Embedding Math and Science Concepts into a Civil Engineering Outreach Program For Middle School Students

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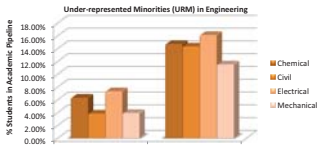
Motivation:

•Minorities are underrepresented across all engineering disciplines[1,2]



•Lack of minorities due to incomplete knowledge about the profession and lack of pre-requisites to be accepted into engineering programs[3,4]

Goals of Program:

•Increase student's understanding of engineering profession and its relation to math and science

•Increase student's desire to continue with math and sciences throughout high school

•Provide introduction to foundational high school mathematical concepts (i.e., trigonometry) through engineering concepts

Program Implementation:

•Launched during the spring session of a five week program

•Participant demographics:

- 2011 – 9 males, 2 females
- 2012 – 2 males, 9 females
- Race – primarily under-represented minorities
- Academics:
  - Variety of private & public schools from large metropolitan area
  - 8th and 9th grade students
  - Minimum grade point average of 2.0

2011 participants

2012 participants

[1]M.T. Gibbons. Engineering by the Numbers.: http://www.asee.org/papers-and-publications. 2010.
[2]D.J. Nelson. "A National Analysis of MINORITIES in Science and Engineering Faculties at Research Universities". 2007.
[3]L.M. Frehill *et al.*"Confronting the New American Dilemma", NACME, 2008.
[4]R.J. Burke, "Women and minorities in STEM: A Primer", 2007.

Curriculum Development

Week 1: *Introduction to Engineering; Introduction to Environmental Engineering*

•Learn Eng. Design Process (EDP)

•Perform oil spill clean-up activity

Week 2 *: Surveying Buildings*

•Learn/review necessary trigonometric principles - SohCahToa

•Make a basic surveying tool

•Measure the height of a building

Week 3*: Introduction to Bridges*

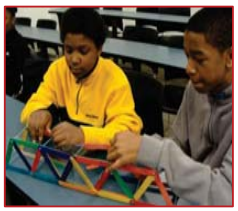
•Learn about types of bridges

•Discuss tension and compression

•Build and test a popsicle stick bridge

Week 4: *Redesign Bridge*

•Based on previous weeks test results, employ EDP and redesign (and improve) bridge design



Program Assessment:

- Interest Survey :
  - 8 five-point Likert scale questions
  - Designed to assess understanding of engineering and its connection to mathematics and science
- Mathematics Survey:
  - 4 math problems with five-point Likert scale confidence questions
  - Designed to assess understanding of concepts discussed in class
- Assessment of Survey:
  - Reliability – Cronbach's α= 0.8094 (acceptable)
  - Validity – confirmed through insight from experienced instructors
  - Analyzed results with Wilcoxon Signed Rank Test

Interest Survey Results:

Statement	Pre-Test Avg.	Post-Test Avg.	z-value
Q1. I know what engineering is.	4.32	4.68	2.345**
Q2. I know what civil and environmental engineering is.	3.27	4.55	4.025†
Q3. I will choose to study engineering when I go to college.	3.32	3.23	-0.299 (p = 0.7648)
Q4. I will choose to study civil and environmental engineering when I go to college.	2.68	2.73	0.076
Q5. I am very confident in my math skills.	4.27	4.27	0.610
Q6. I am confident that I can apply basic math skills to solve engineering problems.	4.64	4.45	-1.362 (p = 0.1731)
Q7. I am very confident in my science skills.	4.05	4.09	0.378
Q8. I am confident that I can apply basic science skills to solve engineering problems.	4.09	4.0	-0.447 (p = 0.6547)

*p<0.1, **p<0.05, ***p<0.01, †p<0.001 (5 = Agree, 1 = Disagree)

Math Survey Results:

Statement	Pre-Test Avg.	Post-Test Avg.	z-value
Q1. Pythagorean theorem	0.636	1.200	2.357**
Q1. Confidence	2.000	2.200	1.543
Q2. Cosine	0.000	0.800	2.974***
Q2. Confidence	1.440	2.330	1.982**
Q3. Surveying (tangent)	0.455	0.500	0.783
Q3. Confidence	2.270	2.700	2.639***
Q4. Truss height (Pythagorean theorem)	0.273	0.667	2.236**
Q4. Confidence	1.300	2.250	2.330**
Total score on math survey	1.050	2.710	2.957***
Average confidence across all questions	1.790	2.530	2.344**

*p<0.1, **p<0.05, ***p<0.01, †p<0.001

All math questions were based on a two point scale, all confidence questions on a five point scale

Conclusions:

- Students gained better understanding of engineering and civil and environmental engineering
- Students demonstrated increased comprehension in trigonometric principles
- Students had a *self-proclaimed* decrease in confidence when applying math and science to engineering applications but demonstrated increased capabilities