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MEMORANDUM
Salvadori Meta-Analysis Study

The analysis described below summarizes findings from eight separate evaluation studies of Salvadori Center science, technology, engineering, and math (STEM) programs implemented in various schools and after-school settings between 2011 and 2017. In each of these programs, the Salvadori Center implemented an 8-week or 12-week hands-on, inquiry based program based on a specific curriculum designed by Salvadori's educational staff. These curricula were designed to address grade-specific learning objectives and National Common Core Learning Standards.

Youth Studies, Inc. (YSI) evaluation studies examined the following eight programs:

School Year	Salvadori Curricula
2011-2012	*Engineering Cities*
2012-2013	*Skyscrapers*
2012-2013	*Skateparks*
2013-2014	*Bridges*
2015-2016	*Bridges*
2016-2017	*Bridges (Scranton)*
2016-2017	*Bridges (Riverside)*
2016-2017	*Bridges*

Table 1: Evaluation Studies of the Salvadori Program Conducted by YSI (2011-2017)

In each of these evaluation studies, YSI administered pre- and post-assessments of participating students at the beginning and conclusion of the multi-week program cycle. In addition to basic demographic questions, these assessments included standardized measures of students' confidence in their ability to be successful in math and science, and their future-orientated motivation to pursue math and science careers. Moreover, in each evaluation study, YSI's assessments included standardized measures of specific skills and knowledge that were relevant to the content being taught during that particular program cycle.

Table 2 below details the curriculum-specific skills and knowledge that were assessed as part of that semester's evaluation study.

Salvadori Curricula	Description
Engineering Cities	○ General engagement and interest in math and science ○ Personal confidence in one's ability to be successful in math and science ○ Future-oriented motivation to pursue math and science careers and education

	○ Knowledge of basic urban planning concepts and definitions
Skyscrapers	○ Personal confidence in one's ability to be successful in math and science ○ Future-oriented motivation to pursue math and science careers and education ○ Comprehension of scale and proportion concepts ○ Knowledge of basic architectural and engineering concepts relevant to skyscrapers
Skateparks	○ Personal confidence in one's ability to be successful in math and science ○ Future-oriented motivation to pursue math and science careers and education ○ Comprehension of scale and proportion concepts ○ Understanding of the effects of common forces on objects ○ Ability to recognize shapes
Bridges	○ Personal confidence in one's ability to be successful in math and science ○ Future-oriented motivation to pursue math and science careers and education ○ Familiarity with various types of bridges and their relative benefits ○ Understanding of the effects of common forces on objects ○ Ability to read and interpret a chronological timeline ○ Ability to generate accurate measurement data using a ruler ○ Understanding of the scientific inquiry process

Table 2: Skills and Knowledge Assessed in YSI Evaluation Studies of Salvadori After-School (2011-2017)

Global Findings

To assess how Salvadori participants' attitudes about math and science may have changed over the course of their participation, YSI evaluators included survey items from the Fennema-Sherman Attitudes Scale, a math and science attitude scale that has been used extensively in education research. Using students' responses to questions from the Fennema-Sherman Attitudes scale, we constructed measures of students' personal *confidence* in their ability to do math and science. These attitudes were assessed prior to and after students participated in the Salvadori program.

More specifically, students were asked in both pre- and post-test surveys to agree or disagree with the following statements related to these attitudes. Students' responses to similar statements were averaged to form measures of students' confidence in math and science.

Math and Science Confidence Items *(Answer Choices: 1-Strongly Disagree, 2-Disagree, 3-Agree, 4-Strongly Agree)*
Math is hard for me
Science is hard for me
I know I can do well in math
I know I can do well in science
I am sure I can learn math
I am sure I can learn science
I think I could do advanced math and science

Table 3: Modified Fennema-Sherman Attitude Scales

As seen in Table 4 below, Salvadori participants in seven of eight programs demonstrated a significant increase in their confidence that they can be successful in math and science.

In each study, a paired-samples t-test was conducted to compare students' self-efficacy at the beginning and completion of the *Salvadori Center* program. The range of possible efficacy scores using this scale ranged from 1 (lowest efficacy) to 4 (highest efficacy). In 7 of the eight programs, there was a significant increase in pre-test vs. post-test conditions.

The average change in self-efficacy scores ranged from an increase of 0.18 in the *Bridges-Riverside (2017)* program to a 1.26 increase in the *Bridges (2014)* study. A standardized mean difference (SMD)[1] was calculated for this meta-analysis (see Figure 1 below) to summarize the overall effect of the Salvadori After-School program on students' personal confidence to perform well in math and science. In this case, the standardized mean difference in students' science and math self-confidence was 0.34.

Math and Science Self-Efficacy	
	Mean Difference: Post-test vs. Pre-test (Scale Range = 1-4)
Engineering Cities (2011)	+ 0.24#
Skyscrapers (2013)	+ 0.15#
Skateparks (2013)	+ 0.58#
Bridges (2014)	+ 1.26#
Bridges (2016)	+ 0.75#
Bridges - Scranton (2017)	+ 0.21#
Bridges - Riverside (2017)	+ 0.18
Bridges - IS349 (2017)	+ 0.31#
Standardized Mean Difference (SMD)	+ 0.34#

Statistically significant change from baseline to follow-up ($p<.05$)

[1] The standardized mean difference is used as a summary statistic in meta-analysis when the studies all assess the same outcome but measure it in a variety of ways (for example, all studies measure depression but they use different psychometric scales). In this circumstance it is necessary to standardize the results of the studies to a uniform scale before they can be combined. The standardized mean difference expresses the size of the intervention effect in each study relative to the variability observed in that study.

Table 4: Pre- vs. Post-test Assessments of Students' Confidence in their Ability to Succeed in Math and Science

Figure 1 below provides a visual representation of the Salvadori program's effect on students' math and science self-confidence.

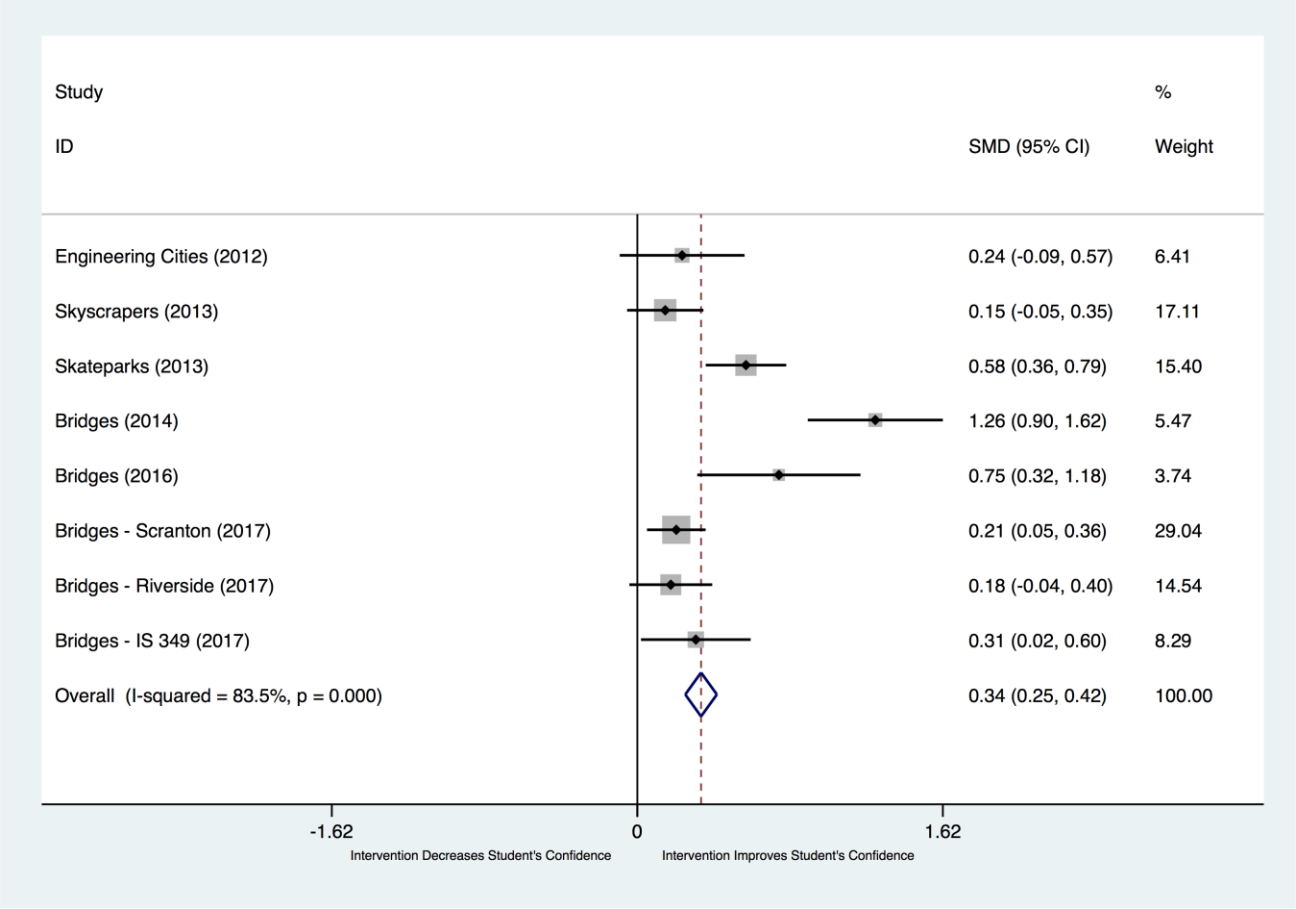

Figure 1: The Salvadori Program Effect on Students' Confidence in their Ability to Succeed in Math and Science

To assess how Salvadori participants' motivation to pursue educational and career choices in science may have changed over the course of their participation, YSI evaluators included survey items from the Programme for International Student Assessment (PISA), an international study by the Organization for Economic Co-operation and Development (OECD) of member nations' scholastic performance on mathematics, science, and reading.

Those items are listed below in Table 5.

Future-Orientated Science Motivation
I would like to work in a career involving science.
I would like to study science when I go to college.
I would like to work on science projects as an adult.

Table 5: PISA Future-Oriented Science Motivation Scale

Students' responses to these statements were averaged to form a measure of students' motivation to pursue future career and education opportunities in STEM. The range of possible motivation scores using this scale ranged from 1 (lowest efficacy) to 4 (highest efficacy).

As seen in Table 6 below, Salvadori students demonstrated a significant increase in motivation to pursue educational and career choices in math and science.

In all eight programs, there was a significant increase in pre-test vs. post-test conditions. The average change in STEM motivation scores ranged from an increase of 0.14 in the *Bridges-Scranton (2017)* program to a 0.70 increase in the *Bridges* (2016) study. A standardized mean difference (SMD) was calculated for this meta-analysis (see Figure 2 below) to summarize the overall effect of the Bridges program on students' future-oriented motivation to pursue math and science. In this case, the standardized mean difference in students' science and math self-confidence was 0.28.

Math and Science Motivation	
	Mean Difference: Post-test vs. Pre-test (Scale Range = 1-4)
Engineering Cities (2011)	+ 0.35[#]
Skyscrapers (2013)	+ 0.46[#]
Skateparks (2013)	+ 0.39[#]
Bridges (2014)	+ 0.57[#]
Bridges (2016)	+ 0.70[#]
Bridges - Scranton (2017)	+ 0.14[#]
Bridges - Riverside (2017)	+ 0.16[#]
Bridges - IS349 (2017)	+ 0.20[#]
Standardized Mean Difference (SMD)	+ 0.28[#]

[#] Statistically significant change from baseline to follow-up ($p<.05$)

Table 6: Pre- vs. Post-test Assessments of Students' Future-Oriented Motivation to Pursue Math and Science Careers and Education

Figure 2 below provides a visual representation of the Salvadori program's effect on students' science-related motivation.

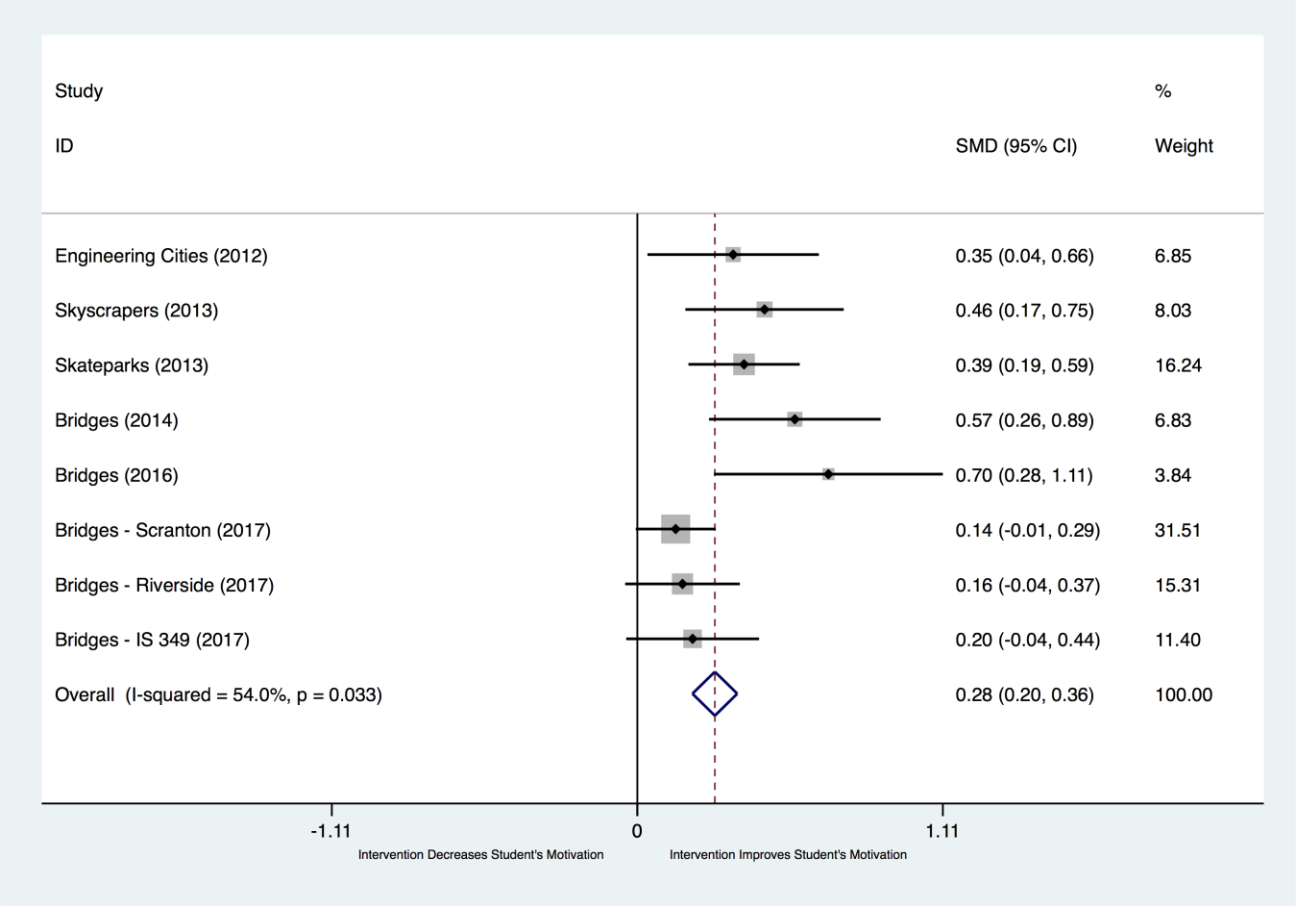

Figure 2: The Salvadori Program Effect on Students' Motivation to Pursue Math and Science

Curriculum-Specific Findings

Below we summarize specific outcome findings that pertain to each of the four Salvadori programs studied by YSI from 2011 to 2017.

Engineering Cities:

- *Engineering Cities* participants experienced significant gains in their perception of mathematics and science as useful subjects.

- *Engineering Cities* participants also experienced significant gains in their knowledge of basic urban planning terminology and concepts.

Skateparks:

- *Skateparks* participants demonstrated a statistically significant increase in their comprehension of *scale* and *proportion* concepts relevant to the *Skateparks* curriculum.

- *Skateparks* participants demonstrated a statistically significant increase in their understanding of the effects of common forces on moving objects.

- *Skateparks* participants demonstrated a statistically significant increase in their ability to correctly recognize and analyze three-dimensional forms.

Skyscrapers:

- *Skyscrapers* participants demonstrated a statistically significant increase in their comprehension of *scale* and *proportion* concepts relevant to the Skyscrapers curriculum.

- *Skyscrapers* participants demonstrated a significant increase in their knowledge of core engineering, design, and architecture concepts relevant to the *Skyscrapers* curriculum.

Bridges (2016 & 2017 including Scranton and Riverside):

- *Bridges* participants demonstrated a statistically significant increase in their understanding of various types of bridges, and the advantages and features of different bridge designs.

- *Bridges* participants demonstrated a statistically significant increase in their understanding of the effects of common forces on moving objects.

- *Bridges* participants demonstrated a statistically significant increase in their ability to correctly interpret a map scale and, using a ruler, estimate the actual length of a specific map detail.

Update on Gender-specific Impact *(2 April 2018)*

A follow-up analysis was conducted to determine whether there were any observed differences in program impact between male and female students. To accomplish this, we aggregated all assessment data collected across the eight programs identified in Table 1 above. Separate paired-samples t-tests were conducted to compare changes in male and female students' math and science efficacy and motivation.

As demonstrated in Table 7 below, both male and female students experienced statistically significant improvements in their math and science-related confidence, and their future-oriented motivation to pursue math and science careers.

	Mean Pre-Test Score	Mean Post-Test Score	Mean Difference: Post-test vs. Pre-test (Scale Range = 1-4)
Math and Science Confidence			
Male Students	76.8	81.2	+ 4.4[#]

Female Students	74.5	79.1	+ 4.5[#]
Math and Science Motivation			
Male Students	58.3	62.0	+ 3.7[#]
Female Students	55.8	61.1	+ 5.4[#]

[#] Statistically significant change from baseline to follow-up (p<.01)

Table 7: A comparison of Male and Female Students' changes in Math and Science Efficacy and Motivation

Across participating programs, the mean pre-test score on our standardized math and science efficacy measure was 76.8% for male students (M=76.8, SD=12.9) and 74.5% for female students (M=74.5, SD=12.7). After participating in their Salvadori program, male students experienced an average gain of 4.4% (M=81.2, SD=12.2). The average gain for female students was an almost identical 4.5% (M=79.1, SD=11.9). Figure 3 below presents a visual representation of the pre-test vs. post-test comparison for both male and female students.

The mean pre-test score on the math and science motivation score was 58.3% for male students and 55.8% for female students. Male students experienced an average gain of 3.7% on this scale. This represents a statistically significant improvement. Female students experienced an average gain of 5.4%. Hence, we conclude that the Salvadori program has had an even greater impact on increasing female students' math and science motivation. Figure 4 below presents a visual representation of the pre-test vs. post-test comparison for both male and female students.

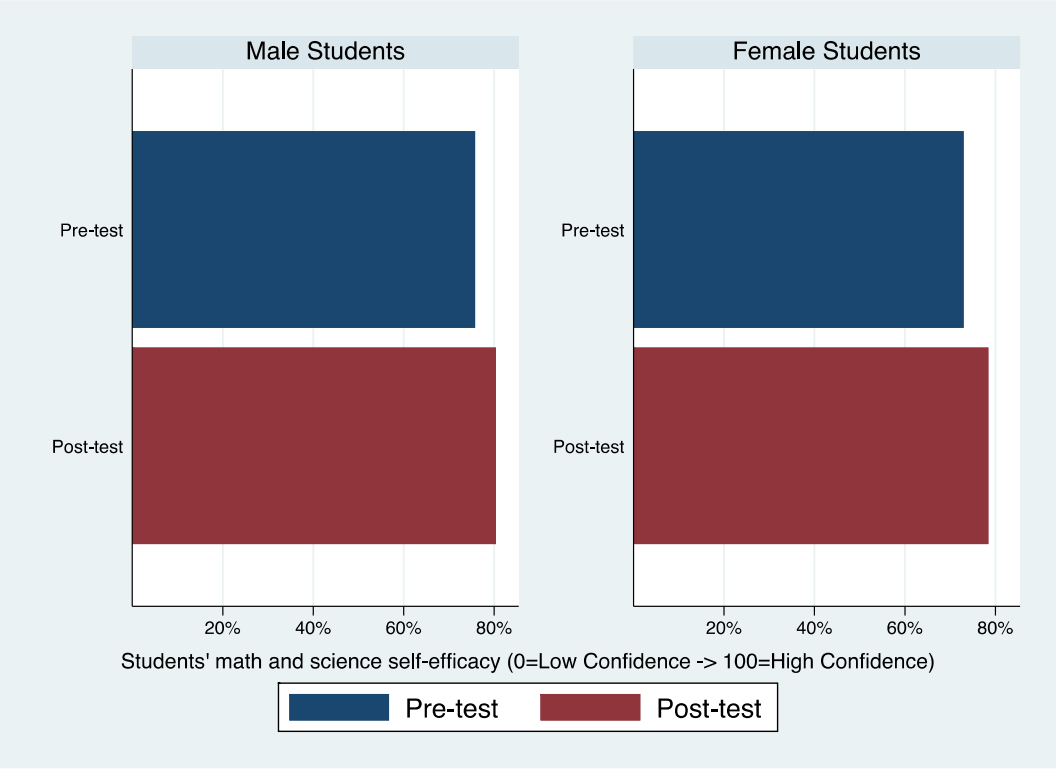

Figure 3: The Salvadori Program Effect on Students' Confidence in their Ability to Succeed in Math and Science

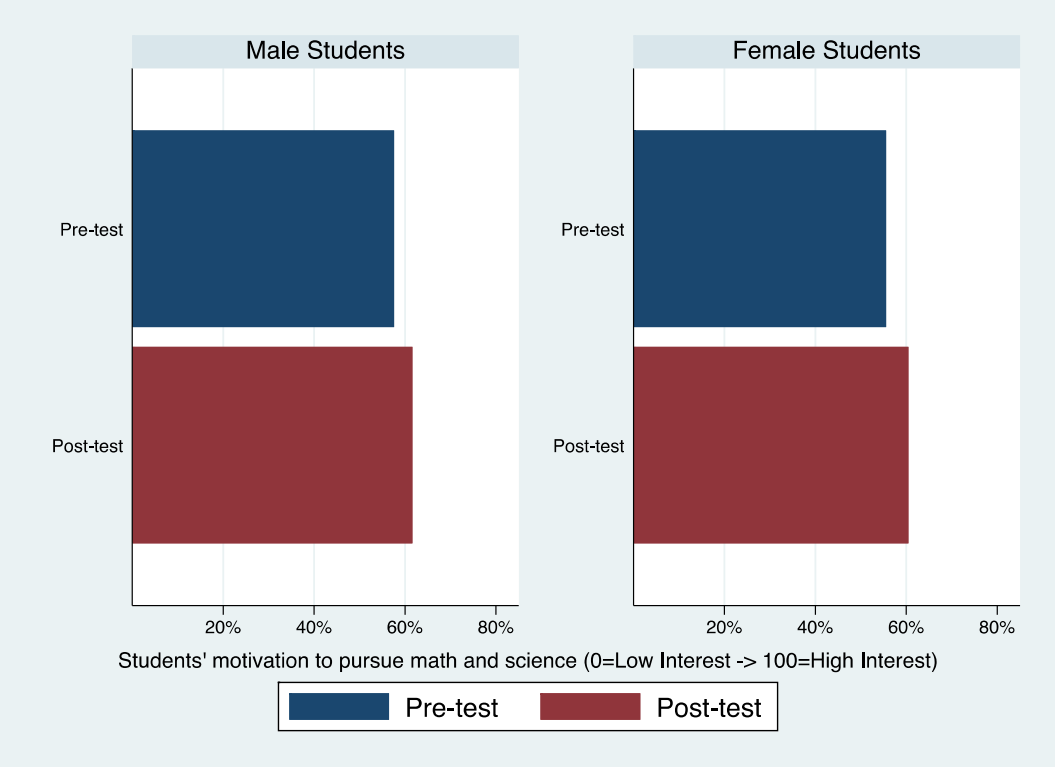

Figure 4: The Salvadori Program Effect on Students' Motivation to Pursue Math and Science