Development of a Model Middle School Engineering Club

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Abstract

This paper provides a description of a service learning program developed in 2009 that focuses on creating engineering clubs for elementary school students. Villanova Community Action by New Engineers, NovaCANE, was established with the initial membership limited to graduate students and upperclassmen interested in structural engineering. In the inaugural year the goal of the organization was to inspire young minds by offering hands-on educational opportunities in the fields of engineering and science. To this end a group of 14 active members and the faculty advisor initiated and ran an engineering club for sixth grade students at an inner city, Catholic, elementary school. The club met on a monthly basis at their school. The engineering topics covered included stability, brittle and ductile behavior, connections, earthquakes and energy, bridges, foundations, and structural materials. Activities included a newspaper cross, gum-drop dome, popsicle stick bridge, ginger bread house subjected to an earthquake simulation, egg-drop competition, timber bridge construction, concrete batching, and testing of concrete and steel specimens. The year ended with a field trip to Villanova University's campus and Structural Engineering Teaching and Research Laboratory.

Learning outcomes were developed for the club and learning outcomes were developed for each activity. Each meeting started with a 10-15 minute presentation on a structural engineering topic, and was followed with a 50-60 minute hands-on activity. In the second year of this program, NovaCANE membership will be expanded to other engineering disciplines and underclassmen, and one new middle school will be added. The 6th grade engineering club will continue with a focus on structural engineering, while an additional 7th grade club will be formed that explores elements of water resources, environmental engineering, sustainability, and chemical engineering. The methodology of program development, specific activities, and service learning aspects are discussed herein.

Background

The mission of Villanova University includes developing an environment in which students may experience a Christian intellectual and moral perspective. A medium-sized comprehensive university, founded by the Augustinian Order of the Roman Catholic Church, Villanova University emphasizes undergraduate instruction and is committed to a strong liberal arts component in each of its degree programs, including engineering. The University is devoted to the development of well-rounded students and has a strong service culture. Every year, hundreds of students, faculty, and staff participate in extracurricular service activities. These include week-long mission trips over spring, summer, fall and winter breaks, coupled with a number of service learning opportunities embedded within its curricula.

Villanova Community Action by New Engineers, NovaCANE, was initiated in the fall of 2009 by the authors and several other dedicated civil engineering students interested in structural engineering. The focus of the group was to find a way to serve the local community by applying their engineering skills and knowledge. The organization decided to focus on one task that could have an impact on disadvantaged youth, who may not have the benefit of engineering role models in their lives. Villanova University already has a successful summer program for high school students, so the decision was made to serve middle school students. A Monsignor at an underprivileged parish in Philadelphia, St. Martin of Tours, had requested some assistance in a career day event at the parish school. The school in turn became the recipient of the first engineering club. The principal of the school was excited about our interest, as was one of the sixth grade teachers. An engineering club announcement was sent out to the sixth grade. In one night, the club was filled to capacity with twenty-five sixth grade students.

This paper discusses the format and learning outcomes of the club, the curriculum, observations and outcomes, lessons learned, and expansion plans, assessment needs, and conclusions.

Format and learning outcomes

The organization planned to host monthly meetings after school at St. Martin of Tours run by the faculty advisor and students, with a minimum of four participants from NovaCANE in attendance. The time allotted for the lessons was a maximum of one hour and fifteen minutes per meeting. Each meeting included an introductory lecture in Powerpoint format on the topic of the month, followed by a hand-on activity. The lectures were typically 10 – 15 minutes long while the activities were 50 – 60 minutes long.

At the initial meeting NovaCANE established the following learning outcomes for the club:

1. Learn what engineers do
2. Learn some important aspects of structural engineering
3. Use what you learn to make structures
4. Relate engineering to what you are learning in school
5. Learn to work in teams
6. Make some new friends while having fun

Curriculum

At the first meeting of NovaCANE the group brainstormed ideas for topics to include in the curriculum. After a list of about ten projects were established, each student picked one or two projects to lead. Each project had two student leaders who were responsible for preparing the lecture and procuring the supplies for the activity. This section provides a brief description of the lecture topics and group activity. The learning outcomes of the club were highlighted at the beginning of each meeting; then lessons learned from the previous meeting were reviewed. Afterwards, the specific learning outcomes for the lesson of the day were introduced.

Meeting 1 – Introduction to Engineering and Service

At the first meeting an introduction to Villanova, civil engineering, and structural engineering was presented. The story was told about the Catholic boys' orphanage in Honduras that Villanova civil engineers had served for the past eleven years and the impact of the first project, a thirty foot tall reinforced concrete cross. The students were divided into five groups, with each group given a large stack of newspapers and three rolls of masking tape. They were required to construct a five foot tall cross that could stand freely within twenty-five minutes. The crosses needed to resist a wind loading provided by an oscillating fan. Students working on the cross and the final designs are shown in Fig. 1. Each design was reviewed, similarities and differences were highlighted, and the designs were critiqued by the club membership. Teamwork skills were discussed.

a. A group planning their design.

b. Final designs

Figure 1. Freestanding newspaper cross project.

Meeting 2 – Material Properties and Stability

At the second club meeting, different types of material were discussed and samples passed around to all groups. The concepts of ductile and brittle behavior were introduced. Each student was given a bag with a gummie worm, Tootsie Roll, pretzel rod and Airhead to perform pull tests on. A group discussion of performance and snacking followed. The stability of structures with an emphasis of domes was reviewed. The domes were load tested to failure and the failure modes were discussed. Figure 2 provides photos of a working group and the final designs.

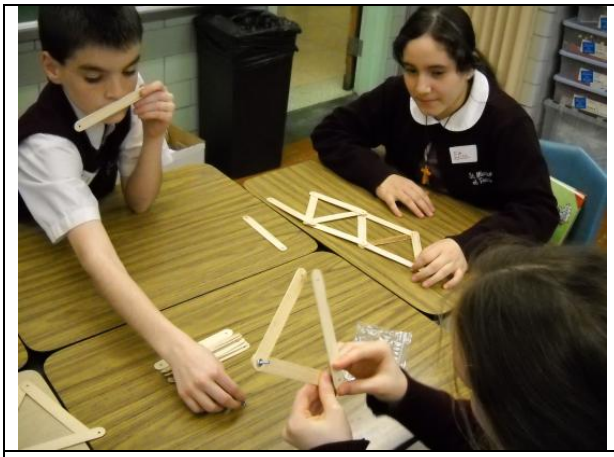
a. Students constructing their gumdrop domes.

b. Final designs

Figure 2. Gumdrop dome project.

Meeting 3 – Introduction to Bridges

In meeting three the NovaCANE students introduced club members to different types of bridges, and showed them photos of the bridges in Philadelphia. Specific elements of truss bridges were discussed and the concepts of compression and tension were introduced. The 6th graders were divided into teams and had to construct a two dimensional truss using pre-drilled tongue depressors, small bolts, washers and nuts. They were allowed to reinforce one member. They were asked to predict the location of the weakest element, and place their initials at their predicted failure point. All bridges were loaded to failure. Figure 3 shows a group assembling their truss and a truss being tested.



a. Students constructing their trusses.

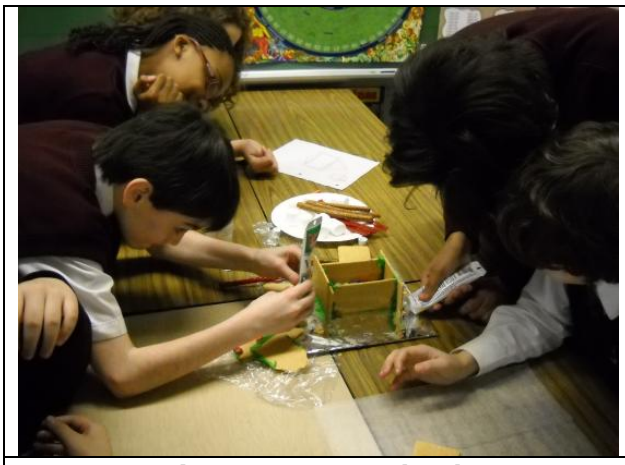
b. Load test to failure.

Figure 3. Construction and load testing of a two dimensional popsicle stick truss bridge.

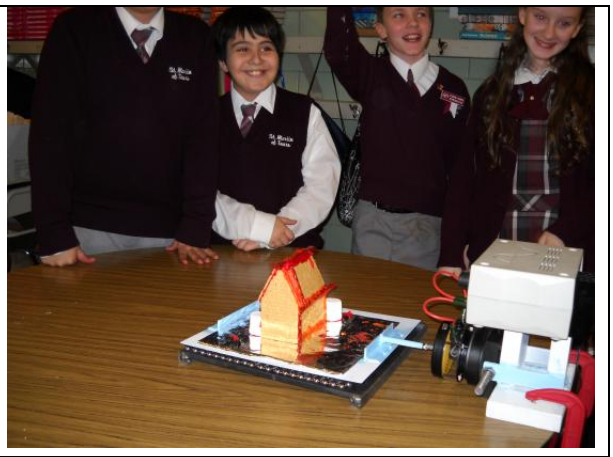
Meeting 4 – Earthquake Engineering

In the weeks prior to meeting four, all of the 6th graders learned about seismicity and how earthquakes are created as part of their school science curriculum. They also completed a class project on volcanoes. The fourth meeting provided an introduction to engineering ethics and

earthquake engineering. Common ways of designing to prevent the loss of life in seismic events were discussed, and photos of damage from recent earthquakes were reviewed. The project focused on groups constructing an earthquake resistant ginger bread house. The club members were given graham crackers and an assortment of candies and icing. All houses were subjected to shake table testing as shown in Fig. 4. All successes and failures were analyzed and eaten.



a. Students constructing their house.



b. Shake table testing.

Figure 4. Construction of earthquake resistant houses and shake table testing.

Meeting 5 – Energy

In meeting five the topic of energy was discussed. The concepts of potential and kinetic energy were reviewed. A discussion of how structures can absorb energy, similar to their houses at the previous meeting, by using ductile materials. Each group was given an egg and a bag of supplies (cotton balls, string, straws, sponge, tape, etc.). They were given twenty minutes to design a protective device for the egg drop competition. Figure 5 shows two student groups prior to testing.

a. Students celebrating their completed design.

b. A team just prior to the drop.

Figure 5. Egg drop competition.

Meeting 6 – Reading Engineering Drawings and Construction

At the sixth meeting the entire club had to work together to interpret engineering drawings and construct a full-scale two by four wood truss bridge. Figure 6 shows the construction process and a rudimentary load test. The club kept the bridge on display at school for two months.

a. Assembly of truss members.

b. Load testing and celebration.

Figure 6. Full scale timber bridge construction.

Meeting 7 – Concrete Materials

Concrete materials were the focus of the seventh meeting. A lecture on ingredients, applications, and strength testing of concrete was presented. Students were given a mix design and the supplies, and they hand mixed concrete. Each group prepared a cylinder for testing at the final club event. Figure 7 shows groups making concrete.

a. One group mixing dry ingredients.

b. One group mixing wet ingredients.

Figure 7. Mixing of concrete and constructing cylinders.

Meeting 8 – Field Trip to Villanova University

The club culminated with a field trip to Villanova University's Structural Engineering Teaching and Research Lab. A lecture was presented on lessons learned throughout the year. Student groups cycled through four areas. Students were able to test their concrete cylinders to failure and calculate the concrete strength. They worked on creating a NovaCANE sign to hang in the laboratory. They placed a painted hand print and signature on the sign to commemorate the first year of the club. They worked with drills and hammers at a wood working station, and they had pizza with graduate students. One of the graduate students actually grew up in their neighborhood. He gave them firsthand accounts of his experience in the neighborhood and the dedication required for them to go on to college and become an engineer. Figure 8 shows the four activity areas. Following the four activities the entire club observed the full-scale testing of an open web steel joist.

a. Group with concrete souvenirs.

b. Hand prints for the 2010 NovaCANE sign.

c. Construction with wood

d. Lunch seminar on engineering.

Figure 8. On campus final event and celebration.

Observations and outcomes

The St. Martin of Tours 6th graders came into the club with no knowledge of engineering and a desire to learn. As the school year went on, the excitement and interest in structural engineering grew dramatically. Students clearly satisfied learning outcomes 1 and 2. By the fourth activity

they were already asking about 7th grade, and during the 7th activity they were begging to do more projects.

In regards to learning outcomes 3 and 4, students constructed and tested many structures. The earthquake engineering and egg drop activities tied directly to course material on seismicity. Based on comments from their teacher, they were discussing their engineering activities in school with classmates not in the club. The enrollment was capped and new students could not be accommodated. Their teacher requested that we continue the program.

As noted previously, one of the learning outcomes was related to teamwork. During each activity the group leaders would comment on pertinent teamwork skills. Positive teamwork attributes were highlighted and those that could potentially hinder team progress were shared. Over the course of the curriculum, the students' progress in this area was clearly evident to the authors.

While the benefits to the middle school students were numerous, there was a tremendous value to the Villanova students. The four key elements of a service learning pedagogy are Preparation, Service, Reflection, and Celebration. The students were responsible for all preparation. They taught the lessons and ran the activities at St. Martin of Tours; they interacted directly with the children in a formal and informal manner. We reflected in an informal manner following each activity. This is an area for potential improvement for future offerings. The celebration element was the year end campus event, where all NovaCANE members were present. It was an extraordinary mechanism for Villanova students to provide a much needed service directly related to their chosen field of study.

Lessons learned and expansion

Significant effort was expended in planning and executing this engineering club. Based on the many successful outcomes, the group desired to continue and expand its efforts. As planned, the group would need to expand its membership in order to sustain additional engineering clubs and other engineering service activities. Expansion efforts for the following year were to attract water resources, environmental, and chemical engineering students to run the 7th grade engineering club. The following year will require attracting mechanical and electrical engineering students for formation and execution of an 8th grade club. Interested students will then be eligible to participate in Villanova's engineering summer program for highs school students.

In order to make the middle school clubs sustainable and add new middle schools it was necessary to add a formal element of teacher training to all of our projects. Preparing video lectures of all modules is being considered. The new model involves NovaCANE running the initial offering of a club at a school, with a teacher in the school running the club in subsequent years. NovaCANE will continue to provide support as necessary for schools that lack the resources for supplies and travel to campus. In theory, after a three year period, a middle school will be able to run its middle school engineering club with minimal assistance from NovaCANE.

Again, based on personal relationships at middle schools, St. Edmond's Academy, an all boys' private Catholic school was selected for inclusion in 2010 – 2011, and Villa Maria Academy, an all girls' private Catholic school was selected for inclusion in 2011 – 2012. It is anticipated that another inner city Catholic school will be included for 2012 – 2013.

Besides the development of an additional engineering club, NovaCANE, participated in Villanova's Day of Service for the first time in 2010 by assisting in cleaning up a wetlands area at a nearby shopping center. Villanova's Day of Service has over 4,000 volunteers that work in the greater Philadelphia area on one Saturday to celebrate St. Augustine. Villanova students also run and host the largest Special Olympic games in the state of Pennsylvania. As part of the Olympic Town, NovaCANE will be hosting an engineering activities tent this year.

Assessment

This initial offering of an engineering club was not intended to become a recurring activity; consequently, no formal assessment mechanism was developed. Given that the implementation of these clubs will be ongoing, it is essential that an assessment methodology be developed. There exists an significant opportunity to capture important data from three different populations in the coming years given the substantial differences of the initial three Catholic schools selected for the engineering clubs (inner city - coed, private male, private female). The assessment tools will be developed with these populations in mind. Furthermore, an assessment mechanism must be developed to capture the learning outcomes of the Villanova students. Surveys are currently being developed.

Conclusion

Engineering service learning projects can take on many forms. The work of NovaCANE presented herein demonstrates that a small group of engineering students dedicated to service can have a dramatic impact on the lives of middle school students. The curriculum presented can serve as a model for other engineering students and faculty interested in middle school engineering education. NovaCANE continues to use this model for the 7^{th} grade club at St. Martin of Tours. A new 6^{th} grade club has been launched this year and the Special Olympics event is on the horizon. Assessment methodologies are being developed to properly quantify the full impact of NovaCANE on the middle school students and the impact of the service activity on the engineering students.