to engineer or tuned out and started grabbing supplies." On the other hand, the signage seemed more well received. As noted by Rosaline,

Today an adult used the sign at the counter to explain in another language to their child what we were trying to accomplish! I do wonder if table signs would encourage this more, and maybe capture some of the caregivers who were not present for the introduction.

Katy also observed "one caregiver point[ing] out the EDP sign to their child at [the] Hub."

Discussion

Based on the findings from this research, it seems that our interventions made a difference in the number of adult caregivers referencing the engineering design process, particularly steps framed around moments of failure - create, test, and improve. This is promising considering that adult caregivers may have possible discomforts and misconceptions around engineering concepts⁶, as well as the importance of an iteration

process for young children's growth as STEM learners⁷. We further contend the significance of this finding because of the scant research on ways to support adult caregiver's language specific to the engineering design process. In addition, based on anecdotal observations and reflections from educators, it seemed that the hung signs made the biggest impact as caregivers were observed pointing to them directly, at times before they even approached the counter, which may suggest that the hung signs were effective at getting visitors thinking about the EDP before even hearing about the challenge. The introduction appeared not to engage all visitors in using language around the engineering design *process*, and the tabletop signage may not be as visible to adult caregivers who took a step back when children were at the counter hearing the introduction. This aligns with the study by Letourneau et al.⁸ in that facilitator-offered prompts were less effective in promoting caregiver-child engagement than prompts provided within the exhibit itself. Future research can continue to build on these findings, as well as consider the influence of repeat visitors and if the visitor's ongoing presence in the space permeates caregivers' languages both in and outside exhibits grounded in the engineering design process.

We recommend other museum spaces be intentional about ensuring your spaces reinforce what you value. Our museum values the engineering design process. From our point of view, the EDP informed the design of the entire exhibit, the design challenges, and our introductions, yet it was not physically represented in our space. Visitors may have absorbed the EDP through engagement but we did not include signage around the process. We considered the inclusion of the signs hanging from the ceiling to be a low lift for a potentially big impact. We plan to make the EDP more visible and permanent within exhibits throughout the gallery, particularly through hanging signs referencing the different steps (e.g., ask, create, test). We are also interested in continuing to

experiment with the introduction and adding additional signage (i.e. tabletop signs with example questions for adult caregivers) to reinforce the engineering design process as the primary learning goal for design challenges.

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Notes

¹ Callanan et al., “Exploration, explanation, and parent–child,” 7-137; Dietmeier & Devane, “Understanding adult social stances,” 609-612.; Dooly & Welch, “Nature of interactions,” 125-132.

² Degotardi et al., “How parent–child interactions,” 171-191.

³ Wood & Wolf, “When parents stand back,” 35-50.

⁴ National Science Foundation, “Public perceptions, awareness,” sec. 3; Scheufele & Krause, “Science audiences, misinformation,” 7662-7669; Zulkifli et al., “Singaporean parents' engineering awareness,” para. 29.

⁵ Kupiec et al., “effectiveness of museum intervention,” 82-101; Letourneau et al., “Effects of facilitation,” para. 47-48.

⁶ Zulkifli et al., “Singaporean parents' engineering awareness,” para. 29.

⁷ Jackson et al., “Learning from failure,” 1853-1873; Ryoo & Kekelis, “Reframing “failure” in making,” 49-67; Simpson et al., “Co-construction of iteration,” 184-206.

⁸ Letourneau et al., “Effects of facilitation,” para. 47-48.

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