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

An Evaluation of the Salvadori Center's Skyscraper STEAM Enrichment Program in NYC

Evaluation Report

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Executive Summary

This report includes findings from Youth Studies Inc.'s (YSI) evaluation of the Salvadori Center's multi-day in-school residencies and after-school enrichment programs implemented at various sites throughout New York City during the 2021-2022 school year. YSI's evaluation examined students' experiences in the *Skyscrapers* program implemented at six different sites throughout New York City. The goals of this curricula included using hands-on activities and design challenges to foster student learning and exploration of topics relating to skyscrapers – forces, simple machines, scale, proportion, and design.

During the 2021-22 school year, Youth Studies, Inc. administered pre- and post-assessments to students participating in the following programs: MS 331 Bronx School of Young Leaders, Farragut Cornerstone, PS 277X, Sunnyside Community Services Woodside Houses, PS 188 The Island School, and PS 256 Benjamin Banneker Magnet School.

A total of 369 assessments were completed by 237 students. The following are key highlights from YSI's evaluation of the *Skyscrapers* initiative as implemented across six NYC sites:

- A total of 237 students participated in YSI's assessment of the *Skyscrapers* program. 51% were female, and 85% of surveyed students self-identified as "Black" or "Hispanic/Latino."
- Salvadori participants demonstrated a statistically significant increase in their comprehension of *scale* and *proportion* concepts relevant to the *Skyscrapers* curriculum (See Page 8). Assessment results found that Salvadori participants improved their knowledge by 84%.
- Salvadori participants 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 10). YSI observed a 21% improvement in participants' STEM-related self-efficacy.
- Salvadori participants demonstrated a significant increase in their motivation to pursue educational and career choices in math and science as measured by the assessment items from the Programme for International Student Assessment (PISA) (See Page 11). YSI observed a 20% improvement in students' future-oriented motivation to pursue STEM from pre- to post-test.
- Salvadori participants demonstrated a significant increase in their knowledge of core engineering, design, and architecture concepts relevant to the *Skyscrapers* curriculum (See Page 12). Students experienced an 86% improvement in their understanding of these core 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 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 for 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). This approach to instruction challenges 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).

The rest of this report summarizes current findings from an evaluation of student outcomes from 6 sites that implemented the Salvadori Center's *Skyscrapers* program during the 2021-22 program year. This evaluation is being 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.

The *Skyscrapers* program uses hands-on activities and design challenges to foster student learning and exploration of topics relating to skyscrapers – forces, simple machines, scale, proportion, and design. The curriculum consists of 12 Sessions: 7 hands-on sessions focused on important background knowledge and 5 sessions dedicated to the final design project. The *Skyscrapers* curriculum is aligned to the Common Core Math Standards and the New York State Standards for Math, Science, and Technology. The curriculum emphasizes important science and math skills including measurement, data collection, making predictions, drawing conclusions, use of scale and proportion, application of the design process, and presentation of findings. Activities are designed to reinforce the scientific inquiry process of investigating, hypothesizing, testing, and drawing conclusions. Below we provide an overview of the structure and schedule of the *Skyscrapers* program:

Session 1: Introduction to Skyscrapers

Students understand the historical context of skyscrapers and identify the characteristics that make skyscrapers unique.

Session 2: Structural Elements of a Skyscraper- Columns

Students will understand how buildings are supported by a structural grid and how a column's shape and height affect its load bearing capacity.

Session 3: Structural Elements of a Skyscraper- Beams

Students will understand how the shape of a beam affects its load bearing capacity.

Session 4: Structural Grids and Facades

Students will understand how columns and beams come together to make a structural grid and learn about building facades.

Session 5: Scale and Square Footage

Students will understand how to calculate the usable square footage of a structure using a scale model.

Session 6: Understanding Proportion

Students will explore scale and proportion when designing models.

Session 7: Materials Exploration

Students will explore the different properties of various building materials and their impact on architectural design choices.

Session 8: Tall Buildings and Introduction to the Design Challenge

Students will learn about two technological advances that made skyscrapers possible and create a fixed and moveable pulley system. They will be introduced to the final Design Challenge.

Session 9: Design Challenge- Planning

Students understand how to construct a skyscraper's structural frame according to specific constraints.

Sessions 10: Design Challenge- Construction

Students will understand how to construct a skyscraper's structural grid according to specified constraints.

Session 11: Designing a Facade and PIP

Students will design a façade and Project Information Panel to reflect the function of their model skyscraper.

Session 12: Final Presentations

Students will conduct a collaborative oral presentation of their design concepts and scale model section of a

10-story skyscraper.

Description of Evaluation Process

Participant Assessments

YSI developed pre- and post-participation student assessments that were administered by Salvadori instructors 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 relevant to the *Skyscrapers* curriculum.

A total of 237 students participated in YSI's assessment of the *Skyscrapers* program. Of those 237 students, 132 (or approximately 56%) completed *both* a pre- and post-test assessment. The remaining 105 students either only participated in the pre-test (60) or only submitted a post-test assessment (45). Table 1 includes some background characteristics for the 237 students who participated in the evaluation. 51% percent were female, and 85% of surveyed students self-identified as "Black" or "Hispanic/Latino."

Table 1. Background Characteristics of Salvadori Participants

Background Characteristic	Percent
School/Program	
MS 331 Bronx School of Young Leaders	38
Farragut Cornerstone	4
PS 277X	22
Sunnyside Community Services Woodside Houses	8
PS 188 The Island School	8
PS 256 Benjamin Banneker Magnet School	20
Gender	
Female	51
Male	49
Ethnicity *(categories are not mutually exclusive)	
Black or African-American	60
Hispanic/Latino (of any race)	25
White	11
American Indian or Alaska native	10
Other	8
Asian	5

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 ability to do math and science. These attitudes were assessed prior to and after students participated in the *Skyscrapers* 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.

Table 2. 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

Moreover, 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 3.

Table 3. 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.

To assess changes in participants' knowledge of specific concepts related to the *Skyscrapers* curriculum, participant surveys included a set of 14 "content" items that were drawn directly from the curriculum.

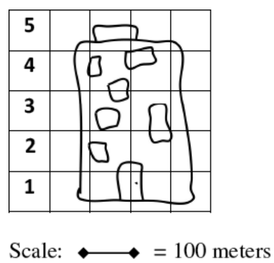
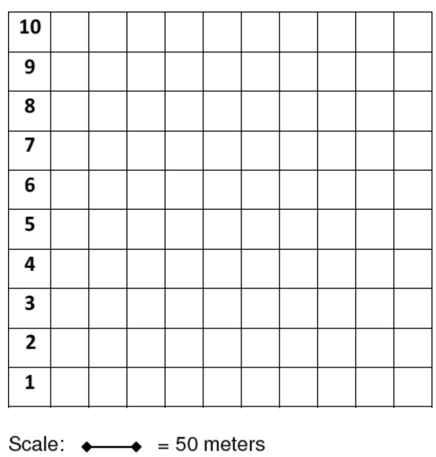
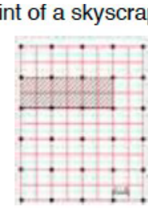
Participant Outcome Findings

Skyscrapers participants were surveyed at the beginning and conclusion of the 12-week program cycle during the 2021-22 school year. 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 and proportion**; 2) **students' confidence in their ability to succeed in math and science**; 3) **students' future-oriented motivation to pursue math and science careers**; and 4) **students' knowledge of architectural and engineering concepts relevant to skyscrapers**.

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 4. 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).

As seen in Table 5 below, Salvadori participants demonstrated a significant increase in their comprehension of scale and proportion concepts. A paired-samples t-test was conducted to compare students' knowledge of scale and proportion at the beginning of the program and after the *Skyscrapers* module was completed. There was a significant improvement in pre-test vs. post-test conditions ($M_{difference}$=27.3, SD=44.1); $p < .000$.

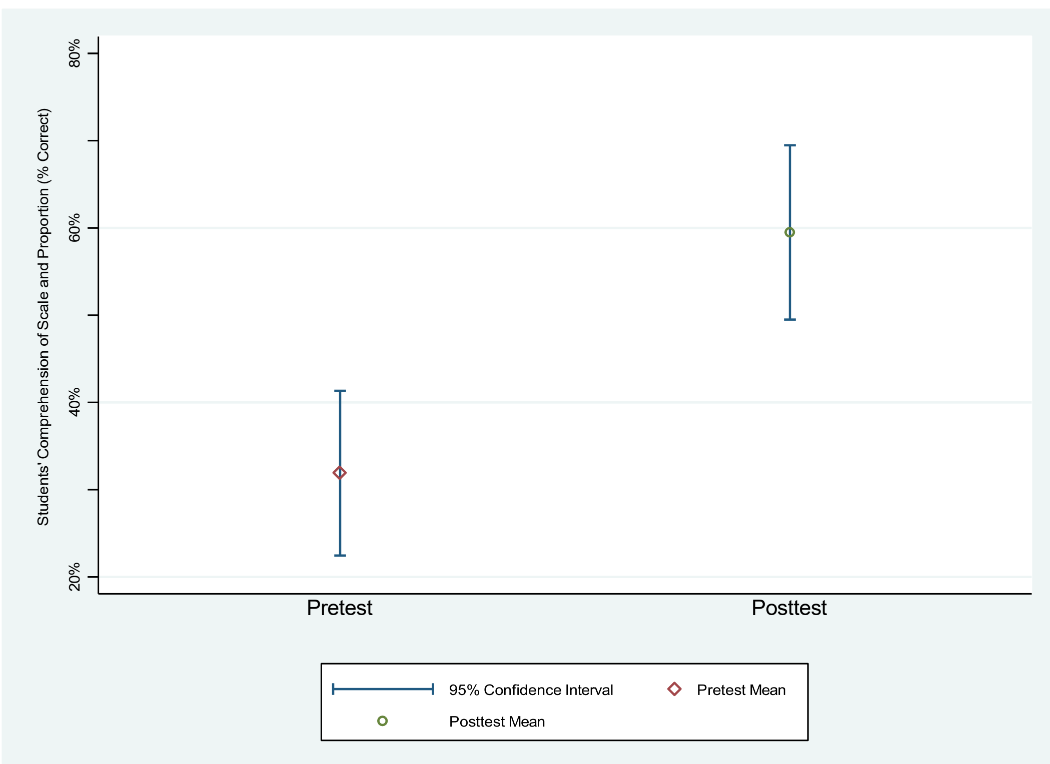
These findings represent an 84 percent improvement in students' basic understanding of scale and proportion. Figure 1 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 5. 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	32.4
Post-test Score	59.7
Change	+ 27.3[#]

[#] Statistically significant change from baseline to follow-up (p<.00)

Figure 1. Pre- vs. Post-test Assessments of Students' Comprehension of Scale and Proportion



Note: The circle and diamond markers indicate the pretest and posttest score mean performance on this measure and the brackets above and below these mean scores display 95 percent confidence intervals for these mean scores.

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 year 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 *Skyscrapers*. The assessment items included:

Table 6. 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

As seen in Table 7 below, Salvadori participants demonstrated a 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 *Skyscrapers* program. There was a significant improvement in pre-test vs. post-test conditions ($M_{difference}$=.56, SD=.59); p = .00).

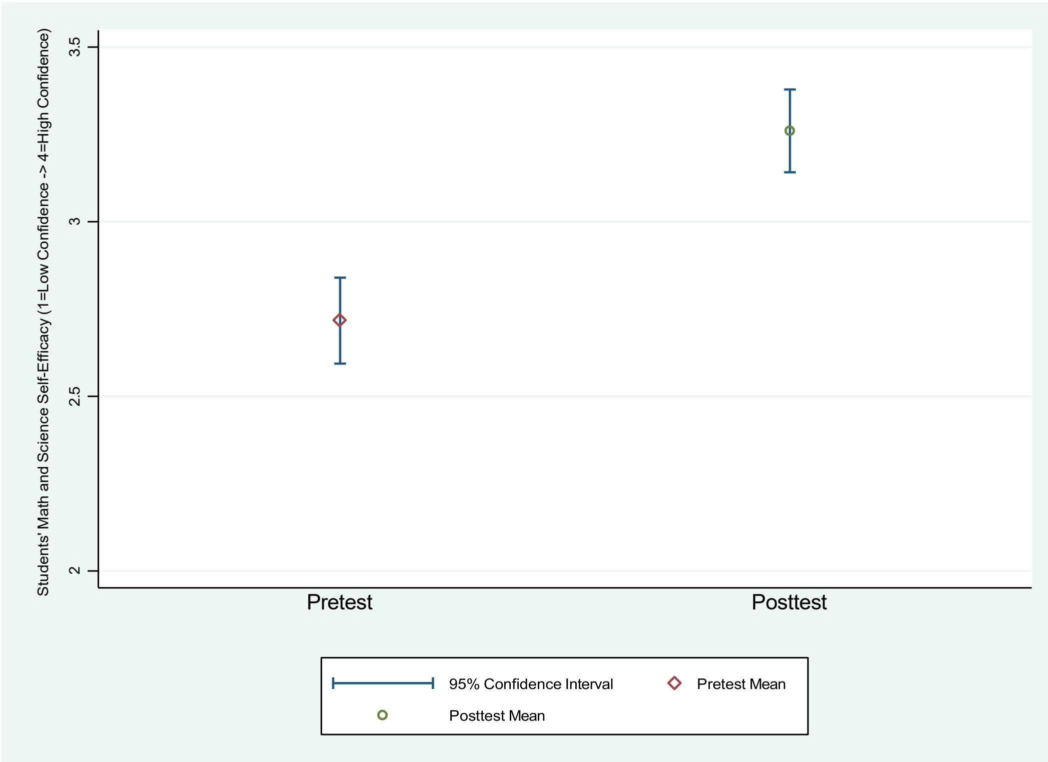
These findings represent a 21 percent improvement in students' STEM-related self-confidence from pre- to post-test for Salvadori Center students participating in the *Skyscrapers* after-school program. Figure 2 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 7. Pre- vs. Post-test Assessments of Students' Confidence in their Ability to Succeed in Math and Science

	Math and Science Motivation
Mean (range 1-4)	
Pre-test Score	2.69
Post-test Score	3.25
Change	+ 0.56#

Statistically significant change from baseline to follow-up (p<.00)

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 Math and Science Careers

The Skyscrapers participant survey included three items to measure students' motivation to pursue future education and careers in math and science. These items included:

Table 8. 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.

As seen in Table 9 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 the *Skyscrapers* program. There was a significant improvement in pre-test vs. post-test conditions ($M_{difference}$=.46, SD=.96); p = .00).

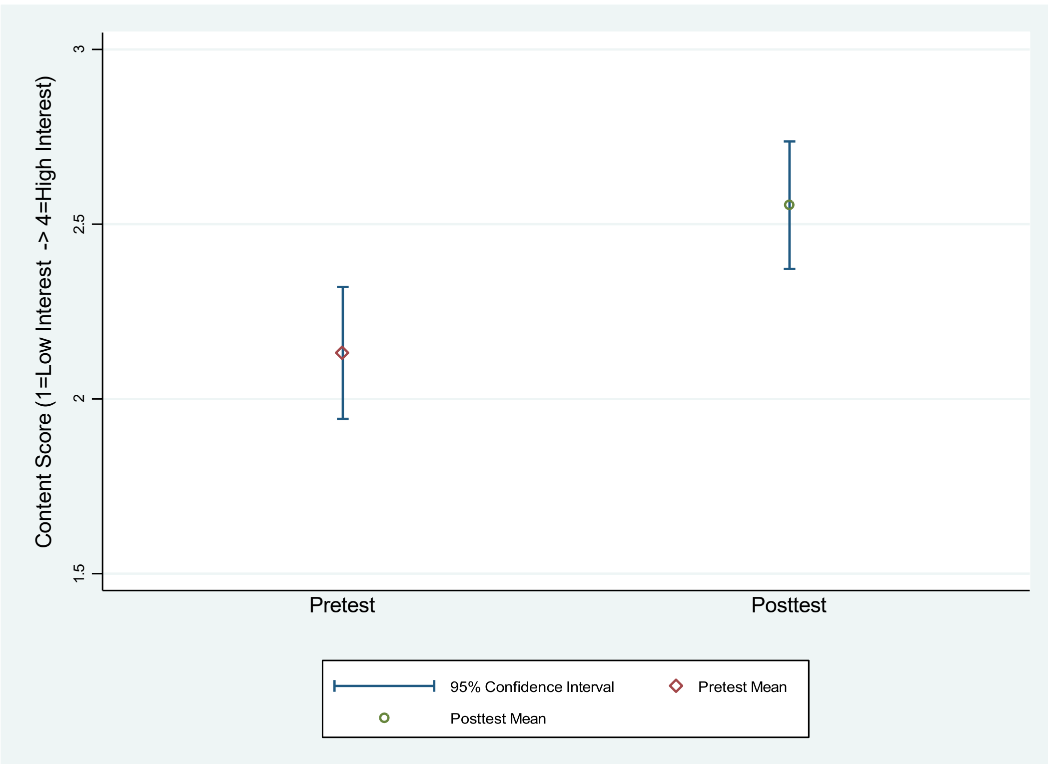
These findings represent a 20 percent improvement in students' future-oriented motivation to pursue STEM from pre- to post-test for Salvadori Center students participating in the *Skyscrapers* after-school program. Figure 3 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 9. Pre- vs. Post-test Assessments of Students' Future-Oriented Science Motivation

	Math and Science Motivation
Mean (range 1-4)	
Pre-test Score	2.10
Post-test Score	2.56
Change	+ 0.42[#]

[#] Statistically significant change from baseline to follow-up (p<.00)

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



<u>Students' Knowledge of Basic Engineering and Architecture Concepts and Definitions</u>

The Salvadori participant 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 10. 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)

As seen in Table 11 below, Salvadori participants demonstrated a significant increase in their knowledge of core engineering, design, and architecture concepts relevant to the *Skyscrapers* curriculum. A paired-samples t-test was conducted to compare students' comprehension at the beginning and completion of the *Skyscrapers* program. There was a significant improvement in pre-test vs. post-test conditions ($M_{difference}$=20.4, SD=24.7); $p < .000$.

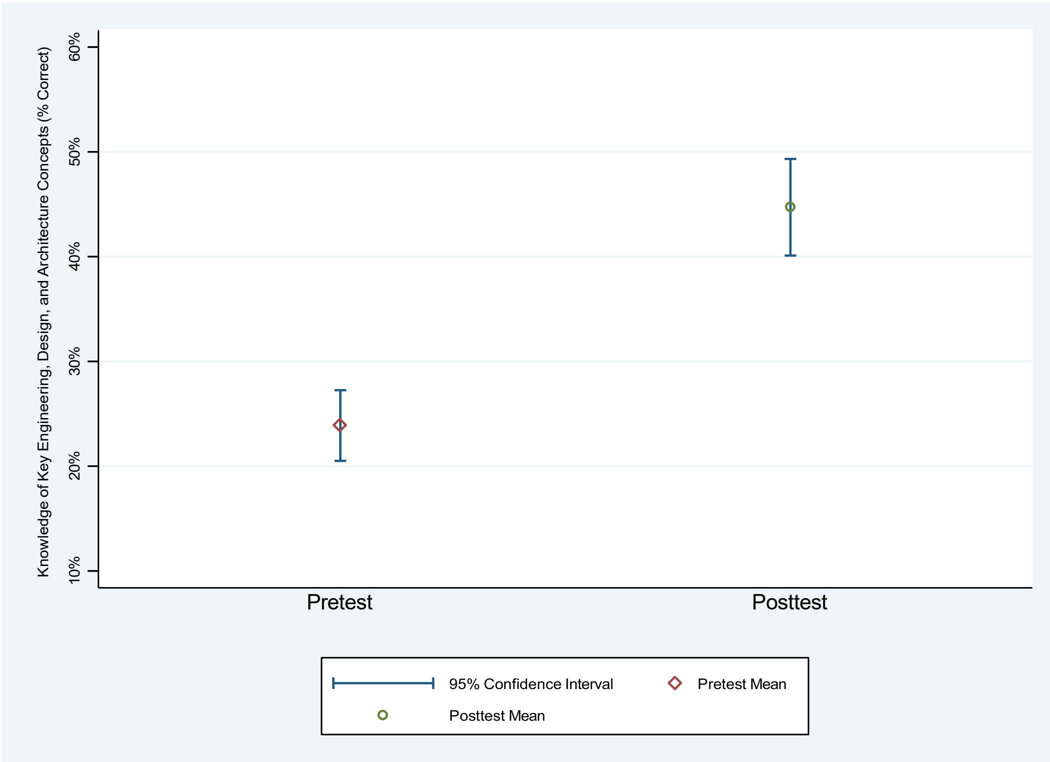
These findings represent an 86 percent improvement in students' understanding of core concepts from the *Skyscrapers* curriculum. Figure 4 below presents a visual representation of the pre-test vs. post-test comparison for all participating sites.

Table 11. Pre- vs. Post-test Assessments of Students' Knowledge of Engineering, Design, and Architecture Concepts

	Student Comprehension Score
Mean (range 0-100)	
Pre-test Score	23.6
Post-test Score	44.0
Change	+ 20.4#

Statistically significant change from baseline to follow-up (p<.00)

Figure 4. Pre- vs. Post-test Assessments of Students' Knowledge of Engineering, Design, and Architecture Concepts



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Appendix A: Skyscrapers Participant Assess

❑ Pre-Survey ❑ Post-Survey

***Skyscraper* Curriculum**

FIRST NAME (Print in boxes) **LAST NAME**

DATE:

Dear Salvadori Center Participant:

We are asking students to fill out this survey to help us improve our programs. **This is not a test**, but rather a questionnaire that gives us an idea of how knowledge grows over the course of our programs. We appreciate and thank you for your participation!

1. Have you participated in a Salvadori Center program before? (*Check one*)

   ❑1 Yes ❑0 No (If your answer is **NO**, you can skip to question #3)

2. If you answered **YES** to Question #1, which Salvadori Center programs did you participate in? (*Please check all that apply*)

   ❑1 *Skyscrapers* ❑2 *Skateparks* ❑3 *Building Green* ❑4 *Bridges*

   ❑5 *My Community* ❑6 *Animal Habitats* ❑7 *Landmarks, Monuments & Memorials* ❑8 *Ancient Greece*

3. Do you identify as a ❑0 Male (a boy) ❑1 Female (a girl)

4. What grade are you in? *[Check only one box.]*

   ❑0 Kindergarten ❑3 3rd grade ❑6 6th grade
   ❑1 1st grade ❑4 4th grade ❑7 7th grade
   ❑2 2nd grade ❑5 5th grade ❑8 8th grade

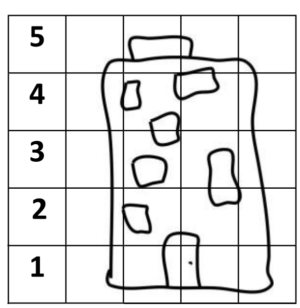
5. What ethnicity do you identify as? *[Please check all that apply.]*

   ❑1 White ❑3 Native American ❑5 Hispanic/Latino
   ❑2 Black ❑4 Asian or Pacific Islander ❑6 Other: _______________

Please <u>circle</u> the number that shows how you feel about each of the following statements:

	Strongly Agree	Agree	Disagree	Strongly Disagree
6. I am sure I can learn math.	1	2	3	4
7. I know I can do well in science.	1	2	3	4
8. I think I could do advanced math and science.	1	2	3	4
9. Math is hard for me.	1	2	3	4
10. I know I can do well in math.	1	2	3	4
11. I would like to work in a career involving science.	1	2	3	4
12. I would like to study science when I go to college.	1	2	3	4
13. Science is hard for me.	1	2	3	4
14. I would like to work on science projects as an adult.	1	2	3	4
15. I am sure I can learn science.	1	2	3	4
16. I'm very good at working with other students.	1	2	3	4
17. I'm good at taking turns and sharing things with others.	1	2	3	4
18. I know how to give helpful advice to other students.	1	2	3	4
19. I know how to cooperate with other students to achieve a goal.	1	2	3	4
20. I know how to plan out the steps for a complex project.	1	2	3	4

Use the following picture to answer questions 21 and 22.



Scale: ◆———◆ = 100 meters

21. Please estimate the height of the building based on the scale drawing above.

Write your estimate here: __________meters

22. In the graph below, please sketch the building to a larger scale where every square is equal to 50 meters (Scale: ◆———◆ = 50 meters).

10										
9										
8										
7										
6										
5										
4										
3										
2										
1										

Note: Your building doesn't need to look exactly like the drawing. But do your best to make the size correct.

Scale: ◆——◆ = 50 meters

23. When a column starts to fail under compression, the type of failure is called_________.

- ❑ 1 extension
- ❑ 2 buckling
- ❑ 3 load
- ❑ 4 structure

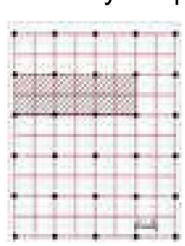
25. A column's orientation is

- ❑ 1 horizontal
- ❑ 2 diagonal
- ❑ 3 vertical
- ❑ 4 sideways

26. The weight of people, furniture and equipment in a building is called________.

- ❑ 1 a web
- ❑ 2 dead load
- ❑ 3 cross-section
- ❑ 4 live load

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

28. Which of the following two terms are opposite forces?

- ❑ 1 tension and compression
- ❑ 2 tension and structural grid
- ❑ 3 lateral and compression
- ❑ 4 curtain wall and structural grid

29. Which of the following shapes would make the strongest column?

- ❑ 1 circle
- ❑ 2 square
- ❑ 3 triangle
- ❑ 4 pentagon

30. Architects use a _________which is a miniature representation of the structure they are building.

- ❑ 1 façade
- ❑ 2 scale
- ❑ 3 model
- ❑ 4 structural grid

35. A ________is a linear representation of important events in the order in which they occurred.

- ❑ 1 bar graph
- ❑ 2 scatterplot
- ❑ 3 timeline
- ❑ 4 line graph

32. How do you calculate area?

- ❑ 1 multiply length X width
- ❑ 2 multiply length X width X height
- ❑ 3 add length + width.
- ❑ 4 subtract length –width

33. Elevators use a simple machine called a _____.

- ❑ 1 spring scale
- ❑ 2 Newtons
- ❑ 3 technology
- ❑ 4 pulley

34. A force placed on a structure from a horizontal direction is called______.

- ❑ 1 lateral force
- ❑ 2 counterweight
- ❑ 3 tension
- ❑ 4 compression