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Engagement in Practice: CAE Education via Service-Learning

Dr. David C. Che, Mount Vernon Nazarene University

Dr. Che had worked in the industry for eleven years (8 years with General Motors in Michigan and 3 years with Stafast in Ohio) before beginning a fulltime teaching career. He first taught at Geneva College in Pennsylvania for 7 years and then at Anderson University in Indiana for one year before joining Mount Vernon Nazarene University in Mount Vernon, Ohio. He is now Chair and Professor of Engineering at MVNU. His research interests include CAD/CAM/CAE, automotive engineering, manufacturing engineering, mechanical design, engineering mechanics, engineering education, engineering ethics, technology and society. He is a member of ASEE, ASME and SAE.

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The Call

"*To Seek to Learn is to Seek to Serve*." This is our university's motto [1]. It fits well with the intents and purposes of service-learning for students. Service-Learning has long been proven to be an effective tool for engineering education [2], [3], [4]. In a National Academy of Engineering (NAE) report titled *Educating the Engineer of 2020 - Adapting Engineering Education to the New Century,* service-learning is listed as one of six areas as focus areas of delivering a quality engineering education [5]:

- multidisciplinary education
- undergraduate research
- global learning or study abroad
- service-learning
- cooperative education or internship
- leadership/team work development

Mount Vernon Nazarene University (MVNU) is a small, private, Christian liberal arts college with about 2,000 students in total. Although we do have some graduate students in a few Master's programs, the majority of our students are undergraduate students. The general engineering program (BSE) was started four years ago and currently enrolls about 50 students. Most (about 80%) are in the mechanical engineering concentration, with the rest of them in electrical engineering concentration.

In the fall semester of 2016, we heard a "call" from the community of Mount Vernon, Ohio. It was a need expressed to us - the Ariel Foundation Park Learning Trails project needed help from our engineering students to conduct a study of the history of a century-old bridge and create educational materials for the community. We gladly took it on as a class project since students were studying finite element methods and learning a new software – ANSYS. We were rewarded for it - students loved this service project as it created a link between abstract engineering theory and everyday objects they could touch and see. Along the process they learned what they needed to learn - the CAE tool. It was a win-win situation. In the following sections, we will document the project activities and share some lessons learned. ABET outcome assessment results are also shared.

The Ariel Foundation Park Learning Trails Project

Ariel Foundation Park, located in Mount Vernon, Ohio, is a 250-acre civic park that was created by community lovers and philanthropists on the site of formerly abandoned factory grounds. Now, the park is a stunning example of adaptive reuse. It offers architectural ruins, lakes, observation tower, walking trails, steel sculptures, a museum, and connections to both the Kokosing Gap Trail and the Heart of Ohio Trail [6].

The city of Mount Vernon boasted one of the largest flat panel glass manufacturers in the world at the time - a division of Pittsburgh Plate Glass (PPG) Company, in the middle of the twentieth century. However, after about twenty years of operation, new technologies of glass making left the city behind in the 1970s, as PPG moved its factory to other places. Obviously it was cheaper to build a new factory than retooling an existing factory. The massive PPG factory was eventually abandoned and became an eye sore for the community.

In the early 2010s, the city and the community came together and made it into a beautiful community park without the use of any public money. It was all supported by corporate donations and local volunteers. See Figure 1 for a glimpse of this beautiful park.

Figure 1 Ariel Foundation Park with Ruins of the Old PPG Factory Building and the Smoke Stack

The Learning Trails Projects were a continuation of this community funded and volunteer supported site renewal effort. According to the project guidelines [7], “The Learning Trails will present interpretive materials at various specific sites throughout the park. The sites comprising the trails will explore three major themes: nature, industry, and culture. First, the trails will enhance visitors’ experience of the park by enriching their understanding and appreciation of the sites they encounter. Second, the trails will provide educational materials on a variety of subjects to be used by area schools. Third, the trails will promote environmental and cultural tourism in Knox County. The trails were designed for everyone who might visit the park. This includes a diverse population of different ages, educational levels and backgrounds. In addition to park visitors, the trails will be available online to a global audience.”

One of the learning trails projects is to study the construction and history of the old Lucerne Road Bridge. The bridge was initially built in 1900 and had a posted load limit of 6 tons [8]. See Figure 2 for a picture of the bridge.

Figure 2 Lucerne Road Bridge in Knox County, Ohio

The author was teaching a Computer Aided Engineering class in which students were to learn structural analysis using state-of-the-art finite element analysis software ANSYS [9]. He adapted the class project to a study of the load capacity of the bridge. Students were asked to take measurements of the bridge and build an ANSYS model and see if it indeed can carry a maximum load of 6 tons. Six junior mechanical engineering students worked in teams of two and did some modeling and analysis of the bridge. Figures 5 and 6 show the results of two different teams. Their ANSYS model all included a 2D truss system model and an I-beam model as the truss bridge is supported by several I-beams beneath it (Figure 3). The results show that the posted load limit seems reasonable. Even though their modeling and load analysis approaches are slightly different, their conclusions are the same, that the bridge would be safe to carry 6 tons. The students made presentations towards the end of the semester and it was open to the public. There were several community guests in attendance. Over the summer, learning trail project files were generated ready for posting to the website for all to see.

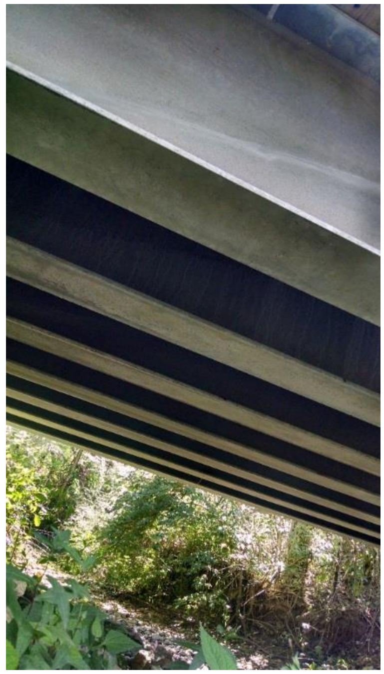

Figure 3 I-beam Bed of the Truss Bridge as Viewed from the Bottom of the Bridge

At the end of the project, one team shared their excitement of working on a real project like this:

> *From a personal aspect, we feel very good about the work we did for this project. It is one thing to analyze imaginary problems from a textbook, but it really brings the material to life when you can be out in the real world with a project like this.*

Many end-of-course survey comments from students also confirmed that ANSYS was fun to learn and they liked the real world practical nature of the project. ABET learning outcome k assessment results on ANSYS will be shown in the next section.

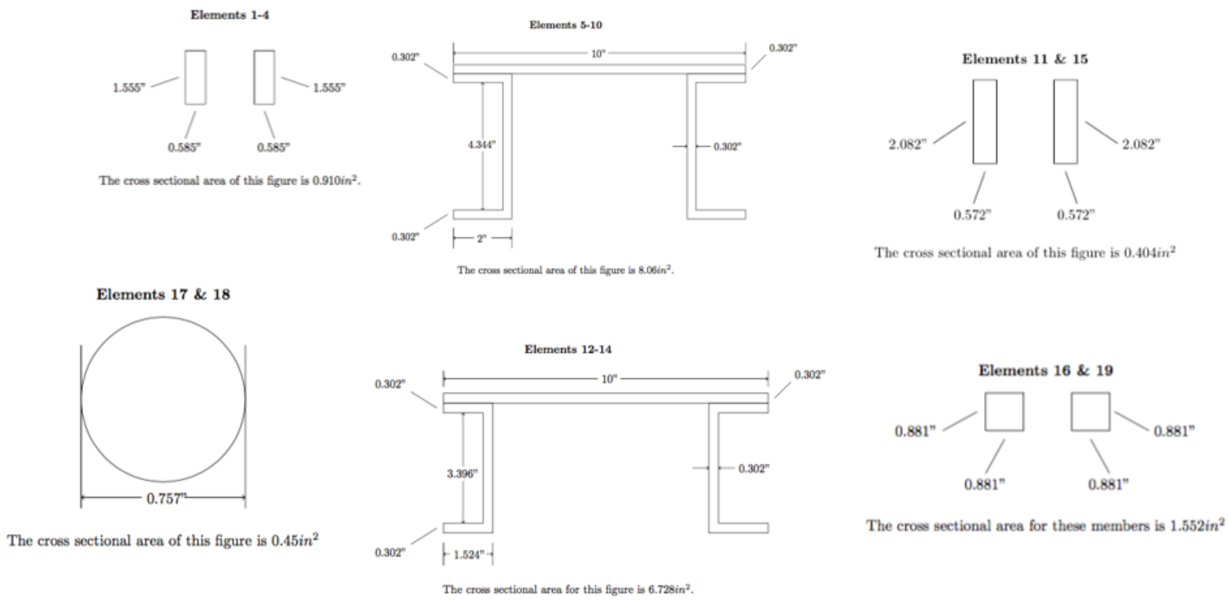

Figure 4 Dimensions of Key Components of the Bridge as Measured On-site [10]

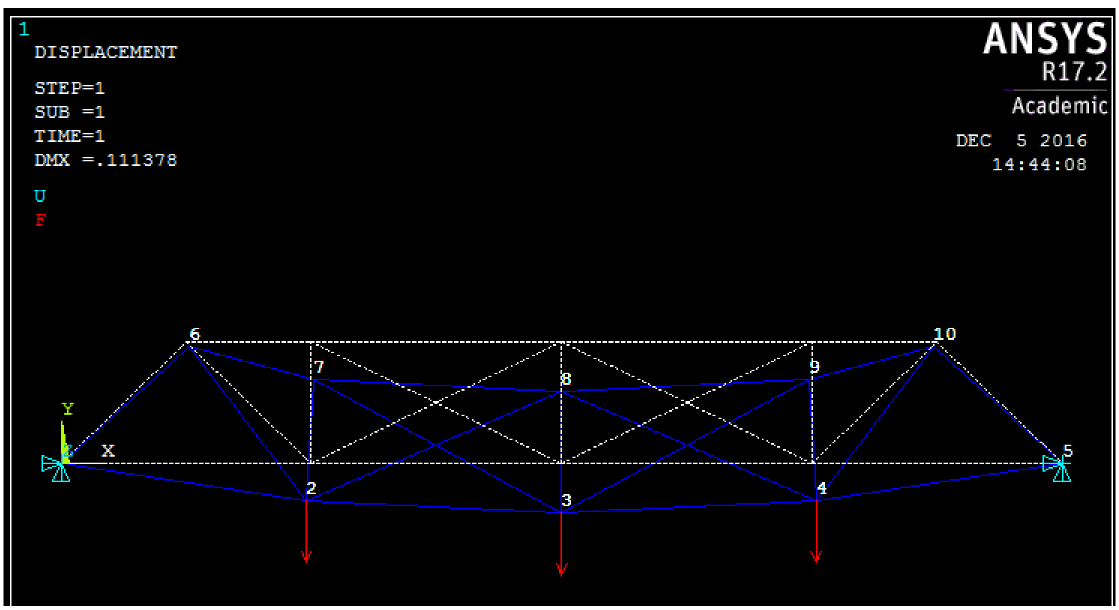

Figure 5 Analysis Results of One Student Team [10]

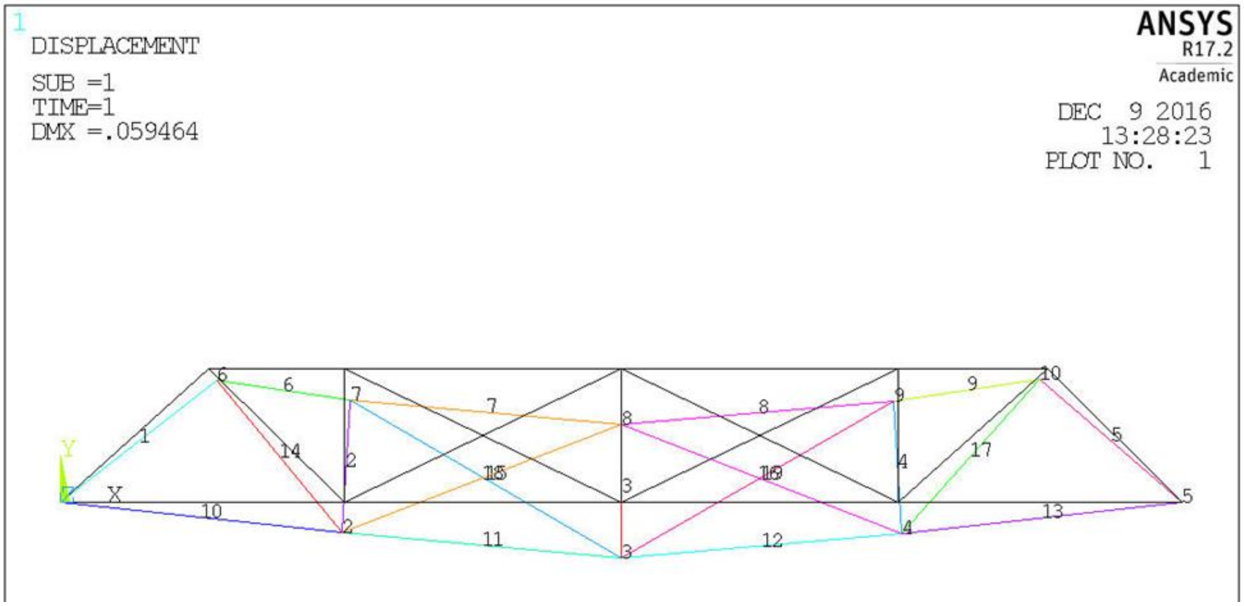

Figure 6 Analysis Results from an ANSYS Model of the Bridge [11]

Outcome Assessment for the CAE Class

EGR 3103 (Computer Aided Engineering) was a senior or junior-level mechanical engineering required course in 2016-2017 academic year at MVNU. One of the course outcomes that relates to ABET outcome **k** (an ability to demonstrate that graduates possess an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice) as published in the syllabi is:

> *After successfully completing this course, the student will have an ability to use professional finite element method software (ANSYS) to do linear elastic structural analysis.*

The course was re-designed in fall of 2016 to increase the emphasis on using modern engineering tools such as ANSYS to solve engineering optimization problems, especially nonlinear ones. In fall semester of 2016, roughly 56.6% of the overall homework grade was

ANSYS related. The final project was a team-oriented group project analyzing load capacity of a local bridge using ANSYS.

Continued training and application of the ANSYS software were conducted throughout the semester. Usually the instructor uses the first 20-30 minutes of the class to teach on theory and concepts, and then devote the remainder of the class to teaching hands-on use of the software. The classroom is a teaching lab and each student has his/her own laptop computer to use. Most of the time students work individually under the supervision of the instructor, with some discussions among themselves. The instructor also encouraged them to help each other out as much as possible in and outside of the classroom. Sometimes students would come to ask software related questions during office hours and the instructor would go with the student to his/her computer and help debug the problem or teach them how to use certain features of the software.

Table 1 shows the rubric that was used to assist in the assessment process and the assessment results for various outcomes. Target score is 3.00, which is the measure of a student who is able to use the tool but needs some assistance and occasionally applies the tool inappropriately. Average scores for all three software tools indicate the target goal is met in this course.

Figure 7 shows the aggregated scores (in percentage) of each student for their performance that relate to outcome k in their homework and test. Six of the eight performed better in the test than in their homework, which indicates that the majority of them show a continuous improvement in the use of this tool. Students #5 and #6 are good students but sometimes lack the discipline to do or turn in their homework, which explains why they did better in the test than on the homework. The target threshold for the test is 70%, since C- is the lowest grade students could achieve to prevent them from repeating a course. All are above the target threshold except one student.

Table 1 Rubric and Assessment Results

Numbers in the table are the number of students at the level indicated in the heading

Technique, Skill, Tool	Means for Observation	Clueless – unable to use tool and does not try (0)	Attempts to use tool but does so incorrectly and consistently gets incorrect results (1)	Occasionally able to use tool correctly by guess work (2)	Able to use tool but needs some assistance and occasionally applies the tool inappropriately (3)	Proficient use of tool with minimal assistance and consistently applies tool appropriately (4)	Average Score
Using ANSYS to do linear structural analysis	a, b, c			1	3	4	3.37

a. Observation of students during tests
b. Homework assignments
c. Final project

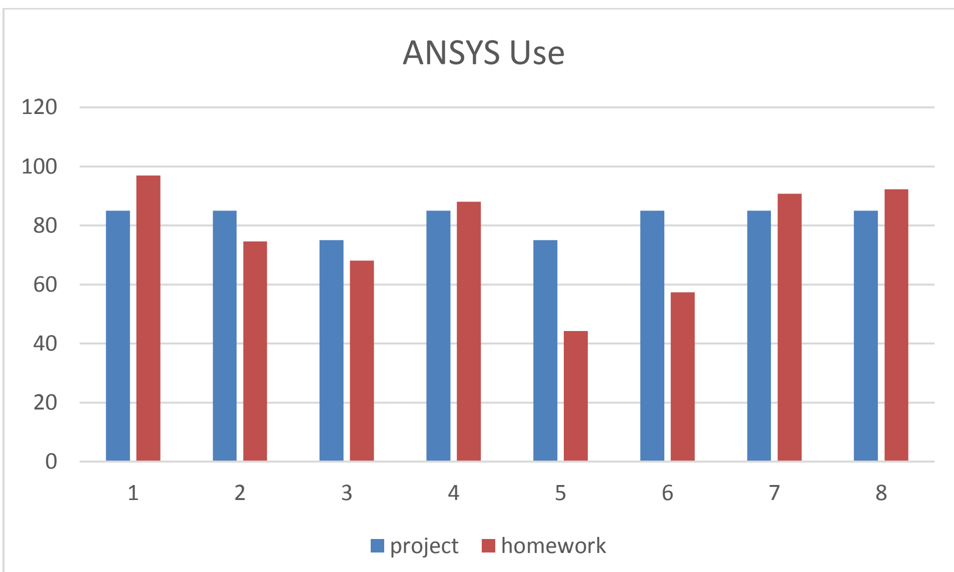

Figure 7 Aggregate percent scores for each of the eight students in ANSYS related homework and final project

Lessons Learned

Overall, it can be concluded that the majority of the class achieved a satisfactory outcome in mastering the use of the software tool ANSYS. It is not always convenient to commence a class project any time of the year. As instructors, we have to make it fit with the academic calendar. It does take some thinking to make it work. For this project, when it was initially provided to us, it was quite open-ended. There were no stipulations as to how we should do the project. There was no stipulations even on what to do as a project. We were simply given the bridge and asked to develop some learning materials surrounding it and make it presentable to the general audience. The engineer faculty had to think of something that is both beneficial for the community and our students. That was why we narrowed our focus to verifying the load capacity of the bridge. It is of interest to the community because the bridge was quite old and no one knows if the load capacity stipulated by the engineers over a century ago was valid.

The goal was clear and students were challenged to create a computer model that not only mimic the design of the bridge but also simple enough so that it is manageable. They had to figure out how the load should be applied. Should it be applied at one point (node) of the bridge model or should it be spread out and applied as a uniformly distributed load? Or do they need to do both? The complexity of the bridge also showed itself in the way it was constructed. It is not a pure truss bridge because there are several I-beams beneath it. Should the model include all the components or should we separate the modeling of truss from the modeling of the I-beam support of the bridge? These are all scenarios students have to think through and make decisions on.

It is a perfect project for students to not only learn how to use the tool of ANSYS, but also learn how to set up the model correctly. There is a process of systematic thinking involved. It is very similar to a design problem students will encounter when they start working in the industry. This project-based training can bring out the best from the students – it is very motivating and educational, yet at the same time not overwhelming and unreachable. It does take some expertise and vision from the instructor to set proper goals for the project in order to make it a success for all involved.

Conclusions

Project-based learning, or experiential learning, has been proven effective in engineering education. Finding these projects requires community engagement on the part of the instructor. Sometimes the instructor has to be creative in redefining the project scope in order to integrate them smoothly in engineering courses. The example project in this paper demonstrated that community-based activities and resources are adequate for such purposes. The example is related to the learning trail project of the Ariel Foundation Park in Mount Vernon, Ohio. There is a need to verify the load capacity of an old truss bridge. Students in a Computer Aided Engineering class used this occasion to hone their ANSYS skills. It has been a service-learning experience for students. Service-Learning projects can be integrated with CAE courses so students not only learn the usage of the tools but also see its impact on real life. These community based projects give students a platform to practice their skills, while at the same time give students a context to see where engineering tools fit in the grand scheme of things. Student feedback were very positive for such projects. It has been a win-win situation for everyone involved.

Acknowledgement

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William L. McGrath at Mount Vernon Nazarene University for their enthusiasm and initiatives in completing these projects in a very short amount of time.

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