Promoting Student Engagement in Science, Technology, Engineering, and Math:

An Evaluation of Salvadori's In-School and After-School 2022-23 Enrichment Programs

Evaluation Report

October 2023

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Executive Summary

This report includes findings from Youth Studies Inc.'s (YSI) evaluation of Salvadori's multi-day in-school residencies and after-school enrichment programs implemented at various sites throughout New York City during the 2022-2023 school year. YSI's evaluation examined students' experiences in several different program models, including:

- Salvadori In-Depth: year-long intensive in-school residencies;
- Salvadori After-School: 12-week extended-length programs; and
- Salvadori Starter: 8-week in-school residencies.

YSI collected and analyzed assessment data from programs implemented across 14 different sites throughout New York City. Five different project-based curricula were taught across these programs, including 1) *Bridges, 2*) *Skateparks, 3*) *Skyscrapers*, 4) *Landmarks, Monuments, and Memorials, and 5) Building Green.* The goals of these curricula included:

- *Bridges*: Throughout the *Bridges* program, students identify the characteristics that make a bridge unique and investigate the different types of bridges and their functions. Students will be able to identify the structural parts that make up different types of bridges and understand the forces that enable each bridge to support a load. Students work in teams to develop a proposal that addresses a community problem, construct a scale model of a truss bridge, create an itemized budget, and test their prototypes.
- *Skateparks*: The *Skateparks* program uses hands-on activities and design challenges to foster student learning and exploration of topics relating to skateparks – the advantages of different surfaces, the effect of curved vs. straight ramps on rider experience, differences between shape, form, and elevation, and the forces involved in skateparks. Students learn to apply a given scale when measuring distances on a map and understand how different layouts can impact movement within a space. Students work in teams to design a three-dimensional scale model of a skatepark and present their model to peers.
- *Skyscrapers*: In the *Skyscrapers* program, students identify the characteristics that make skyscrapers unique and learn how columns and beams work together to support tall structures. Students work in teams to design and construct a structural grid, then calculate its usable square footage.
- *Landmarks, Monuments, and Memorials*: In *Landmarks, Monuments, and Memorials,* students explore the significance of the structures that commemorate people, places, and events, and investigate how integral these structures are to the built environment and to a sense of identity--be it international, national, or local. Students learn model-making techniques, then design and construct their own site-specific scale model of a proposed landmark, monument or memorial for their school neighborhood.
- *Building Green*: The *Building Green* program focuses on the fundamentals of green design in relation to the built environment. Students identify and study sustainable ways of heating, cooling, lighting, and powering buildings, learning how to reduce their

environmental impact, and understanding the value of green design. Students work in teams to design and construct a scale model of an energy-efficient building.

During the 2022-23 school year, Youth Studies, Inc. administered pre-and post-assessments to students participating in the following programs:

Skateparks: Rutgers Community Center (After-school) Sunnyside Community Services Woodside Houses (After-school) PS/MS 278 - The Paula Hedbavny School (After-school) PS 111 Adolph S. Ochs (Starter)
Skyscrapers: PS/MS 278 - The Paula Hedbavny School (After-school) PS 58X (After-school) PS 160Q (After-school)
Bridges: St. Mary's (After-school) MS 328: New Millennium Bronx Academy of the Arts (In-depth) Manhattanville Cornerstone (After-school)
Building Green: IS 349: School for Math, Science, & Technology (In-depth) MS 594: New Pathways Academy (In-depth) MS 331 Bronx School of Young Leaders (In-depth)
Landmarks, Monuments, and Memorials PS 58X (In-depth) PS 223 Q Lyndon B. Johnson School (After-school)

A total of 1,070 assessments were completed by 620 students. The following are key highlights from YSI's evaluation of Salvadori's NYC programs in 2022-23:

- A total of 620 students participated in YSI's assessment of Salvadori's Center's NYC programs. Fifty-one (51) percent were female. Eighty-six (86) percent of surveyed participants self-identified as "Black or African American" or "Hispanic/Latino." Six (6) percent of participants self-identified as "Asian," (13) percent as "White," (13) percent as "Native American," and (8) percent as "Other."
- The evaluation results reported below include evidence that Salvadori programs support several national math and science learning standards, including:
  - Common Core Math CCSS.MATH.CONTENT.HSG.MG.A.3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).
  - CCSS.MATH.CONTENT.3.MD.B.4: Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch.
  - Next Generation Science learning standard MS-PS2-1. Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.

- YSI analyzed assessment results from Salvadori programs utilizing five different curricula: *Bridges, Skateparks, Skyscrapers, Building Green, Landmarks, Monuments, and Memorials.*
- Students across these five different programs demonstrated a significant increase in their confidence that they can be successful in math and science as measured by the Fennema-Sherman Attitudes Scale, a math and science attitude scale that has been used extensively in education research (See Page 11). **YSI observed a 7 percent improvement in participants' STEM-related self-efficacy**.
- Salvadori participants across all five programs demonstrated a significant increase in their motivation to pursue educational and career choices in science as measured by the assessment items from the Programme for International Student Assessment (PISA) (See Page 12). **YSI observed a 23 percent improvement in students' future-oriented motivation to pursue STEM from pre- to post-test.**
- Salvadori participants in the *Bridges* program demonstrated a statistically significant increase in their understanding of the effects of common forces on moving objects (See Page 14). **Students in *Bridges* experienced a 40 percent improvement in their knowledge of common forces.**
- Salvadori participants in the *Skateparks* program demonstrated a statistically significant increase in their understanding of scale, proportion, and measurement concepts (Page 17). **Students in *Skateparks* experienced a 32 percent improvement in their knowledge of these concepts.**
- Salvadori participants in the *Skateparks* program demonstrated a statistically significant increase in their understanding of the effects of common forces on objects (Page 20). ***Skateparks* students experienced a 44 percent improvement in this area.**
- Salvadori participants in the *Landmarks, Monuments, and Memorials (LMM)* program demonstrated a statistically significant improvement in their understanding of concepts central to this subject, including what distinguishes landmarks, monuments, and memorials, and the properties of various building materials used in these structures (Page 23). **Students experienced a 28 percent improvement in their understanding of core concepts relevant to the LMM curriculum.**
- Salvadori participants in the *Skyscrapers* program demonstrated a statistically significant increase in their understanding of scale and proportion concepts (Page 26). ***Skyscrapers* students experienced an 89 percent improvement in this area.**
- Salvadori participants in the *Skyscrapers* program demonstrated a statistically significant increase in their understanding of basic engineering, design, and architecture concepts (Page 28). ***Skyscrapers* students experienced a 111 percent improvement in this area.**
- Salvadori participants in the *Building Green* program demonstrated a statistically significant increase in their understanding of fundamental green design concepts (Page 30). ***Building Green* students experienced a 25 percent improvement in their understanding of green design concepts.**

Background

A challenge facing many educational institutions, especially those in urban settings serving culturally and linguistically diverse populations, is the disconnect that often exists between schools and students' home communities. Science education researchers have argued that this disconnect between school and home/community life may result in students feeling that science is impractical, alien, and in contradiction with the beliefs and practices of their lives (Basu & Barton, 2007). Urban and low-income students, in particular, are more likely to hold negative sentiments about science, such as boredom, anxiety, confusion, and frustration. Bouillion and Gomez (2001) have argued that this decoupling leads to a disengagement in which some learners fail to see schooling as an avenue for life progress. With respect to science education, this phenomenon jeopardizes our nation's goal to become first in the world in science achievement among students (U.S. Department of Education, 1991).

In response to this challenge, many are advocating an instructional approach that emphasizes hands-on activities and learning by doing. In fact, many of the recent national reports on the conditions of science teaching and learning in schools call for, "More active learning for students and less passivity; more hands-on, direct opportunities to 'make meaning'" (Schmieder & Michael-Dyer, 1991). To that end, science education standards set forth by the American Association for the Advancement of Science and the National Research Council now urge less emphasis on memorizing decontextualized scientific facts and more emphasis on students investigating the everyday world and developing deep understanding from their inquiries (Marx et al., 2004). These approaches to instruction challenge educators to transform students' experiences in science classrooms. For teachers who are used to using instructional methods based on recitation and direct instruction, inquiry teaching challenges them to develop new content knowledge and pedagogical techniques (Basu & Barton, 2007; Bouillion & Gomez, 2001).

This report includes recent (2022-23) findings from YSI's evaluation of various Salvadori programs implemented in sites across New York City. These programs were implemented as either a 12-week after-school program or as an in-school residency. Five different Salvadori-designed curricula were utilized for these programs. They include: a) *Bridges*, b) *Skateparks*, c) *Skyscrapers*, d) *Building Green*, and e) *Landmarks, Monuments, and Memorials*. All five curricula represent an effort to engage disadvantaged students in math and science using a hands-on, project-based approach. Salvadori collaborates with providers including NYC Public Schools, New York City Housing Authority community centers, and non-profit, community-based providers to implement these programs. Salvadori uses the principles of architecture and engineering to help students in schools and out-of-school time programs to master mathematics and science concepts. All five programs aim to use investigations of the built environment to introduce and reinforce STEM concepts and skills. The program highlights engineering concepts and the design process through hands-on investigations of the built environment with an emphasis on collaborative, project-based learning.

The rest of this report summarizes current findings from an evaluation of students' experiences in five different programs implemented across 13 different sites throughout New York City. The goals of these five Salvadori-designed curricula include:

- *Bridges:* Throughout the *Bridges* program, students identify the characteristics that make a bridge unique and investigate the different types of bridges and their functions. Students will be able to identify the structural parts that make up different types of bridges and understand the forces that enable each bridge to support a load. Students work in teams to develop a proposal that addresses a community problem, construct a scale model of a truss bridge, create an itemized budget, and test their prototypes.
- *Skateparks:* The *Skateparks* program uses hands-on activities and design challenges to foster student learning and exploration of topics relating to skateparks – the advantages of different surfaces, the effect of curved vs. straight ramps on rider experience, differences between shape, form, and elevation, and the forces involved in skateparks. Students learn to apply a given scale when measuring distances on a map and understand how different layouts can impact movement within a space. Students work in teams to design a three-dimensional scale model of a skatepark and present their model to peers.
- *Skyscrapers:* In the *Skyscrapers program*, students identify the characteristics that make skyscrapers unique and learn how columns and beams work together to support tall structures. Students work in teams to design and construct a structural grid, then calculate its usable square footage.
- *Landmarks, Monuments, and Memorials:* In *Landmarks, Monuments, and Memorials,* students explore the significance of the structures that commemorate people, places, and events, and investigate how integral these structures are to the built environment and to a sense of identity--be it international, national, or local. Students learn model-making techniques, then design and construct their own site-specific scale model of a proposed landmark, monument, or memorial for their school neighborhood.
- *Building Green:* The *Building Green* program focuses on the fundamentals of green design in relation to the built environment. Students identify and study sustainable ways of heating, cooling, lighting, and powering buildings, learning how to reduce their environmental impact, and understanding the value of green design. Students work in teams to design and construct a scale model of an energy-efficient building.

This evaluation was implemented by Youth Studies, Inc. (YSI), an evaluation firm that provides research and program evaluation services to a variety of youth-serving organizations, including schools and community-based youth programs. All five curricula are aligned with the Common Core Math Standards and the New York State Standards for Math, Science, and Technology and Blueprint for the Arts. Each lesson uses a collaborative, hands-on, project-based approach. Activities in the earlier sessions focus on developing students' skills of measurement, observation, classification, and drawing conclusions based on the results of a controlled experiment.

Description of Evaluation Process

Participant Assessments

YSI developed pre- and post-participation student assessments that were administered by Salvadori educators during the first and final sessions, at participating sites. In addition to basic background questions (e.g. gender, age, and ethnicity), the pre- and post-assessments included standardized measures of students' confidence in their ability to succeed in math and science, and their future-oriented motivation to pursue math and science careers. In addition to these general outcomes, YSI's assessments included tasks and measures of content and skills that were relevant to the specific program the participant was enrolled in: *Bridges, Skateparks, Skyscrapers, Building Green, and Landmarks, Monuments, and Memorials*. These included:

Table 1: Program-specific content and skills evaluated.

Salvadori Program	*Program-specific Content/Skills Assessed by YSI*
Bridges	• Students' familiarity with various types of bridges and their relative benefits • Students' understanding of the effects of common forces on objects • Students' ability to read and interpret a chronological timeline • Students' ability to generate measurement data using a ruler • Student understanding of the scientific inquiry process
Skateparks	• Students' comprehension of scale and proportion • Students' understanding of the effects of common forces on objects • Students' ability to recognize and analyze three-dimensional shapes and forms
Landmarks	• Students' ability to define and differentiate landmarks, monuments, and memorials • Students' ability to read and interpret maps • Students' comprehension of scale and proportion
Building Green	• Students' knowledge of the fundamentals of green design
Skyscrapers	• Students' knowledge of basic engineering and architecture concepts and definitions

A total of 620 students participated in YSI's assessment of Salvadori programs. Of those 620 students, 450 completed *both* a pre- and post-test assessment. The remaining 170 students participated in the pre-test only (147) or only submitted a post-test assessment (23).

Moreover, 51 percent of the participants assessed were female. Eighty-six (86) percent of surveyed participants self-identified as "Black or African American" or "Hispanic/Latino." Six (6) percent of participants self-identified as "Asian," 13 percent as "White," 13 percent as "Native American," and 8 percent as "other."

Table 2. Background Characteristics of BRIDGES Participants

Demographic Characteristics	% of Students
Gender	
Male	49
Female	51
Ethnicity*	
Black or African-American	62
Hispanic/Latino (of any race)	24
White	13
American Indian or Alaska native	13
Asian	6
Other	8

* *Participants were allowed to select as many ethnicities as they wanted. Hence, the percentages associated with these responses total to greater than 100.*

To assess how Salvadori participants' attitudes about math and science may have changed over the course of the program, 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 math and science ability. These attitudes were assessed prior to and after students participated in one of five Salvadori programs: *Bridges, Skateparks, Skyscrapers, Building Green or Landmarks, Monuments & Memorials*. 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.

Table 3. Modified Fennema-Sherman Attitude Scales

Confidence Items
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

Three survey items from the Programme for International Student Assessment (PISA) were included to assess students' future-oriented motivation to pursue science education and careers (OECD, 2007). Those items are listed in Table 4.

Table 4. PISA Future-Oriented Science Motivation Scale

Future-Orientated Science Motivation
I would like to work in a career involving science.

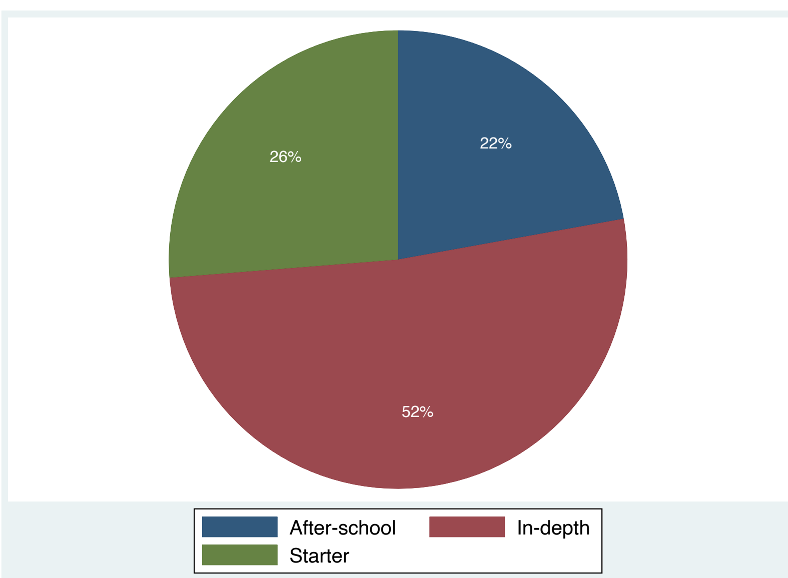
I would like to study science when I go to college.
I would like to work on science projects as an adult.

Salvadori Center In-School Residency and After-school Findings

YSI assessed knowledge and skill gains among students who participated in the Salvadori Center's *Bridges* program in one of three formats (see Figure 1):

- *Salvadori Starter:* Twenty-six (26) percent of survey respondents participated in Salvadori Starter programs, consisting of 8-week in-school residencies. These residencies utilized Salvadori educators incorporating lessons within 45-minute classroom sessions. All of these *Starter* programs utilized the *Skateparks* curriculum.
- *Salvadori In-depth:* Fifty-two (52) percent of survey respondents participated in Salvadori *In-depth* programs, consisting of year-long intensive in-school residencies. *These residencies utilized Salvadori educators incorporating lessons within 45-minute classroom sessions.* These programs explored either the *Bridges, Building Green, or Landmarks, Monuments, and Memorials* curricula.
- *Salvadori After-School*: Twenty-two (22) percent of survey respondents participated in Salvadori after-school programs which consisted of 12 weeks of after-school programming. In the after-school setting Salvadori content was delivered in 90-minute weekly sessions. These programs explored one of four of the Salvadori curricula, including *Bridges, Skateparks, Skyscrapers, and Landmarks, Monuments, and Memorials.*

Figure 1: Salvadori Program Format



Salvadori participants were surveyed at the beginning and conclusion of their program. Regardless of which program format and curricula students participated in, assessments included standardized measures of: 1) s**tudents' confidence in their ability to succeed in math and science**; and 2) **students'**

future-oriented motivation to pursue math and science careers. Below, we first summarize our findings on these two outcome areas and then discuss assessments of specific knowledge and skill outcomes tied to a particular curriculum.

STEM-Related Attitudinal Changes for Participants in Bridges, Skyscrapers, Skateparks, Building Green, and Landmarks, Monuments, and Memorials

This section of the report discusses YSI's assessment of the impact of Salvadori programs on participants' STEM-related attitudes. YSI's assessments include measures of participants' confidence in their ability to be successful in math and science tasks and their future-oriented motivation to pursue math and science-related education and careers. The findings below encompass all five Salvadori programs: *Bridges, Skyscrapers, Skateparks, Building Green, and Landmarks, Monuments, and Memorials.*

Students' Confidence in their Ability to Succeed in Math and Science

To assess how Salvadori students' attitudes about math and science may have changed during the time they participated in the program, evaluators administered a modified version of the Fennema-Sherman Attitudes Scale (see description above). Responses to this assessment were used to develop a measure of students' personal *confidence* in their ability to do math and science. These attitudes were assessed prior to and after students participated in their Salvadori program. The assessment items included:

Table 5. Student Confidence Items

Question #	**Confidence Item** (Answer Choices: Strongly Disagree, Disagree, Agree, Strongly Agree)
6	I am sure I can learn math
7	I know I can do well in science
8	I think I could do advanced math and science
9	Math is hard for me
10	I know I can do well in math
13	Science is hard for me
15	I am sure I can learn science

YSI created an overall measure of students' math and science self-efficacy. Possible values for this measure ranged from 0 (indicating the lowest possible confidence) to 100 (indicating that the students answered reported the highest possible confidence).

As seen in Table 6 below, *Salvadori* participants demonstrated a statistically significant increase in their confidence that they can be successful in math and science. A paired-samples t-test was conducted to compare students' self-efficacy at the beginning and completion of the Salvadori program. There was a significant improvement in pre-test (M=72.3, SD=14.3) vs. post-test (M=77.5, SD=15.8) conditions ($M_{difference}$=5.2, SE=1.1); t (307)=4.4, p < .0001.

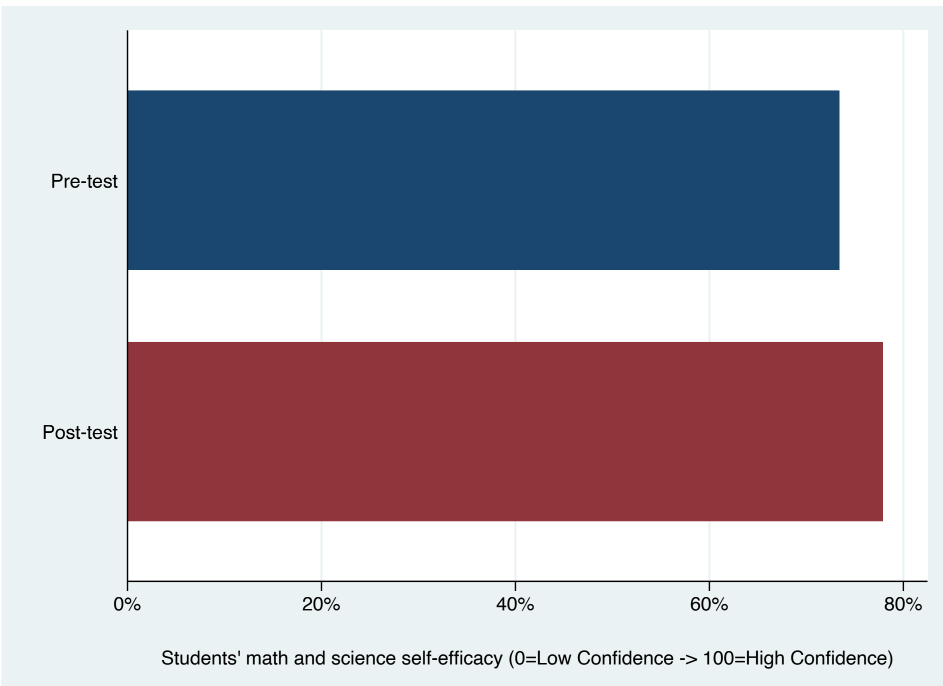
These findings represent a 7 percent improvement in students' confidence in their math and science abilities from pre- to post-test for students participating in Salvadori programs. Figure 2 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 6. Pre- vs. Post-test Assessments of Students' Confidence in their Ability to Succeed in Math and Science

	Math and Science Confidence
Mean: range 0 (low) - 100 (high)	
Pre-test Score	72.3
Post-test Score	77.5
Change	+ 5.2[#]

[#] Statistically significant change from baseline to follow-up ($p<.0001$)

Figure 2. Pre- vs. Post-test Assessments of Students' Confidence in their Ability to Succeed in Math and Science



Students' Future-oriented Motivation to Pursue Science Careers

YSI's assessments also included three items to measure students' motivation to pursue future education and careers in math and science. These items included:

Table 7. Future-Oriented Motivation Assessment Items

Question #	**Motivation Item** (Answer Choices: Strongly Disagree, Disagree, Agree, Strongly Agree)
11	I would like to work in a career involving science.
12	I would like to study science when I go to college.
14	I would like to work on science projects as an adult.

YSI created an overall measure of students' motivation to pursue STEM-related careers. Possible values for this measure ranged from 0 (indicating the lowest possible motivation) to 100 (indicating that the students answered reported the highest possible motivation).

As seen in Table 8 below, Salvadori participants demonstrated a significant increase in motivation to pursue educational and career choices in math and science. A paired-samples t-test was conducted to compare students' future-oriented motivation to pursue math and science as measured at the beginning and completion of their Salvadori program. There was a significant improvement in pre-test (M=51.5, SD=22.1) vs. post-test (M=63.6, SD=22.9) conditions ($M_{difference}$=12.1, SE=1.8); t (319)=6.9, p < .0001).

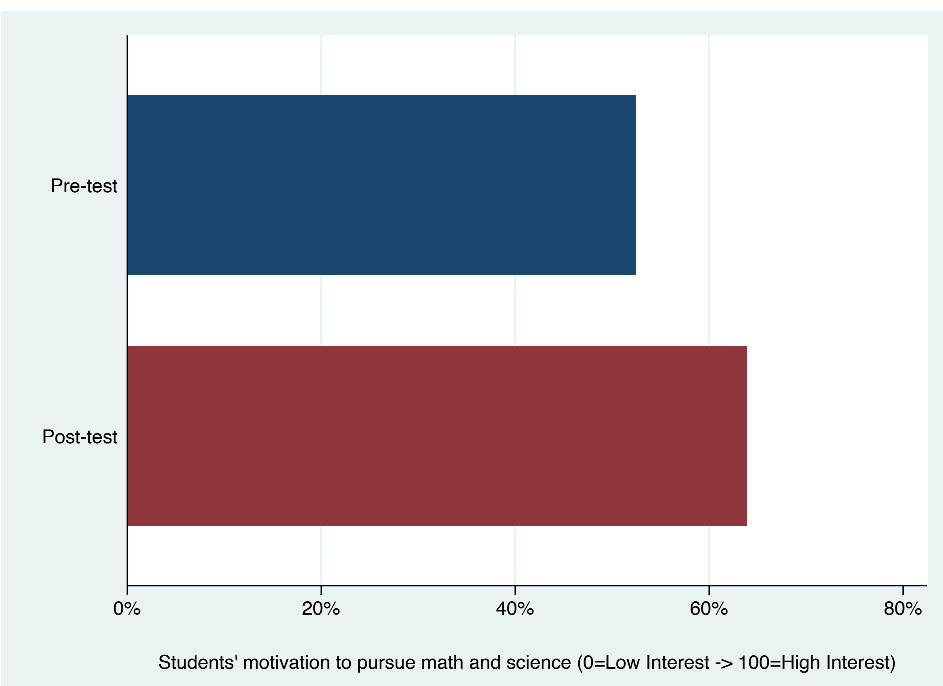
These findings represent a 23 percent improvement in students' future-oriented motivation to pursue STEM from pre- to post-test for Salvadori students participating in in-school and after-school residency programs. Figure 3 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 8. Pre- vs. Post-test Assessments of Students' Future-Oriented Science Motivation

	Science Motivation
Mean (range 1-100)	
Pre-test Score	51.5
Post-test Score	63.6
Change	+ 12.1[#]

[#] Statistically significant change from baseline to follow-up (p<.0001)

Figure 3. Pre- vs. Post-test Assessments of Students' Future-Oriented Science Motivation



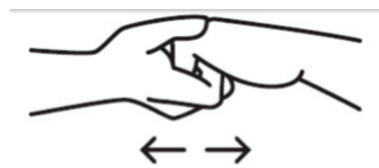
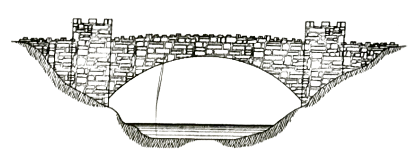
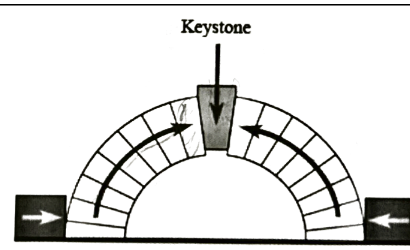
Knowledge and Skill Gains Related to Participation in the Bridges Program

Students' Understanding of the Effects of Common Forces on Objects

The pre-and post-test student assessments administered to students who participated in the *Bridges* program included several items to assess students' understanding of the effects of common forces on moving objects. More specifically, these items required students to distinguish between the forces of tension and compression and to interpret Newton's Third Law of Motion. These concepts are central to the *Bridges* curriculum.

The specific assessment items included the following:

Table 9. Common Forces Assessment Items

Question #	Assessment Item
23	Label which force is being used in each picture below. ☐ Tension ☐ Compression  
25	Newton's Third Law states that for every action there is an equal and _____________ reaction. ❑ opposite ❑ perfect ❑ stable ❑ positive
28	The image to the right is a picture of an arch bridge. If a truck weighing 500 pounds crosses this bridge, how will the weight of the truck be distributed? ____ pounds will be distributed to the right side of the arch and____ pounds will be distributed to the left side of the arch. 
29	If a pile of snow pushes down on the keystone of an arch bridge so that 25N are distributed to the left side of the bridge, how much force will the ground "push back" with on that side of the bridge? ____________Newtons 

30	Label each box in the diagram below to show which force is applied on that part of the bridge: TENSION or COMPRESSION. 

YSI created an overall measure of student comprehension of common forces that summarizes how well students performed on the assessment items listed above. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

As seen in Table 10 below, *Bridges* participants demonstrated a small increase in their ability to recognize and analyze the effects of common forces on objects. A paired-samples t-test was conducted to compare students' knowledge at the beginning and conclusion of the *Bridges* program.

There were significant improvements in measured pre-test vs. post-test knowledge observed for students participating in the *Bridges* program. At the participating *Bridges* sites, the mean pre-test score was 52% (M=52.2, SD=26.3). After the program was completed, Salvadori participants scored an average of 73% (M=73.1, SD=28.2) on the post-test assessment. This represents an average improvement of 17% observed over the course of the 8 or 12-week intervention ($M_{difference}$=20.9, SE=5.23); t (106)=3.98, p = .0001.

This assessment finding offers evidence that the *Bridges* program supports student learning for the following New York State Standard for Math, Science, and Technology:

Standard 4, Key Idea 5

Energy and matter interact through forces that result in changes in motion.

Describe the effects of common forces (pushes and pulls) of objects, such as those caused by gravity, magnetism, and mechanical forces

- For every action there is an equal and opposite reaction

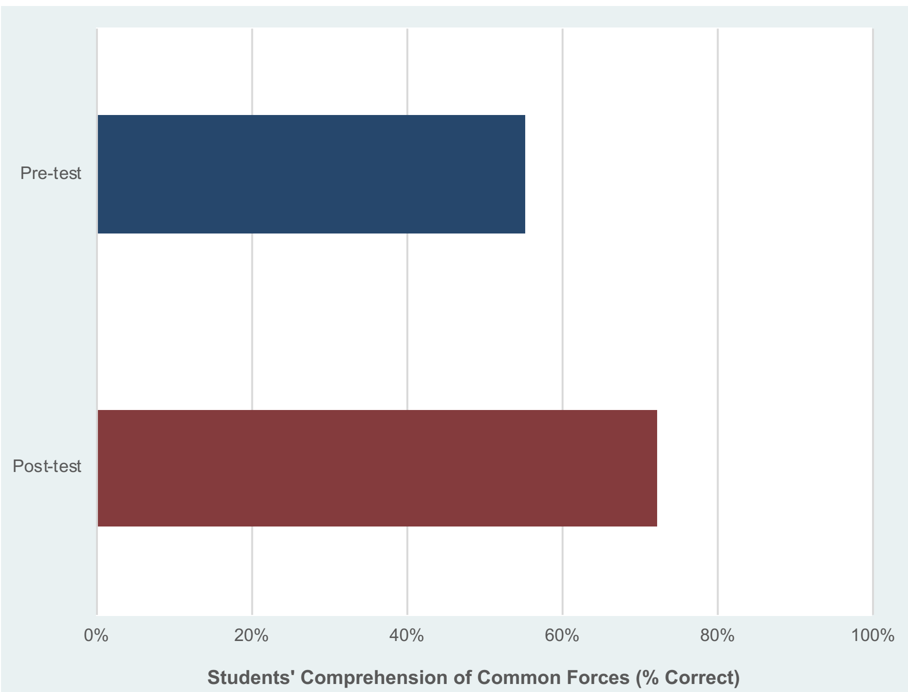
These findings represent a 40 percent improvement in students' understanding of the effects of common forces from pre- to post-test for Salvadori students participating in either the *Bridges* in-school residency or the *Bridges* after-school program. Figure 4 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 10. Pre- vs. Post-test Assessments of Students' Understanding of the Effects of Common Forces

	Student Understanding of the Effects of Common Forces
Mean (range 0-100)	
Pre-test Score	52.2
Post-test Score	73.1
Change	+ 20.9[#]

[#] Statistically significant change from baseline to follow-up (p<.0001)

Figure 4. Pre- vs. Post-test Assessments of Students' Comprehension of Common Forces



Students' Ability to Read and Interpret a Timeline

The pre- and post-test questionnaires included two items that asked students to correctly read and interpret a chronological timeline. The specific items included the following:

Table 11. Chronological Timeline Assessment Items

Question #	**Assessment Item**
21	Which of the following is the missing year that belongs in the timeline below? 1927 1940 1953 1966 1979 ? ❑ 1994 ❑ 1992 ❑ 2005 ❑ 1953

22	The timeline below includes a starting and end year, but the years in between are not labeled.  What is the correct scale for this timeline? ❑ 3 years ❑ 5 years ❑ 14 years ❑ 2 years

YSI created a measure of students' ability to correctly interpret a chronological timeline using the items above. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

As seen in Table 12 below, Salvadori participants demonstrated a small, but not statistically significant increase in their ability to read and interpret a timeline. A paired-samples t-test was conducted to compare students' timeline interpretation skills at the beginning and conclusion of the *Bridges* program. At the participating *Bridges* sites, the mean pre-test score was 57% (M=57.2, SD=29.1). At the conclusion of the *Bridges* program, Salvadori students scored an average of 64% (M=64.3, SD=28.4) on the post-test assessment. This represents an average improvement of 7% observed over the course of the *Bridges* intervention ($M_{difference}$=7.1, SEM=5.4); t (112)=1.32, p = .1901.

The magnitude of the observed improvement in timeline reading skills among *Bridges* participants was *not* sufficient to conclude that the program led to a significant improvement in students' ability to read and interpret a chronological timeline.

Table 12. Pre- vs. Post-test Assessments of Students Ability to Read and Interpret a Chronological Timeline

	Students Ability to Interpret a Timeline
Mean (range 0-100)	
Pre-test Score	57.2
Post-test Score	64.3
Change	+ 7.1[&]

[&] This result was not found to be statistically significant.

Knowledge and Skill Gains Related to Participation in the Skateparks Program

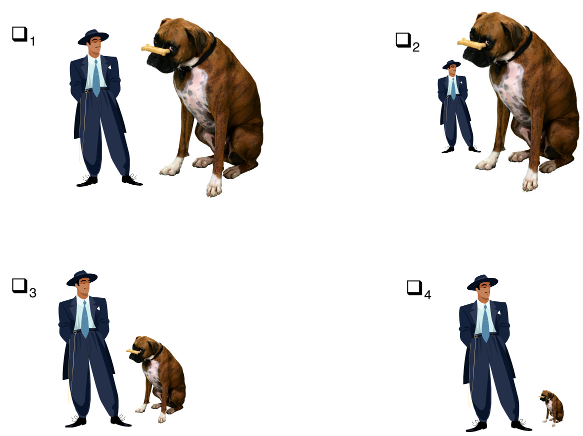
YSI assessed knowledge and skill gains among students who participated in Salvadori's Skateparks Starter in-school residency and after-school programs. Salvadori participants were surveyed at the beginning and conclusion of their program. In addition to basic background questions (e.g. gender, age, and ethnicity), the pre- and post-assessments included standardized measures of: 1) **students'**

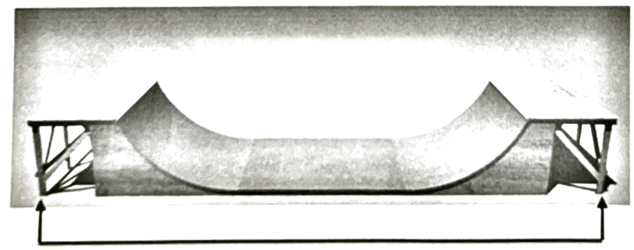
comprehension of scale, proportion, and measurement concepts; 2) **students' understanding of the effects of common forces on objects**; 3) **students' ability to recognize and analyze three-dimensional shapes**.

Students' Comprehension of Scale and Proportion

The pre- and post-test questionnaires included three performance tasks that were designed to assess students' understanding of scale and proportion concepts central to the *Skateparks* curriculum. The specific items included the following:

Table 13. Scale and Proportion Assessment Items

Question #	Assessment Item
21	Which picture below shows the dog and his owner in correct proportion? 
35	Use the Architect Scale Ruler to measure the objects in the pictures below. (Scale: ½" = 1') This skateboard would be ______' long. 

36	Use the Architect Scale Ruler to measure the objects in the pictures below. (Scale: ½" = 1') This half-pipe would be ______' long. 

YSI created an overall measure of student comprehension that summarizes how well students performed on these four tasks. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

As seen in Table 14 below, Salvadori *Skateparks* participants demonstrated a significant increase in their comprehension of scale, proportion, and measurement concepts. A paired-samples t-test was conducted to compare students' knowledge of scale and proportion at the beginning of the *Skateparks* program and after the *Skateparks* module was completed.

There was a significant improvement in measured pre-test vs. post-test knowledge observed for students participating in the *Skateparks* program. At the participating *Skateparks* sites, the mean pre-test score was 48.7% (M=48.7, SD=35.1). After the program was completed, Salvadori participants scored an average of 63% (M=64.2, SD=36.2) on the post-test assessment. This represents an average improvement of 16% observed over the course of the 12-week intervention ($M_{difference}$=15.5, SE=4.39); t (262)=3.53, p = .0005.

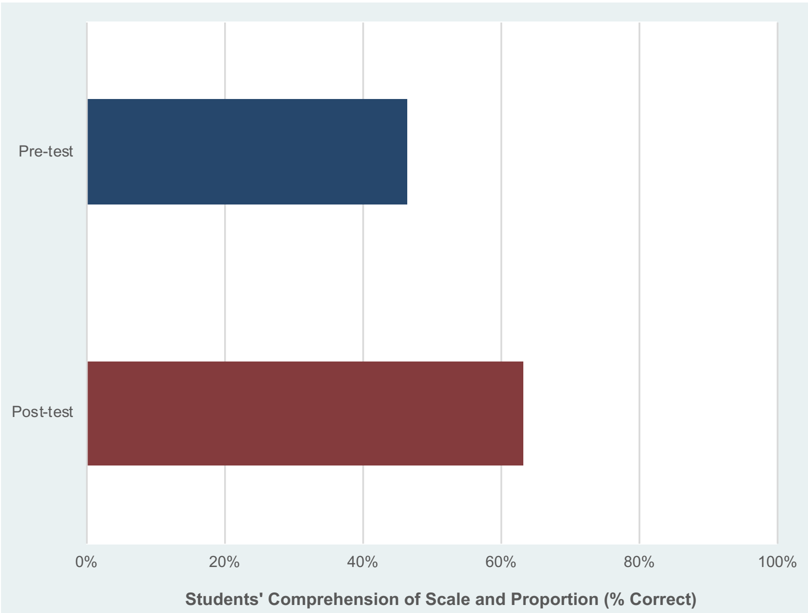
These findings represent a 32 percent improvement in students' understanding of scale, proportion, and measurement from pre- to post-test Salvadori students participating in the *Skateparks* program. Figure 5 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 14. Pre- vs. Post-test Assessments of Students' Comprehension of Scale and Proportion

	Student Understanding of Scale, Proportion, and Measurement
Mean (range 0-100)	
Pre-test Score	48.7
Post-test Score	64.2
Change	+ 15.5[#]

[#] Statistically significant change from baseline to follow-up (p=.0031)

Figure 5. Pre- vs. Post-test Assessments of Students Comprehension of Scale and Proportion

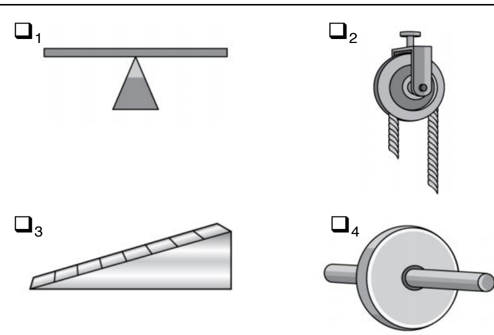


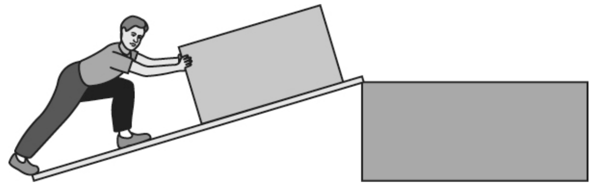
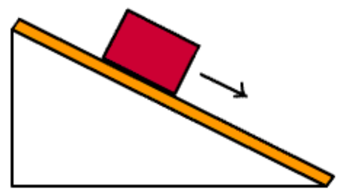
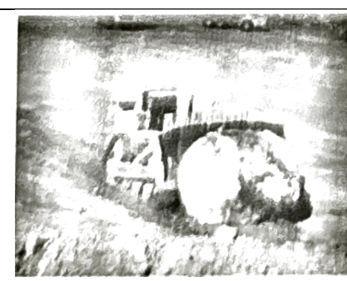
Students' Understanding of the Effects of Common Forces on Objects

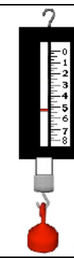
The pre- and post-test student questionnaires included seven items to assess students' understanding of the effects of common forces on moving objects. More specifically, these items required students to recognize an inclined plane, to understand how the length of an inclined plane impacts the force needed to move an object, how friction impacts movement, and how to calculate the amount of work done when moving an object. These concepts are central to the *Skateparks* curriculum.

The specific assessment items included the following:

Table 15. Common Forces Assessment Items

Question #	Assessment Item
23	Which of the pictures below shows an inclined plane? 

24	Look at the picture below of a box being pushed up a ramp. This man will need **less** force to push the box if he … ❑1 uses a shorter ramp ❑2 gets someone to encourage him ❑3 uses a longer ramp ❑4 does not use a ramp at all 
25	A heavy block is released at the top of a rough wooden ramp, and slides down to the bottom (see picture below). The ramp is then covered with a strip of smooth wax paper, and the same block is then released from the top. Which of these **best** explains the motion of the block as it slides down the smooth wax paper?  ❑1 The block will move faster. ❑2 The block will move slower. ❑3 The block will move at the same speed on the smooth surface as it did on the rough surface. ❑4 The block will not slide down since there is no force acting on it.
26	Which units are used to measure **Force**? ❑1 Meters ❑3 Inches ❑2 Newton-meters ❑4 Newtons
27	Which units are used to measure **Work**? ❑1 Meters ❑3 Inches ❑2 Newton-meters ❑4 Newtons
32	If a shopper pushed a cart 5 meters down the aisle with a force of 20 Newtons, how much work did he do? Please show your work.  Answer: ___________ Newton-meters
33	If a bulldozer has done 60 Newton-meters of work to move a rock 6 meters, how much force was used? Answer: ___________ Newton 
34	Which of the following best describes the force being placed on the spring scale below? ❑1 The force is a little less than 5 Newtons ❑3 You cannot measure force with a spring scale

	❑2 The force is a little more than 5 Newtons	❑4 I don't know	

YSI created an overall measure of student comprehension of common forces that summarizes how well students performed on the assessment items listed above. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

As seen in Table 16 below, Salvadori *Skateparks* participants demonstrated a significant increase in their ability to recognize and analyze the effects of common forces on objects. A paired-samples t-test was conducted to compare students' knowledge at the beginning of the *Skateparks* program and after the *Skateparks* module was completed.

There was a significant improvement in measured pre-test vs. post-test knowledge observed for students participating in the *Skateparks* program. At the participating *Skateparks* sites, the mean pre-test score was 35% (M=34.8, SD=22.3). After the program was completed, Salvadori participants scored an average of 50% (M=50.2, SD=21.1) on the post-test assessment. This represents an average improvement of 15% observed over the course of the 12-week intervention ($M_{difference}$=15.4, SE=2.67); $t(262)=5.76$, $p < .0001$.

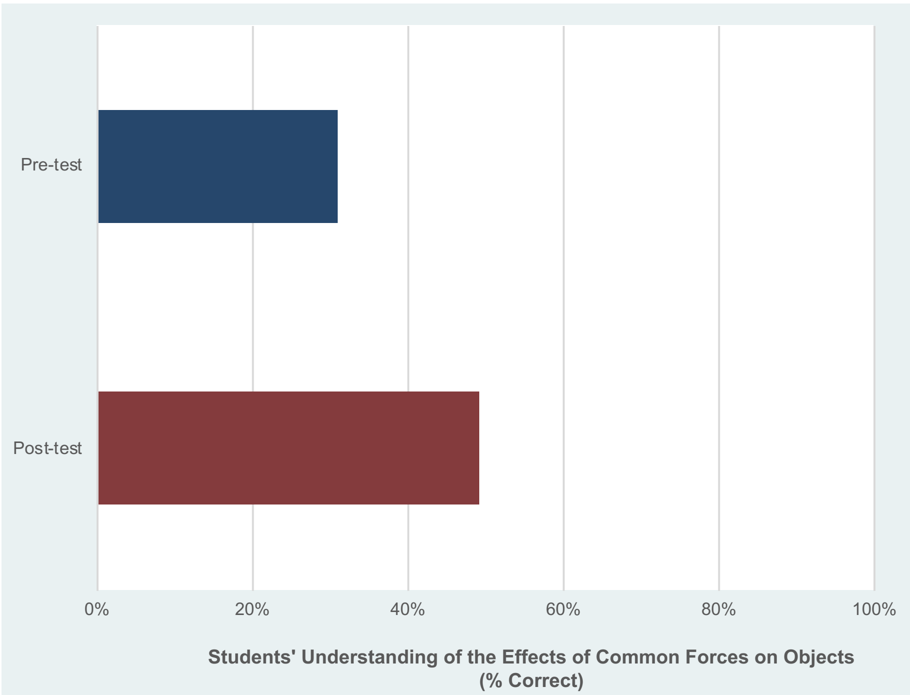
These findings represent a 44 percent improvement in students' understanding of the effects of common forces on objects from pre- to post-test Salvadori students participating in the *Skateparks* after-school program. Figure 6 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 16. Pre- vs. Post-test Assessments of Students Comprehension of Common Forces

	Student Understanding of the Effects of Common Forces
Mean (range 0-100)	
Pre-test Score	34.8
Post-test Score	50.2
Change	+ 15.4[#]

[#] Statistically significant change from baseline to follow-up ($p<.0001$)

Figure 6. Pre- vs. Post-test Assessments of Students Comprehension of Common Forces



<u>Knowledge and Skill Gains Related to Participation in the Landmarks, Monuments, and Memorials Program</u>

YSI assessed knowledge and skill gains among students who participated in Salvadori's *Landmarks, Monuments, and Memorials (LMM)* program, which was implemented in both in-depth school residencies and after-school programs.

Salvadori participants were surveyed at the beginning and conclusion of the program. In addition to basic background questions (e.g. gender, age, and ethnicity), the pre- and post-assessments included standardized measures of: 1) **students' comprehension of scale, proportion, and measurement concepts**; 2) **students' map interpretation skills, and** 3) **students' ability to distinguish landmarks, monuments, and memorials and other urban planning concepts.**

Students' Comprehension of Landmarks, Monuments, and Memorials

The pre- and post-test questionnaires included several items designed to assess students' understanding of core concepts in the *LMM* curriculum, including what distinguishes a landmark, monument, or memorial, and the properties of building materials. The specific items included the following:

Table 17: LMM Comprehension Assessment Items

Question #	Assessment Item	
21	Label each of the pictures below indicating if they are a Landmark, a Monument, or a Memorial.	 Brooklyn Bridge  9/11 Memorial Lights  Statue of Liberty  Ghost Bike
26	Properties of a material are used to describe:	❑ How much land the material can occupy. ❑ The features/characteristics of the material. ❑ The mineral breakdown of the material. ❑ Ownership of the material.

27	Which of the properties below applies to **brick?**	❑ Smooth ❑ Hard ❑ Flexible ❑ Transparent
31	A licensed professional who is trained in developing economical and safe solutions to practical problems by applying mathematical and scientific knowledge is called …	❑ an architect ❑ a project manager ❑ an engineer ❑ an urban planner

YSI created an overall measure of student comprehension that summarizes how well students performed on the above tasks. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

As seen in Table 18 below, Salvadori *LMM* participants demonstrated a significant increase in their comprehension of core concepts from the *LMM* curriculum. A paired-samples t-test was conducted to compare students' knowledge of scale and proportion at the beginning of the *LMM* program and after the *LMM* module was completed.

There was a significant improvement in measured pre-test vs. post-test knowledge observed for students participating in the *LMM* program. At the participating *LMM* sites, the mean pre-test score was 48% (M=48.4, SD=22.9). After the program was completed, Salvadori participants scored an average of 62% (M=61.9, SD=20.7) on the post-test assessment. This represents an average improvement of 12% observed over the course of the 12-week intervention ($M_{difference}$=13.5, SE=5.22); t (58)=2.58, p = .0118.

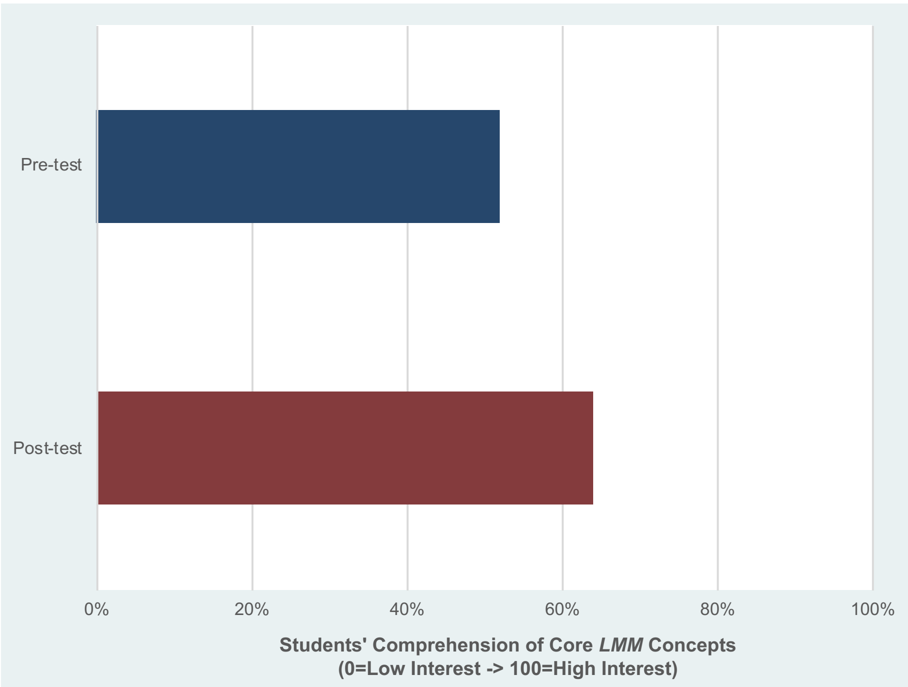
These findings represent a 28 percent improvement in students' understanding of core concepts in the *LMM* curriculum, including what distinguishes landmarks, monuments, and memorials, and the properties of various building materials. Figure 7 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 18. Pre- vs. Post-test Assessments of Students Comprehension of LMM Core Concepts

	Student Understanding of Core *LMM* Concepts
Mean (range 0-100)	
Pre-test Score	48.4
Post-test Score	61.9
Change	+ 13.5[#]

[#] Statistically significant change from baseline to follow-up (p=.0118)

Figure 7. Pre- vs. Post-test Assessments of Students' Comprehension of Scale and Proportion



Knowledge and Skill Gains Related to Participation in the Skyscrapers Program

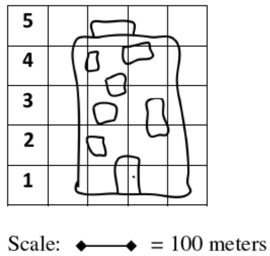
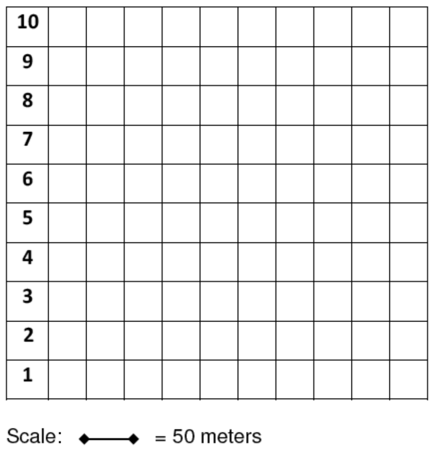
YSI assessed knowledge and skill gains among students who participated in Salvadori's *Skyscrapers* program, which was implemented exclusively in after-school settings.

Salvadori participants were surveyed at the beginning and conclusion of the program. In addition to basic background questions (e.g. gender, age, and ethnicity), the pre- and post-assessments included standardized measures of: 1) **students' comprehension of scale, proportion, and measurement concepts**; 2) **students' map interpretation skills, and** 3) **students' ability to distinguish landmarks, monuments, and memorials and other urban planning concepts.**

Students' Comprehension of Scale and Proportion

The pre- and post-test questionnaires included three performance tasks that were designed to assess students' understanding of scale and proportion concepts central to the *Skyscrapers* curriculum. The specific items included the following:

Table 19. Scale and Proportion Assessment Items

Question #	Assessment Item
21	 Please estimate the height of the building based on the scale drawing above: ________ meters
22	 In the graph below, please sketch the building to a larger scale where every square is equal to 50 meters.
27	27. What is the square footage of the footprint of a skyscraper pictured below?  ❑₁ 4 sq ft ❑₂ 16 sq ft ❑₃ 12 sq ft ❑₄ 10 sq ft

YSI created an overall measure of student comprehension that summarizes how well students performed on these three tasks. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

YSI observed a significant improvement in measured pre-test vs. post-test knowledge observed for students participating in the *Skyscrapers* program. At the participating *Skyscrapers* after-school sites, the mean pre-test score was 31% (M=31.3, SD=21.9). After the program was completed, Salvadori participants scored an average of 59% (M=59.2, SD=21.7) on the post-test assessment. This represents an average improvement of 28% observed over the course of the intervention ($M_{difference}$=27.9, SE=4.88); t (78)=5.72, p = .0001.

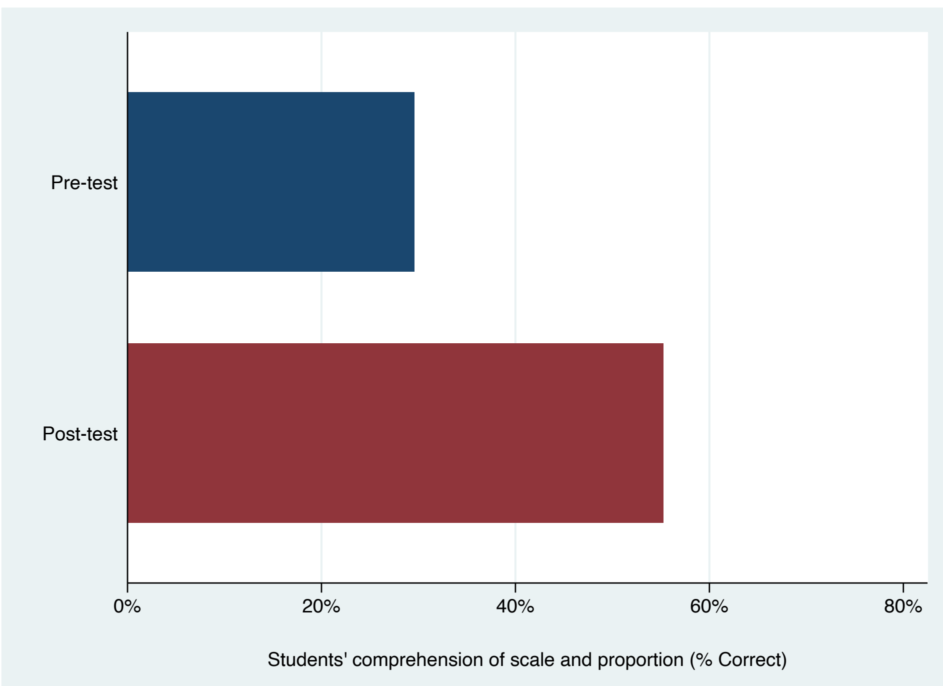
These findings represent an 89 percent improvement in *Skyscrapers* students' basic understanding of scale and proportion. Figure 8 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 20. Pre- vs. Post-test Assessments of Students' Comprehension of Scale and Proportion

	Student Understanding of Scale and Proportion
Mean (range 0-100)	
Pre-test Score	31.3
Post-test Score	59.2
Change	+ 27.9[#]

[#] Statistically significant change from baseline to follow-up ($p<.0001$)

Figure 8. Pre- vs. Post-test Assessments of Students' Comprehension of Scale and Proportion



Students' Knowledge of Basic Engineering and Architecture Concepts and Definitions

The *Skyscrapers* assessment survey included 11 items measuring students' knowledge of basic engineering, design, and architecture definitions and concepts. These items were scored, and a "Knowledge of Engineering and Architecture" scale was created to measure the proportion of those 11 questions that a student answered correctly. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all 11 questions correctly). These items included:

Table 21. Knowledge of Key Engineering, Design, and Architecture Concepts Assessment Items

	Content Knowledge Items
23	When a column starts to fail under compression, the type of failure is called _____. (Correct Response [CR] = buckling)
25	A column's orientation is: (CR = vertical)
26	The weight of people, furniture, and equipment in a building is called ______. (CR = live load)
27	What is the square footage of the footprint of a skyscraper pictured below? (CR = 12 sq ft)
28	Which of the following two terms are opposite forces? (CR = tension and compression)
29	Which of the following shapes would make the strongest column? (CR = circle)
30	Architects use a ______ which is a miniature representation of the structure they are building. (CR = model)
35	A ________ is a linear representation of important events in the order in which they occurred. (CR = timeline)
32	How do you calculate area? (CR = multiply length x width)
33	Elevators use a simple machine called a ______? (CR = pulley)
34	A force placed on a structure from a horizontal direction is called ______. (CR = lateral force)

YSI observed a significant improvement in measured pre-test vs. post-test knowledge observed for students participating in the *Skyscrapers* program. At the participating *Skyscrapers* after-school sites, the mean pre-test score was 23% (M=22.6, SD=21.9). After the program was completed, Salvadori participants scored an average of 48% (M=47.7, SD=21.7) on the post-test assessment. This represents an average improvement of 25% observed over the course of the intervention ($M_{difference}$=25.1, SE=4.88); t (78)=5.14, p = .0001.

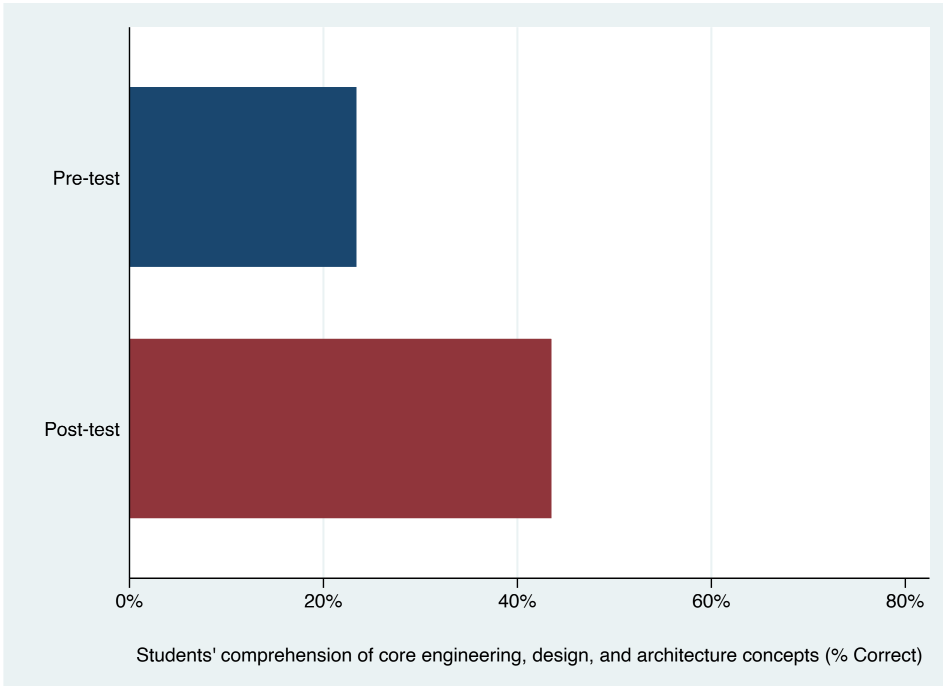
These findings represent a 111 percent improvement in students' understanding of core concepts from the *Skyscrapers* curriculum. Figure 9 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 22. Pre- vs. Post-test Assessments of Students' Knowledge of Engineering, Design, and Architecture Concepts

	Student Comprehension Score
Mean (range 0-100)	
Pre-test Score	22.6
Post-test Score	47.7
Change	+ 25.1[#]

[#] Statistically significant change from baseline to follow-up (p<.0001)

Figure 9. Pre- vs. Post-test Assessments of Students' Knowledge of Engineering, Design, and Architecture Concepts



<u>Knowledge and Skill Gains Related to Participation in the Building Green Program</u>

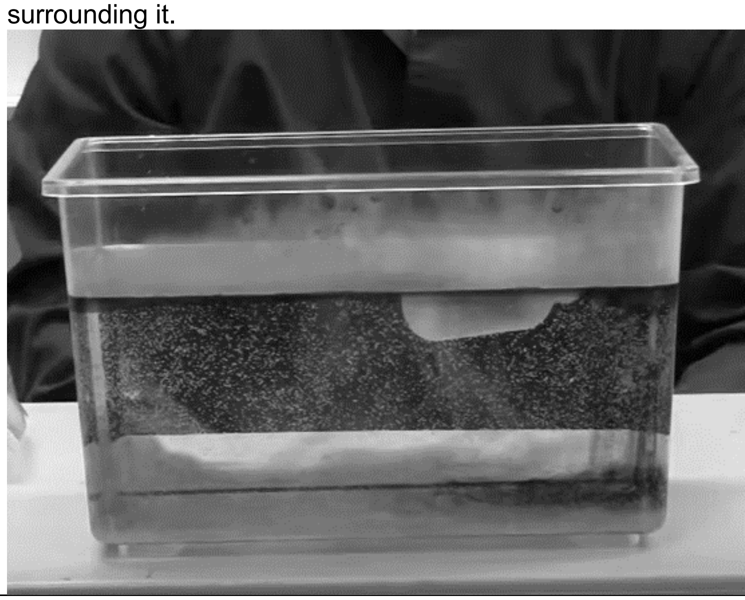
YSI assessed knowledge and skill gains among students who participated in Salvadori's *Building Green* program, which was implemented exclusively during in-depth in-school residencies.

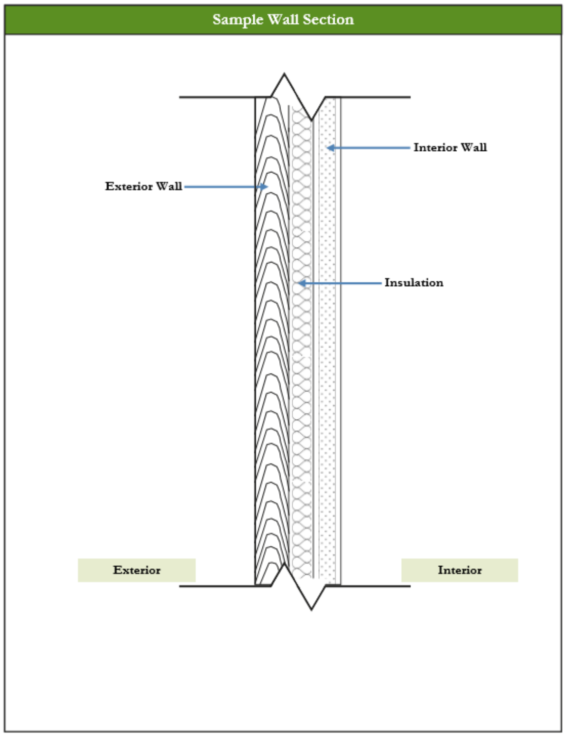
Students' Knowledge of the Fundamentals of Green Design

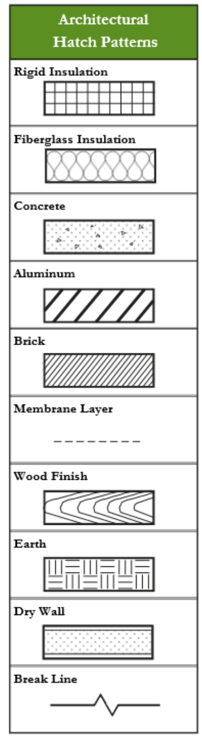
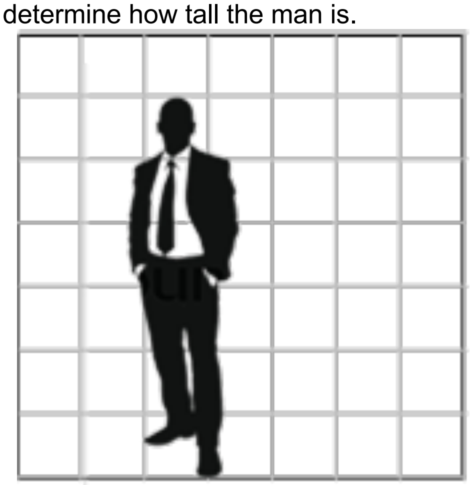
The pre- and post-test assessments administered to Salvadori participants in the *Building Green* program included a series of questions assessing students' knowledge of core concepts relevant to green design and building. These items were used to determine whether the program improved participating students' understanding of energy consumption and sustainable building. The specific items included the following:

Table 23. Green Design Items

Question #	Assessment Item
21	Which of the following energy sources will have the *least* impact on the environment? ❑ coal power ❑ solar power ❑ oil ❑ natural gas ❑ nuclear power
22	Which of the light bulbs types below is the most energy-efficient? ❑ Halogen ❑ Incandescent ❑ LED ❑ Compact Fluorescent
23	Which of the following is *not* a fossil fuel? ❑ coal ❑ wind

	❑ natural gas ❑ oil
24	Solar panels work by… ❑ converting light from the sun into electricity ❑ by allowing photons, or particles of light, to knock electrons free from atom ❑ generating a flow of electricity ❑ all of the above
25-30	Match the following terms to their proper definition: ____ built environment ____ green design ____ energy-efficient ____ solar power ____ watt ____ building orientation a. using less energy to provide the same service. b. heat radiation from the sun converted into electrical power. c. an approach to building that reduces harmful effects on the environment and on human health, and conserves energy. d. the structures made by people, that are designed and built around us. e. the way a building is situated on a site and the positioning of windows, rooflines, and other features. f. a unit for measuring the force of electric power.
31	Below we describe the three different methods of how heat is transferred. Match each description with the correct method. a) Conduction, b) Convection, and c) Radiation ___The transfer of heat through a fluid ___The transfer of heat from one substance to another due to direct contact ___Energy that is transmitted in the form of rays or waves or particles
32	One kilowatt is equal to how many watts? ____________
34	The photograph below shows an experiment where hot water and cold water are poured into a container of room temperature water. The ________ water is floating at the top because it has less density than the water surrounding it. 
35	The image below shows an example of a section of a wall. What material is the exterior wall made out of? _________________________

<table>
<tr><td></td><td>


</td></tr>
<tr><td>36</td><td>Each square in the grid below measures ¼ inch. Use the scale ¼ inch equals 1 foot to determine how tall the man is.

_______ feet tall</td></tr>
</table>

Responses to these questions were used to develop a measure of students' comprehension of basic green design concepts. Possible values for this measure ranged from 0 (indicating 0 correct responses) to 100 (indicating that the students answered all questions correctly).

As seen in Table 24 below, *Building Green* participants demonstrated a significant increase in their recognition and understanding of various green design concepts dealing with energy consumption and transfer, sustainable approaches to powering a building, and how to interpret a scale drawing. A paired-samples t-test was conducted to compare students' knowledge of green design concepts at the beginning of the *Building Green* program and after the module was completed.

YSI observed a significant improvement in measured pre-test vs. post-test knowledge observed for students participating in the *Building Green* program. At the participating *Building Green* in-school residency sites, the mean pre-test score was 62% (M=61.8, SD=18.1). After the program was completed, Salvadori participants scored an average of 77% (M=77.3, SD=14.1) on the post-test assessment. This represents an average improvement of 16% observed over the course of the intervention ($M_{difference}$=15.5, SE=1.71); t (358)=9.06, p = .0001.

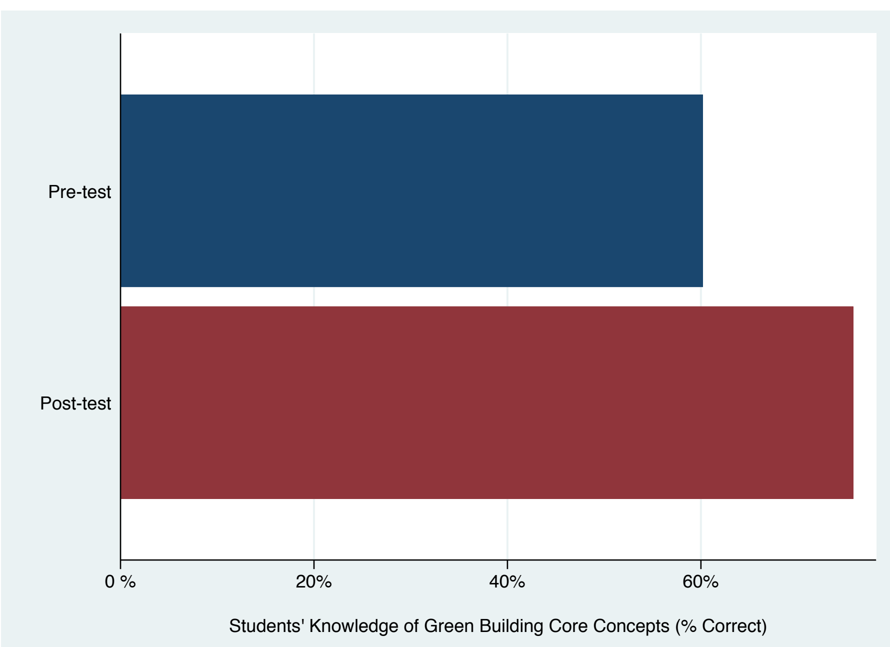
These findings represent a 25 percent improvement in students' understanding of core concepts from the *Building Green* curriculum. Figure 10 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 24. Pre- vs. Post-test Assessments of Students' Knowledge of Engineering, Design, and Architecture Concepts

	Student Comprehension Score
Mean (range 0-100)	
Pre-test Score	61.8
Post-test Score	77.3
Change	+ 15.5#

Statistically significant change from baseline to follow-up (p<.0001)

Figure 10. *Pre- vs. Post-test Assessments of Students' Comprehension of Green Design Concepts*



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