# Assessing the Impact of STEM Project-Based Learning Using Curiosity Machine: Classroom Implementation Study Findings

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## Executive Summary

This summary describes key findings from the classroom implementation study of the Curiosity Machine (CM) design challenges during the Spring 2017 semester at Barack Obama School and Michelle Obama School. The study was designed to address the following research question: Can approaches around engineering design challenges have a significant impact on students' STEM identities, Possible selves, Self-efficacy, Interest in learning about STEM, and academic performance?

We used a pre-post survey to understand any changes that resulted for students as a result of participating in the CM challenges. These results were compared to a control group of students at the same school who completed the pre-post survey but did not complete any of the CM design challenges. The survey data was also complemented by classroom observations and review of students' design challenge portfolio. In our analysis, we also made comparisons by dosage (i.e., how many CM design challenges students completed/contact hours and participation in the fall family events) and by variables such as attendance, GPA, test scores, and grades from school records provided by the district.

After analyzing the classroom implementation data, we noted the following key study findings:

- **STEM Identities:** There were no significant changes on STEM identity as a result of the classroom implementation. We also made comparisons by dosage and did not find evidence of changes due to dosage.
- **Possible Selves:** There were no significant changes on this construct as a result of classroom implementation. However, we did find a difference due to dosage. Students who completed three design challenges had greater changes on this construct as compared to students who completed only one.
- **Self-Efficacy:** To understand self-efficacy, we tested students' constructive coping and resilience as well as their perceived competence in STEM. While there were no changes for competence, we did find positive changes related to students' constructive coping and resilience after participating in the classroom design challenges. We also found some statistically significant differences due to dosage. Specifically, students who

completed at least three design challenges had significantly greater changes as compared to students who only completed one.

- **Interest in STEM Learning:** There were no significant changes in students' interest in STEM learning as a result of the classroom implementation. There were also no differences as a result of dosage.
- **Beliefs about STEM:** There were no significant changes in students' beliefs about STEM learning as a result of the classroom implementation. We did note some differences by dosage for students who completed three design challenges as compared to those who only completed one.
- **Academic Performance:** When we compared changes in students' academic performance (e.g., GPA, test scores, grades, attendance) to changes in the control group, we found no significant difference. We also found no differences on academic performance as a result of dosage.

**Study Conclusions**

The study was designed to understand the impact of Curiosity Machine engineering design challenges on students' STEM identities, possible selves, self-efficacy, interest in STEM learning, and academic performance. Overall, we found limited evidence of changes on these constructs after one semester of implementation in the classroom. However, we did find evidence that there were some positive changes on students' constructive coping and resilience following participation in the classroom design challenges.

## Introduction

The Center for Research on Lifelong STEM Learning at Oregon State University collaborated with Iridescent Learning to conduct a study of the implementation of engineering design experiences in two Illinois Schools – Barack Obama School of Leadership and STEM (BOS) and Michelle Obama School of Technology and the Arts (MOS) – using the Curiosity Machine platform. The Curiosity Machine program is designed to motivate students for STEM topics and ideas, create "possible selves" as STEM learners and STEM users (including seeing oneself in a STEM career), and increase or stabilize a sense of self-efficacy for STEM. This summary describes key research findings that resulted from the implementation of 3 design challenges in the classroom during Spring 2017, facilitated by teachers, with students in grades 4-8 at both BOS and MOS.

## Study Context

The research study examined the Curiosity Machine as an intervention in grades 4-8 classrooms in BOS and MOS schools in Illinois. The study during the Spring of 2017 specifically investigated the implementation of the Curiosity Machine challenges in the Fusion STEM enrichment program facilitated by the Illinois Mathematics and Science Academy (IMSA). The intervention included the implementation of 3 design challenges, estimated to be approximately 6-8 contact hours for students. The Design Challenges implemented at each school included:

- Barack Obama School of Leadership and STEM
    1. Vertical Jumping Machine
    2. Crane
    3. Robotic Face
- Michelle Obama School of Technology and the Arts
    1. Vertical Jumping Machine
    2. No Wire Circuit
    3. Robotic Face

The Spring 2017 classroom study build on our previous study of the implementation of the Family Science events held in the Fall of 2016 at each of the school as well as additional take-home design challenges that were sent home with families to complete through the Curiosity Machine website and online submission tool.

## Research Questions

Our research study focused on measuring outcomes for students, especially related to academic achievement, interest in STEM careers, and higher-order cognitive skills. We hypothesized that students' participation in hands-on engineering design challenges, building on challenges completed with their families as part of the fall Family Science program, would result in positive impacts on students' critical thinking skills, problem solving skills, and their academic performance. Additionally, we posited that participation would result in increased interest in future STEM engagement (e.g., STEM careers and degree programs) as well as higher-order cognitive skills such as persistence, creativity, and curiosity. To explore these hypotheses, the following research questions guided the study:

Can approaches around engineering design challenges have a significant impact on students':

a. STEM identities (e.g., how students think of themselves in science);
b. "Possible selves" (see STEM as a component of their own career or future learning pathways, e.g., course taking in STEM areas);
c. Self-efficacy (e.g., beliefs in their abilities in STEM subject areas, self-perception of confidence in STEM);
d. Interest in learning about STEM;
e. Students' academic performance (e.g., grades, test scores in science, math, ELA) and overall engagement in school (e.g., changes in attendance)?

## Research Design and Data Collection Methods

Our overall study uses a complementary, mixed methods design to gain insight related to our research questions. Using this methodological approach, complementary data are collected using both quantitative and qualitative data collection strategies that occur in parallel and are interpreted to provide a comprehensive understanding of the Curiosity Machine intervention (Creswell, 2013). The quantitative data are used to test the stated hypotheses while the qualitative data will provide a more detailed, nuanced account of students' experiences in the program and resulting outcomes.

The classroom implementation study described in this report used a pre-post design with both a treatment (n=173) and control group (n=130). Students in the treatment group (n=173) were those who completed Curiosity Machine design challenges in their classrooms. As appropriate, we used information from the Fall 2016 Family Science events to analyze and interpret the data, specifically in terms of how dosage (i.e., number of design challenges completed and contact hours) influenced outcomes on the survey. Our data collection efforts included:

- Pre- and post-surveys administered before and after the implementation of the design challenges;
- Attendance records from Fall Family Science events;
- Design Challenge participation from Spring classroom implementation;
- Classroom observations;
- Compiled district data (e.g., GPA, truancy rates, standardized test scores, grades).

**Data Analysis**

As a first step in our analysis process, we matched students' responses on the pre- and post-surveys and categorized them into groups based on their level of participation in the Curiosity Machine programming over the school year: control group, family science participation only, classroom implementation only, and participation in both family science and classroom implementation. After this initial step, our sample included a total of 254 students with the following breakdown:

- Family Science and Classroom (n=13);
- Family Science (n=74);
- Classroom (n=102);

- Control (n=65).

Table 1 displays the various groups that participated with each of the treatment levels identified.

**Table 1: Study Participant Groups**

| | |
|---|---|
| *Treatment Group 1* | Participation in Fall 2016 Family *Curiosity Machine Events*<br>Participation in Spring 2017 Classroom *Curiosity Machine* programming |
| *Treatment Group 2* | Participation in Fall 2016 Family *Curiosity Machine Events*<br>No participation in Spring 2017 Classroom *Curiosity Machine* programming |
| *Treatment Group 3* | No participation in Fall 2016 Family *Curiosity Machine Events*<br>Participation in Spring 2017 Classroom *Curiosity Machine* programming |
| *Control Group* | No participation in Fall 2016 Family *Curiosity Machine Events*<br>No participation in Spring 2017 Classroom *Curiosity Machine* programming |

The pre-post survey instrument was designed to address the following key constructs: learner identity, STEM learner identity, future engagement and career, constructive coping and resilience, cognitive engagement, purpose and relevance of science, and competence and self-efficacy. The survey was previously tested and validated in another study conducted by O'Connell et al. (2016).

**Table 2. Survey Constructs and Sample Items**

| Construct | Sample Items |
|---|---|
| **Learner Identity** | I am persistent<br>I am curious |
| **STEM Learner Identity** | My friends think of me as someone who likes science related things.<br>My teacher thinks of me as someone who likes science related things. |
| **Future Engagement/Career** | I could imagine studying science or engineering in college<br>I want to be a scientist or engineer when I'm older |
| **Constructive Coping and Resilience** | If I don't understand something, I ask for help<br>If a problem is really difficult, I just work harder |
| **Cognitive Engagement** | I wonder a lot about how things work<br>I like to talk about how things work with family and friends |
| **Purpose and Relevance of Science** | Science and engineering helps solve problems<br>I believe that engineering can help make the world a better place |
| **Competence and Self-efficacy** | With enough effort, I could succeed in science and engineering<br>I am pretty good at math |

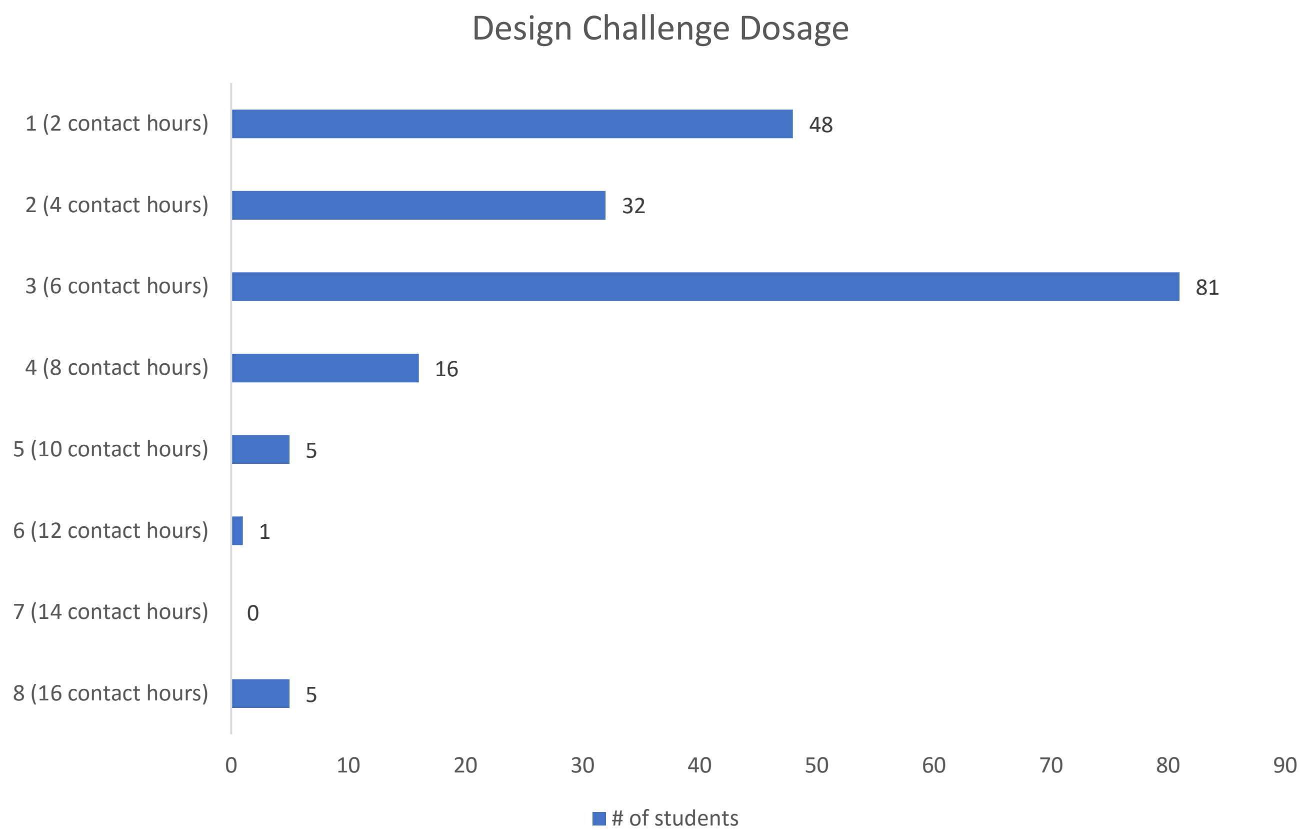
All of the survey data was entered into Qualtrics, an online survey platform. The quantitative survey data were analyzed using tools in Qualtrics to generate descriptive statistics and SPSS to generate inferential statistics.

## Key Findings from Curiosity Machine Classroom Implementation

### Design Challenge Dosage

We used Qualtrics to generate descriptive statistics of the participation and attendance data to understand dosage for students in the treatment group. The dosage data represents the total number of Design Challenges that students participated in across the Family Science nights (5 weeks total/10 total contact hours) and the Classroom Implementation (3 Design Challenges/ 6 contact hours). As displayed in Table 1, 3 was the most common number of Design Challenges (6 contact hours) completed among students in the treatment group.

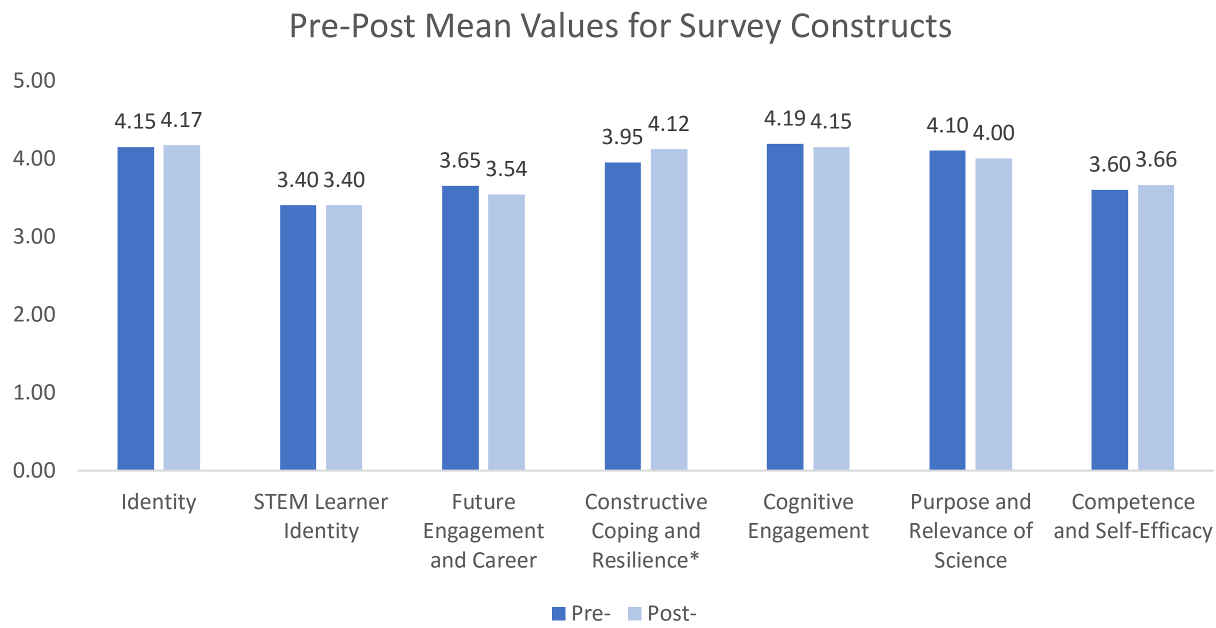
**Figure 1. Design Challenge Dosage for Students in the Treatment Group**




**Overall Survey Findings**

Figure 2 displays the mean values from the pre- and post-survey for each of the survey constructs. As illustrated in the figure, there were some minor changes for some constructs such as identity and competence and self-efficacy from the pre- to post-survey, but these changes were not found to be statistically significant. We did, however, find a significant improvement from the pre- to post-survey for constructive coping and resilience that can be attributed to the Curiosity Machine intervention. This suggests that students may be more likely to work harder on difficult problems and challenges, ask for help, or try new ways to solve problems or tasks after completing the Curiosity Machine design challenges in their classrooms.

**Figure 2. Pre-Post Mean Values for Each Survey Construct**




We further explore each construct and related findings from our analysis in the next section.

**STEM Identities.** Two constructs on the pre-post surveys aimed to understand how students' identities as learners and as learners of STEM specifically were influenced by the Curiosity Machine classroom implementation. Overall, we did not find any statistically significant changes on either of these constructs. We also analyzed whether participation in the Fall Family Science events or dosage (total number of Design Challenges completed/contact hours) influenced STEM identities and found no statistically significant differences.

**Possible Selves.** One construct, future engagement and career, aligned with the research question regarding possible selves. Overall, there were no statistically significant differences from the pre- to post-survey or between the treatment and control for this construct. However, there were statistically significant differences between students who completed three design challenges as compared to students who only completed one.

**Self-Efficacy.** The constructs constructive coping and resilience as well as competence were used to understand students' self-efficacy. While there were no statistically significant differences from the pre- to post-survey or between the treatment and control groups for competence, we did find some differences on the constructive coping and resilience construct. There was a statistically significant difference between the treatment and control groups suggesting that participation in the Curiosity Machine classroom implementation had a positive effect on students' constructive coping and resilience. Moreover, we found some statistically significant differences due to dosage. Specifically, students who completed 3 or 4 design challenges (6 to 8 contact hours) had significantly greater changes from the pre- to post-survey on this construct as compared to students who completed only one design challenge.

**Interest in STEM Learning.** Overall, there were no statistically significant differences from the pre- to post-survey or between the treatment and control for the construct designed to measure interest in STEM learning – Cognitive Engagement. There were also no differences as a result of dosage.

**Beliefs about STEM.** Beliefs about STEM were measured through the purpose and relevance of STEM construct. While there were no statistically significant differences from the pre- to post- or between treatment and control students, we did identify some differences by dosage. Specifically, there were statistically significant improvements on beliefs about STEM between students who completed three design challenges as compared to students who only completed only one.

### Academic Performance

We used compiled data from the district to examine any effects of participation in Curiosity Machine programming on students' academic performance specifically related to: school attendance, GPA, standardized test scores, and grades. We found that there were some statistically significant changes from the beginning to end of the school year for students in the treatment group (increase in number of absences, GPA, math and ELA grades). However, when we compared these to changes in the control students' data, we did not find any statistically significant differences in students' academic performance. Therefore, we were not able to conclude that the changes in academic performance were a result of the Curiosity Machine program.

We also explored any potential differences that might emerge as a result of dosage, using the number of design challenges as a co-variate. Similarly, we found no statistically significant differences on academic performance as a result of dosage.

## Classroom Implementation Study Conclusions

The study was designed to understand the impact of Curiosity Machine engineering design challenges on students' STEM identities, possible selves, self-efficacy, interest in STEM learning, and academic performance. Overall, we found limited evidence of changes on these constructs after one semester of implementation in the classroom. We speculate that dosage might be a factor contributing to these limited impacts. That is, we assume that as students participate in additional design challenges and contact hours in future iterations of the study, we may see increases on these constructs. We also suspect students may have overestimated on their pre-surveys. This phenomenon, known as response-shift bias in the literature, may account for some of the findings noted in this study. One strategy to address this issue in the future is to use adjusted study designs such as a retrospective pre-post survey or asking students to rate their confidence in their responses for items on the pre-survey. Finally, we postulate that allowing flexibility of implementation might have influenced the fidelity of implementation. While we wanted to allow teachers to implement the materials flexibly in a way that best met the needs of their context, this might have resulted it too much diversity in implementation which can impact the research study. Allowing this flexibility also resulted in limited data from the design portfolios, a data source which might have helped elucidate further outcomes of the design challenges.