Assessing Competition in Engineering (ACE)

Research Report

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EXECUTIVE SUMMARY

This pilot study was funded by the Museum of Science's Women in Science Committee to examine the impact of competition on children participating in Design Challenges engineering experiences, and in particular, to see what effect, if any, the competitive design of these engineering activities had on girl participants. The research questions for this study included:

1. How does competition affect participants' engagement in engineering activities?
   1.a Does this differ for boys and girls?
2. How does competition affect participants' desire to take part in future engineering activities?
   2.a. Does this differ for boys and girls?
3. How does competition affect participants' self-efficacy?
   3.a. Does this differ for boys and girls?

To answer these questions, the Echo Based Bobsleds activity was performed in one of two formats at Design Challenges – a competitive or a non-competitive setup – where the non-competitive setup was modified so that a leaderboard was removed and bobsled records were not posted for other visitors to see. For both of these scenarios, data were collected through observations, interviews, and surveys from adults and children.

Overarching findings indicate that the addition of a competitive element, in this case, a leaderboard, did not affect how children engaged in this particular engineering activity. Children tested comparable numbers of designs, stayed for similar lengths of time, rated the activity in a similar manner, and gave similar reasons for why they stopped or continued participating in the challenge. These findings were also found when analyzing engagement within gender group comparisons for both scenarios.

Furthermore, when looking at survey responses for participants' interest in future engineering activities or ratings of engineering self-efficacy, no differences were seen between groups participating in the competitive or non-competitive design or within gender-group comparisons for each format. All together these findings suggest there are no ill-effects from having a leaderboard and fostering a competitive environment within this design-based activity space.

Nonetheless, this study points to possibilities for future research because follow-up interviews suggest that depending on the activity format, slight differences exist in how and, at times, why participants compared themselves to others, along with differences in how they talked about their engineering self-efficacy. Moreover, a future study with a larger sample would provide more statistical power for detecting differences between groups or could investigate how other Design Challenge activities may affect participants in unique ways.

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I. INTRODUCTION

For over 10 years, the Museum of Science (MOS) has offered facilitated drop-in engineering activities in the Design Challenges space. Here, families and school groups are encouraged to address a challenge of the day by planning, creating, testing, and improving upon a prototype using materials supplied by the program. By participating in iterative testing, visitors actively experience the engineering design process. Over the lifespan of this program, 19 different challenges have been created, 12 of which are currently used on a rotating basis. Since 2003, over half a million visitors have participated, 106,000 in 2013 alone.

Since the opening of this hands-on engineering space, the Research and Evaluation Department at the Museum of Science has repeatedly partnered with Design Challenges educators to study visitors' engagement, learning, and interest in future engineering activities. In 2013, the Museum's Women in Science Committee funded this study to examine the impact of competition on children participating in Design Challenges engineering experiences, and in particular, to see what effect, if any, the competitive design of these engineering activities had on girl participants. The research questions for this study included:

1. How does competition affect participants' engagement in engineering activities?
    1.a Does this differ for boys and girls?
2. How does competition affect participants' desire to take part in future engineering activities?
    2.a. Does this differ for boys and girls?
3. How does competition affect participants' self-efficacy?
    3.a. Does this differ for boys and girls?

Study background

Previous studies at MOS have indicated that the engineering activities facilitated by Design Challenges educators engage girls and boys comparably. Most recently, research has demonstrated that not only do girls and boys plan, create, test, and improve their engineering designs equally, but furthermore, girls demonstrate a firm understanding of having participated in an activity "like what an engineer does," with 81% of all girls interviewed mentioning at least one aspect of the engineering design cycle in their responses (Auster, R. & Lindgren-Streicher, A., 2013).

Despite these findings, literature comparing boys and girls in *formal* education environments has often cited findings to the contrary. As women comprise only 11% of all U.S. corporate engineers (Buse, K., Perelli, S., & Bilimoria, D., 2009), much work has been undertaken in recent years to examine how and why gender gaps continue to proliferate within the STEM fields, with particular attention on middle and high school years as formative to attitudes and beliefs held later in life. Psychological and sociological gender theories have been used to examine the gender gap in STEM orientation that develops in middle school and persists through high school (Legewie, J., & DiPrete, T., 2011). Case study analysis has also been used to examine pathways to careers in STEM fields, noting in particular the barriers women face in K-

12, college, grad school, and their professions (Jacobs-Priebe, L., & Crowley, K., 2013). A common theme in many of these studies is “being female in engineering,” in which women compare themselves more negatively to male peers in both confidence and ability relating to engineering; notably, competition in engineering classes was found to be discouraging to girls in particular, and had the strongest negative effect in early STEM education (Goodman, et al., 2002).

The negative consequences of competition on females in formal education environments have been well-documented. Findings suggest that, in mixed-sex settings, women fail to perform well in competitions relative to their male peers and shy away from environments in which they have to compete (Niederle, M., & Vesterlund, L., 2010). One study examining gender differences in engineering through an introductory robotics course found that although both genders reported competition to be enjoyable and integral to the course atmosphere, females preferred the cooperative class format over the competitive format, while males “flourished” in the competitive setting, overshadowing their female counterparts (Milto, E., Rogers, C., & Portsmore, M., 2002). Despite this, another study of late middle and early high school students found that girls from single-sex schools matched the traditional role assumed by boys in their behavior in competitive environments, suggesting that previously observed gender differences might reflect social learning rather than inherent gender traits (Booth, A., & Nolen, P., 2009).

Given these demonstrated gender differences in formal education environments and the lack of such gender differences in previous Design Challenges research in the Museum’s informal education environment, conversations arose within MOS about the qualities of the design-based activities offered in Design Challenges that might be leading to gender-equitable engineering opportunities. Specifically, questions came up about the nature of the competitive aspects of Design Challenges activities, and whether or not these played a role in boys’ and girls’ engagements. The study detailed herein is the result of these conversations and attempts to answer questions about the effects of competition on girls and boys participating in a Design Challenges engineering activity.

Study setup

Echo Base Bobsleds was the Design Challenges activity used in this study. Typical of a Design Challenges activity, it encourages participants to use the engineering design process and provided materials to construct something and then test and improve upon the design. In this case, visitors are encouraged to build either a fast or slow bobsled. For this study, the activity was performed in one of two formats – a competitive or non-competitive setup, defined as the following:

- the traditional, **competitive** activity format included a leaderboard that posted and updated the record for the fastest and slowest bobsleds times at that point of the day, and
- the experimental **non-competitive** format was modified so that the leaderboard was removed and no records were posted for other visitors to see.

By adapting the activity and running it according to these two formats, this research was designed to investigate how competition affects several factors relating to participants' experiences in engineering activities: their engagement in the activity, their desire to take part in future engineering activities, and their engineering self-efficacy.

Although the Design Challenges team typically runs all of their activities with some sort of leaderboard or competitive aspect, the Bobsleds activity was considered an especially strong activity to focus on when studying the effects of competition on participants. Because the Bobsled activity's setup allows participants to test their creations simultaneously, competition may be a particularly central aspect of this experience. Learning more about effects of competition in regards to an activity, like Bobsleds, that is considered to have some inherently competitive elements would be an important starting point for researchers trying to understand how competition, in general, may affect participants in an informal setting. The Bobsled activity was also chosen as the focus activity because it is run often by the Design Challenges team, thus, facilitating data collection efforts.

II. METHODS

For this pilot study, which occurred in the fall of 2013 and early winter of 2014, a range of data collection methods was employed. Like previous research and evaluation work done at Design Challenges, data were collected through observations, interviews, and survey methods. These methods were chosen because they provide a rich combination of data to help researchers understand people's experiences at the Design Challenges space. Data were collected from both adults and children.

When collecting data, researchers looked for several factors when choosing groups to be included in the study. Because Design Challenges activities are aimed at students in the age range of 4^{th}-10^{th} grade, family groups were eligible for selection in this study if they had a child between the ages of 8 and 14. Since this study was specifically looking at the effect of competition on boys' and girls' participation in engineering Design Challenges, data collectors also took gender into consideration when selecting a focus child to observe. And, finally, the presence of an adult was necessary for selection in this study not only because the MOS Institutional Review Board requires adult permission for children to be interviewed, but also because researchers hoped to capture adult feedback about the experience.

Instruments were developed in collaboration with Design Challenges staff and specifically designed to be of an appropriate length and cognitive level for children visitors. Furthermore, care was taken to modify instruments used in previous MOS research into study-specific protocol to allow some comparison (although not inferential analysis) with previous findings. Each method is described in more detail below.

Observations

Observational data were gathered to understand more about how girls and boys engage in an engineering activity when it has competitive or non-competitive elements. For each group, data collectors not only tracked the number of bobsleds tested by each focus child but also each child's behaviors related to competition and engagement. To provide further context about the whole group's experience at Design Challenges, additional open-ended notes were taken during data collection.

When counting the number of bobsleds tested, data collectors considered several factors. A bobsled design that was tested more than once only counted if the focus child had changed a distinct feature of the bobsled before re-testing or if they decided to use a different style of track, as this is considered a design element by Design Challenges educators. If the bobsled was simply re-tested with no change to either of these conditions, then that bobsled run did not count as a separate test. Accounting for iterations in this manner builds off of the Design Challenges philosophy that a re-designed creation is something that develops out of being tested, measured, or evaluated in some way.

During observations, data collectors also tracked the total time the child spent at the activity. For this study, total time at the activity included any time the child spent listening to the staff members introducing the activity and providing instructions. Data collectors considered a child to have stopped interacting with the activity when he or she returned materials and either choose to receive a magnet for participation or started to walk away. The complete observation instrument can be found in Appendix A.

Child interview

Post-activity interviews were designed to gather information from the focus child about their experience at a Design Challenges activity. In particular, the brief interview instrument had questions aimed at understanding how the child viewed the competitive aspects of the Bobsled challenge. Children who participated in either scenario were asked "how did you decide if the designs you were testing were good or not?" and "at any point during the activity, did you compare your design to anyone else's?" Follow-up questions asked children to whom they compared themselves and why. Additional questions on the interview asked whether or not the child had previously participated in a Design Challenges activity, and how they might perceive their own self-efficacy or capability to perform engineering tasks. The full post-activity interview can be found in Appendix B.

Child post-activity survey

After the interview, children were given a brief survey to complete while data collectors interviewed the parent. These post-activity surveys were used to learn how the focus child would rate their engagement in the Design Challenges activity and their interest in future engineering activities. To collect these data, children were asked to rate on a 4-point agreement scale (Really Disagree, Sort of Disagree, Sort of Agree, Really Agree) statements such as "I would like to be an engineer" or "I would like a job where I design and create things." Like the interview, the post-survey for this study asked questions about the child's engineering self-efficacy. On the survey children were asked to consider how successful they would be at participating in a Bobsled activity similar to what they had just completed and then consider how successful they might be at participating in a different engineering Design Challenge that they may not be familiar with. They were asked to rate their agreement with the following statements--"I can successfully build a mini-bobsled to be raced down a track" and "I can successfully build a trophy to hold up a sports ball." The full survey instrument can be found in Appendix C.

Adult interview

While the child was filling out the survey, an adult was asked to participate in a short interview. This was typically the adult who had been most involved in the child's engineering activity or closest to the researcher. This interview consisted of a few questions about the adult's own involvement in the activity and how they perceived their child's experience. In both the competitive and non-competitive scenarios, adults were specifically asked "how do you think [your child] felt about the competitive aspects of the activity?" For those who had experienced the competitive scenario, the adults were then probed about the impact of the leaderboard on their child. By asking these questions, this study considered how adults perceive their child's engagement and how competition affects their child's overall participation in these engineering activities. The full adult interview protocol can be found in Appendix D.

Discussion of sample

In total, data were collected from 114 groups. However, only complete data from 100 groups were used for analysis. Complete data included observational data, follow-up interviews, and surveys from the child. For this study, in order to answer questions about the competitive and non-competitive scenarios, it was especially important to have complete data from the focus child. Thus, data from the 14 observed groups who declined to participate in the follow-up interview/survey pieces were not included in analysis. This decision was made to ensure that equal numbers for both competitive and non-competitive design situations were analyzed. Data collectors also monitored the number of girls and boys in each scenario so that equal gender group sizes would be included in analysis. The breakdown of complete data according to scenario type and gender is shown in the table below.

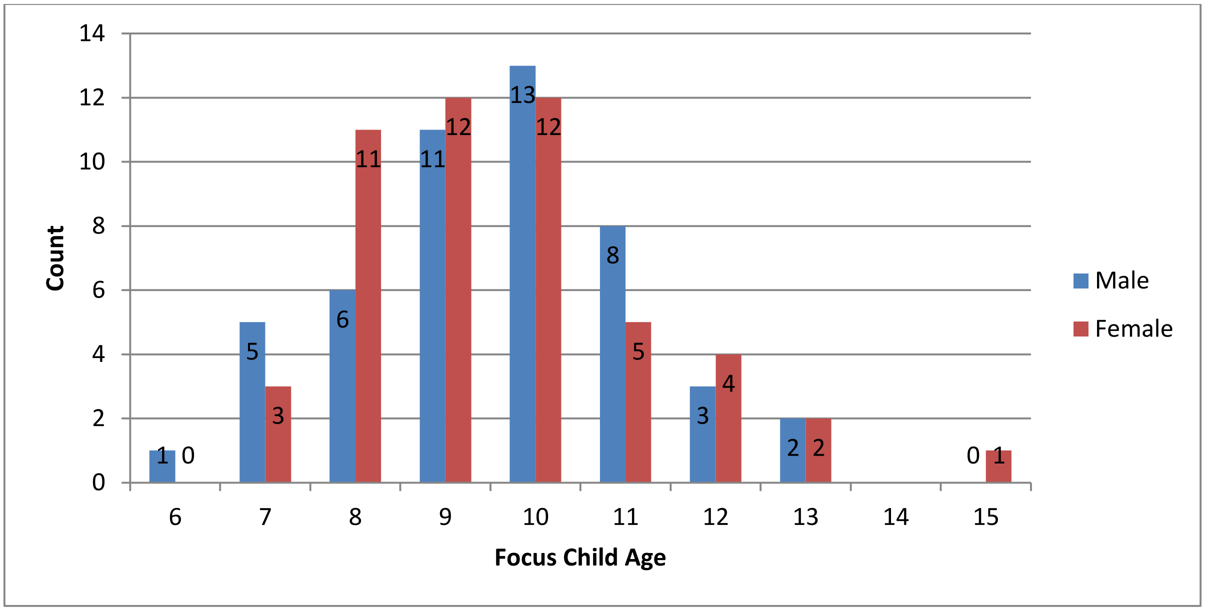
TABLE 1: Number of complete data gathered by gender and competitive scenario (*N*=100).

	Competitive	Non-Competitive
Girls	25	25
Boys	25	25
Total	50	50

Interview data were also collected from the 100 accompanying adults of these focus children. Because it was critical to have both observational and follow-up data, if either the adult or the observed child declined to answer only one or two questions while completing the interviews or survey, their data were still included in the final numbers.

Although data collectors intended to observe children in the target age range of 8-14, the graph below shows that study participants actually ranged from 6-15 years old. As can be seen in Figure 1, six boys along with three girls fell below the target age while one girl who participated was above the target age. Of the 99 children who reported their age, 90% fell within the age target range of 8-14. Overall, the ages were relatively well distributed between girls and boys, with slightly more younger females taking part. The average age of participants was 9.5 years old due predominantly to the large number of 9 and 10 years olds sampled.

FIGURE 1: Age of focus child (*N*=99).



Descriptive statistics

Overall, data indicate that visitors spent 20.2 minutes at Design Challenges on average and built just over five bobsleds (5.1). Based on these indictors of engagement according to gender, results show that boys spent statistically significant longer periods of time and built more bobsleds than girls. These findings are in contrast to what was seen in the Design Challenges summative evaluation report which indicated no meaningful differences in stay time and number of builds according to gender (Auster, R., & Lindgren-Streicher, A., 2013).[1]

A question on the child interview asked about previous participation in Design Challenges. Overall, 52% of the competitive design participants and 46% of the non-competitive design participants had visited the MOS drop-in engineering space before, and 21% of the competitive design participants (*n*=10) and 14% of the non-competitive design participants (*n*=7) had specifically done a Bobsled challenge previously. Likewise, 58% of girls and 40% of boys reported having visited Design Challenges before, with 22% of girls (*n*=11) and 13% of boys (*n*=6) having participated in the Bobsled activity.

However, data from this study include two outliers that needed to be taken into consideration. Both of the outliers were boys (ages 10 and 13) participating in the competitive design scenario who stayed for 44.5 minutes and 72 minutes and built 38 and 31 bobsleds, respectively. To have a better sense of the typical stay time and number of iterations that participants performed, researchers calculated these figures before and after the outliers were removed from the sample. Table 2 summarizes this information.

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[1] See Auster, R. & Lindgren-Streicher, A. (2013) for more detailed findings and additional analyses.

TABLE 2: Mean stay time and number of designs made by gender.[2]

	Girls (*n*=50)	Boys (*n*=50)	Boys (*n*=48), outliers removed
Total stay time (minutes)*	17:12	23:12	21:42
Number of designs*	3.7	6.5	5.4

* Here and throughout the report, an asterisk (*) indicates a statistically significant difference between categories of analysis, $p<.05$.

As can be seen in Table 2 and the relevant footnotes, when outliers are excluded from the analysis, there continues to be a difference between how much time girls and boys spent at Design Challenges and how many designs they build. Once these outliers were removed from the dataset, the overall stay time and number of builds for boys and girls together becomes 19.4 minutes and 4.5 bobsleds.

While there are certainly some visitors who spend extended amounts of time at Design Challenges, the male outliers noted above heavily skew this study's data, and researchers decided that eliminating these two cases made the most sense in attempting to understand how competition affects a *typical* participant's experience in this engineering space. A brief case study of the two outliers can be found in Appendix E.

Data analysis

Due to the quantitative and qualitative nature of these data, several different analysis techniques were employed. Quantitative data were summarized using descriptive statistics, including counts and means, as well as inferential analyses. Inferential analyses included: independent means *t*-tests when comparing girls/boys or competitive/non-competitive scenarios on continuous measures; and chi-square tests when examining Likert responses. Qualitative data for both child and adult interview responses were analyzed through inductive coding for emergent themes and a deeper analysis that involved examining the child interviews to see if differences emerged between the competitive and non-competitive scenarios.

Limitations

This study provides an in-depth look at the effects of competition on only one Design Challenges activity – Echo Base Bobsleds. While it is possible that findings from this study may apply to other Design Challenges activities in which an explicit competitive element such as a leaderboard is typically included, the results presented below should be interpreted only in the context of the Bobsled activity.

[2] With outliers included: total stay time, $t=2.658$, $p=.009$; number of designs tested, $t=2.475$, $p=.015$.
With outliers removed: total stay time, $t=2.252$, $p=.027$; number of designs tested, $t=2.053$, $p=.043$.

III. RESULTS AND DISCUSSION

This study set out to examine how competition affects several factors relating to participants' experiences in drop-in engineering activities: their engagement in the activity, their desire to take part in future engineering activities, and their engineering self-efficacy. For each of these factors, this study considered how competition may impact girls and boys differently. Results from both the quantitative and qualitative data are presented in the following section along with a discussion providing further interpretation of these findings. Research questions guiding the analyses were:

1. How does competition affect participants' engagement in engineering activities?
    1.a Does this differ for boys and girls?
2. How does competition affect participants' desire to take part in future engineering activities?
    2.a. Does this differ for boys and girls?
3. How does competition affect participants' self-efficacy?
    3.a. Does this differ for boys and girls?

1. COMPEITITION AND PARTICIPANTS' ENGAGEMENT

As noted earlier, previous research in the MOS Design Challenges space has demonstrated comparable engagement of boys and girls, by exploring typical indicators such as dwell time, number of iterations tested, and children's self-ratings of their enjoyment of the activity. These indicators are used once again in this study, with data coming from all instruments – the observation protocol, the child survey, and both child and parent interviews. The section that follows first examines these indicators of engagement by looking at differences between the competitive and non-competitive design scenarios and includes data from both boys and girls; then, differences between girls in competitive and non-competitive activities are examined along with differences between boys in the two activity designs.

1.1 Children engaged similarly in both competitive and non-competitive engineering design scenarios.

Data indicate that participants engaged similarly in both the competitive and non-competitive engineering Design Challenges Bobsled activities. When looking at two common indicators of engagement for informal education settings, how long visitors stayed (dwell time) and the number of designs they tested (iterations), no meaningful differences were found between the two design scenarios. In both scenarios, children stayed for a fairly lengthy period of time and built multiple iterations of bobsleds. Table 3 shows the average length of engagement and number of builds for both the competitive and non-competitive activities; interestingly, although the dwell time was shorter for non-competitive participants, the number of designs tested by this group was higher, on average.

TABLE 3: Mean stay time and number of designs by competitive scenario (*N*=98).

	Competitive (*n*=48)	Non-competitive (*n*=50)
Total stay time (minutes)	20:06	18:42
Number of designs	3.9	5.1

Besides the similarities that were seen in how long participants stayed and how many designs they built at the two types of Design Challenges, data also show that across scenarios, visitors enjoyed their time at the activity. When children were asked what they thought of the Design Challenges activity overall, 62% of children felt it was "tons of fun," 31% felt it was "a lot of fun" and 7% felt it was "a little fun." None of the children regarded it as "no fun at all." Table 4 shows the breakdown of how children who participated in the different scenarios rated the activity; again no statistical differences were seen between competitive and non-competitive setups.

TABLE 4: Children's ratings of the Bobsled activity by competitive scenario (*N*=97).

	Competitive (*n*=48)	Non-competitive (*n*=49)
Tons of fun	65%	59%
A lot of fun	27%	35%
A little fun	8%	6%

Furthermore, the type of scenario did not seem to affect how adults viewed their child's engagement in the Design Challenges activity. When asked to think about their child's experience in the Bobsled activity and rate how engaged they felt they were, overall data indicate that most adults felt their child was either "Extremely" (57%) or "Very engaged" (34%). A small number of adults felt their child was only "Somewhat" (8%) or "Minimally" (1%) engaged. Table 5 shows the similarity in breakdown across activity-type.

TABLE 5: Adults' ratings of child's engagement in the Bobsled activity by competitive scenario (*N*=97).

	Competitive (*n*=48)	Non-competitive (*n*=49)
Extremely engaged	56%	57%
Very engaged	35%	33%
Somewhat engaged	8%	8%
Minimally engaged	0%	2%

As can be seen, adults provided similar ratings of their child's engagement regardless of the type of design scenario; there were no statistical differences. Instead, in both situations, adults' ratings were found to be positively correlated with how long their child stayed at Design Challenges.[3] That is, the longer the child stayed at the activity, the higher the parent's rating of engagement, and vice versa.

Across both scenarios, adults provided a range of responses when talking about how their child may have felt about the competitive aspects of the activity. Example quotes below highlight how, regardless of the activity design, parents had a range of feelings about the role competition played in their child's engagement.

Example quotes from parents of children participating in the non-competitive design:

> *I think she tends to be pretty competitive. She decides she wants to win.*
> [adult male]

> *I don't think he was that concerned. He was not worried about winning. [Asked M,6 and he nodded.] More interested in whether it was faster.*
> [adult female]

Example quotes from parents of children participating in the competitive design:

> *I think she enjoyed the challenge, feels excited to see the broken record.*
> [adult female]

> *He didn't care. The competition was with himself. He compared himself to the time.*
> [adult female]

Together these data suggest that the addition of a competitive element, in this case, a leaderboard, did not affect how children engaged in this particular engineering activity. Children tested comparable numbers of designs, stayed similar lengths of time, and rated the activity in a similar manner. Similarly, competitive elements do not seem to influence how adults' view their child's engagement in the activity.

1.2 The type of scenario did not affect how girls or boys participated in the engineering activity.

When analyzing engagement by gender in both the competitive and non-competitive scenarios, again no statistically significant differences were seen. Although, as was mentioned in the methods, boys tended to stay longer at the Bobsled activity and build more iterations, these data suggest that competitive factors did not affect how participants of either gender engaged in the activity. Table 6 shows the statistics for girls' and boys' engagement in the two Design Challenges scenarios.

[3] A statistically significant positive moderate correlation was found between children's total time at activity and parents' ratings of their child's engagement (r=.340, p=.001). While this significant correlation implies a meaningful relationship between the two variables, no predictive analysis was conducted.

TABLE 6: Mean stay time and number of designs by gender in both scenarios (*N*=98).

	Girls		Boys	
	Competitive (*n*=25)	Non-competitive (*n*=25)	Competitive (*n*=23)	Non-competitive (*n*=25)
Total stay time (min.)	18:00	16:24	22:24	21:06
Number of designs	3.32	4.12	4.61	6.08

When analyzing responses by gender for what participants thought of the Design Challenges activity overall, once again no statistically significant differences were found. For girls, the competitive aspects of the engineering activity did not seem to be a factor in their overall enjoyment of the Bobsled activity; similarly, boys' responses were not impacted by the competitive design. Table 7 below shows girls' and boys' ratings of the activity by competitive scenario.

TABLE 7: Children's ratings of the Bobsled activity by gender in both scenarios (*N*=97).

	Girls		Boys	
	Competitive (*n*=25)	Non-competitive (*n*=24)	Competitive (*n*=23)	Non-competitive (*n*=25)
Tons of fun	60%	58%	70%	60%
A lot of fun	28%	33%	26%	36%
A little fun	12%	8%	4%	4%

Once again, for parents of girl participants and parents of boy participants separately, the type of scenario did not affect adults' views of their child's engagement. Table 8 shows the similarity in breakdown across activity-type.

TABLE 8: Adults' ratings of child's engagement in the Bobsled activity by gender in both scenarios (*N*=97).

	Girls		Boys	
	Competitive (*n*=25)	Non-competitive (*n*=24)	Competitive (*n*=23)	Non-competitive (*n*=25)
Extremely engaged	44%	54%	70%	60%
Very engaged	44%	33%	26%	32%
Somewhat engaged	12%	13%	4%	4%
Minimally engaged	0%	0%	0%	4%

For both girls and boys, the length of stay time and the number of iterations were comparable across competitive and non-competitive scenarios. Likewise, no significant differences were found when looking at girls' or boys' ratings of enjoyment or parents' ratings of their child's engagement, suggesting that the competitive design does not influence how either gender participates in this engineering activity.

1.3 Across scenarios, children gave similar reasons for why they stopped or continued participating in the Design Challenge; when describing why they stayed, only occasionally did children mention competition as the driving factor for engagement.

Data from the follow-up interviews also support the finding that competitive elements did not impact how participants experienced this activity. Although most children tested more than three designs, for those who stopped participating in the Design Challenges activity after testing just one or two designs, the type of scenario did not seem to affect why they moved on from the activity. Children who had participated in either competitive or non-competitive scenarios provided similar reasons for why they stopped engaging in the activity.

TABLE 9: Reasons given for why children stopped participating in the Bobsled activity by competitive scenario (*N*=36).[4]

Code	Overall	Competitive (*n*=20)	Non-competitive (*n*=16)	Example Quote
Child made decision to move on	**19**	10	9	Kinda wanted to run off and see something else.
Child mentions their desired outcome or their bobsled's performance	**6**	3	3	I wanted mine to be slowest.
Child doesn't know why he/she stopped '	**6**	4	2	I don't know.
Adult made a decision to move on	**5**	2	3	I wanted to do more, but I stopped because AF said let's do other stuff.
They were out of time or the activity was ending	**3**	2	1	Because we ran out of time.

As the table indicates, the child was typically the one who made the decision to stop participating (*n*=19), even though at times other factors such as the adult's wishes or the activity's closing time played a role. When specifically describing why they wanted to move on, children provided several different reasons. Some explained that they thought they had completed the activity or achieved their goals, while others mentioned that they simply wanted to go someplace else or that they felt the setting was crowded. These reasons came from children who participated in either the competitive or non-competitive scenario, further emphasizing the similarities in how children experienced both setups.

When asking children who had tested multiple iterations of their bobsled why they stayed to test so many, similar responses were heard from those who participated in the competitive and non-competitive scenarios. Overall, children in both scenarios overwhelmingly said that they had a specific outcome in mind and kept testing in order to try and achieve this outcome. Those children who didn't have a particular outcome in mind explained that they kept testing to see differences between their own trials or simply because they didn't want to give up. Table 10

[4] For all interview data, here and throughout the report, the sum of overall codes may not equal the sample size noted in the table title as responses were double-coded if they pertained to two or more codes.

shows the frequencies for these responses overall, broken down by those in competitive/non-competitive scenarios.

TABLE 10: Reasons given for why children continued participating in the Bobsled activity by competitive scenario (*N*=62).

Code	Overall	Competitive (*n*=28)	Non-competitive (*n*=34)
Child states a specific outcome for bobsled	**50**	23	27
Child just wanted to see differences between trials or designs	**11**	4	7
"I don't want to give up" or "I want to try my best"	**3**	2	1

The different types of outcomes that children mentioned were also similar across scenarios. For instance, children who participated in either the competitive or non-competitive activity frequently described re-testing in order to get a particular bobsled time (fast/slow). They also mentioned wanting to improve their design, in general, or specifically in regard to their own previous attempts. The full list of specific objectives that children provided for re-testing can be seen in Table 11.

TABLE 11: List of outcomes that children mentioned as reasons for staying and testing several designs by competitive scenario (*N*=50).

Code	Overall	Competitive (*n*=23)	Non-competitive (*n*=27)
Going for a fast bobsled	**35**	16	19
Wanting to improve without explicitly comparing to self or others	**29**	14	15
Competing against or comparing self to others to improve	**12**	6	6
Going for a slow bobsled	**9**	5	4
Competing; specifically mentioning winning against others	**8**	3	5
Wanting to improve; specifically mentioning competing against self or improving individual bobsled	**4**	1	3

As the table above shows, various reasons were heard from children who participated in both types of scenarios. Example quotes for all codes can be found in Appendix F; however, the following series of quotes highlight just how comparable responses were from children who participated in either scenario. These quotes are from children who mentioned the two most frequent reasons for re-testing.

Example quotes from children going for a fast bobsled:

> *Because I was thinking if I made it different, it could go faster.*
> [non-competitive, female, age 12]

> *Because I thought the more things that were fuzzy that I get, the faster it would go. The more things I got [added to the sled] it went faster.*
> [competitive, female, 8]

Example quotes from children wanting to improve, in general:

> *I wanted to get a better score or a worse one.*
> [non-competitive, male, 12]

> *Because the first didn't work that well and I tried to improve it and find the best technique.*
> [competitive, female, 10]

These quotes underscore just how similar children's responses were regardless of whether they had participated in the competitive or non-competitive scenario.

Data also indicate that, although not the most frequent reason for re-testing, children did occasionally indicate they were driven to retest for competitive reasons. Children in both scenarios described competing against others to improve (*n*=12) or competing against others to win (*n*=8). Below are example quotes from children who participated in either scenario describing this competitive impetus to re-test.

> *Because I didn't have the fastest time and I wanted to go faster.*
> [non-competitive, male, 9]

> *Because I just wanted to see if I could win. I tried slowest and fastest because both ways work.*
> [competitive, female, 10]

These responses show how competition played a motivational role for a few individuals in both competitive and non-competitive scenarios. It's interesting to note that the addition of a leaderboard did not greatly increase the number of people citing a competitive reason for staying. Indeed, for both scenarios, non-competitive reasons for re-testing, such as trying to obtain a specific time or generally wanting to improve, were mentioned with more frequency. The fact that children who participated in the non-competitive scenario mentioned competitive reasons at all may reflect the inherent design of the Bobsled activity which allows several people to test their designs at once.

Overall the data presented in this section suggest that children were motivated to participate in competitive and non-competitive engineering activities for similar reasons. Few differences were seen in regards to why children kept retesting their bobsleds or why they stopped. Moreover, these data suggest that competition is just one reason why the participants may have stayed engaged in the activity. As was seen, even for competitive scenarios, children most frequently cited reasons for staying that related to obtaining a specific type of time or making general improvements rather than mentioning competitive reasons for retesting.

1.4 Boys and girls gave similar reasons for staying or leaving regardless of whether they had participated in the competitive or non-competitive design scenarios.

Just as similarities were seen across competitive or non-competitive scenarios in terms of why participants left after a few iterations or stayed, similarities were seen between girls and boys who participated in either type of scenario. Although more girls (*n*=23) than boys (*n*=13) left the Design Challenges activity after just one or two tests, when looking at how girls who participated in the competitive scenario and girls who participated in the non-competitive scenario described why they left, little differences exist. While girls who participated in non-competitive scenarios (*n*=2) reported that adults had made the decision to leave more frequently than those who participated in competitive scenarios (*n*=0), this was only reported by a small number of individuals overall. For all the other reasons that girls provided for leaving the activity, there was an even split between those in competitive or non-competitive scenarios. There were also no major differences of note in how boys who participated in competitive or non-competitive scenarios described their motivations for leaving, as shown in Table 12.

TABLE 12: Reasons given for why children stopped participating in the Bobsled activity by gender in both scenarios (*N*=36).

		Girls (*n*=23)		Boys (*n*=13)	
Code	**Overall**	**Competitive**	**Non-competitive**	**Competitive**	**Non-competitive**
Child made decision to move on	**19**	6	6	4	3
Child mentions their desired outcome or their bobsled's performance	**6**	3	2	0	1
Child doesn't know why he/she stopped	**6**	2	2	2	0
Adult made a decision to move on	**5**	0	2	2	1
They were out of time or the activity was ending	**3**	1	1	1	0

Likewise, even though data indicate that boys tested multiple designs more often than girls, the reasoning girls and boys provided to explain why they stayed did not differ according to design scenario. Girls in both competitive and non-competitive scenarios were trying to achieve specific objectives such as creating a fast bobsled or improving their time. These were also the main motivating objectives for boys in either competitive or non-competitive scenarios. Table 13 breaks these outcomes down between girls and boys who participated in either scenario.

TABLE 13: List of outcomes that children mentioned as reasons for staying and testing several designs by gender in both scenarios (*N*=50).

		Girls (*n*=20)		Boys (*n*=30)	
Code	**Overall**	**Competitive**	**Non-competitive**	**Competitive**	**Non-competitive**
Going for a fast bobsled	**35**	7	9	9	10
Wanting to improve without explicitly comparing to self or others	**29**	6	5	8	10
Competing against or comparing self to others to improve	**12**	2	3	4	3
Going for a slow bobsled	**9**	3	1	2	3
Competing; specifically mentioning winning against others	**8**	1	3	2	2
Wanting to improve; specifically mentioning competing against self or improving individual bobsled	**4**	1	0	0	3

As seen in this section, similarities existed across gender-group comparisons in terms of why participants in either scenario decided to leave or continue testing their designs. Again these data point to how competition was not the main reason why girls or boys stayed, even in the competitive format.

1.5 Participants in competitive and non-competitive scenarios compared themselves to different people, yet participants in both scenarios saw this as a way to learn and improve.

In follow-up interviews, just over half of the children (*n*=52) who participated in this study indicated that they compared their bobsled designs to others. Although non-competitive participants (*n*=31) more frequently compared themselves to others than those who had participated in competitive scenarios (*n*=21), there were definite similarities in terms of why participants in either scenario compared themselves.

Children in both competitive and non-competitive scenarios mentioned comparing their bobsled design to those of other general visitors, members in their family or immediate group, or visitors who were doing better than themselves. Table 14 shows the full list of people that children mentioned comparing themselves to during either the competitive or non-competitive Bobsled activity.

TABLE 14: Other people children compared themselves to at Design Challenges by competitive scenario (*N*=48).

Code	Overall	Competitive (*n*=20)	Non-competitive (*n*=28)	Example Quote
Other visitors; strangers; everyone	**24**	5	19	The fastest. On the race track I compared which one was fastest and saw some attachment to add.
Siblings; peer family members; known peers	**18**	9	9	My sister.
Anyone doing well or better than me; others with ideas I want to use	**14**	4	10	I did see someone else use gold skin, and it worked slowly for them so I tried it.
People in my race; on the track	**6**	3	3	One next to it.
Anyone whose ideas did not work well	**2**	2	0	Some people were putting on lots of details, but weren't worrying about friction.
Parents; known grown-ups	**1**	0	1	Dad [AM].
Not really comparing; just looking	**1**	1	0	Wasn't comparing, just looking.

While similar groups of people were mentioned by participants in either scenario, these data indicate slight differences between the competitive and non-competitive scenarios. Participants in non-competitive scenarios were more likely to compare their bobsleds with those of other visitors and with anyone getting better results. Participants in competitive scenarios primarily looked at other peers in their immediate group. These data may indicate that, when put in a competitive situation, children may be more comfortable comparing themselves to people they know.

Even though differences were seen in terms of whom competitive and non-competitive participants compared themselves to, when asked why they did this, children’s responses from both scenarios suggest that they were primarily motived to learn from others. Table 15 below shows the nuanced way that children in both types of scenarios thought about how they might improve their bobsled by comparing it to others. As can be seen, some children talked generally about being able to learn from others and improve their design while some mentioned learning specifically from those who had successful ideas. Moreover, children mentioned noticing how other people’s designs were either different or similar to theirs.

TABLE 15: List of reasons why children compared themselves to others by competitive scenario (*N*=48).

Code	Overall	Competitive (*n*=19)	Non-competitive (*n*=29)	Example Quote
Because I can learn from them, get ideas; improve my design	**25**	11	14	To see if it was faster, like theirs.
You can learn from other people's successful bobsleds	**11**	4	7	Because he had a record. He held it 3 times.
We had different designs, ideas and I was comparing to see how ours were different	**7**	2	5	Because his design was a lot different.
I wanted to beat them; to win	**5**	3	2	Because they said it would be good to defeat the fastest time. I raced against him and won.
We had similar designs, ideas and I was comparing to see how ours were similar	**5**	1	4	He and I used the same bottom fabric.
I am competitive/ like to compete	**3**	1	2	I'm sort of competitive and I like to see how stuff works and do better next time.
I was not comparing mine to theirs, just learning from it	**2**	1	1	My sister found out that putting weight on the front or back mattered, so I was not comparing myself, but I used her information.
Other	**1**	0	1	Wanted to do it naturally.

Table 15 indicates how few children from either scenario mentioned competitive reasons for comparing with others. When they did, it was because they wanted to win (n=5) or simply because they described themselves as a competitive person (n=3). Since competitive reasons such as these were only heard from a few individuals, it seems that children mainly wanted to learn something from whomever they were comparing themselves against rather than to compete.

1.6 Girls and boys who participated in the non-competitive rather than the competitive scenario were more likely to have compared themselves to others; across scenarios boys compared themselves for different reasons.

The data suggest slight differences in terms of how girls and boys who participated in non-competitive scenarios, as opposed to competitive ones, compared themselves to others. It was more common for girls who had participated in the non-competitive scenario to compare themselves to others than it was for girls who had participated in the competitive scenario (14 to 9). For boys, too, those who participated in the non-competitive scenario compared themselves more often than those in the competitive design (14 to 11). This suggests that competitive scenarios may make participants more inward-focused when building or testing instead of looking to others for ideas.

Patterns emerged as to whom participants reported comparing themselves to, as can be seen in Table 16. Slightly more girls who participated in the non-competitive activity cited looking to other visitors as compared to girls in the competitive design, while slightly more boys who participated in the non-competitive activity did the same or stated they observed anyone doing better than they were. Boys in the competitive activity, on the other hand, mentioned looking to anyone whose ideas did not work well.

TABLE 16: Other people children compared themselves to at Design Challenges by gender in both scenarios (*N*=48).

		Girls (n=23)		Boys (n=25)	
Code	**Overall**	**Competitive**	**Non-Competitive**	**Competitive**	**Non-competitive**
Other visitors; strangers; everyone	**24**	2	7	3	12
Siblings; peer family members; known peers	**18**	4	5	5	4
Anyone doing well or better than me; others with ideas I want to use	**14**	3	5	1	5
People in my race; on the track	**6**	1	2	2	1
Anyone whose ideas did not work well	**2**	0	0	2	0
Parents; known grown-ups	**1**	0	1	0	0
Not really comparing; just looking	**1**	0	0	1	0

When asked *why* such comparisons were made, girls stated similar reasons across both competition design activities. On the other hand, boys in non-competitive scenarios tended to mention the fact that they could learn from others or were comparing their designs in order to see how they were similar or different. This may suggest that boys consider the types of information they can gain from other people differently depending on the situation. Table 17 below illustrates these findings.

TABLE 17: List of reasons why children compared themselves to others by gender in both scenarios (*N*=48).

		Girls (*n*=23)		Boys (*n*=25)	
Code	**Overall**	**Competitive**	**Non-competitive**	**Competitive**	**Non-competitive**
Because I can learn from them, get ideas; improve my design	**25**	7	7	4	7
You can learn from other people's successful ideas	**11**	2	3	2	4
We had different designs, ideas and I was comparing to see how ours were different	**7**	2	3	0	2
I wanted to beat them; to win	**5**	1	1	2	1
We had similar designs, ideas and I was comparing to see how ours were similar	**5**	0	1	1	3
I am competitive/ like to compete	**3**	0	0	1	2
I was not comparing mine to theirs, just learning from it	**2**	0	0	1	1
Other	**1**	0	0	0	1

Although overall findings from this study indicate that engagement was very similar across scenario types and within gender-group comparisons, the data in this section and section 1.5 suggest that slight differences exist in terms of how the competitive or non-competitive design of an activity may impact *how* one compares themselves to others and, in the case of boys, *why* they may choose to do so.

2. COMPETITION AND PARTICIPANTS' DESIRE TO TAKE PART IN FUTURE ENGINEERING ACTIVITIES

Survey items relating to interest in future engineering activities were previously used in MOS Design Challenges research, and involved asking participants questions that combine facets relating to general enjoyment of an activity as well as to the likelihood of participating in similar activities in the future. Below, differences between the competitive and non-competitive designs are once again explored first, with the competitive design scenario broken down by gender second.

2.1 Children who participated in both design scenarios expressed interest in future engineering activities.

When children were asked to rate four survey questions about their desire to take part in future engineering activities or engineering-related careers, there were no meaningful differences between the competitive and non-competitive scenario participants. Table 18 shows the four different statements participants were asked to rate along with mean scores for participants in the non-competitive and competitive groups.

TABLE 18: Children's responses to future engineering-related questions by competitive scenario (*N*=98).

	Competitive (*n*=48)	Non-competitive (*n*=50)
I would like to be an engineer	3.08	3.06
I would like a job where I design and create things	3.50	3.46
I would like to do this design activity again	3.67	3.60
I would like to do another design activity	3.85[5]	3.86

As can be seen in Table 18, both competitive and non-competitive participants expressed similar levels of interest in future engineering activities. The fact that none of the differences were statistically significant suggests that when competitive aspects are added to the Bobsled activity, there is no deterring effect on how participants viewed future engineering participation.

2.2 For both girls and boys competitive and non-competitive design scenarios produced comparable ratings on items relating to their desire to participate in future engineering activities.

Analyzing all four survey questions pertaining to future engineering activities for girls and boys separately again reveals no differences between competitive and non-competitive activities for either gender, as seen in Table 19 below.

[5] *n*=47.

TABLE 19: Children's responses to future engineering-related questions by gender in both scenarios (*N*=98).

	Girls (*n*=50)		Boys (*n*=48)	
	Competitive	**Non-competitive**	**Competitive**	**Non-competitive**
I would like to be an engineer	2.92	3.00	3.26	3.12
I would like a job where I design and create things	3.40	3.28	3.61	3.64
I would like to do this design activity again	3.68	3.64	3.65	3.56
I would like to do another design activity	3.83[6]	3.88	3.87	3.84

Table 19 shows that ratings between the competitive and non-competitive Bobsled activities were very similar for girls in terms of their interest in participating in future engineering activities; the same was true for boys. In short, the competitive aspects introduced by the leaderboard had no negative effect on participants' future engineering-related interests.

3. COMPETITION AND PARTICIPANTS' SELF-EFFICACY

Self-efficacy is an individual's perception that he or she can do something. Below, questions from both the child survey and child interview are discussed to explore whether or not adding competitive elements to the Bobsled activity affected participants' self-efficacy. As with previous sections of this report, differences are first analyzed between the competitive and non-competitive designs by looking at data for both boys and girls, and then differences are analyzed for each design scenario broken down by gender.

3.1 The type of design scenario did not affect participants engineering self-efficacy.

Children in both scenarios were asked to rate statements about how they viewed their engineering self-efficacy. These statements were designed to have them think about their ability to perform specific engineering tasks, one similar to the engineering activity they had just participated in and one that was different from what they just experienced. Table 20 below highlights the mean score for how participants in both design scenarios responded to these questions.

[6] *n*=24.

TABLE 20: Children's responses to engineering self-efficacy related questions by competitive scenario (*N*=98).

	Competitive (*n*=48)	Non-competitive (*n*=50)
I can successfully build a mini-bobsled to be raced down a track	3.52	3.64
I can successfully build a trophy to hold up a sports ball	2.91[7]	3.12

Although in general, respondents were less confident in their abilities to successfully participate in a *different* design challenge, analysis indicates no meaningful differences in how competitive or non-competitive participants rated their engineering self-efficacy. These data suggest that competitive elements do not affect how participants view their engineering abilities.

Moreover, when asked in the follow-up interviews about how good they think they are at designing and building things similar to a bobsled at home, participants from both scenarios generally felt they were good at this type of work. Table 21 shows the breakdown of responses along with example quotes.

TABLE 21: Children's description of how good they are at designing and building engineering challenges by competitive scenario (*N*=98).

Code	Overall	Competitive (*n*=48)	Non-competitive (*n*=50)	Example Quote
Good to really good	**51**	24	27	Pretty good.
Somewhere in the middle	**31**	16	15	Maybe a middleish.
I could do better/not good	**6**	4	2	Maybe worse.
I don't know	**8**	3	5	Not sure.
Other	**2**	1	1	Because you probably can do different things with it and test different things with it.

Participants in both scenarios gave multiple reasons to explain why they rated themselves in this way. The full list of reasons can be seen in Table 22. Across scenarios, children often referred to prior engineering experiences they may have had or how they performed in today's Bobsled challenge. For instance, when describing prior engineering experience, one 10 year-old boy who had participated in the non-competitive scenario mentioned how he has "made some wooden models by myself," while an 8-year-old girl from the competitive scenario explained, "Me and my friends are making a fort in my backyard." As these examples illustrate, similar types of responses were heard across scenarios.

[7] *n*=47.

TABLE 22: Children's reasons for why they may or may not be good at designing engineering challenges by competitive scenario (*N*=96).

Code	Overall	Competitive (*n*=47)	Non-competitive (*n*=49)	Example Quote
Based on my experience level (either high/low)	**25**	11	14	Because in a final derby I won 2 years. And this year- at this I did pretty good.
Based on today's performance	**20**	11	9	Because no one's perfect and my bobsled got first and second.
I don't know; no reason	**14**	10	4	I don't know. Not an expert, but…
I enjoy this kind of activity and am good at it	**12**	4	8	I'm kinda interested in how to build stuff and what you need to do.
Doing it at home would make it a different experience	**11**	6	5	I'd have different materials
Based on my building, constructing, engineering skills	**8**	2	6	Because I build things all the time, and they turn out great.
Based on my imagination, creativity, design ideas	**7**	3	4	I build a lot with Legos. I'm really creative.
I don't give up and I keep trying different things	**6**	1	5	Do it often and find different ways to make things and different ideas.
I get help from my Dad	**3**	3	0	I had my dad helping me today and he helped with a few things I didn't think about.
Because I achieve my own goals	**2**	0	2	Because I try to make a goal, and then I reach the goal.

Although the data indicate that non-competitive participants more frequently explained their rating by saying they "enjoy this kind of activity," by referring to their "building, constructing, engineering, skills," or by indicating that they "don't give up," in general, similar explanations were expressed by participants in competitive and non-competitive scenarios. Thus, data from both the interview and the survey suggest that the competitive element of a leaderboard does not greatly influence how children view their engineering self-efficacy.

3.2 While survey responses suggest that the type of scenario does not impact how girls or boys view their engineering self-efficacy, follow-up interviews point to some slight differences.

When analyzing self-efficacy ratings in regards to gender, statistical differences were seen for only one item: boys were more likely to agree with the statement "I can successfully build a mini-bobsled to be raced down a track." [8] However, this difference did not show up when controlling for the competitive design of the activity. In other words, no differences were observed for the rating of this statement between girls who participated in either the competitive or non-competitive design and no difference was seen between boys who participated in either scenario. The same was true of the self-efficacy question asking about a Design Challenges activity similar to bobsleds but not observed, building a trophy to support a sports ball: no differences were observed across design scenarios for either gender. Again, even though gender differences were found related to participants' engineering self-efficacy, survey data suggest that the competitive aspect of the Bobsled activity is not what is triggering this difference.

TABLE 23: Children's responses to self-efficacy questions by gender in both scenarios (*N*=98).

	Girls (*n*=50)		Boys (*n*=48)	
	Competitive	Non-competitive	Competitive	Non-competitive
I can successfully build a mini-bobsled to be raced down a track	3.32	3.48	3.74	3.80
I can successfully build a trophy to hold up a sports ball	2.96	3.24	2.86	3.00

Despite this, follow-up interview data do suggest that the type of scenario may play a role in how boys and girls think about their engineering self-efficacy. Although boys and girls generally rated themselves highly when describing how good they are at building things like a bobsled, there were differences seen for boys across the two scenarios. It was more likely to see boys who participated in the non-competitive type Bobsled activity say they would be "good to really good" at this type of work while boys who participated in the competitive scenario felt they were "somewhere in the middle." See Table 24.

TABLE 24: Children's description of how good they are at designing and building engineering challenges by gender in both scenarios (*N*=98).

		Girls (*n*=50)		Boys (*n*=48)	
Code	Overall	Competitive	Non-competitive	Competitive	Non-competitive
Good to really good	**51**	12	14	7	18
Somewhere in the middle	**31**	9	6	10	6
I could do better/not good	**6**	1	2	2	1
I don't know	**8**	2	2	0	4
Other	**2**	1	1	0	0

[8] t=3.494, p=.001.

Although girls' ratings across the two scenarios were fairly similar, differences were seen in terms of the reasoning they provided for explaining why they rated themselves in this way. Girls who participated in the non-competitive scenario were more likely to rate themselves "based on their prior experience" while girls who participated in competitive scenarios were more likely to say "they got help from their Dad." This can be seen in Table 25.

TABLE 25: Children's reasons for why they may or may not be good at designing engineering challenges by gender in both scenarios (*N*=96).

		Girls (*n*=48)		Boys (*n*=48)	
Code	**Overall**	**Competitive**	**Non-competitive**	**Competitive**	**Non-competitive**
Based on my experience level (either high/low)	**25**	4	8	7	6
Based on today's performance	**20**	4	4	7	5
I don't know; no reason	**14**	4	0	6	4
I enjoy this kind of activity and am good at it	**12**	4	4	0	4
Doing it at home would make it a different experience	**11**	3	2	3	3
Based on my building, constructing, engineering skills	**8**	0	2	2	4
Based on my imagination, creativity, design ideas	**7**	2	1	1	3
I don't give up and I keep trying different things	**6**	1	2	0	3
I get help from my Dad	**3**	3	0	0	0
Because I achieve my own goals	**2**	0	2	0	0

Differences were also seen in how boys who participated in competitive scenarios as opposed to those in non-competitive scenarios described their ratings. For instance, it was more likely for boys in non-competitive scenarios to say they "enjoy this kind of activity" or that their rating was "based on their building, constructing, engineering skills" or that they "don't give up" than it was for boys in the competitive setup. These data suggest non-competitive scenarios may lend themselves to more self-reflection than the competitive design.

IV. CONCLUSION

Although the purpose of this study was not to assess the overall effects of the Design Challenges Echo Base Bobsleds activity, results generally indicate that engagement was high, individuals are interested in participating in additional engineering activities, and participants feel confident in their abilities to complete engineering activities similar to the Design Challenge they participated in. Furthermore, what was evident for each of the research questions was a distinct lack of statistical differences between groups participating in the non-competitive design setup when compared to those who were "competing" in their Design Challenges experience. For the Bobsleds activity, at least, there are no ill-effects from having a leaderboard and fostering a competitive environment within this design-based activity space. Indeed, evidence from this study indicates that competition is just one reason why participants in both types of scenarios may have stayed engaged in the activity.

These findings carry over to within gender-group comparisons: girls engage equally, report similar future interest, and score as high on engineering self-efficacy whether they participate in the competitive or non-competitive design scenario as do boys. So, unlike prior research from formal education which suggests that girls may be negatively impacted by competitive environments, it seems that in this drop-in, free-choice, informal learning space, girls show no signs of discomfort when faced with learning opportunities that many suggest may be harmful for them. What is more, when taking into account the competitive or non-competitive setting, girls perform comparably with boys on all measures of engagement, desire to participate in the future, and engineering self-efficacy.

Despite these similarities across scenario type and within gender group comparisons, it is important to note that the qualitative data does suggest that slight differences exist in how and, at times, why participants compared themselves to others. Interview data also point to differences in terms of how girls and boys participating in the competitive scenario, as compared to those in the non-competitive scenario, talked about their engineering self-efficacy. By highlighting these differences, this pilot study underscores the need for further research examining the effect of competitive design elements in informal learning programs. It should also be reiterated that the study summarized here was carried out on only one of many possible Design Challenges activities, and exclusively with family groups – no school groups or students were observed or surveyed as a part of this study. Furthermore, while the balanced design of this study enabled statistically sound comparisons between both competition and gender groups to be made, a larger sample would provide more statistical power for detecting differences between groups.[9] Both the Museum of Science's Design Challenges program and the larger field – including science centers using programs with competitive designs or other informal learning environments with design-based activity spaces – would benefit from additional research expanding upon the findings of this study.

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[9] A sensitivity power analysis was conducted post hoc based on the given experimental design. With an overall sample size of 100, the calculated effect size was found to be d=0.566, indicating that smaller magnitude differences between groups would not be detected. Further reducing this sample to examine the gender group comparisons that were made (n=50), the effect size jumps to d=0.809 – only differences on the order of eight-tenths of a standard deviation difference would be found with enough power to detect such differences. In short, more individuals (data) are needed to increase the power of future studies.

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APPENDIX A: OBSERVATION INSTRUMENT

Visitor Information

Educator: ❑ Lydia
❑ Tricia
❑ Adrian
❑ Other
❑ Not observed

Focus Child: ❑ Boy ❑ Girl

Other group members: # Adult F _____ # Adult M _____
Child F _____ # Child M _____

Activity: ❑ Bobsleds

Design: ❑ Competitive ❑ NON-competitive

Bobsled

	Times:	Record?		Times:	Record?
1.	________________	❑	11.	________________	❑
2.	________________	❑	12.	________________	❑
3.	________________	❑	13.	________________	❑
4.	________________	❑	14.	________________	❑
5.	________________	❑	15.	________________	❑
6.	________________	❑			
7.	________________	❑			
8.	________________	❑			
9.	________________	❑			
10.	________________	❑			

Total number of designs tested: __________

Total time at activity: ___________

Notes on activity:

APPENDIX B: CHILD INTERVIEW

1. a. [If the child did **3 or more** iterations]: We saw you test several different designs of your bobsled. Why did you decide to test so many versions?

   b. [If the child did **1-2 iterations**]: We saw you test just a few different designs of your bobsled. Why did you decide to stop testing your design?

2. a. How did you decide if the designs you were testing were good or not?

   b. [Follow-up] Based on that, were your designs good?

3. a. At any point during the activity, did you compare your design to anyone else's?

   Yes No

   [If no]: Not even when racing your bobsled down the track?

   b. [If yes]: Who were you comparing yourself to?

   c. [Follow-up]: Why did you compare yourself to them?

4. a. Do you think that you could design, create, and test something different than today's bobsled by yourself if you had materials at home?

   Yes No

   b. [Follow-up]: How good do you think you are at designing and building things like this?

   c. Why do you say that?

5. a. Before today, had you ever participated in a Design Challenges activity here at the Museum?

   Yes No

   b. [If yes]: Was it bobsleds? Yes No

APPENDIX C: CHILD SURVEY

1. What did you think of the Design Challenges activity you did today? (Circle one only.)

   No fun at all ☹ **A little fun…** **A lot of fun** **TONS OF FUN!**

2. Please tell us how much you agree or disagree with each statement. (Circle one each.)

Statement				
a. I would like to be an engineer.	Really disagree	Sort of disagree	Sort of agree	Really agree
b. I would like a job where I design and create things.	Really disagree	Sort of disagree	Sort of agree	Really agree
c. I would like to do this design activity again.	Really disagree	Sort of disagree	Sort of agree	Really agree
d. I would like to do another design activity.	Really disagree	Sort of disagree	Sort of agree	Really agree
e. I can successfully build a mini-bobsled to be raced down a track.	Really disagree	Sort of disagree	Sort of agree	Really agree
f. I can successfully build a trophy to hold up a sports ball.	Really disagree	Sort of disagree	Sort of agree	Really agree

3. **How old are you?** ____________ years old

APPENDIX D: PARENT INTERVIEW

1. a. Did you take a hands-on approach to the [bobsled / trophy] activity today?
   [NOTE: should be visible from observation – prompt with comments about observed behavior.]
   Yes No

   a. Why did you decide to participate in this way?

2. a. Thinking about your child's experience in today's activity, how <u>engaged</u> do you think he/she was on a scale of 1 to 5, with 1 being "not at all engaged" and 5 being "extremely engaged"?

   1 – Not at all engaged
   2 – Minimally engaged
   3 – Somewhat engaged
   4 – Very engaged
   5 – Extremely engaged

   a. [Follow up:] Why did you choose that rating to describe your child's engagement?

3. a. How do you think s/he felt about the competitive aspects of the activity?

   a. [Probe, if competitive design]: How did the day's leaderboard impact your child's participation, if at all?

How would you describe your background in science or engineering?

APPENDIX E: OUTLIERS

In looking more closely at the two outlier cases, the data suggest some interesting similarities and differences in how highly engaged individuals may take part in an engineering Design Challenges activity. Both of the outliers were boys who took part in the competitive activity, and both had participated in a Bobsled Design Challenges previously. From observation notes, the data indicate that upon arrival at the Design Challenges area, one of the boys even told educators that he had been there before and already knew what the process was.

In follow-up interviews, when describing why they decided to test so many bobsleds, both of these boys referenced obtaining a specific outcome, in particular going for a fast bobsled.

- [CM, 10]: Because I don't know, I was just trying to get to my goal, to get below 1:05.
- [CM,13]: Well I wanted to get the fastest and the slowest [records]. I would have named them opposite inversions. I got the slowest so I named it "Fastest."

As can be seen in the following quotes, time and speed also seemed to be a factor in how both of these boys decided if their designs were good or not.

- [CM,10]: I've done this three times before. The one with the straws on the bottom were the fastest, so I kept using those and trying to perfect it.
- [CM,13]: I decided by how slow or fast they were.

Yet these two boys differed in terms of who they compared themselves to while at the Design Challenges. In the interview, one boy explained that he was "just trying to beat [his] own time" and did not compare himself to others, while the other indicated that he had, indeed, been comparing himself to someone else. For the 13-year-old boy who compared himself to others, the competitive factor of wanting to win and also wanting to learn from someone who had a successful idea seemed to play into why he made this comparison. These two cases illustrate that competition with one's self and competition with others can be two motivating factors.

Although both boys felt they would be able to design, create, and test something similar at home, the younger boy could not explain why. While the 13-year old felt he was "pretty good" and referenced the fact that he "did well" and "got on the board," the 10-year-old was not able to come up with a response when asked to explain why he would be good at designing and building things like a bobsled. However, even though he was not very descriptive in the interview, observation notes show that he would often give tips to other groups or tell other adults about his records. This suggests that he may feel more confidence about his abilities than he described.

When looking at the adult responses connected with each of these outliers, it is interesting to note that they support how each of the children described their experiences. For instance, the adult with the child who said he didn't compare himself with anyone else said, "He enjoyed beating his best time, not with the other kids" while the other adult noted her child "seem[ed] very competitive today."

Both adults agreed that their boys were "extremely" engaged and pointed out that their child had either stayed a long time or done a high number of trials. Both of these adults also seemed to have taken a fairly hands off approach to the day's Bobsled activity. One indicated that she "tried one" while the other explained she did not participate at all. Although she did say "we've done it before together," she went on to indicate that today it was an "independent learning" experience for the child. Both adults also said that they did not have high background levels in science or engineering.

Figure E.1 Plot of Engagement Indicators (Dwell Time & Iterations) with Outliers Included

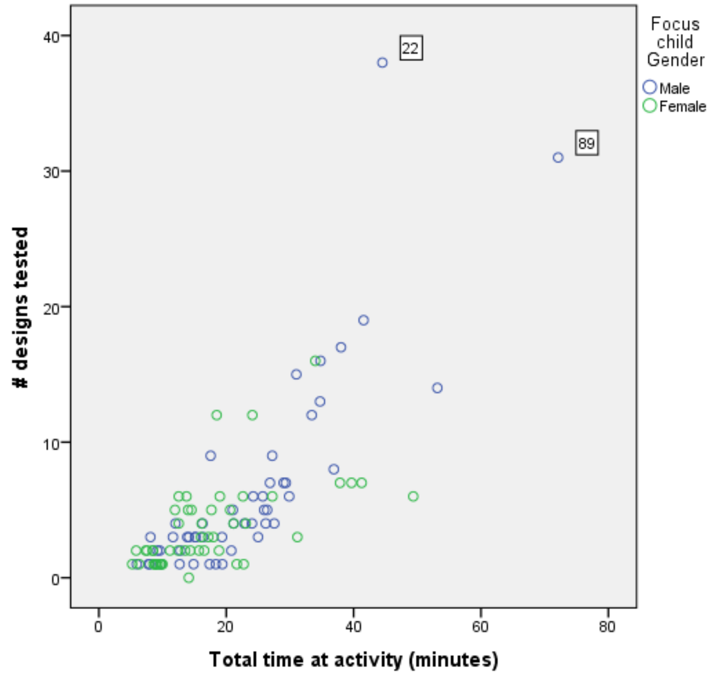
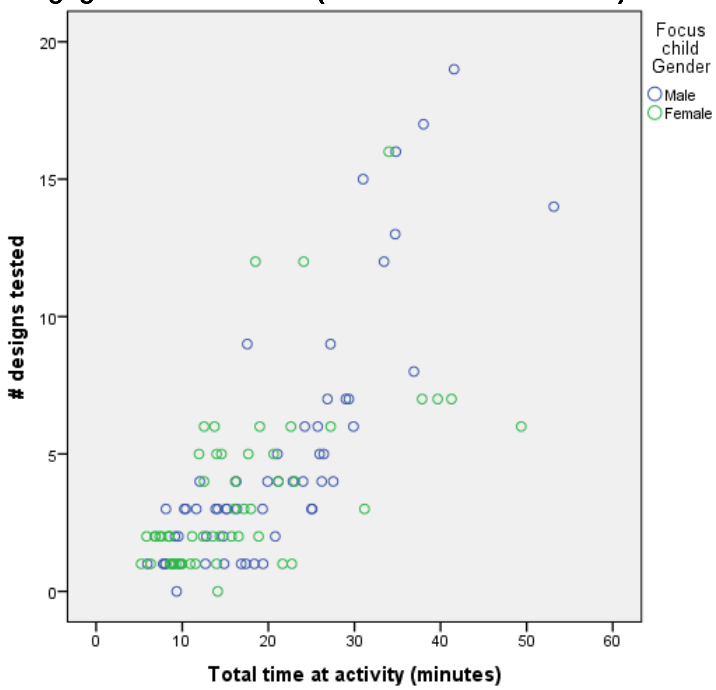


Figure E.2 Plot of Engagement Indicators (Dwell Time & Iterations) with Outliers Removed



APPENDIX F: TABLE 11 EXAMPLE QUOTES

Table F.1: List of outcomes that children mentioned as reasons for staying and testing several designs, including example quotes (*N*=50).

Code	Overall	Example Quote
Going for a fast bobsled	**35**	I wasn't positive one was going to work. I wanted to see which one went fastest.
Wanting to improve without explicitly comparing to self or others	**29**	Because I thought maybe with something different it would go faster, wanted to see all the different ways.
Competing against or comparing self to others to improve	**12**	Because I didn't have the fastest time and I wanted to go faster.
Going for a slow bobsled	**9**	Sometimes the goal is to make it faster or slower. More friction is slower. Less friction is faster. I needed to know which fabric created more friction.
Competing; specifically mentioning winning against others	**8**	Because I just wanted to see if I could win. I tried slowest and fastest because both ways work.
Wanting to improve; specifically mentioning competing against self or improving individual bobsled	**4**	Because I was trying to compete against myself to make the best. Figured I'd learn from my mistakes to find out which is the best.