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Straight from the girls: The importance of incorporating the EDGE Design Attributes at exhibits

by
Veronica Garcia-Luis and Toni Dancstep (née Dancu)
Exploratorium, San Francisco, CA

Abstract

This paper describes a follow-up focus group study for the larger Exhibit Designs for Girls' Engagement (EDGE) project. Grounded in Culturally Responsive Pedagogical theory (CRP), the project aimed to understand the relationship between female responsive designs and girls' engagement at STEM exhibits. After developing a Female-Responsive Design (FRD) Framework and conducting a large-scale study to determine the most important design attributes for engaging girls at exhibits, the final step involved a qualitative investigation into those design attributes. Four focus groups with 22 girls total explored 8–13 year-old girls' exhibit experiences and discourse. Participants were videotaped while using four exhibits, half of which incorporated the EDGE Design Attributes. Focus group results replicate the quantitative study: participants had a largely positive response to the EDGE Design Attributes and evinced greater engagement when the attributes were present at exhibits. As expected, girls' responsiveness to the design attributes varied— aligning with the CRP approach and highlighting the important fact that not all attributes will work for all girls. To share girls' voices more broadly with practitioners we provide direct quotes for each design attribute. Finally, of the kinds of learning expressed, girls more often practiced scientific skills by repeating or varying activities at the EDGE exhibits. The results of this study, and the larger project, provide evidence that CRP works well when designing for females and serves as a valuable theory for creating museums that are truly inclusive.

Key words: girls, equity, gender, STEM, engagement, museums, informal science education, interactive exhibits

TITLE

Straight from the girls: The importance of incorporating the EDGE Design Attributes at exhibits.

*All names changed to protect the privacy of the Girl Advisory Committee members and focus group participants.

Introduction

The quotes above provide a glimpse into the persistent inequities girls face when engaging in science, technology, engineering, and math (STEM). The stubborn reality backed up by research and national surveys is that fewer girls report liking math and science compared to boys (Alexander, Johnson, and Kelly 2012, Haussler and Hoffman 2002, Jones, Howe, and Rua 2000, Morgan, Isaac, and Sansone 2001, US Department of Labor Employment and Training Administration by Jobs for the Future 2007). Females report lower levels of interest and engagement in STEM than males (Alexander, Johnson, and Kelly 2012, Jones, Howe, and Rua 2000). Females have less access to out of school experiences that are typically aligned with

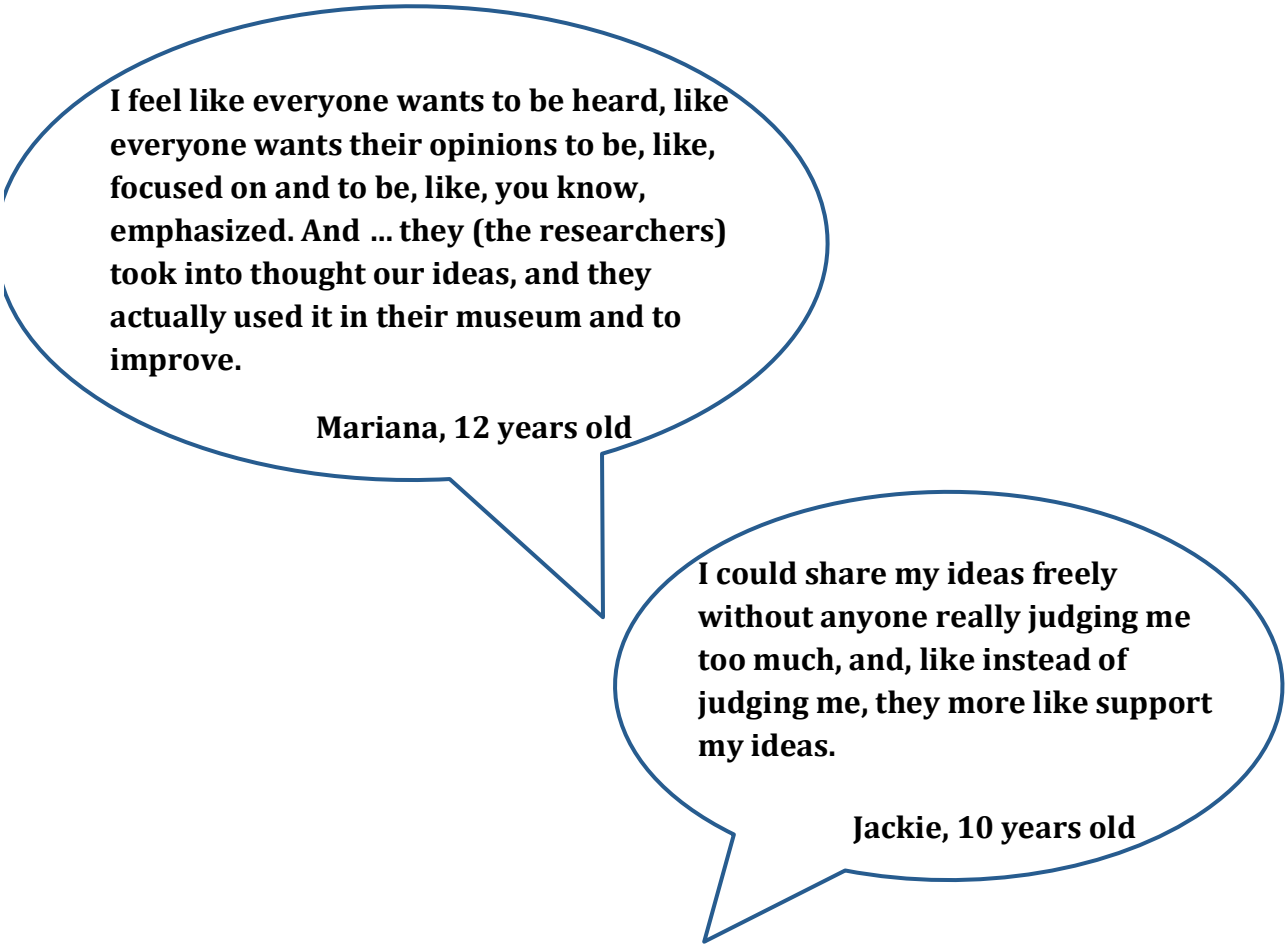
STEM (Baenninger and Newcombe 1995, Jones, Howe, and Rua 2000, McCreedy and Dierking 2013). And females remain underrepresented in Advanced Placement classes in high school as well as in STEM careers (Brotman and Moore 2008, Girls Inc. 2004, Hill, Corbett, and St Rose 2010, National Research Council 2009, National Science Board 2008, 2016, National Science Foundation and National Center for Science and Engineering Statistics 2013, Scantlebury and Baker 2007). We must pull together to create a more equitable and inclusive STEM field (National Science Foundation and National Center for Science and Engineering Statistics 2013, President's Council of Advisors on Science and Technology 2010, US Department of Labor Employment and Training Administration by Jobs for the Future 2007).

The quotes hint at issues in informal science education (ISE) that echo those found in STEM more broadly. Regrettably, ISE institutions are struggling to appeal to diverse audiences or provide equitable experiences (Dawson 2018 and 2019b, Feinstein 2017). For example, research has found that girls visit science museums less often than boys (Borun 1999, Hamilton et al. 1995, National Science Foundation 2003). Other studies suggest that girls are less likely than boys to use certain STEM exhibits, such as those pertaining to physical science and computer programming (Anderson et al. 2005, Baranowski and Delorey 2007, Greenfield 1995, Kremer and Mullins 1992, Verheyden 2003). Further, females spend less time than males exploring some of the exhibits they do use, particularly physics, engineering, and math exhibits (Anderson et al. 2005, Baranowski and Delorey 2007, Diamond 1994, Kremer and Mullins 1992, National Science Foundation 2003, 2007, Taylor 2005, 2006, Verheyden 2003). These issues in science museums reverberate back to society: museums not only foster scientific thinking and engagement, but people with careers in the sciences often connect their initial interest in STEM to earlier visits (Bell, Besley, Cannady, Crowley, Grack Nelson, Philips, Riedinger, and Storksdieck 2019, Cosmos Corporation 1998, Falk and Dierking 2010, Hamilton et al. 1995,

Humphrey and Gutwill 2005, National Research Council 2009, National Science Board 2008, Randol 2005, Salmi 2001, 2002).

Science centers are ready to address this disparity. In fact, museums and researchers worldwide are working to better engage females in STEM topics through exhibitions, programs, and research studies (Achiam and Holmegaard 2015, Brown, Huerta Migus, and Williams 2012, Cardella, Svarovsky, and Dorie 2013, Dancstep and Sindorf 2018a, b, Laursen 2011, Munley and Rossiter 2013, National Science Foundation and National Center for Science and Engineering Statistics 2013, Roughneen 2011, Verheyden 2003). The National Science Foundation has compiled best practices, which provide a good starting point (National Science Foundation 2003, 2007). ISE researchers have focused efforts on ways to enhance females' experiences with single STEM topics, such as engineering, as well as single design features, such as incorporating a female image into labels (Cardella, Svarovsky, and Dorie 2013, Crowley et al. 2001, Dancu 2010, Sinkey, Rosino, and Francisco 2014). However, these efforts do not yet cover the wide range of topics and designs currently represented in the field.

Researchers agree that more inclusive practices are necessary to better engage females in STEM (Archer et al. 2012, Cheryan et al. 2009, Good, Woodzicka, and Wingfield 2010, Hill, Corbett, and St Rose 2010, Master, Cheryan, and Meltzoff 2016, Murphy, Steele, and Gross 2007, Sadker and Sadker 1994). While the ISE field is identifying and incorporating designs that better engage females, we posit that such an exploration must incorporate females' voices. In so doing, we will not only expand practice, but help to alleviate many of the issues expressed at the opening of this paper. The following quotes are emblematic of that approach:



Culturally Responsive Pedagogy: Using Girls' Voices to Shift the Paradigm

We believe that museums can broaden their pedagogical approach and be more inclusive if they create exhibits that resonate with females' preferred ways of engaging in STEM. Still, we acknowledge that this is a tricky endeavor. Developing exhibits that resonate with females' learning preferences poses some risks, for example, alienating learners who do not share those preferences, stereotyping females, or lumping females into a single essentialized category (Achiam and Holmegaard 2015). Throughout this paper and our larger research agenda we employ Culturally Responsive Pedagogy to help address these risks.

Culturally Responsive Pedagogy (CRP) situates learning within a social, historical, and cultural context (Gay 2010, Vygotsky 1978). CRP identifies cultural-historical patterns of learning for nondominant groups whose learning processes may not align with dominant educational culture (Gay 2010, Ladson-Billings 1995). Those patterns are then used to create educational approaches that are meaningful, appealing, and effective. CRP also acknowledges that those patterns will not work for everyone and will evolve over time.

Current inequities in STEM suggest that there is a particular need to specifically attend to and integrate females' interests (Francis et al. 2016, Francis and Paechter 2015). Applied to females, CRP explores commonalities that women and girls may share in the ways they experience and prefer to participate in STEM learning opportunities. Those commonalities are then used to identify various meaningful and effective ways of folding females' preferences into STEM practices. CRP celebrates variability within and across genders. Therefore, it also helps to address the concern that female-friendly pedagogy will emphasize stereotypical extremes that may alienate some learners. Instead, CRP strategies are nonprescriptive, anticipate evolution, and are often more broadly inclusive.

Exhibit Designs for Girls' Engagement (EDGE)

The study described in this paper is part of the larger Exhibit Designs for Girls' Engagement (EDGE) project. Using Culturally Responsive Pedagogy, EDGE identified females' ways of learning and engaging in STEM, and then examined ways to apply those findings in informal science education. Overall the project employed a mixed-methods, multistudy approach (e.g., Creswell 2009, Crook and Garratt 2011). The EDGE project included three phases: the development of a Female-Responsive Design (FRD) Framework; a large-scale quantitative study to pinpoint the most important design attributes from the framework; and follow-up focus groups

that sought to understand girls' varied experiences with those design attributes and the learning they might foster. Before we detail the focus group phase we provide context by describing the first two phases.

Developing the Female-Responsive Design Framework

The first phase of the EDGE project involved the development of a Female-Responsive Design (FRD) Framework (described in full in Dancstep and Sindorf 2018a). Using the theoretical lens of Culturally Responsive Pedagogy (CRP), the framework defines "female" inclusively, acknowledging that gender occurs along a spectrum and that there is considerable variability among females. At the same time, the CRP model allows us to identify patterns across females' social, historical, and cultural repertoires of STEM learning. The FRD Framework synthesized prior research, literature, and best practices from various fields (ranging from psychology to gaming). We further developed the framework by incorporating interviews and conversations with expert advisors, practitioners, and a Girl Advisory Committee (GAC) comprised of girls' ages 8–13. Such collaborations between learners and researchers strengthen the knowledge base for the education field (Banks et al. 2007). The synthesis led to four key design strategies to better support females' STEM learning:

- **Enable Social Interaction and Collaboration.** Offering experiences that are social and cooperative can support females' historical preferences, deeper learning, and engagement in STEM opportunities (Boiano et al. 2006, Cacace, Colonnello, and Olmi 2011, Denner et al. 2005, Froschl et al. 2003, Liston, Peterson, and Ragan 2008, National Science Foundation 2003, 2007, Peterson and Fennema 1985, Taylor 2005).

- **Create a Low-Pressure Setting.** Females' preference for low-pressure STEM activities can be supported by developing safe, comfortable, playful, or open-ended

experiences (e.g., Baker 2013, Gontan 2013, Sammet and Kekelis 2016, Vossoughi et al. 2013).

- **Provide Meaningful Connections.** Creating meaningful, contextualized ways to connect to content can create STEM experiences that align with females' previously successful learning opportunities (Baranowski and Delorey 2007, Ford et al. 2006, Froschl et al. 2003, Kekelis, Heber, and Countryman 2005, Milgram 2005).

- **Represent Females and their Interests.** Museums must address inequities brought about by historically underrepresenting nondominant communities, such as females. They can do this by thoughtfully considering the identities they reflect, and finding ways to represent females and their interests, in STEM practices (Archer et al. 2012, Calabrese Barton 2013, Brickhouse, Lowery, and Schultz 2000, Master, Cheryan, and Meltzoff 2016).

Within these four strategies, the FRD Framework identifies 55 exhibit-specific female-responsive design attributes (and variations of those attributes) that have the *potential* to better engage females at STEM exhibits. While much of the research referenced in the FRD Framework drew on small studies (such as those assembled by the National Science Foundation 2003, 2007), the framework sets us up to investigate those recommendations. The next phase of our research entailed a broader exploration of the design attributes to determine which of those best engaged girls at exhibits.

Identifying the EDGE Design Attributes

The second phase of the EDGE project, a large-scale exploratory research study, aimed to determine which of the specific design attributes from the FRD Framework were strongly related to girls' engagement (detailed in Dancstep and Sindorf 2018b, and Dancstep and Sindorf 2016). This allowed us to narrow the set of 55 promising design attributes to a smaller more practitioner-friendly set. We explored four types of engagement: exhibit use, time spent at the exhibit, return visits to the exhibit, and high-level engagement behaviors. We tracked 450 girls ages 8-13 at over 300 physics, engineering, math, and perception exhibits. We then used correlational and regression analyses to identify which attributes were consistently, positively, and strongly related to girls' engagement at STEM exhibits. The large-scale study winnowed the initial list of design attributes to a subset of nine that were most important for girls' engagement: the EDGE Design Attributes (see Table 1).

Table 1. EDGE Design Attributes

	**The exhibit's look-and-feel is playful, whimsical, or humorous.** The central experience or aesthetic fosters a feeling of playfulness rather than a need to "be serious" or "get it right."
	**The exhibit's look-and-feel is homey, personal, homemade, or delicate.** Homey design aesthetics deal with materials such as soft fabrics, wood cabinetry, or a small, intimate scale that may give a more personal feeling.
	**The exhibit has multiple stations or sides, allowing more than one person to experience the phenomenon.** These exhibits give each visitor ownership of a personal space to experience the phenomenon or do the activity.
	**The exhibit is open-ended, providing multiple outcomes, activities, or ways to interact.** Exhibits may be open-ended in many ways, for example: the outcome is different every time or it is designed for a multitude of iterations with an assortment of variables.
	**The exhibit has been designed with space to accommodate three or more people.** A large room, spacious floor plan, or large table surface create physical space, or elbow room at the exhibit.
	**The exhibit label includes at least one image of a person.** An exhibit label might include an image of a person to add real-world context or help visitors use the exhibit.
	**The exhibit is designed so visitors can watch others to preview what to do.** When visitors can see the actions or reactions of another person using an exhibit, it may orient them to the activity.
	**The exhibit label includes a use drawing, giving visitors an idea of how to use the exhibit.** These drawings often show a person doing an action, or how to use an interactive element.
	**The exhibit includes at least one familiar object that most people have seen before.** Includes everyday things such as kitchen items, household tools, musical instruments, or stuffed animals.

Table 1 *Note.* This table was originally presented in Dancstep and Sindorf (2018b).

For each of the nine EDGE Design Attributes listed here, we examined data collected from 450 boys ages 8-13. We found that none of the attributes were harmful, and in some instances the attributes were also useful, to boys' engagement.

Having developed the FRD framework and quantitatively identified the most promising design attributes for girls, the groundwork was laid for this final phase of the project. In this phase, the research team worked toward a more nuanced, qualitative understanding of our prior findings through a series of focus groups. Specifically, the team sought to triangulate the quantitative engagement results; to explore girls' varied reactions to the nine EDGE Design Attributes; and to understand if, beyond engagement, girls' learning differs when the attributes are present.

Before we describe the focus group study, we acknowledge overlap in the terms *engagement* and *learning*. In 2009 the National Research Council convened a Committee on Learning Science in Informal Environments to examine the ways in which informal educational opportunities promote science learning. The committee described features of scientific learning that are more specific to informal environments, such as the experience of excitement, interest, and motivation in relation to science. In the education literature these components are often termed affective learning, cognitive engagement, or simply engagement (Bloom and Krathwol 1956, Greene 2015, Krathwohl, Bloom, and Bertram 1973, Miller 2015). Falk & Dierking (2000) connected these features of learning to the free-choice nature of museums; visitors choose which exhibits to explore and for how long based on their own internal motivations. Others in the ISE field refer to these aspects of learning as initial or affective engagement (Bell et al. 2019).

The committee also detailed the ways in which informal environments can encompass the kinds of learning more typically seen in schools (see also National Research Council 2012),

such as manipulating and testing properties of the natural world, engaging in scientific reasoning, and gaining scientific concepts or knowledge. In the education literature this is frequently referred to as cognitive learning or cognitive engagement (Ben-Eliyahu, Moore, Dorph, and Schunn 2018, Bloom and Krathwol 1956, Krathwohl, Bloom, and Bertram 1973, Kutnick and Kington 2005, Meyer 1998, Rodríguez, Plax, and Kearney 1996), and in the ISE field these components are regularly considered cognitive engagement (Bell et al. 2019, Ben-Eliyahu et al. 2018). While we agree with the committee and consider all of these to be important aspects of learning, for the study described in this paper we will refer to the initial engagement and affective aspects of learning as *engagement*, and the remaining, deeper and more cognitive aspects of learning as *learning*.

The research questions we explored via focus group research were:

> Research Question 1. How does girls' engagement at exhibits that incorporate the EDGE Design Attributes contrast with engagement at exhibits that do not incorporate the design attributes?
>
> Research Question 2. In what ways are girls' responses to each of the EDGE Design Attributes consistent, and how do they vary?
>
> Research Question 3. How does girls' learning at exhibits that incorporate the EDGE Design Attributes contrast with learning at exhibits that do not incorporate the design attributes?

Methods

Context

Focus groups were conducted in an off-floor research laboratory at the Exploratorium, a museum of science, art, and human perception located in San Francisco during October 2015. We populated the focus group space with four interactive STEM exhibits (detailed in Table 2). Two of the exhibits each featured a subset of the EDGE Design Attributes, together representing

all nine of the attributes. In contrast, the other two exhibits did not include any of the EDGE Design Attributes.

Table 2. Focus group exhibits

EDGE Exhibits

(Design Attributes in bold)

Through the Looking Glass

6/9 DESIGN ATTRIBUTES

This exhibit is about human perception and mirror reflection, providing visitors with a hands-on experience with reflection and its impact on hand-eye coordination.

At Through the Looking Glass, visitors use **multiple stations**; each station challenges visitors to complete a different task while looking at the reflection in a mirror. The four **homemade-looking** stations provide **space for many people** and offer activities including writing one's name on a **familiar** chalkboard, navigating a maze, and guiding a washer along a twisting rod. The variety of tasks lead to an **open-ended** experience that people can **preview** before approaching. Most visitors find these tasks quite challenging because the mirror reflects an image that is backwards, upside down, or reversed from left to right.

Mix and Match

4/9 DESIGN ATTRIBUTES

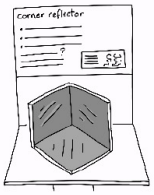
This exhibit is about color mixing and perception, providing visitors with a hands-on experience with the infinite number of colors that can be created with red, green, and blue light (RGB), and how surprisingly difficult it can be to match color.

At Mix and Match visitors attempt to make a **whimsical** elephant disappear from the center of a computer screen by mixing red, green, and blue lights. The **open-ended** experience allows visitors to vary the color of the elephant or background multiple times and explore the pixels in the monitor using a **familiar** magnifying glass. The label includes an **image of a person** to illustrate how television screens use similar RGB pixels.

Non-EDGE Exhibits

Corner Reflector

NO DESIGN ATTRIBUTES



This exhibit is about mirror reflection and shows how mirrors aligned at 90° always reflect light back to its source.

At Corner Reflector visitors cover one eye and move their head around while looking into the corner of three mirrors that are joined together at 90° (the inside half of a mirrored cube). Visitors are encouraged to switch eyes. Visitors discover that the image of their open eye does not change locations in the mirror, but can always be seen in the corner where the three mirrors join.

Hysteresis Motor

NO DESIGN ATTRIBUTES

This exhibit is about how the magnetism of a motor is slightly out of step with the magnetic field below the motor, and how one's interference with that magnetic field can alter that hysteresis.

At Hysteresis Motor visitors can interact with a magnetic field by altering the speed of a small red motor that is responding to a magnetic force. Due to the magnetic force, the motor's response is often slow, which is called *hysteresis*. Visitors can try to change the speed of the motor by spinning the red motor in either a clockwise or counterclockwise direction, altering the effect of the magnetic field.

Table 2 *Note.* Artwork by Lisa Sindorf.

We narrowed the number of exhibits in the study based on the limited number of hours recommended for conducting a focus group with our participant age range (two hours or less).

The following constraints informed our choice of exhibits:

- The space available in the 324 square foot laboratory, along with the size of all four exhibits. Exhibits range in size from small wall hangings to the size of large cars. We needed four exhibits that could all fit in the space together and allow for comfortable roaming along with a group discussion table.
- Camera angles available for recording exhibit use. For example, taller exhibits could block video angles of the other exhibits in the room; we avoided exhibits that could cause visual interference.
- Audio interference from noisier exhibits. Some exhibits clank and clatter; we tested potential exhibits in the laboratory and avoided those that would have obscured audio data of girls' learning conversations.

Participants

Based on existing focus group guidelines (Krueger and Casey 2000), the team recruited four groups aiming for six girls per group. In the end, 22 girls aged 8–13 participated. Selected participants were given a $50 gift card, lunch, free parking or transit, and admission for up to five people. The research team made two concerted efforts to ensure variability in participant's prior social, historical, and cultural experiences. First, we created the opportunity to learn about variability based on girls' age by conducting two focus groups with 8–10 year olds (55%) and two with 11–13 year olds (45%). This age split was based on children's developmental shift from school-age and concrete thinking to adolescence and more abstract thinking (Sigelman and Rider 2012).

Second, we partnered with Girl Scouts (GS) of Northern California to actively recruit girls from a range of economic and ethnically diverse communities, with a focus on Latinx girls. The larger aim was to avoid a pitfall commonly seen in equity studies, which more often focus on white, middle-class participants (Gay 2002, West and Fenstermaker 1995). Our emphasis on Latinx participants aligns with the Exploratorium's existing commitment to better engage Latinx communities. The GS partners selected six Bay Area counties based on economic and ethnic diversity. Bilingual recruitment flyers were developed with the GS partners to reach a broader set of participants. Ninety-five girls applied and 27 were invited to participate.

Participants were chosen based on age, ethnic and geographic diversity, Latinx overrepresentation, and ensuring that the girls in each focus group did not come from the same troop. The girls represented counties with varied economic profiles; however, we did not collect socioeconomic home data based on a strong recommendation from the GS partners regarding guardian comfort. The resulting focus group participants were 41% Latinx, 18% African-American, 18% Asian, 13% Caucasian/White, 5% Middle Eastern, and 5% Native Hawaiian and Pacific Islander.

Data Collection

Each participant wore a wireless microphone and was videotaped throughout a two-hour session. After the participants used the four exhibits on their own (two which incorporated the EDGE Design Attributes and two which did not) the focus group researcher conducted a group discussion. The discussion questions were developed using existing methodological guidelines (Krueger and Casey 2000, Rennekamp and Nall 2012). The conversations centered around girls' experiences and learning at each of the exhibits. The majority of the exhibit explorations and discussion took place while the participants were unaware of the study purpose or the EDGE

Design Attributes. Then, near the end of the focus group discussion, the researcher described the EDGE project and its top-level findings. This allowed us to gain in-depth input from the participants that was directly tied to the two kinds of exhibits—EDGE and non-EDGE—and each of the nine EDGE Design Attributes.

Analysis

Focus group videos and discussions were transcribed by onsite data collectors. Transcriptions and videos were systematically coded and analyzed using Krueger's (2002) step-by-step methodology. This entailed reading the transcripts and reviewing the videos iteratively while noting context, internal consistency, frequency, extensiveness, intensity, and big ideas. The research team, with input from seminal literature and expert advisors, identified and coded emergent learning themes, as well as indicators of interest and experience (Miles and Huberman 1994). Quantitative data from the video observations (such as the length of time girls chose to spend at exhibits, whether they chose to return to any exhibits, and their depth of engagement at the exhibits) were folded into the qualitative analysis of the focus group interactions and discussions, such as girls' embodied interactions, visual attention, and exclamations (Patton 1990, Strauss and Corbin 1990). Here we share the results of this analysis, interwoven with discussion.

Results and Discussion

Girls are more engaged at exhibits that incorporate the EDGE Design Attributes

The following results answer our first research question: *How does girls' engagement at exhibits that incorporate the EDGE Design Attributes contrast with engagement at exhibits that do not incorporate the design attributes?*

Science museums excel at sparking interest and providing engaging learning experiences (Falk and Dierking 2010, Hamilton et al. 1995, Humphrey and Gutwill 2005, National Research Council 2009, National Science Board 2008, Randol 2005, Salmi 2001, 2002). The focus group study aimed to triangulate the large-scale quantitative findings by exploring whether the exhibits that incorporated the EDGE Design Attributes engaged girls better than the exhibits that did not. The following vignette shares 8 year old Leah's experience, exemplifying the findings for the first research question.

> Each focus group began with a brief introduction around a table. Girls were given instructions to explore the four exhibits as they wished. Leah excitedly leapt from the table, scanning the room with the four exhibits, and deciding where to start. She begins by diving into Through the Looking Glass (EDGE exhibit), where she spends a little more than two minutes. She commences at one of the four stations, the ball maze, by trying multiple times to get the ball into the hole while looking in the mirror. She then moves to the station with chalk where she tries very diligently to write her name on the chalkboard while only looking in the mirror. After several tries, she appears satisfied with her reflected name. She moves to the next station where she coaches and carefully watches Lucy's technique for getting a washer through a twisty rod without touching it. Once Lucy leaves, Leah gives it a try and quickly discovers it's harder than it looks and requires several attempts. Leah skips the fourth station at Through the Looking Glass (EDGE exhibit) and advances to Mix and Match (EDGE exhibit).
>
> At Mix and Match (EDGE exhibit) Leah explores the hanging magnifying glass and the computer screen while also pushing buttons to adjust the levels of Red, Green, and Blue color in an attempt to make the elephant match the background and disappear. She doesn't get them to match and after a short period, she briefly moves on to Hysteresis Motor (non-EDGE exhibit). For less than a minute, she touches the brass knob, spins the red wheel, and looks at the label. She then returns to Through the Looking Glass (EDGE exhibit) for an additional two minutes. During this time she re-explores the ball maze.
>
> Leah then returns to Mix and Match (EDGE exhibit) for a deeper dive adjusting the color levels while looking through the magnifying glass. Lucy joins her and they begin to work together on making the funny looking elephant disappear into the colored background. Two more

> girls join in the challenge and one of them says, "put more green" as they all continue to work together. "Yay, I did it!" says Leah and she leaves after spending a little over 3 minutes there.
>
> Leah scans the room again and heads to Corner Reflector (non-EDGE exhibit) for less than a minute, touching the three-sided cubed mirror and taking a quick peek. She returns to Through the Looking Glass (EDGE exhibit) for a third time. She goes back to the twisty rod to try again and then returns to the ball maze for a third time, determined. In her last minute before joining the group she visits the fourth station with the pen maze. She quickly tries it out, but doesn't have time to complete it.
>
> Back at the table, when asked which exhibits they liked, Leah enthusiastically joins the others in her group in pointing to the two EDGE exhibits, Mix and Match and Through the Looking Glass. Expanding on her feelings about Through the Looking Glass (EDGE exhibit), Leah shares, "It was pretty fun when you were writing it, it was a challenge." Like most of the others in her group, Leah reports that she doesn't like the other two non-EDGE exhibits, Corner Reflector and Hysteresis Motor, as much. Partway through the discussion, the researcher described the EDGE Design Attributes to the focus groups. When asked which exhibits have the attributes, Leah animatedly points to Mix and Match (EDGE exhibit) and Through the Looking Glass (EDGE exhibit), and shakes her head no when referring to the two non-EDGE exhibits.

Leah's exhibit journey was reflected in the overall findings. Girls' experiences were highly positive at the EDGE exhibits compared to the non-EDGE exhibits. We found that the focus group participants were in fact more engaged at the exhibits that incorporated the EDGE Design Attributes:

- **Girls reported liking the EDGE exhibits more than the non-EDGE exhibits.** Nearly all of the girls reported liking the EDGE exhibits, while very few reported liking the non-EDGE exhibits. Similarly, girls made far more positive comments about the EDGE exhibits than about the non-EDGE exhibits.

- **Girls' discourse and affect demonstrated more enjoyment at the EDGE exhibits.** Nearly all of the girls used the words fun or enjoyable to describe their experience at the EDGE exhibits, while very few used those kinds of words to describe their non-EDGE exhibit experiences. This result was also mirrored in the joyful tone of their exclamations while discussing the exhibits.

- **Girls displayed more enjoyment at the EDGE exhibits through their behavior.** In addition to emotional enjoyment, the participants also showed behavioral enjoyment by doing the exhibit activities multiple times. This repeated exploration typically occurred for girls while at the EDGE exhibits, but rarely at the non-EDGE exhibits.

- **Girls had higher dwell times at the EDGE exhibits than the non-EDGE exhibits.** Most girls used the EDGE exhibits for far longer than they used the non-EDGE exhibits. Leah's time spent at each of the exhibits is an accurate depiction of dwell time for most of the participants. Dwell time is a common measure of engagement or holding power in free-choice settings (Diamond 1986, Falk 1983, Humphrey and Gutwill 2005, Sandifer 2003, Serrell 1998, Yalowitz and Bronnenkant 2009).

- **Girls more often returned to the EDGE exhibits.** Nearly all girls returned to at least one of the EDGE exhibits, while they rarely returned to use a non-EDGE exhibit. Similar to other indictors of engagement in situations where learners are free to choose, we believe returning to use an exhibit again suggests higher interest and engagement (Dancstep, Gutwill, and Sindorf 2015, Diamond 1986, Falk 1983, Humphrey and Gutwill 2005, Sandifer 2003, Serrell 1998, Yalowitz and Bronnenkant 2009).

- **Girls were able to identify when the EDGE Design Attributes were present, and related the design attribute presence to their own enjoyment.** After learning about each of the EDGE Design Attributes, all but one of the girls were able to identify when each attribute was present at the exhibits, and when each was missing. Relatedly, many girls noticed that they better enjoyed the exhibits that incorporated the EDGE Design Attributes. One of the girls sums it up best, "The ones [exhibits] that I didn't like were the ones with less of these [EDGE Design Attributes] and the ones I liked were the ones with more of them."

Taken together, these results triangulate the findings from the large-scale quantitative study, and provide a more in-depth understanding of girls' initial and affective engagement at exhibits with and without the EDGE Design Attributes. Participants' strong positive response to the attributes align with the aspects of learning considered to be of special value in informal science education by the Committee on Learning Science in Informal Environments (2009). Research has found that nondominant communities are able to perceive that museums are not designed for them (Dawson 2014, 2019a, 2019b). Opening our practices to include, represent, and value a broader variety of female perspectives clearly provides a more engaging environment (Banks et al. 2007, Bell et al. 2012, Calabrese Barton 1998, Taub 2006, Thorne 1993). The EDGE Design

Attributes amplify the value of ISE environments for a broader audience providing motivating evidence for museums to incorporate the attributes into the exhibit development process.

Girls are varied and so are their responses to the EDGE Design Attributes

Below we answer our second research question: *In what ways are girls' responses to each of the EDGE Design Attributes consistent, and how do they vary?*

Given our grounding in Culturally Responsive Pedagogy (CRP), and the variability within communities that is celebrated by CRP, we expected reactions to the EDGE Design Attributes would not be the same for all girls. To learn how girls' responses to the design attributes varied, we posed two discussion questions designed to comfortably allow participants to share their positive and contrary reactions. The first question asked why focus group participants thought each attribute was engaging for a large number of girls. Table 3 provides direct quotes from the participants. The quotes show girls' strong positive reactions to each of the attributes, while also serving to highlight the variability in their reasoning for why the attributes might work (e.g., "trying different things" and "use with others" for **Multiple stations or sides**).

Table 3. Participants' quotes explaining why they think the EDGE Design Attributes work for girls

EDGE Design Attribute	Quotes
Playful, whimsical, or humorous	*"It's fun for everyone if it's something fun or whimsical because it catches your attention..."* *"Sometimes when it's playful, you can't resist but going over and playing with it. Also, with the "funny" [aspect of the attribute]: people like to laugh…."*
Homey, personal, homemade, or delicate	*"Homey, I feel like it wraps you up in a warm, comfy blanket."* *"When something is delicate, girls are not like boys, all rough. Girls like to keep the personal to themselves and girls like to feel at home. Girls are also very creative so they like making homemade stuff."*
Multiple stations or sides	*"Exhibits with multiple stations keep you stimulated for a longer amount of time; you can try different things and then go back to the one you like and try something else with it."* *"Because you can be with your friends or other people, not just by yourself."*
Open-ended	*"I like sitting down and going through and looking at the multiple possibilities for things."* *"There's different ways to do it, so it never gets boring."*
Space to accommodate three or more people	*"I think people like that because multiple people can be doing it at the same time, but they'll still have their own space to do it."* *"So if it has [space to accommodate three or more people], then it wouldn't get as crowded as easily, and you wouldn't feel like you were being pushed in with everyone else who's there."*
Image of a person	*"Well sometimes if an exhibit has a photo or drawing of a person, that could make you think, 'Oh people can do this in everyday life, I could try this out and see what it's like.'"*
Watch others to preview	*"Sometimes they have long instructions and you don't want to do that. But if you watch others play with it, you might understand it."* *"It helps you understand it more, like when you look at it, you already know what to do, and then you understand it as you play it."*
Use drawing	**"Some people are visual learners ... pictures help them learn how to do the exhibit."* ** "I wouldn't want to read [the label] but I could see someone in the picture doing it."*
Familiar object	** "It's like you're playing with something like a regular toy ... but just at a museum."*

In practice, we recommend that teams read these quotes to connect with girls' real experiences and voices regarding each of the EDGE Design Attributes.

Second, we asked the participants to mark and discuss the EDGE Design Attributes they found most surprising. Sharing what was surprising for the girls allowed us to get at contrary reactions in a more comfortable manner, avoiding pleasing bias. Multiple focus group girls[1] were surprised by two of the nine design attributes from the large-scale study.

Nearly half of the girls were surprised by **Image of a person.** For those who were surprised, they reported not always understanding the appeal a photo or drawing of a person might add, especially if it was one that didn't resonate with them. As one participant said,

"Image of a person [surprised me] because I don't see how it affects you."

Further, a few of the girls thought they might feel like they were being watched depending on the image:

> "… it's kind of weird to be looking at a person while you're doing something, or maybe it's the staring thing, where you're looking at a picture of a person in the eyes, I find that kind of creepy and it weirds me out."

Notably, the majority of the participants who were surprised by **Image of a person** were 11–13 year olds. The sensitivity around this issue may in part align with this age group's shift into adolescence, which is accompanied by improved social-perspective-taking skills and more common preoccupations with how they present themselves in public due to increased social pressures (Sigelman and Rider 2012). In practice, museums should continue to explore how images affect girls of multiple ages.

[1]It is important to note that due to the timing with one of the groups, we were only able to address this question to three of the four focus groups (17 of the 22 girls). Further, we were unable to share or discuss **Use drawing** or **Familiar objects** with the focus groups because these attributes emerged as part of the most important set later in the quantitative research study analysis process.

The second EDGE Design Attribute that was surprising to multiple focus group girls was **Multiple stations or sides**. While only a few of the girls found this surprising, for those who did, they reported that sometimes girls prefer to work alone or independently. As one participant said,

> "Sometimes I like to work on things on my own, so it's weird that people want multiple sides."

In practice, museums should incorporate multiple sides and stations when it makes sense, but not aim to design multiple stations or sides into every exhibit.

The remaining design attributes did not have any shared surprise among girls. However, we do want to celebrate and acknowledge all aspects of variability. There were two additional comments regarding surprise about the EDGE Design Attributes, each represented by a single participant. First, regarding **Homey, personal, homemade, or delicate** one girl noted surprise because:

> "… if it isn't yours, you shouldn't mess it up." [Probe: Can you say more?] "It's surprising because in your head, you see something you want to do, something you want to make ... but it's not actually yours."

Second, a solitary girl noted surprise about **Watch others to preview** because she felt it could not stand alone**:**

> "... even though you want to know before you read the instructions, I think it's still better to read the directions, so that it's more detailed on what to do."

Together, these results suggest that the EDGE Design Attributes really resonate for most girls, triangulating the original quantitative results (Creswell 2009). However, not every attribute works for every girl—a notion that aligns with our theoretical framework grounded in Culturally Responsive Pedagogy (Dancstep and Sindorf 2018a, Gay 2002, 2010, Ladson-Billings 1995, Paris 2012). In fact, these findings provide further evidence that the CRP approach can answer

the conundrum: *How can we design for females, yet not reinforce stereotypes?* This variability recommends a flexible approach to incorporating the EDGE Design Attributes, and reinforces the need for nuanced audience research as museums develop exhibitions. Practitioners should not expect any single exhibit to engage every female, nor incorporate every attribute; instead, they should thoughtfully draw upon the set of design attributes to reach a wider audience.

Girls' learning appears to deepen in particular ways when exhibits include the EDGE Design Attributes

The subsequent results begin to address our third question: *How does girls' learning at exhibits that incorporate the EDGE Design Attributes contrast with learning at exhibits that do not incorporate the design attributes?*

Science centers' hands-on interactivity and playful exploration has been linked to their ability to foster scientific thinking in addition to engagement (Hamilton et al. 1995, Humphrey and Gutwill 2005, National Research Council 2009, Randol 2005). To answer the third research question, we looked for indicators of learning that the EDGE Design Attributes may support. The research team began by reviewing video with expert advisors and identifying potential learning themes, looking at girls' embodied interactions, visual attention, exclamations, and discourse. The team then narrowed those potentials to a smaller set of common themes based on girls' learning behaviors and their descriptions of their experiences. Two of the themes were difficult to disentangle. To further hone their definitions we turned to the definitions and descriptions of the learning strands set forth by the Committee on Learning Science in Informal Environments

(2009). In the end four learning themes emerged from the video data and discussion transcripts: Skill Building, Connected Learning, Engaging in Scientific Reasoning, and Understanding Scientific Knowledge. To determine whether the EDGE Design Attributes supported different aspects of learning, we examined whether each of the learning themes occurred more or less often at the EDGE exhibits.

We define all four learning themes and discuss their prevalence at the EDGE and non-EDGE exhibits. First, we provide a contextual sense of the learning themes via the following vignette of 11 year old Avi's exhibit explorations and reflections:

> Before Avi begins to explore the four exhibits she takes a quick look around the room and then heads over to Through the Looking Glass (EDGE exhibit). Once there she begins at the twisty rod station working very intently on not touching the rod with the washer while looking in the mirror. She then goes to the 3-D ball maze station where she repeatedly tries to get the ball into the hole by tilting the platform back and forth, all while looking only in the mirror. She ends her four-minute stay at Through the Looking Glass (EDGE exhibit) by navigating the 2-D concentric circle maze station with her finger while looking in the mirror. Later, while discussing the exhibits with the group, Avi evidences Skill Building when she describes her learning experience at Through the Looking Glass (EDGE exhibit): "Yeah, the mirror with the maze I was trying to get the little ball to move, to move it. It looked like there was a hole there through the mirror, but it wouldn't go through and then I figured out I was looking at the wrong spot, so I had to try it all over again." Avi expressed this kind of Skill Building talk at Mix and Match (EDGE exhibit) as well, but not at the non-EDGE exhibits.
>
> Avi decides to go to Corner Reflector (non-EDGE exhibit) where she reads the label and starts to cover one eye while moving her head side to side and looking at the three-sided mirror cube. She then covers her other eye and repeats the previous steps. In total she spends about minute and a half exploring. During group discussions, Avi signals her own Engagement in Scientific Reasoning: "Some parts of it were interesting, where you could look into the mirror and see how your eye is not moving, but then it got a little bit confusing when you

> could look at [it with] both eyes. I couldn't really see anything, like which one was closer, which was my dominant eye." She showed similar Engagement in Scientific Reasoning across all four exhibits.
>
> Next she makes her way to Mix and Match (EDGE exhibit) where she begins by pushing the buttons to adjust the red, green, and blue lights that make up the color of an elephant on a computer screen. Avi attempts to make the elephant disappear from the center of overlapping RGB "spotlights" by matching the elephant's color to the background. She gets very close to making it disappear when Maya joins her. Avi uses Mix and Match (EDGE exhibit) for nearly three minutes, and then gives her seat to Maya. She begins to coach Maya. Subsequently, Avi shows an Understanding of Scientific Knowledge at Mix and Match (EDGE exhibit) in conversations with the group: "From clicking one of the buttons that shows the colors and what they make together, I learned that red and blue could make pink and I didn't know that blue would be needed to make pink. So that's pretty interesting." Avi shows a similar Understanding Scientific Knowledge at Hysteresis Motor (non-EDGE exhibit) and Corner Reflector (non-EDGE exhibit), but not at Through the Looking Glass (EDGE exhibit).
>
> Avi returns to Through the Looking Glass (EDGE exhibit) to experience the fourth station where she repeatedly tries to write her name in chalk while looking in the mirror. She smiles and moves on to Hysteresis Motor (non-EDGE exhibit) for a little less than a minute. At Hysteresis Motor (non-EDGE exhibit) she quickly turns the knob to adjust the motor speed and also manually moves the red wheel. She reads the label some and then joins the rest of the girls in the group. In discussion with the group, Avi shares an instance of Connected Learning at Hysteresis Motor (non-EDGE exhibit): "It was fun. It sort of reminded me of fourth grade when we learned about magnets and energy and things like that." Such connections were common for Avi at Hysteresis Motor (non-EDGE exhibit), Corner Reflector (non-EDGE exhibit), and Mix and Match (EDGE exhibit), but not at Through the Looking Glass (EDGE exhibit).

One of the four learning themes was more common at the EDGE exhibits compared to the non-EDGE exhibits. Learning that involved repeating and varying activities, or Skill Building, occurred much more often at the EDGE exhibits. The remaining three learning themes were equally prevalent at the EDGE and non-EDGE exhibits.

Skill Building. Skill Building involved girls repeating and varying actions, activities, and tasks. This code arose in both video observations and discussion responses. The following quotes exemplify girls' Skill Building remarks:

> "When I was writing it [her name on the chalkboard, reflected in the mirror], I figured out the pattern of what it was so then I retried it, and it ended up looking a lot better than the first time," and
>
> "I also liked when you mixed the color and then you got the right color and then you switch the color, it's equally hard the next time you do it when it's a different color, it's not like it gets easier. It's the same [still challenging]."

Formal and informal learning researchers have found that skills practice is important to many aspects of STEM learning, such as inquiry, spatial reasoning, and computational thinking (Allen et al. 2008, Ansbacher 2005, National Research Council 2009, Kafai and Burke 2015, Gutwill and Allen 2010, Humphrey and Gutwill 2005, Newcombe, Uttal, and Sauter in press). Repeating and varying elements of an exhibit is also considered evidence of high-level engagement (Barriault and Pearson 2010, Van Schijndel, Franse, and Raijmakers 2010), and we used those behavioral indicators as evidence of engagement in the large-scale quantitative study. Fortunately, the qualitative nature of the focus groups allowed us to expand upon the brief behavioral aspect to get at a deeper more complex version of this kind of learning. In the qualitative Skill Building learning theme, we were able to closely look at girls' embodied interactions, visual attention, and exclamations while repeating and varying, as well as their discourse about their explorations during the exhibit play and group discussions.

Encouragingly, our results suggest that the EDGE Design Attributes support skills practice for girls. In fact this was the most common learning outcome overall, and the only learning outcome that was more common at one kind of exhibit. Far more girls engaged in Skill

Building at the EDGE exhibits, and the majority of those girls engaged in Skill Building more often. However, girls rarely engaged in Skill Building at the non-EDGE exhibits.

Connected Learning. Connected Learning involved girls applying prior knowledge, and/or sharing how the exhibit experience connected to their daily lives. Evidence of Connected Learning includes statements such as "That magnetic field in the wheel is kind of what they use in fast-paced trains to keep it moving faster, so I already knew a little about that too," and "It reminded me of my grandma's mirror in her bathroom. It's a corner, and she has two mirrors. And you look, and there's like 100 of you." Informal and formal educators recognize the importance of learners' linking to their prior knowledge and experiences (Falk and Dierking 2000, Falk and Storksdieck 2005, Gutwill and Allen 2010, Gutwill, Hido, and Sindorf 2015, Hein 1998, Kumpulainen and Sefton-Green 2012, Paris 2012, Roschelle 1995, Vygotsky 1978).

Surprisingly, we found that Connected Learning happened for fewer girls and less often at the EDGE exhibits than at the non-EDGE exhibits. However, only one of the EDGE exhibits had a lower number of girls who engaged in Connected Learning and fewer instances compared to the non-EDGE exhibits.

Engaging in Scientific Reasoning. Engaging in Scientific Reasoning revolved around girls making sense of the natural and physical world by engaging in the processes of exploration, manipulation, testing, observation, prediction, comparing, and questioning (National Research Council 2009). Engaging in Scientific Reasoning included statements such as "I thought it was challenging too, and it was interesting figuring out how it works, but they were all sort of the same to me because they were all kind of backwards [Probe: Say more?] They all work the same way, you figure it out the same way," and "I like how, like it says, when you close one eye then

the other eye always ends up in the corner. And I thought it was really interesting because I didn't know that." Engaging in Scientific Reasoning is related to scientific inquiry, and has been well studied in science museums (Gutwill and Allen 2010, Gutwill and Allen 2012, Humphrey and Gutwill 2005, Kisiel et al. 2012, National Research Council 2009, Randol 2005).

Engaging in Scientific Reasoning was very common among the girls and happened often at the EDGE exhibits and at one of the non-EDGE exhibits.

Understanding Scientific Knowledge. For Understanding Scientific Knowledge girls demonstrated some understanding of explicitly scientific concepts, arguments, explanations, models, or facts (National Research Council 2009). Examples of Understanding Scientific Knowledge include, "I learned that the mirror makes it the opposite, where the writing is upside down, but in the mirror, it made it right-side up," and "I kind of learned that the concept of mixing light is different than the concept of mixing paint in a way. They're similar, but if you mix paint, it will end up different than if you mix light." Understanding Scientific Knowledge is paramount to formal education (National Research Council 2000, Plummer and Krajcik 2010, Wilson et al. 2010). Scientific knowledge has been studied in informal science education (Lee et al. 2011, National Research Council 2009, Stavrova and Urhahne 2010); however, ISE has shifted toward a broader focus on learning processes like those described above (Ansbacher 2005, National Research Council 2009).

Understanding Scientific Knowledge was more prevalent for girls at the EDGE exhibits; however, that difference was driven by only one exhibit.

The results for Connected Learning, Engaging in Scientific Reasoning, and Understanding Scientific Knowledge suggest that learning was less dependent on the presence or

absence of the EDGE Design Attributes. Instead, exhibit-by-exhibit differences play a larger role. Based on those three learning themes there is little evidence that the EDGE Design Attributes contribute to enhancing girls' learning beyond engagement. However, the fact that Skill Building was far more common at the EDGE exhibits suggests that museums should incorporate the EDGE Design Attributes to not only enhance girls' engagement, but also their learning.

The Skill Building results provide additional support for prior research on *family* learning at exhibits with two of the EDGE Design Attributes: families engage and learn more when exhibits have Multiple stations and are Open-ended (Borun and Dritsas 1997, Borun et al. 1998, Humphrey and Gutwill 2005). While the focus group data does not allow us to directly explore the connections between specific design attributes and Skill Building, it is notable that some skills practice comments also reference the open-ended design of the exhibits. It would be interesting for future research to explore connections between each of the design attributes and girls' Skill Building behavior and conversations. We recommend that such investigations not only examine how the EDGE Design Attributes are directly related to Skill Building, but also the indirect relationships via increased engagement (e.g., use or time spent).

Most importantly the Skill Building results provide an argument for pushing on the boundaries of science. Unfortunately, STEM is not gender-neutral; many STEM practices are associated with traits related to stereotypes of masculinity such as rationality, objectivity, and logic (see, e.g., Achiam and Holmegaard 2015, Archer et al. 2012, Blickenstaff 2005, Fenollosa, Achiam, and Holmegaard 2016), while activities related to stereotypes of femininity such as subjectivity, caring, and aesthetics are not seen as important to science (McCreedy and Dierking 2013, Rosser 1991). This bias toward the masculine, often excludes learners (of all genders)

whose interests and experiences are not aligned with those ideals (Achiam and Holmegaard 2015, Dawson 2014 and 2019a, Fenollosa, Achiam, and Holmegaard 2016, McCreedy and Dierking 2013). A growing body of research supports the important notion that designing with varied female identities in mind can create and enhance learning opportunities (Calabrese Barton et al. 2013, Dawson, 2019a; Rosser, 1991). Experts in Culturally Responsive Pedagogy have revealed similar findings with other nondominant groups (e.g., Gay 2010, Ladson-Billings 1995). The fact that girls engaged in far more Skill Building at the exhibits with the EDGE Design Attributes provides further evidence for this important outcome. By incorporating the EDGE Design Attributes at exhibits museums can consciously add to the message that there is not one way to do science, and begin to provide equitable opportunities for learning.

Limitations

The focus group research was intended to triangulate the results of the larger research study (Dancstep and Sindorf 2018b). Therefore our approach aimed for gaining a deeper understanding of the impacts of the EDGE Design Attributes rather than finding generalizable results. Two limitations within the focus group methodology raise potential concerns. The first limitation has to do with the ecological validity of the results. Conducting the focus groups in a laboratory setting meant that the findings were more vulnerable to pleasing bias. Indications of pleasing bias could manifest in girls' using all exhibits thoroughly instead of picking and choosing as they would on the museum floor (Falk and Dierking 2000). Such behavior was evident across all four exhibits; it is possible that the impacts of the EDGE Design Attributes on engagement and interest were even greater than we were able to detect. Pleasing bias could also have influenced the girls' willingness to make negative comments about the exhibits; fortunately,

the data revealed strong evidence that the girls felt comfortable sharing their positive and contrary experiences.

The second limitation has to do with the restricted representation of the exhibits in the study. This was largely due to the limited number of exhibits in the study based on the constraints of focus group timing (e.g., less than 2 hours for our age group), location (e.g., size), and methodology (e.g., audio interference). The restricted representation of exhibits in the study made the results vulnerable to alternative explanations for the findings. In particular, our practitioners worried that content at the non-EDGE exhibits may be pitched at a higher grade level than the EDGE exhibits; however, this was true of only one non-EDGE exhibit and therefore not likely driving the results. Along the same lines the EDGE exhibits offered challenges to try, while the non-EDGE exhibits did not. Challenges at exhibits have been related to motivation (Perry 2012); therefore it is possible that the challenges could be partially driving the engagement and Skill Building findings. These limitations should be kept in mind when considering the results.

Conclusion

The focus group results offer a more nuanced understanding of the EDGE Design Attributes, and provide motivation to incorporate the attributes into exhibits to broaden participation and learning for females in informal science education (ISE). The participating focus group girls were more engaged when the attributes were present at the exhibits, adding further support for the set of attributes identified in the large-scale quantitative study. Girls also expressed largely positive responses to the EDGE Design Attributes. One of the struggles museums face when attempting to become more inclusive spaces is uncertainty around designs

that keep nondominant groups in mind. Culturally Responsive Pedagogy is typically used when exploring ways to engage learners of marginalized racial, ethnic, or language groups. The results of this study, and the larger project, provide evidence that CRP works well when applied to females and serves as a valuable theory for those museums truly working to be inclusive of nondominant groups. The strong results for our first research question suggest that museums should rely on the Female-Responsive Design Framework and incorporate the EDGE Design Attributes to better engage girls at STEM exhibits. Further, such engagement increases girls' exposure to the learning experiences that informal science education provides.

For our second research question, the two most surprising attributes for the participants were Image of a person and Multiple stations or sides; both are important areas for further investigation. But more importantly, the surprising attributes serve as reminders that strategies grounded in Culturally Responsive Pedagogy are nonprescriptive and are not expected to work for all girls. This result provides further support for CRP as a driving theory in informal science education research and development, especially when working to expand reach beyond the status quo. While we recommend that museums incorporate the EDGE Design Attributes into exhibits to create more inclusive experiences, we also suggest they aim for a variety of exhibit designs and continue to explore and evolve the broader strategies in the Female-Responsive Design Framework.

For our final research question, Skill Building emerged as the most common learning theme and was far more prevalent for girls when the EDGE Design Attributes were present. This finding suggests that incorporating the EDGE Design Attributes can help enhance girls' cognitive learning opportunities.

We stand with many researchers and educators who are seeking inclusive practices in STEM. By incorporating girls' voices into research and design thinking, the informal science education field can adjust its pedagogical approach to better resonate for girls. Museums can broaden engagement and learning for girls by integrating the EDGE Design Attributes into their collections. Simultaneously, the ISE field must continue to explore and develop the Female-Responsive Design Framework. The EDGE project provides a foundation for expanding STEM exhibit practices to incorporate females' ways of learning; a foundation that must be built upon together as a field.

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References

Achiam, M., and H. T. Holmegaard. 2015. *Hypatia project: Criteria for gender inclusion*. edited by University Of Copenhagen.

Alexander, J. M., K. E. Johnson, and K. Kelly. 2012. Longitudinal analysis of the relations between opportunities to learn about science and the development of interests related to science. *Science Education* 96 (5):763-786.

Allen, S., P. B. Campbell, L. D. Dierking, B. N. Flagg, A. J. Friedman, C. Garibay, R. Korn, G. Silverstein, and D. A. Ucko. 2008. *Framework for evaluating impacts of informal science education projects. (available at:* http://insci.Org/resources/eval_framework.Pdf*)* accessed November, 2016. http://www.informalscience.org/sites/default/files/Eval_Framework.

Anderson, D., Z. Zhang, S. Chatterjee, R. Robin, and P. Aldrich. 2005. Punjab students' perceived interest, knowledge and importance of science topics: Challenging outcomes from a front-end study. *Visitor Studies* 8 (2):8-13.

Ansbacher, T. 2005. Rethinking our goals: Putting process first. *Informal Learning Review* 74:1-6.

Archer, L., J. Dewitt, J. Osborne, J. Dillon, B. Willis, and B. Wong. 2012. "Balancing acts:" Elementary school girls' negotiations of femininity, achievement, and science. *Science Education* 96 (6):967-989.

Baenninger, M., and N. Newcombe. 1995. Environmental input into the development of sex-related differences in spatial and mathematical ability. *Learning and Individual Differences* 7 (4):363-379.

Baker, D. 2013. What works: Using curriculum and pedagogy to increase girls' interest and participation in science. *Theory Into Practice* 52 (1):14-20. doi: 10.1080/07351690.2013.743760.

Banks, J., K. Au, A. Ball, P. Bell, E. Gordon, K. Gutiérrez, S. Heath, C. Lee, Y. Lee, J. Mahiri, N. S. Nasir, G. Valdés, and M. Zhou. 2007. *Learning in and out of school in diverse environments: Life-long, life-wide, life-deep.* The LIFE Center.

Baranowski, M., and J. Delorey. 2007. *Because dreams need doing: New messages for enhancing public understanding of engineering*. BBMG and Global Strategy Group.

Barriault, C., and D. Pearson. 2010. Assessing exhibits for learning in science centers: A practical tool. *Visitor Studies* 13 (1):90-106. doi: 10.1080/10645571003618824.

Bell, J., J. Besley, M. Cannady, K. Crowley, A. Grack Nelson, T. Philips, K. Riedinger, and M. Storksdieck. 2019. The Role of Engagement in STEM Learning and Science

Communication: Reflections on Interviews from the Field. Washington, DC: Center for Advancement of Informal Science Education.
Bell, P., L. Bricker, C. Tzou, T. Lee, and K. Horne. 2012. Exploring the science framework: Engaging learners in scientific practices related to obtaining, evaluating, and communicating information. *Science Scope 79* (8):31-37.
Ben-Eliyahu, A., D. Moore, R. Dorph, and C.D. Schunn. 2017. Investigating the multidimensionality of engagement: affective, behavioral, and cognitive engagement across science activities and contexts. *Contemporary Educational Psychology 53*: 87-105.
Blickenstaff, J. C. 2005. Women and science careers: Leaky pipeline or gender filter? *Gender and Education 17* (4):369-386.
Bloom, B.S. and D.R. Krathwol. 1956. *Taxonomy of Educational Objectives: The Classification of Educational Goals*. David McKay: New York, NY.
Boiano, S., A. Borda, J. Bowen, X. Faulkner, G. Gaia, and S. McDaid. 2006. Gender issues in hci design for web access. *Advances in Universal Web Design and Evaluation: Research, Trends and Opportunities*. doi: 10.4018/978-1-59904-939-7.
Borun, M. 1999. Gender roles in science museum learning. *Visitor Studies Today!* 3 (3):11-14.
Borun, M., and J. Dritsas. 1997. Developing family-friendly exhibits. *Curator* 40 (3):178-192.
Borun, M., J. Dritsas, J. I. Johnson, N. E. Peter, K. F. Wagner, K. Fadigan, R. Jangaard, E. Stroup, and A. Wenger. 1998. *Family learning in museums: The PISEC perspective.* Washington D.C: National Science Foundation.
Brickhouse, N. W., P. Lowery, and K. Schultz. 2000. What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching* 37 (5):441-458.
Brotman, J. S., and F. M. Moore. 2008. Girls and science: A review of four themes in the science education literature. *Journal of Research in Science Teaching* 45 (9):971-1002.
Brown, J., L. Huerta Migus, and M. Williams. 2012. *Girls RISE (raising interest in science and engineering) museum network*. National Science Foundation GSE/EXT Award Number 0937245.
Cacace, M., C. Colonnello, and A. Olmi. 2011. *TWIST: Guidelines for communication activities on women in science to be implemented by science centres and museums*. In collaboration with & ASDO Italy.
Calabrese Barton, A. 1998. *Feminist science education*. New York and London: Teachers College Press.
Calabrese Barton, A., H. Kang, E. Tan, T. B. O'Neill, J. Bautista-Guerra, and C. Brecklin. 2013. Crafting a Future in Science: Tracing Middle School Girls' Identity Work Over Time and Space. *American Educational Research Journal 50*: 37–75.
Cardella, M. E., G. N. Svarovsky, and B. L. Dorie. 2013. Gender research on adult-child discussions within informal engineering environments (GRADIENT): Early findings. *American Society for Engineering Education*.
Cheryan, S., V. C. Plaut, P. G. Davies, and C. M. Steele. 2009. Ambient belonging: How stereotypical cues impact gender participation in computer science. *Journal of Personality and Social Psychology* 97 (6):1045-1060. doi: 10.1037/a0016239.

Cosmos Corporation. 1998. *A report on the evaluation of the National Science Foundation's informal science education program*. National Science Foundation.
Creswell, J. W. 2009. *Research design: Qualitative, quantitative, and mixed methods approaches*. 3rd ed. Los Angeles, CA: Sage Publications.
Crook, C., and D. Garratt. 2011. The positivist paradigm in contemporary social science: The interface of psychology, method, and sociocultural theory. In *Theory and methods in social research*, edited by Bridget Somekh and Cathy Lewin, 212-219. Los Angeles, CA: Sage Publications.
Crowley, K., M. Callanan, H. Tenenbaum, and E. Allen. 2001. Parents explain more often to boys than to girls during shared scientific thinking. *Psychological Science* 12 (3):258-261.
Dancstep, T., J. Gutwill, and L. Sindorf. 2015. Comparing the visitor experience at immersive and tabletop exhibits. *Curator: The Museum Journal* 58 (4):401-422. doi: 10.1111/cura.12137.
Dancstep, T., and L. Sindorf. 2016. *Exhibit designs for girls' engagement: A guide to the edge design attributes*. Exploratorium, accessed October, 2016. http://www.exploratorium.edu/sites/default/files/pdfs/EDGE_GuideToDesignAttributes_v16.pdf.
Dancstep, T., and L. Sindorf. 2018a. Creating a female-responsive design framework for stem exhibits. *Curator*.
Dancstep, T., and L. Sindorf. 2018b. Exhibit designs for girls' engagement (edge). *Curator*.
Dancu, T. 2010. *Designing exhibits for gender equity*. Doctor of Philoshophy, Systems Science: Psychology, Portland State University. Retrieved January 30, 2012, from Dissertations & Theses: Full Text. (Publication No. AAT 3439173).
Dawson, E. 2018. Reimagining publics and (non)participation: Exploring exclusion from science communication through the experiences of low-income, minority ethnic groups. *Public Understanding of Science*:1-15.
Dawson, E., l. Archer, A. Seakins, S. Godec, J. DeWitt, H. King, A. Mau, and E. Nomikou. 2019a. Selfies at the science museum: Exploring girls' identity performances in a science learning space. *Gender and Education* . DOI: 10.1080/09540253.2018.1557322
Dawson, E. 2019b. *Equity, Exclusion and Everyday Science Learning*. London and New York: Routledge.
Denner, J., L. Werner, S. Bean, and S. Campe. 2005. The girls creating games program: Strategies for engaging middle school girls in information technology. *Frontiers: A Journal of Women Studies* 26 (1):90-98.
Diamond, J. 1986. The behavior of family groups in science museums. *Curator* 29 (2):139-154.
Diamond, J. 1994. Sex differences in science museums: A review. *Curator* 37 (1):17-24.
Falk, J. H. 1983. Time and behavior as predictors of learning. *Science Education* 67 (2):267-276.
Falk, J. H., and L. D. Dierking. 2000. *Learning from museums: Visitors' experiences and the making of meaning*. New York: Alta Mira Press.
Falk, J. H., and L. D. Dierking. 2010. The 95 percent solution. *American Scientist* 98.
Falk, J. H., and M. Storksdieck. 2005. Using the contextual model of learning to understand visitorlearning from a science center exhibition. *Science Education* 89:744-788.

Feinstein, N. W. 2017. Equity and the meaning of science learning: A defining challenge for science museums. *Science Education* 101:533–538. doi: 10.1002/sce.21287.
Fenollosa, C., M. Achiam, and H. T. Holmegaard. 2016. Attracting girls to science - calling for a new approach. *Spokes* (*#18* April).
Ford, D. J., N. Brickhouse, P. Lottero-Perdue, and J. Kittleson. 2006. Elementary girls' science reading at home. *Science Education* 90:270-288.
Francis, B., L. Archer, J. Moote, J. de Witt, and L. Yeomans. 2016. Femininity, science, and the denigration of the girly girl. *British Journal of Sociology of Education* 38 (8):1097-1110.
Francis, B., and C. Paechter. 2015. The problem of gender categorization: Addressing dilemmas past and present in gender and education research *Gender and Education* 27 (7):776-790.
Froschl, M., B. Sprung, E. Archer, and C. Fancsali. 2003. *Science, gender, and afterschool: A research-action agenda.*, accessed June 22, 2007. http://www.afterschool.org./sga/content/strategies.cfm.
Gay, G. 2002. Preparing for culturally responsive teaching. *Journal of Teacher Education* 53 (2):106-116.
Gay, G. 2010. *Culturally responsive teaching: Theory, research, and practice*. 2nd ed: New York, NY: Teachers College Press.
Girls Inc. 2004. *Girls and science, math, and engineering.*, accessed January 19 2012. http://www.girlsinc.org/resources/fact-sheets.html.
Gontan, I. 2013. *Full spectrum science: Successful strategies in engaging latina girls in stem programming*. Master of Arts in Museum Studies, John F. Kennedy University.
Good, J. J., J. A. Woodzicka, and L. C. Wingfield. 2010. The effects of gender stereotypic and counter-stereotypic textbook images on science performance. *Journal of Social Psychology* 150 (2):132-47.
Greene, B. A. 2015. Measuring cognitive engagement with self- report scales: Reflections from over 20 years of research. *Educational Psychologist* 50:14-30.
Greenfield, T. A. 1995. Sex differences in science museum exhibit attraction. *Journal of Research in Science Teaching* 32 (9):925-938.
Gutwill, J., and S. Allen. 2010. Facilitating family group inquiry at science museum exhibits. *Science Education* 94 (4):710-742.
Gutwill, J., and S. Allen. 2012. Deepening students' scientific inquiry skills during a science museum field trip. . *Journal of the Learning Sciences* 21 (1):130-181. doi: 10.1080/10508406.2011.555938.
Gutwill, J., N. Hido, and L. Sindorf. 2015. Research to practice: Observing learning in tinkering activities. *Curator* 58:151–168. doi: 10.1111/cura.12105.
Hamilton, L. S., E. M. Nussbaum, H. Kupermintz, J. I. M. Kerkhoven, and R. Snow. 1995. Enhancing the validity and usefulness of large-scale educational assessments: ||. Nels: 88 science achievement. *American Educational Research Journal* 32 (3):555-581.
Haussler, P., and L. Hoffman. 2002. An intervention study to enhance girls' self-interest, self-concept, and achievement in physics class. *Journal of Research in Science Teaching* 39 (9):870-888.
Hein, G. E. 1998. *Learning in the museum*. Edited by Eilean Hooper-Greenhill and Flora Kaplan, *Museum meanings*. New York, NY: Routledge.

Hill, C., C. Corbett, and A. St Rose. 2010. *Why so few? Women in science, technology, engineering, and mathematics*. Washington DC: AAUW.
Humphrey, T., and J. Gutwill. 2005. *Fostering active prolonged engagement: The art of creating ape exhibits.* San Francisco: Left Coast Press.
Jones, G., A. Howe, and M. Rua. 2000. Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education* 84:180-192.
Kafai, Y. B., and Q. Burke. 2015. Constructionist gaming: Understanding the benefits of making games for learning. *Educational Psychology* 50(4):313–334. doi: 10.1080/00461520.2015.1124022.
Kekelis, L., E. Heber, and J. Countryman. 2005. A bridge to technology: Designing a program that attracts girls. *ASTC Dimensions* (May/June 2005).
Kisiel, J., S. Rowe, M. A. Vartabedian, and C. Kopczak. 2012. Evidence for family engagement in scientific reasoning at interactive animal exhibits. . *Science Education* 96 (6):1047–1070. doi: 10.1002/sce.21036.
Kremer, K., and G. Mullins. 1992. Children's gender behavior at science museum exhibits. *Curator* 35 (1):39-48.
Krathwohl, D.R., B.S. Bloom, and B.M. Bertram. 1973. *Taxonomy of educational objectives, the classification of educational goals. Handbook II: Affective Domain.* David McKay: New York, NY.
Krueger, R. A. 2002. *Designing and conducting focus group interviews.* http://www.eiu.edu/~ihec/Krueger-FocusGroupInterviews.pdf.
Krueger, R. A., and M. Casey. 2000. *Focus groups: A practical guide for applied research*. 3rd ed. Thousand Oaks, CA: Sage Publications.
Kutnick, P., and A. Kington. 2005. Children's friendships and learning in school: Cognitive enhancement through social interaction. *British Journal of Educational Psychology 75*:521-538.
Kumpulainen, K., and J. Sefton-Green. 2012. What is connected learning and how to research it? *International Journal of Learning and Media* 4 (2):7-18. doi: 10.1162/IJLM_a_00091.
Ladson-Billings, G. 1995. Toward a theory of culturally relevant pedagogy. *American Educational Research Journal* 32 (3):465-491.
Laursen, S. 2011. *Program for gender day*. In *Towards Women in Science and Technology (TWIST)*.
Lee, S. W.-Y., C.-C. Tsai, Y.-T. Wu, M.-J. Tsai, T.-C. Liu, F.-K. Hwang, J.-C. Lai, J.-C. Liang, H.-C. Wu, and C.-Y. Chang. 2011. Internet-based science learning: A review of journal publications. *International Journal of Science Education* 33 (14):1893–1925.
Liston, C., K. Peterson, and V. Ragan. 2008. Evaluating promising practices in informal science, technology, engineering, and mathematics (stem) for girls.
Master, A., S. Cheryan, and A. Meltzoff. 2016. Computing whether she belongs: Stereotypes undermine girls' interest and sense of belonging in computer science. *Journal of Educational Psychology* 108 (3):424-437.
McCreedy, D., and L. Dierking. 2013. *Cascading influences: Long-term impacts of informal stem experiences for girls*. Philadelphia, PA: The Franklin Institute Science Museum.
Meyer, R.E. 1998. Cognitive theory for education: What teachers need to know. In (eds. Nadine M. Lambert and Barbara L. McCombs). *How students learn: Reforming schools*

through learner-centered education. American Psychological Association: Washington DC.
Miles, M. B., and A. M. Huberman. 1994. *Qualitative data analysis* 2nd ed. London: Sage.
Milgram, D. 2005. *Gender differences in learning style specific to science, technology, engineering and math*. http://www.iwitts.org/proven-practices/retention-sub-topics/learning-style/297-gender-difference-in-learning-style-specific-to-science-technology-engineering-and-math-stem, accessed October 5. http://www.iwitts.org/proven-practices/retention-sub-topics/learning-style/297-gender-difference-in-learning-style-specific-to-science-technology-engineering-and-math-stem.
Miller, B. W. 2015. Using reading times and eye-movements to measure cognitive engagement. *Educational Psychologist 50: 31-42*.
Morgan, C., J. D. Isaac, and C. Sansone. 2001. The role of interest in understanding the career choices of female and male college students. *Sex Roles* 44 (5/6).
Munley, M. E., and C. Rossiter. 2013. *Girls, equity, and stem in informal learning settings: A review of literature*. edited by GirlsRISEnet/SAVI Planning Group. http://girlsrisenet.org/sites/default/files/SAVI Lit Review Sept 2013.pdf, Retrieved February 17, 2014.
Murphy, M. C., C. M. Steele, and J. J. Gross. 2007. Signaling threat: How situational cues affect women in math, science, and engineering settings. *Psychological Science* 18 (10):879-885. doi: 10.1111/j.1467-9280.2007.01995.x.
National Research Council. 2000. *Inquiry and the national science education standards.* Washington, DC: National Academy Press.
National Research Council. 2009. *Learning science in informal environments: People, places, and pursuits*. Edited by Philip Bell, B Lewenstein, A.W. Shouse and M.A. Feder. Washington, DC: National Academies Press.
National Research Council. 2012. *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Edited by Division of Behavioral and Social Sciences and Education: Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education. Washington, DC: The National Academies Press.
National Science Board. 2008. Science and engineering indicators 2008. In Arlington, VA: National Science Foundation. Government Report. http://www.nsf.gov/statistics/seind08/ (accessed May 22, 2008).
National Science Board. 2016. *Science and engineering indicators 2016*. Arlington, VA: National Science Foundation.
National Science Foundation. 2003. *New formulas for America's workforce: Girls in science and engineering*. Arlington, VA: NSF 03-207.
National Science Foundation. 2007. *New formulas for America's workforce 2: Girls in science and engineering*. Arlington, VA: National Science Foundation.
National Science Foundation, and National Center for Science and Engineering Statistics. 2013. *Women, minorities, and persons with disabilities in science and engineering: 2013*. Arlington, VA.: Special Report NSF 13-304.
Newcombe, N. S., D. H. Uttal, and M. Sauter. in press. Spatial development. In *Oxford handbook of developmental psychology*, edited by P. Zelazo. Oxford: Oxford University Press.

Paris, D. 2012. Culturally sustaining pedagogy: A needed change in stance, terminology, and practice. *Educational Researcher* 41 (3):93-97.
Patton, M. Q. 1990. *Qualitative evaluation and research methods*. 2nd ed. Newbury Park, CA: Sage.
Perry, D. 2012. *What makes learning fun? Principles for the design of intrinsically motivating museum exhibits*. Lanham, Maryland: Alta Mira Press.
Peterson, P., and E. Fennema. 1985. Effective teaching, student engagement in classroom activities, and sex-related differences in learning mathematics. *American Educational Research Journal* 22 (3):309-335.
Plummer, J. D., and J. Krajcik. 2010. Building a learning progression for celestial motion: Elementary levels from an earth-based perspective. *Journal of Research in Science Teaching* 47 (7):768–787.
President's Council of Advisors on Science and Technology. 2010. *Prepare and inspire: K-12 science, technology, engineering, and math (stem) education for America's future*. Washington, D.C.: Executive Office of the President of the United States,.
Randol, S. 2005. *The nature of inquiry in science centers: Describing and assessing inquiry at exhibits*.Doctoral Dissertation, Education, University of California.
Rennekamp, R. A., and M. A. Nall. 2012. *Using focus groups in program development and evaluation*. accessed December 20, 2012. https://psd.ca.uky.edu/files/focus.pdf.
Rodríguez, J. I. , T.G. Plax, and P. Kearney. 1996. Clarifying the relationship between teacher nonverbal immediacy and student cognitive learning: Affective learning as the central causal mediator, Communication Education, 45:4, 293-305, DOI: 10.1080/03634529609379059
Roschelle, J. 1995. *Learning in interactive environments: Prior knowledge and new experience. , In Falk and Dierking (eds.), public institutions for personal learning* Washington, DC: American Association of Museums.
Rosser, S. V. 1991. *Female friendly science: Applying women' s studies methods and theories to attract students.* Edited by Gloria Bowles, Renate Klein, Janice Raymond and Dale Spender, Athene series. New York: Teacher's College Press.
Roughneen, C. 2011. *The gender issue*. accessed October 23. http://www.the-twist-project.eu/media/dyn/document/Ecsite_88_The_Gender_Issue.pdf?_=1rq1Ns.
Sadker, D., and M. Sadker. 1994. *Failing at fairness: How our schools cheat girls*. Toronto, ON: Simon & Schuster Inc.
Salmi, H. 2001. *Public understanding of science: Universities and science centres*. Management of University Museums; Education and skills; OECD, Paris.
Salmi, H. 2002. *Factors affecting students' choice of academic studies: The motivation created by informal learning*. Heureka: The Finnish Science Center.
Sammet, K., and L. Kekelis. 2016. Changing the game for girls in stem: Findings on high impact programs and system-building strategies.
Sandifer, C. 2003. Technological novelty and open-endedness: Two characteristics of interactive exhibits that contribute to the holding of visitor attention in a science museum. *Journal of Research in Science Teaching* 40 (2):121-137.
Scantlebury, K., and D. Baker. 2007. Gender issues in science education research: Remembering where the difference lies. In *Handbook of research on science education*, edited by S. Abell and N. Lederman, 257-286. Mahwah, NJ: Lawrence Erlbaum.

Serrell, B. 1998. *Paying attention: Visitors and museum exhibitions.* Washington DC: American Association of Museums. Professional Practice Series.

Sigelman, C. K., and E. A. Rider. 2012. *Life-span human development, seventh edition*. 7th ed. Belmont, CA.: Wadsworth, Cengage Learning.

Sinkey, A., L. Rosino, and M. Francisco. 2014. *Designing our world: Public audiences front-end evaluation report*. Portland, OR: Oregon Museum of Science & Industry.

Stavrova, O., and D. Urhahne. 2010. Modification of a school programme in the deutsches museum to enhance students' attitudes and understanding. *International Journal of Science Education* 32 (17):2291–2310.

Strauss, A., and J. Corbin. 1990. *Basics of qualitative research*. Newbury Park, CA: Sage.

Taub, L. 2006. *Playing with gender: Children and computers in the fifth dimension.* http://www.education.miami.edu/blantonw/5dClhse/publications/tech/Taub1.html.

Taylor, D. 2005. Social science: Observing women and girls in the museum. *ASTC Dimensions* May/June:11-12.

Taylor, D. 2006. Girls, boys, moms, and dads: Learning about their different needs in science museums. In *Handbook for small science centers*, edited by Cynthia Yao. Lanham: AltaMira Press.

Thorne, B. 1993. Do girls and boys have different cultures? In *Gender play: Girls and boys in school.* Rutgers University Press.

US Department of Labor Employment and Training Administration by Jobs for the Future. 2007. *The stem workforce challenge: The role of the public workforce system in a national solution for a competitive science, technology, engineering, and mathematics (stem) workforce*. Washington D.C.

Van Schijndel, T., R. Franse, and M. Raijmakers. 2010. The exploratory behavior scale: Assessing young visitors' hands-on behavior in science museums. *Science Education*.

Verheyden, P. 2003. The great sexperiment. *ECSITE Newsletter* 54 (Spring):10-11.

Vossoughi, S., M. Escudé, F. Kong, and P. Hooper. 2013. *Tinkering, learning & equity in the after-school setting*. Paper published as a part of FabLearn Conference Proceedings, Stanford University, Palo Alto, CA.

Vygotsky, L. 1978. *Mind in society: The development of higher psychological processes*. Edited by Michael Cole, Vera John-Steiner, Sylvia Scribner and Ellen Souberman. Cambridge, MA: Harvard University Press. Original edition, Mind in society by L. S. Vygotsky.

West, C., and S. Fenstermaker. 1995. Doing difference. *Gender and Society* 9 (1):8-37.

Wilson, C. D., J. A. Taylor, S. M. Kowalski, and J. Carlson. 2010. The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching* 47 (3):276–301.

Yalowitz, S., and K. Bronnenkant. 2009. Tracking and timing: Unlocking visitor behavior. *Visitor Studies* 12 (1):47-64.