

Case Studies Under Your Nose: Using Campus Projects as Case Studies for Engineering Economy

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The buildings of academic institutions are often considered “hallowed halls,” that are often imagined as floating slightly above the ground in a sea of mist. However, when stepping back and looking deeper, they are just buildings made of brick, mortar, and steel. They contain electrical distribution systems, heating/ventilation ducts, network connections, and much of the technical infrastructure that are the subject of engineering coursework taught within their engineering programs. The campus itself has roads, storm water management, refrigeration compressors, pumps, and electrical transformers to facilitate all the parts of campus needs. Further, the academic organizations have production/distribution supply chains for student housing, food service efficiency challenges, and the whole myriad of other infrastructure that it takes to run a large university. There are practicing engineers, often housed on the periphery of the campus, that support construction of new dorms, facilitate building new roads, and are continually looking at upgrading and new methods to save money, improve efficiency, and enhance sustainability for the institution. With pressure on universities to make college more affordable for all students, it is imperative that these efforts go forth in earnest. Finally, these engineers, some of which are alums of the program, generously want to share their experiences with students and are interested in passing along their knowledge to the newcomers.

For the Ohio State University, these real-life campus based problems represent an opportunity for the engineering economy course. By partnering with the campus facilities engineers, students can see real-life engineering problems and can practice the engineering economic analysis in a way that will match how they will do it in their professional practice.

Premise

The premise of this paper has 4 underlying principles which we will explore more in detail:

- Case studies are an effective way of teaching/learning.

- Connecting to real-life examples is a way to cement students' knowledge through memorable context.
- Using case studies supports the rich complexity and interdisciplinary skills needed by future engineers.
- Using campus based case studies is physically convenient for students because they can see the application without the time, expense, and coordination required to go off campus.

Support for Case Studies as a Method for Teaching & Learning: Significant research has been done showing the effectiveness of case studies as a teaching method. In 1999, the Journal of Engineering Education published an interesting research paper entitled, Teaching Real-World Issues through Case Studies, by P.K. Raju and Chetan S. Shankar. In this paper, they chronicled the benefits of using case studies in their mechanical engineering course. They said, "Engineering students are expected to be not only technically proficient, but also to exhibit a sound awareness of the real-world issues such as marketing, finance, and interpersonal relations. We found that this is best learned by participating in a case study method of instruction."² Further, Niewoehner in the 2009 ASEE conference proceedings said that the case study allows students to increase their critical thinking skills.³ These critical thinking skills enable the students to apply these concepts to their future job roles.

Providing Real-life Contextual support: One of the challenges students face in their engineering education is the ability to understand the real-life context of the subjects of their coursework. Research indicates that if students understand the real-life context of a problem, they are more likely to retain their knowledge. John Bransford chronicled this in his book, *How people learn, Brain, Mind, Experience, and School*.⁴ Real-life context, stories, and personal interactions help frame this in engineering economy courses. Textbook author, William Sullivan, in his 2008 paper said, "Developing examples and exercises that are interesting, engaging, and provide context is a challenging problem for courses with students enrolled from a variety of majors. Yet, we know that without proper context to their discipline, students will not find relevance or understand why they should care to learn engineering economy."⁵

Case studies are recommended for teaching future engineers: *Transforming Undergraduate Education in Engineering (TUEE)*, the multi-year, multi-phase project between ASEE and NSF is undergoing a process to develop a clear understanding of the knowledge, skills, and abilities that the next generation engineering graduates should possess and the changes in curricula, pedagogy, and academic culture that will be needed to instill those qualities.⁶ The first-phase report which was focused on the industry prospective suggested universities should "welcome involvement by industry in supplying case studies, mentorship of students." One of the opportunities of using university based case studies is that students can meet those practicing engineers on campus which blends the industry perspective of project financial analysis with the needs of the university which may answer to a broader reach of stakeholders.

University based case studies are convenient and accessible. The innovative part of this program is ease of execution. Students, on campus, without cars, can access these locations and fit them into their day. Specifically for this program, tours were scheduled outside of class hours to meet with the engineers and learn how the systems really work.

Background of the course

Engineering economy is a 2-credit hour, half semester course at the Ohio State University with 2 sections per semester taught in large lectures that meets twice per week. There are approximately 125 students per section in this course or approximately 500 total per semester. The students primarily come from the disciplines of mechanical, electrical, computer, industrial, food/ag/biological/ecological, and welding engineering. Research was done with the autumn 2016 term 2nd half semester course and in the spring 2017 1st half semester session.

The engineering economy course is structured as follows: Days before the start of the term, the students are put into random groups of four, emailed their group number, and given instructions on how to find their fellow group members' contact information. In the first 5 minutes of class, the students are aggregated into their groups and allowed ~ 10 minutes to meet each other. The group has 2 purposes, to work on practice problems in class and to do the case study which is a project that is analyzed in 2 assignments. In the first-class syllabus review, the case study choices are explained from a list of about 5-8 options. This term, the choices were as follows:

University Based Case Studies:

- Student housing lighting upgrade: This project covers a lighting change in multiple dorms from florescent lights to LED lights. This project considers looking at the direct savings in electricity cost and includes incentives from the utility company that can take the form of upfront rebates or ongoing utility rate reductions. This case study offers the opportunity for students to visit the dorm and hear from the project manager about the possible project.
- Morrill Tower (Dorm) HVAC control Upgrade: This project involves the recommendation to change the controls throughout the 20+ story building from 50-year old pneumatic thermostats to wireless controls. Previously, consultants recommended changing the controls but this was many years ago before wireless controls were popular. Also, the previous data was collected when utility prices were significantly different than today, so it makes sense that this project is worth evaluating. Below are photos from the tour given by the building staff.



Figure 1: First picture from tour of mechanical room current controls

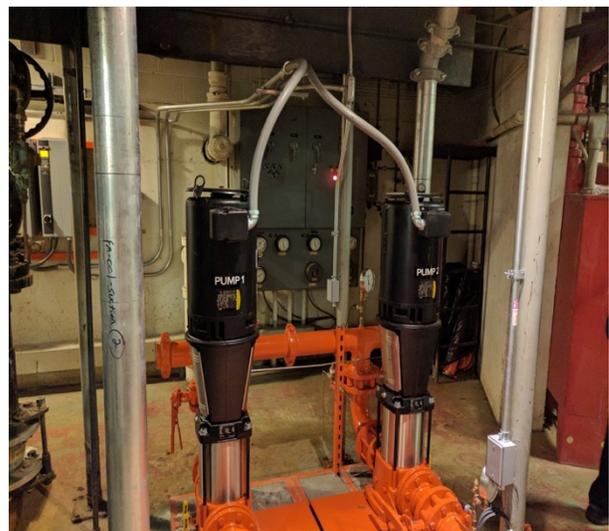


Figure 2: Second picture from tour of mechanical room – condensate pumps

- **Geothermal Well Expansion:** In 2012, Ohio State built a Geothermal well system that has been used to heat a couple of new dorms on south campus. After a bad winter, the facility department realized they had excess heating capacity and did a preliminary cost estimate of installing equipment to add other building heating loads to this system. Use of this additional capacity enhances the efficiency of the entire system by increasing the compressor load. Analysis of this project includes determining the cost savings with each option based on load data provided for the current system and new buildings on a monthly basis and fitting a curve to the compressor data for analysis. Not only does this project save money, but the sustainability component adds to the overall university and student goals. Normally, the Geothermal well facility's group cannot handle taking large groups of students to the compressor area for safety reasons, but they meet them in the dorm that houses the equipment and explains what is downstairs, how it operates, and how the addition would work.



Figure 3: First picture from discussion of project challenges



Figure 4: Second picture from discussion of project challenges

Non-university based:

- **Brewkettle Heat Recovery:** This case study is based off the real-world project at the local brewery of Anheuser-Busch and includes a tour option. This case study is very interesting and students enjoy the tour, but it requires a car to get to the site and about 3 hours of total time including the tour and travel back and forth from campus.
- **Macaroon Cookie Business Expansion:** This is a theoretical case based on ideas from a student capstone project where a small business company is looking at producing a new product line and they need to analyze if their expansion plans will be cost effective. No tour is provided.
- **HCP Laser Project – Heating and Cooling Products (HCP)** is a small US based ductwork components manufacturer about 1-hour drive north of campus. A previous intern helped develop this case study which was based on the need for the company to improve cost effectiveness in terms of labor and scrap for their blank cutting process for their various fabrication pieces. They are considering replacing a reciprocating saw with a large laser

cutting machine. Even though there is no tour, students can meet with the former intern and hear more details about the project.

- Green up your world: The local utility company, in conjunction with the state utility commission, sponsors rebates and other financial incentives to encourage electrical energy usage reduction. These programs include installing energy efficient lighting, home utility usage reduction, and other business incentives to reduce consumption. The students can use existing website data and their own experience to define an application that they see and determine if it is cost justified using engineering economy techniques.

Each case is discussed briefly and where to find the case materials so they can select the case of their choice by the middle of the second week of class. Based on the research data from the case studies that the student group selected slightly less than half of the students chose a campus based case study as show in Figure 5 below.

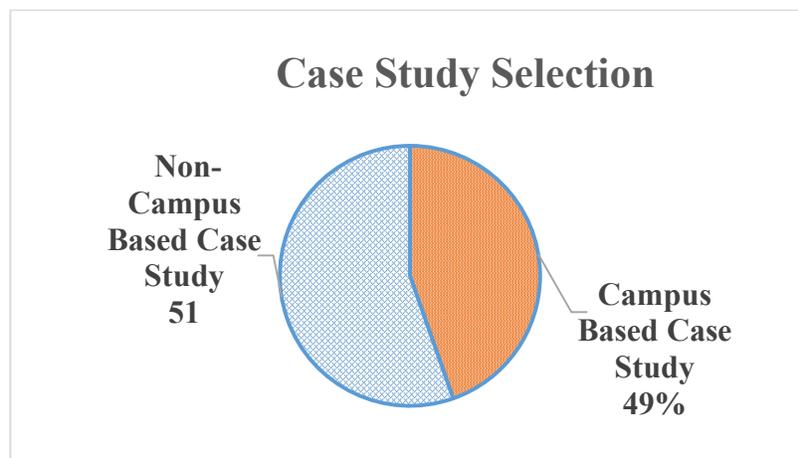


Figure 5: Case Study Selection Type

After the students have selected their case study, there is no class time specifically allocated to the discussion of individual case study details, but examples are brought forward in class as topics are covered. Also, the groups have instructions to write 2 papers based on their individual case study for analysis. A case study approach paper is required half way through the course. This paper is for students to define the objective of the case analysis and what factors they need to analyze to determine if this project should be recommended. This short, 2-page paper ensures that the students have read the case and helps seed the students with questions they will need later to analyze the project properly. At the end of the term, the final case study paper is turned in by the group. This is a full report with a recommendation of the project direction, financial analysis, description of non-economic factors that would influence their recommendation, and inclusion of 2 alternative risk assumption scenarios.

These cases are open ended. There are some financial numbers that give initial investment amounts and possible financial benefits which could be outdated. There is no specified required rate of return listed or expected life of the project dictated. Students are expected to make reasonable assumptions based on the type of business and what the required return for them would

likely be and support those assumptions. They should support their rationale with some small-scale research and describe the rationale for why they are making a valid assumption in their paper. As an example, students have been very astute at estimating a cost of capital for the university by doing things like looking up the bond rate the university pays. They can estimate the project life based on other similar type equipment they see and can use as one of alternative assumptions a change in project life.

Use of Excel's financial functions is taught and emphasized in this class. Being able to use these financial functions not only allows the students to demonstrate this skill in an open-ended approach, but also makes it very easy for them to create alternative assumptions with some quick copy/paste and financial manipulation. For example, analyzing the impact of various possible future inflation factors can be done by adding a geometric gradient factor, something taught using Excel in the course.

Grading the case study is done using a grading rubric that focuses on:

- (1) Validity of assumptions – Do they seem reasonable and supported?
- (2) Correctness of financial calculation methodology
- (3) Description of economic and non-economic factors
- (4) Writing clarity

Unless there is a problem determined in the group performance, all group members receive the same grade on both the case study approach (5% of overall grade) and case study final paper (15% of overall grade).

Research methodology and results:

On the last day of class, students were given a survey after a brief introduction of the IRB approved script. The survey questions were done with a combination of Likert scale ratings (1 = very important to 5 = unimportant), and comment boxes. The comments were transcribed and evaluated by 2 people independently to gauge their validity.

For the two semesters, 312 students completed the survey with results and analysis below to determine the value of using this case study approach with some campus based tours.

1. How many semesters until you graduate?

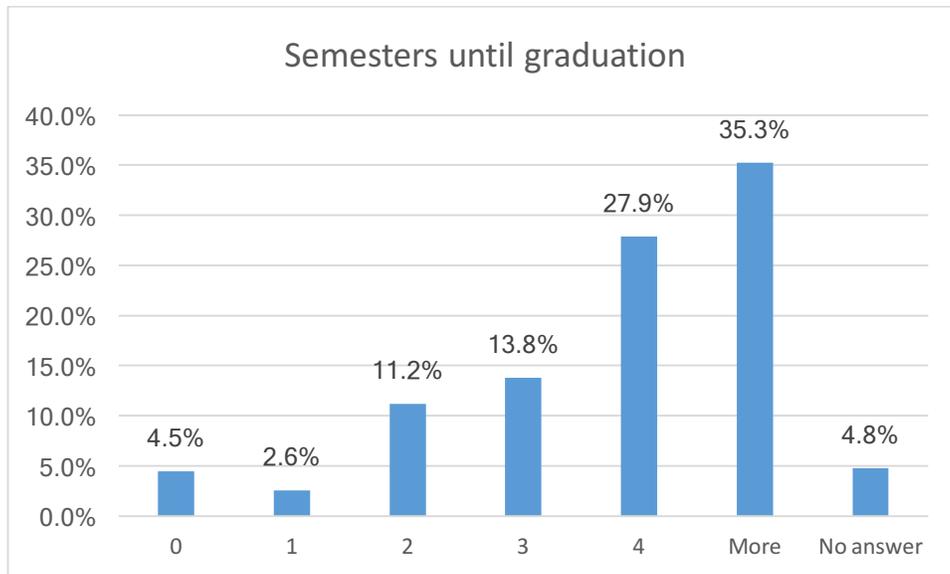


Figure 6: Grade Level of Students in class

The interesting part of this answer is that over half the class taking this course is likely a 2nd year or early 3rd year student and hence may not have access to a car since cars are not allowed for students living on campus and campus living is required for 1st and 2nd year students.

2. Was it important having a case study that was university based for ease of access?

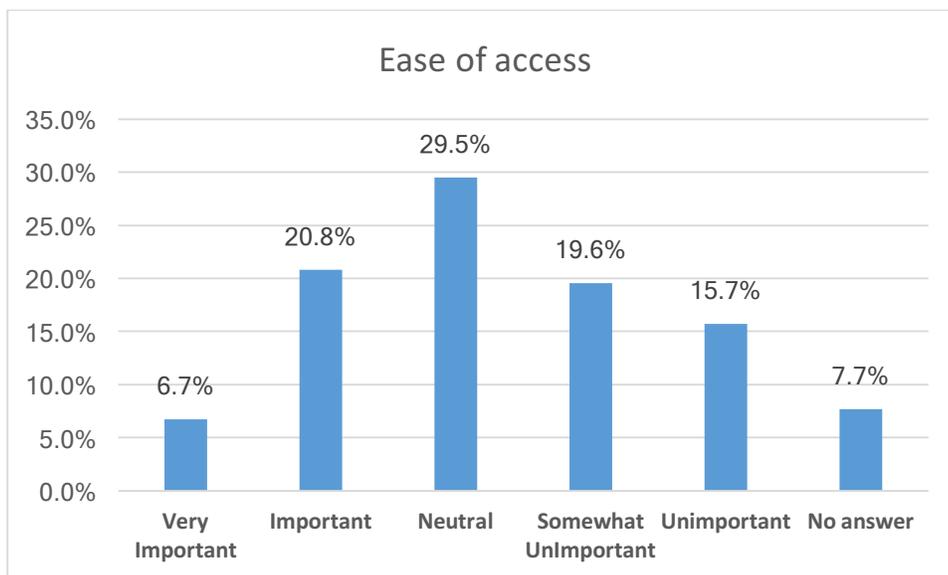


Figure 7: Easy of Access

Analyzing the first 3 groups, about half of the students said it was important to have a case study where they had ease of access which aligns with the number of groups that selected the university based case study.

3. How important was it that at least 1 of your group members sees and/or meets with people familiar with this process?

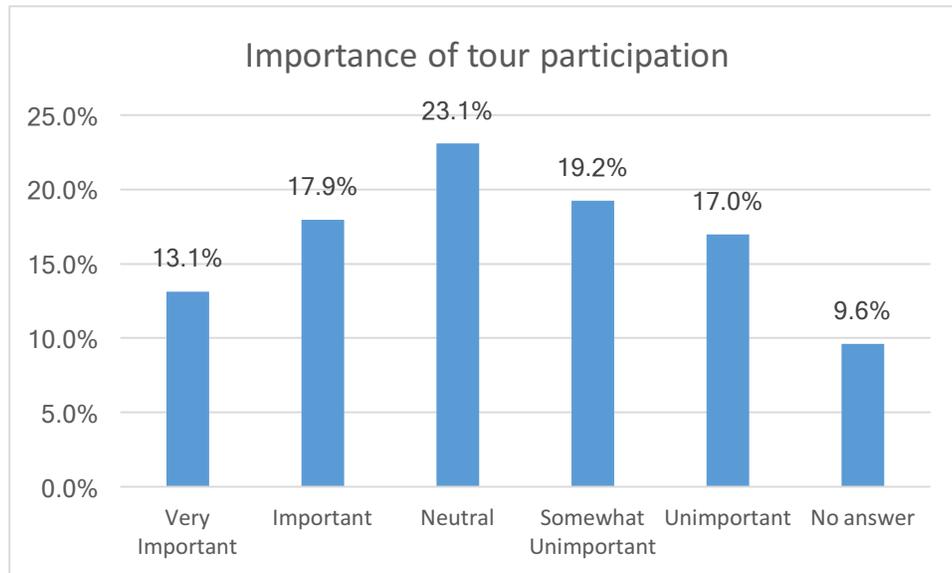


Figure 8: Importance of tour participation

Analysis of this showed it was important to the students that at least someone participates in the tour for their group. Indeed, in class feedback from people participating said it was helpful and interesting.

4. What would increase tour participation?

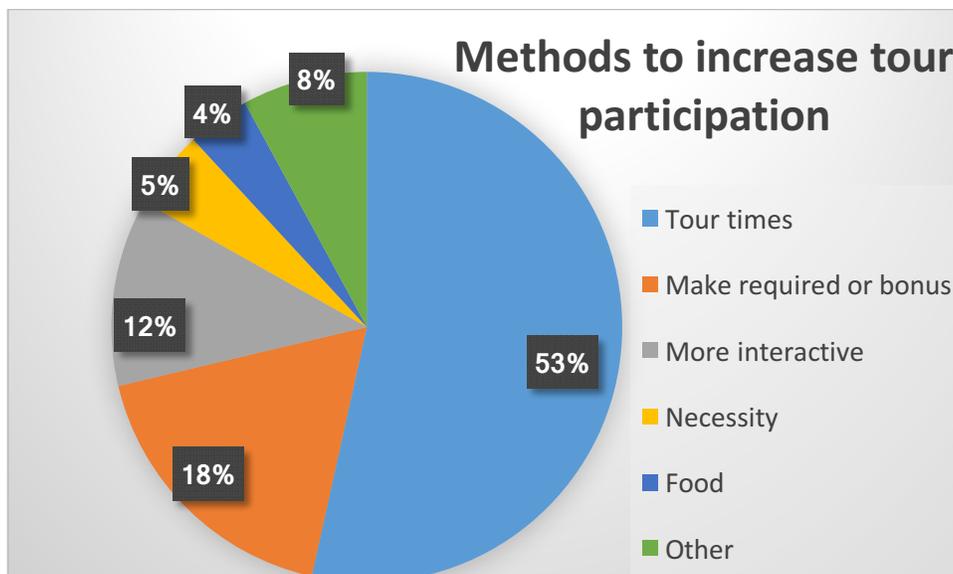


Figure 9: Methods to increase tour participation

One of the challenges with this course is that every major takes it, so there is no way to come up with a convenient time for all students. Further, the operational staff is primarily concentrated on daytime hours and they normally prefer to do these tours in the morning. Some students suggested doing this on weekends, but this probably isn't feasible.

5. Was it significant to see the application of tools learned in class being applied in a real case study for your university instead of a fictitious one?

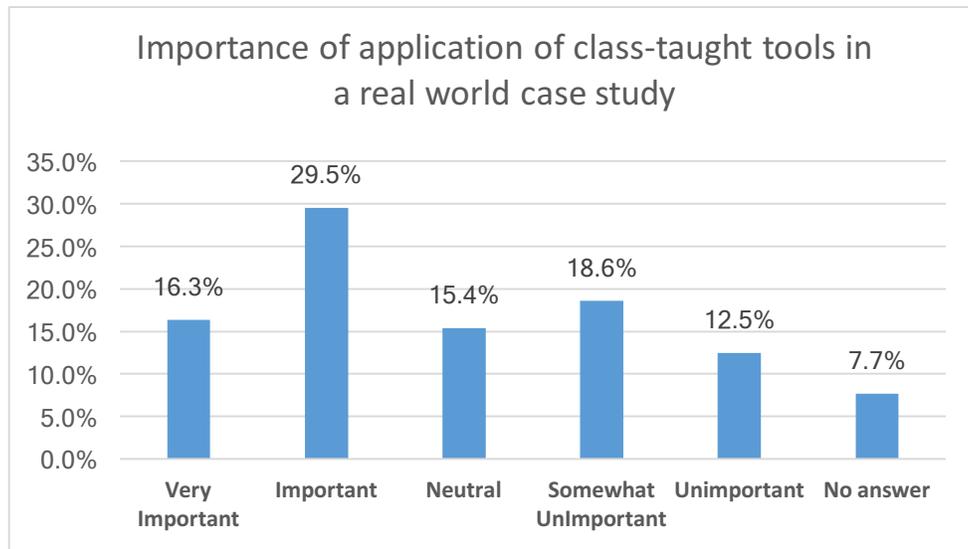


Figure 10: Understand Real Life Applicability

Similarly, about half of the students placed a relatively large importance on using a case study that was based on a real-world situation. It would be interesting to understand why others did not think it was as important.

6. How important was it to do a case study related to your primary major?

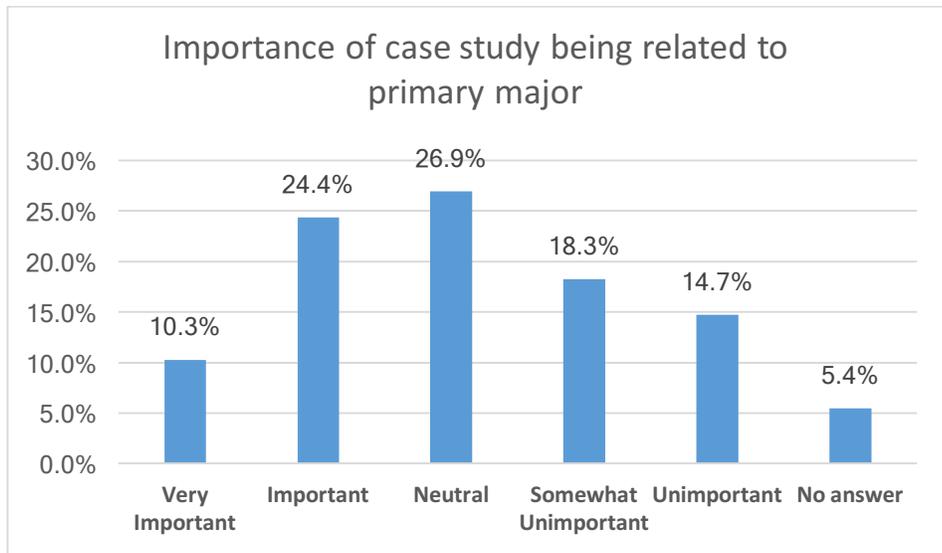


Figure 11: Applicability to your major

Clearly, the students would like to have the case studies aligned with their major. However, this is nearly impossible in this course context because the class has a random set of students in about 7 different majors. As a faculty member trying to facilitate multi-disciplinary teams [ABET d]⁷, it is important to have engineering students from different majors working together because this best simulates what they will see when they graduate. To many students, the case studies favor some particular majors and they may not see how this would be applicable in their future.

7. How important was it to work on a case study for a place you could actually see without needing a car?

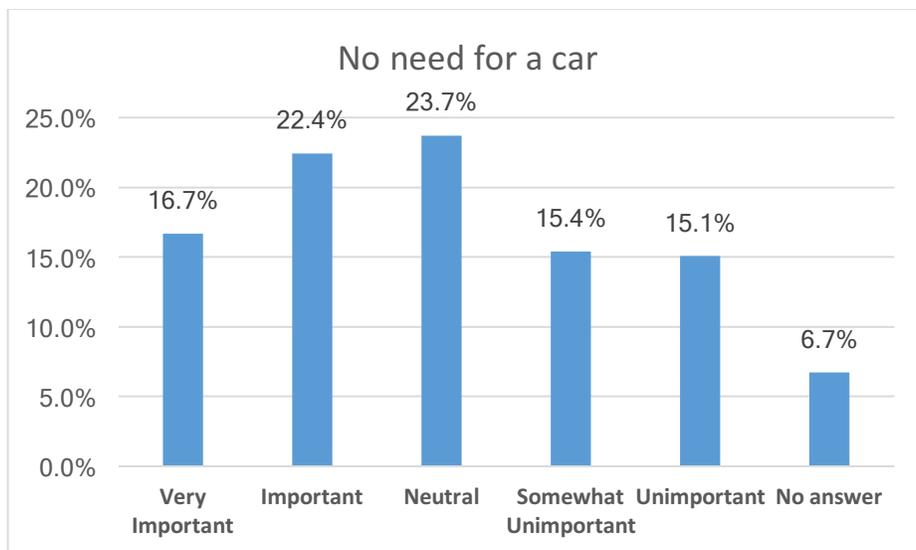


Figure 12: No need for a car

This question seems to be central to this research. Clearly over 30% of the students thought this was important and it probably influenced their case study selection.

8. How important was doing this case study on your overall goal of learning to apply engineering economics to real-world situations?

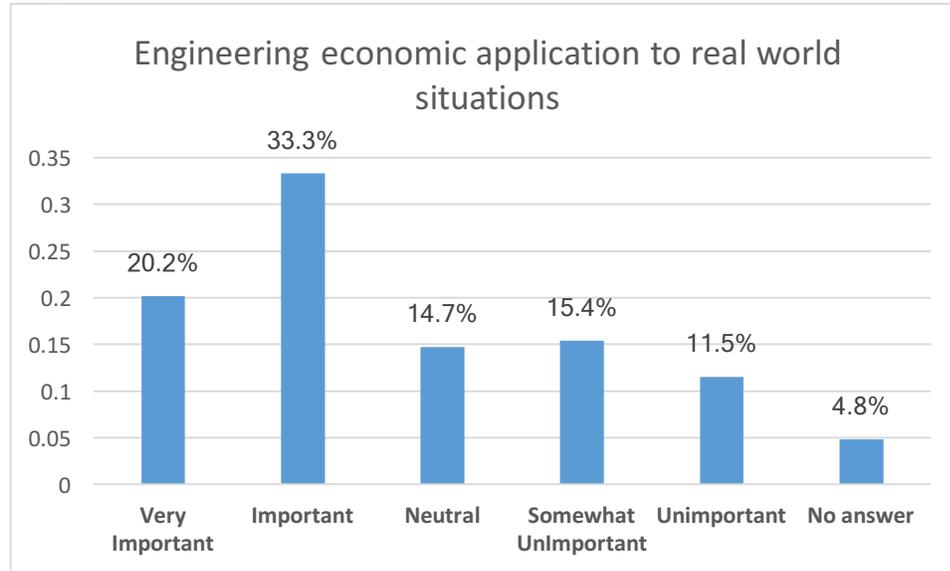


Figure 13: Case study as an application to real world situations

In this area, it is clear that many students thought that doing a real-world case study was important. Knowing that this class was a fairly large burden, added to the 2nd half of their already busy semester, it is encouraging to see that they feel this way despite the amount of work required.

9. Do you have any other recommendations?

The 56 written responses to this were varied, but general covered the following:

- Positive feedback, liked the case study and had no improvement recommendations (11)
- Wanted more information about the case studies to be presented in class regarding details of the case (12)
- Group formation/participation issues, some wanted to choose their own group or group by major (9)
- Better tour times – they were during the day and often students had conflicting classes. Further, they were relatively early (9 am) which might not be preferred. (5)
- Bigger variety of case studies, possible cover of more majors (9)

In addition to talking to the students, the OSU staff responsible for giving the tours for many semesters provided the following feedback:

“When I have given the tours, most of the feedback that I have received has been positive. Most students seemed to be surprised by the initiatives we have already started here and find that we have a good grasp on the direction we need to go with energy conservation. One of the things that I talk about is how sometimes the efficiencies we end up getting as part of a project really are a byproduct. Sometimes it is easier to sell the idea of replacing a piece of equipment as a normal life cycle replacement of it. By going with the best technological option, we end up with substantial energy savings. This usually seems to be very interesting to the students. Many of them comment on that aspect.”

Conclusion

The paper author has taught this class in this manner for 6 half-semester terms and this is the first time that feedback has been gathered. From this data, it appears that the case study approach used in this class is generally appreciated by many students and having case study environments that they can physically see and understand is a plus. Further, having those case study environments, “right under their nose”, in the university and easily accessible makes it possible for more students to participate. However, these results were less significant than anticipated. One challenge is that the students don’t see this problem as their own to personally solve as engineers nor do they have a deep enough understanding of the true economic tradeoffs and non-economic factors to fully appreciate the problem. Even if it is a true campus based case study that they actually visited, the students quickly just view it as an academic exercise which requires analysis, a paper to write, a deadline to manage, and a group to facilitate. The campus based case study tours seemed like a good idea to the author of this paper, but process probably needs to be revised before it is as effective as possible as a tool for student learning in a comprehensive way.

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