REPORT OF FINDINGS CONCERNING DELIVERY OF 'STEM' (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) EDUCATION IN AFTER-SCHOOL AND SUMMER CAMP SETTINGS

INTRODUCTION

The STEM program was delivered in after-school programs in both East and West Aurora in the 2015-2016 school year. In East Aurora, the program was delivered in nine elementary schools: Allen, Beaupre, Brady, Gates, Hermes, Johnson, Krug, Oak Park, and O'Donnell Elementary Schools as well as in Cowherd Middle School. In West Aurora, the program was delivered in seven elementary schools: Freeman, Greenman, Hall, Hill, McCleery, Nicholson, and Smith Elementary schools. The program was also delivered in Jefferson Middle School. Each program lasted for six to twelve weeks.

The programs implemented in 2015-2016 included one on Polymers, one on Microbiology, one on Waves, and one on Programming and Cryptology. Each individual program ran for six weeks: some schools received one program, and some schools received two programs.

Each program was delivered one day per week for a period of approximately 50 minutes. The day selected was based on schedule availability. The model used in the 2015-2016 year was different than that which had been used in the previous year. In the past, a faculty member from Aurora University functioned as the lead teacher in the program, and the faculty member may or may not have been supported by an undergraduate student from Aurora University working in the after-school program. In the 2015-2016 school year, the lead teacher role was filled by science teachers from the local school district. The Aurora University faculty member filled the role, instead, of trainer and facilitator. Undergraduate students from Aurora University continued to serve in this program. The reasons for this adaptation are several: first, Aurora University faculty members are experienced in instruction of college students rather than elementary and middle school students. Second, there was a desire to increase the capacity of the teachers working in the local school district to provide hands-on instruction in STEM topics. This aspect of the new program model is viewed as developmental and is taken on with the understanding that these teachers may be able to migrate some of the new approaches back into their regular classrooms.

The STEM camp delivered during the summer is also considered in this review. The summer camp took place between June 13 and July 21. The camp operated four days per week for six hours per day on the Aurora University campus. Aurora University faculty organized formal STEM activities to be delivered three days per week for two hours and fifteen minutes per day for three weeks. The students served in the camp were in grades K through 5. The topics covered during the summer camp were Geology and Water. Students were also able to participate in a range of additional activities, including a trip to the zoo, a trip to the airport, and a play. Community partners including Triple Threat and the Fox Valley Park District were also able to provide programming. Enrichment activities include art, drama, crafts, indoor and outdoor recreation, and games. Because the summer Olympics was coming up, many of the activities had an Olympics theme. The activities took place in the John C. Dunham STEM Partnership School at Aurora University. In the final three weeks of camp, mathematics and

science enrichment activities were also provided, but these were not organized by Aurora University faculty members.

The evaluation of these programs is somewhat more brief than similar evaluations have been in previous years. Attitude tests were not used in the 2015-2016 school year. This decision was driven by two considerations. First, most of the students participating in the STEM programs in after school and all of the students participating in STEM programs in summer camp were in elementary school. The reading and writing abilities of these children, particularly the younger ones, are not well-developed yet. Furthermore, in each iteration of two, separate attitude tests in the past, no changes in attitude were found. This is primarily due to the fact that attitude scores were somewhat elevated from the beginning.

Knowledge tests were used in the 2015-2016 academic year. In addition, observations of the after-school programs were conducted. This report will present findings pertaining to knowledge tests and observations for the after-school program first and then findings pertaining to knowledge tests for the summer camp.

After-school Program

Polymers

In the Polymers unit, students examined a range of properties of natural and artificial polymers. This included making slime and silly putty, which was enjoyed by the students. The natural polymers investigated included silk and wool. Artificial polymers were isolated from disposable diapers, and their properties were tested. Students also examined recycling of polymers and disolvable polymers. Finally, students investigated edible polymers when they made gummy bears.

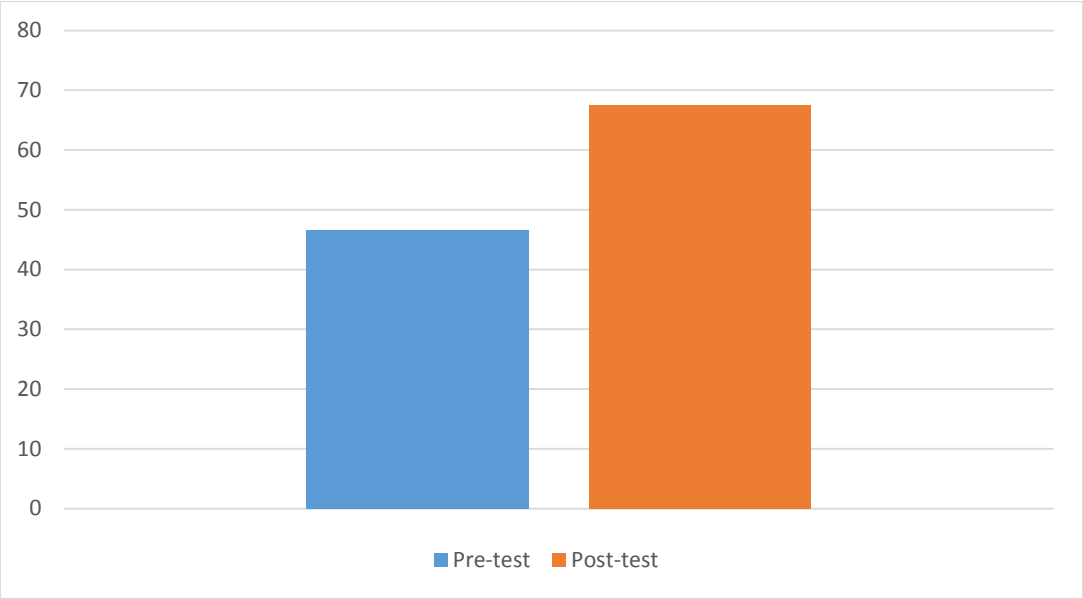

Figure 1. Pre-test and Post-test scores for Polymers.

All of the figures in this report are presented as percentages because the pre-tests and post-tests for different units contained different numbers of questions. The data presented in Figure 1 indicate growth in knowledge from the beginning of the unit to the end. This change was found to be statistically significant (t (92) = -8.719, $p < .001$). This also represents the strongest rate of growth of any of the four, after-school units.

An examination was done to determine if differences were observable between rates of improvement across schools. Differences between schools were found to be significant (F (5, 87) = 6.146, $p < .001$). The lowest rate of improvement was approximately 7.5 percentage points; the highest rate of improvement was approximately 41 percentage points.

Microbiology

In the Microbiology unit, understanding of "germs" and human health was a focus. Students began by developing a basic understanding of microbes. This included an opportunity to grow yeast and mold on bread. Students used different types of bread to observe and graph growth of molds over time. Students were also able to make streak plates (a technique for isolating a pure culture from a mixture by streaking the mixture across an agar plate). Students were able to use digital microscopes brought in for this purpose to examine both what they had grown and a range of slides in order to view the microbes. Students were able to use Glo Germ powder under u.v. light to examine the impact of length of time of hand washing on biological residue on hands. They were also able to gather data to examine how systematically varying the independent variable (length of time of hand washing) impacted the dependent variable (biological residue).

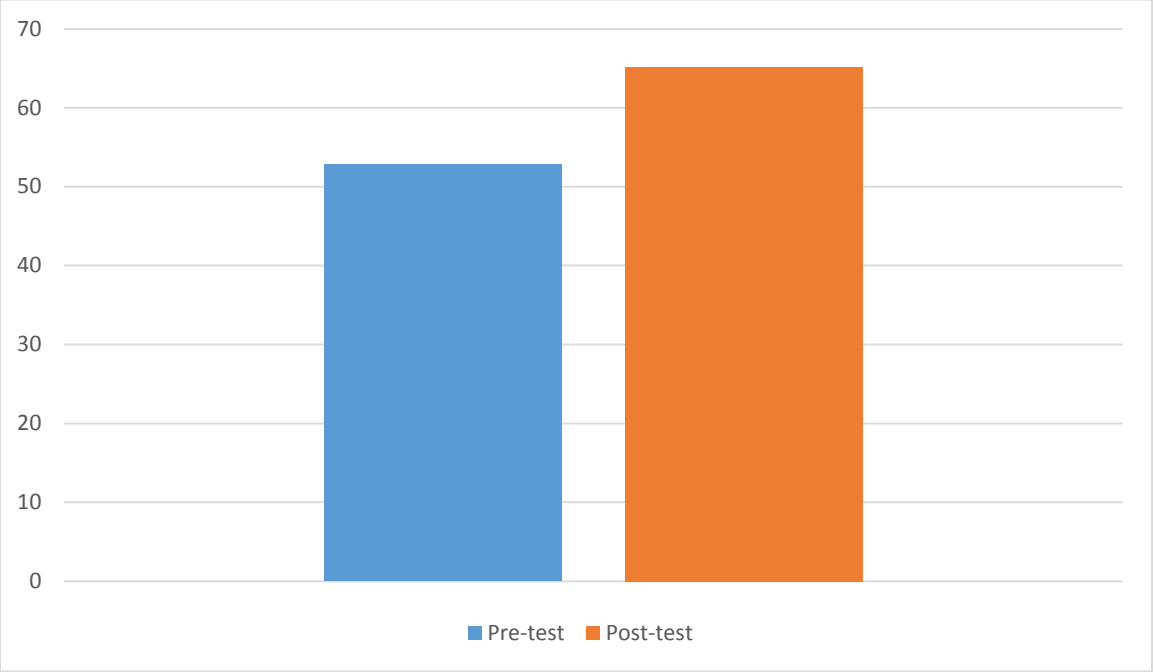

Figure 2. Pre-test and Post-test scores for Microbiology.

The examination of the scores for the pre-tests and post-tests for the Microbiology unit revealed statistically significant growth (t (74) = -3.919), $p < .001$).

Investigation revealed that the amount of growth demonstrated did vary by school (F (3, 53) = 3.965, p = .013. The range of growth varied from approximately 3.33 percentage points to 28 percentage points.

Waves

Students studied types of waves and transmission of waves in a variety of media. Students utilized slinkys and ropes to demonstrate movement of sound waves. They also used an old-fashioned "telephone" made of cans and string. Students would stand in different rooms from one another and communicate using the "telephone." They studied systematically how varying characteristics of the apparatus (for instance, the thickness of the string, and the tautness of the string) would impact the clarity of the communication. They examined how waves travel in water and solid materials. They were able to utilize a wave generator to examine convergence and divergence.

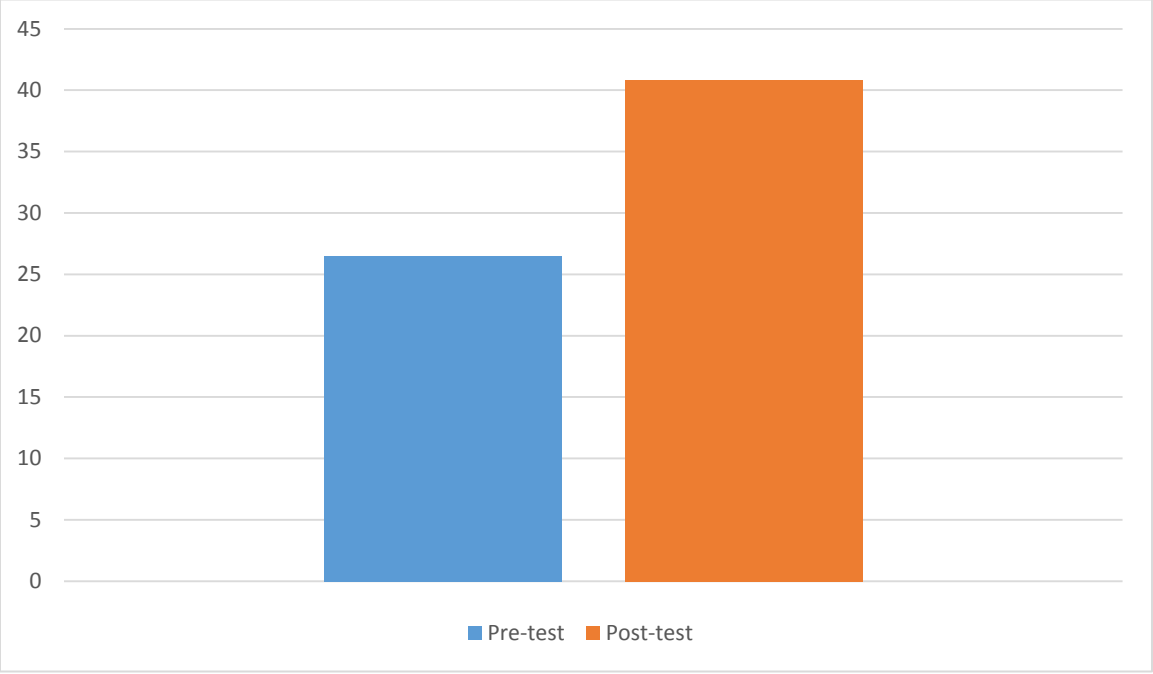

Figure 3. Pre-test and Post-test scores for Waves.

The growth in knowledge related to waves from pre-test to post-test was found to be statistically significant (t (84) = -5.912, $p < .001$). The degree of change demonstrated from school to school was not found to differ significantly.

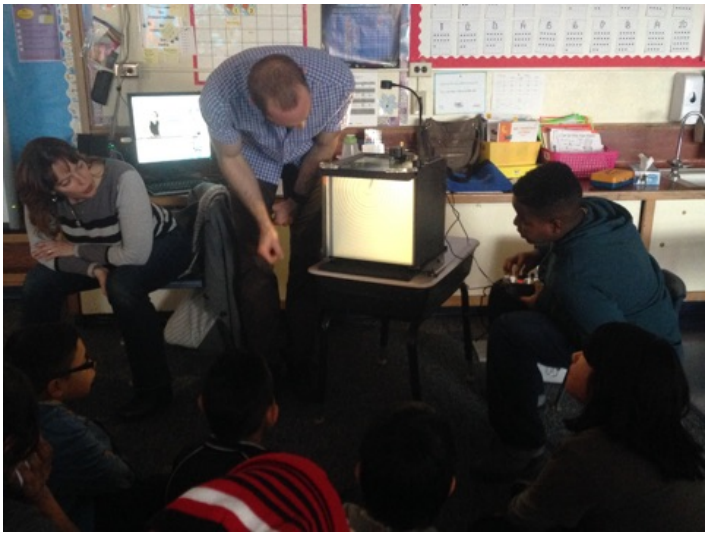

Image 1. Students working with a waveform generator.

Programming and Cryptography

Students participating in the Programming and Cryptography unit learned fundamentals of programming logic. One activity involved having to write explicit, step-by-step instructions for stacking plastic cups in order to introduce the concept of order of programming statements. They visited the 'lightbot' website (https://lightbot.com) to learn programming logic. They examined concepts related to "coding" and cryptography including concepts of decryption and ciphering. They discussed Navajo Code Talkers. They were able to use netbooks with Scratch downloaded to program a Finch robot.

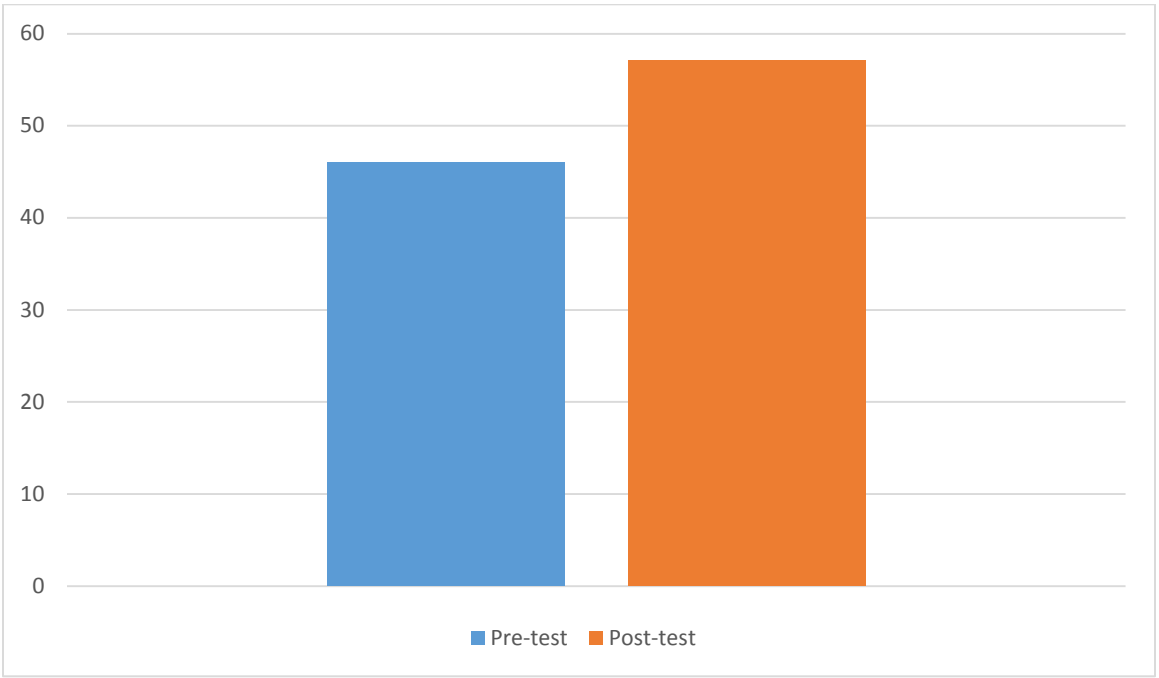

Figure 4. Pre-test and Post-test for Programming and Cryptography.

The findings reflected in Figure 4 represent statistically significant difference in performance on the pre-test and post-test for Programming and Cryptography (t (75) = -4.297, p < .001). Differences between schools were not statistically significant.

Observation

The STEM in after-school program was observed two times. The first time was Gates Elementary. The class was working on the Waves unit. The observer engaged with the students to talk with them about what they were doing. They indicated they were "learning about different types of waves." They indicated that they were excited to be learning about science. One characteristic of the program they enjoyed was being taught by teachers they "don't know." Thus, children were referring to the value of teachers from other schools in the district helping them to develop with regard to STEM topics. Students had a variety of favorite activities. One student found the slinky demonstration to be the favorite, and another student indicated "phones and understanding how vibration works and the wave activity today." When asked what they would change, they said they would not change anything.

A second observation took place at Greenman Elementary. The observer indicated that the teachers conveyed excitement about the activity and were sparking curiosity within the students. The teachers communicated effectively and respectfully with the students. The activity was a little bit challenging to deliver because it involved laptops that needed an application update. Part of the session was taken up with trying to get the laptops operational. When some of the laptops were up and running, students took turns giving commands to make a character on the screen work through an obstacle course. This demonstrated how programming has to be precise, and only one command must be given at a time to achieve the desired outcome. Students experienced a little bit of frustration with needing to share but were all able to participate.

Summer Camp

Water

In the Water unit, students studied the water cycle, weather and wind, oceans, layers of the ocean, and density. The students learned about properties of water, geography of oceans, and properties of oceans such as salinity, temperature, density, pressure, and light. Scientific vocabulary was also emphasized in the lessons. Students conducted experiments on water cycle transpiration, runoff and erosion, build anemometers from paper cups to measure wind speed. Teachers conducted demonstrations to show concepts of pressure and density in oceans. Students also used spectroscopes to view natural light, blue light, and led light and understand the electromagnetic spectrum. In many of these hands-on activities, students made observations, illustrated explanations, collected data, and summarized the results.

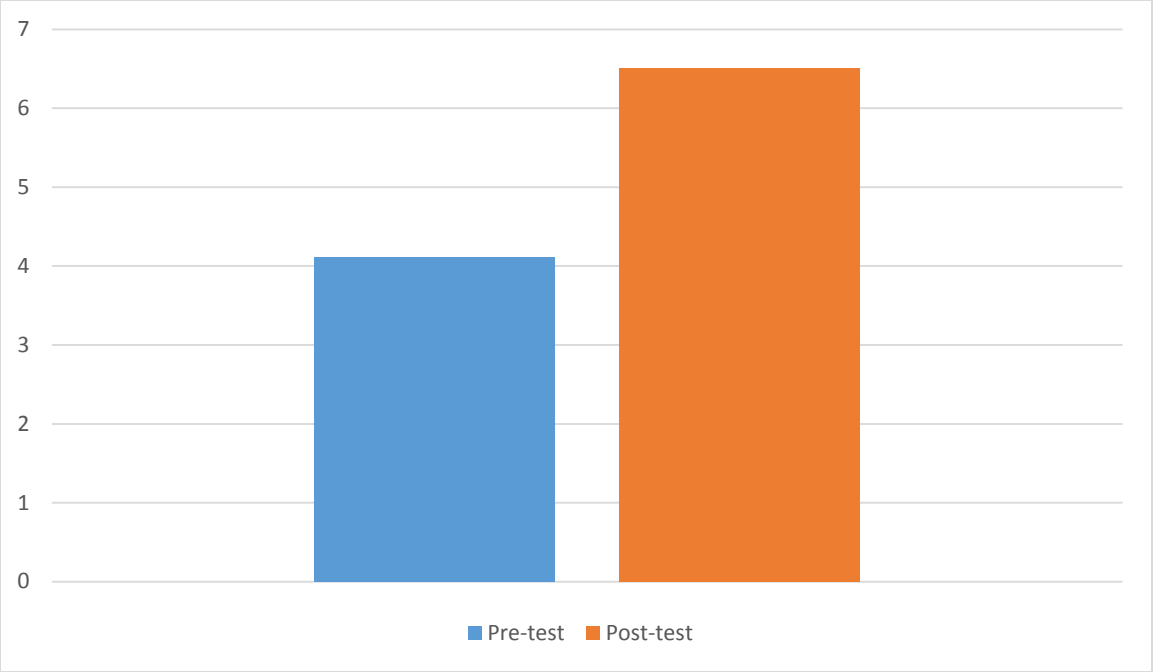

Figure 5. Pre-test and Post-test for Water.

Figure 5 represents the pre-test and post-test scores for the Water unit. Because the knowledge tests for the Water and Geology units both contained 10 questions, the data are not re-scaled as percentages. The differences depicted in Figure 5 are statistically significant (t (102) = -7.825, p < .001).

Geology

In the Geology unit, students studied rock hardness, the rock cycle, plate tectonics, earthquakes, and volcanoes. Students melted chocolate, white chocolate, and butterscotch chips in order to investigate rock hardness. They made structures out of marshmallows and toothpicks while investigating structural stability in cases of earthquakes. They were also able to simulate earthquakes using a shake table. Students were able to actually make volcanoes out of paper and plaster and then to cause eruptions (baking soda and vinegar).

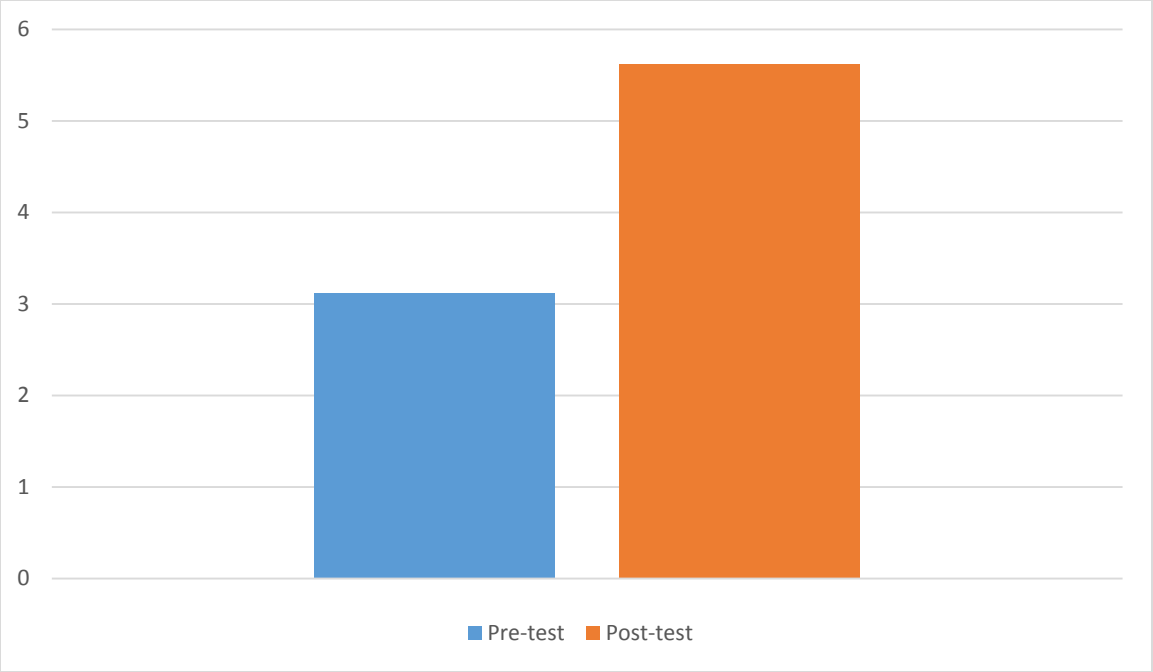

Figure 6. Pre-test and Post-test for Geology.

The differences represented in Figure 6 are statistically significant (t (79) = -6.625, p < .001).

Image 2. Students creating volcanoes.

Interview

An interview was conducted with Dr. Chetna Patel, Coordinator for both the STEM program in the after-school setting and the STEM summer camp. Dr. Patel indicated that the strengths of these activities are several. With regard to the after-school setting, the new structure of having science teachers for elementary school-aged students implement the STEM units appears to have been extremely successful. The Aurora University faculty members are able to provide curricular units and materials as well as professional development, facilitation and program oversight. The teachers from the local school district are able to target and deliver the educational opportunities in a way that is age-appropriate and engaging for young children. The Aurora University undergraduate students are able to gain valuable, hands-on experience working with children in an educational setting and thus to strengthen their skills, professional networks, and resumes. In addition, children were very curious about the roles of the faculty members. They learned the meaning of "professor" and "doctor" and what the difference between a PhD and an MD is. They developed relationships with the AU undergraduate students and seemed to look up to them. The fact that the AU undergraduate students were closer to the after-school program and summer STEM program participants in age created a mentor-like feel to the interactions.

The children appeared were very easy to engage using the hands-on strategies employed. The methods and materials utilized created a very high-quality program that many children would not have access to until later in high school or college. The resources (digital microscope, agar plates, waveform generator, Finch robots, shake tables, and so forth) and hands-on nature of the program provided access to concepts and content that advanced children's understanding of science, technology, engineering and mathematics in measurable ways.

Conclusion

Each of the curricular units developed and taught was associated with statistically significant growth in learning. Because the activities provided were so novel and engaging for children, increased positive affect regarding science, technology, engineering, and mathematics is also a likely outcome. Children were also able to become familiar with structures of higher education and a higher education setting as well as to develop relationships with college-age students. The children also were able to benefit from a range of additional enrichment opportunities in the summer camp. Additional, positive effects are likely to have been realized as well. These include professional development on the part of science teachers in the local school district. The effectiveness of this aspect of the program is evidenced by continued engagement of the science teachers with Aurora University faculty. They have returned to borrow equipment in order to re-create some of the activities developed for the after-school program in their own classrooms. Aurora University undergraduate students also benefited because they were able to gain practical, hands-on experience working with children in a variety of educational settings. The program appears to have generated a number of benefits, both planned and unplanned for the Aurora University community, the local school district, and the children who participated. Longer-term follow up to investigate the impacts of the program over time would be recommended.

Image Gallery

Image 3. Home-made gummy bear.

Image 4: Water soluble bag.

Image 5. Streak plate. Credit: scienceprofonline.

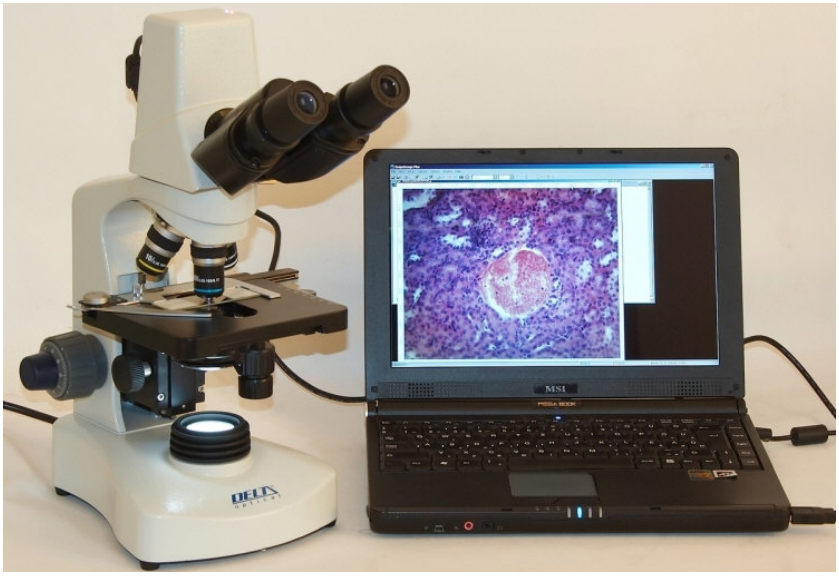

Image 6. Digital microscope. Credit: 365astronomy.com

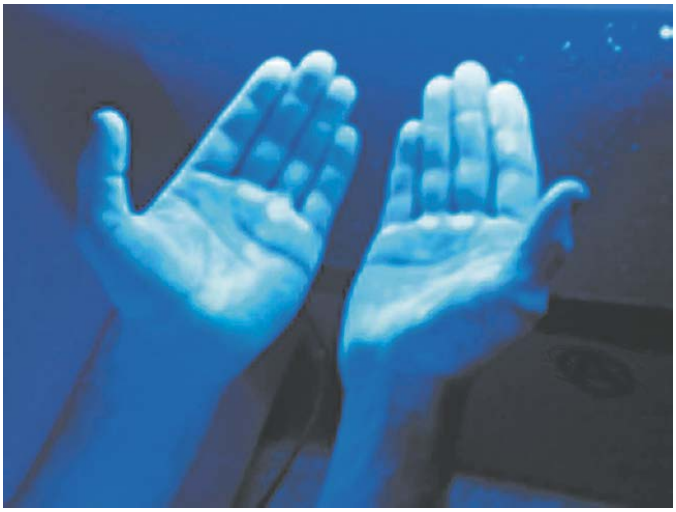

Image 7. Glo Germ powder. Credit: Frey Scientific.

Image 8. Tin can telephone.

Image 9. Finch Robot. Credit: finchrobot.com.