An Effective Way of Teaching Electrical and Computer Engineering Capstone Senior Design Courses for Underrepresented Students

Mr. Vewiser J Turner Jr P.E., Prairie View A&M University

Summary I am a retired Executive from ExxonMobil with 35 years of service at this Corporation. During my tenure with ExxonMobil, I have had a number of engineering, planning, business development, project, and operational assignments. I have extensive leadership experience, strategy development knowledge, and ability deliver superior results. I have been accountable for thousands of employees and millions of dollars as a Manager and Executive.

During my tenure with ExxonMobil, I have had assignments or projects that have taken me on numerous occasions to locations such as: Canada, Brazil, Venezuela, Australia, Norway, United Kingdom, United Arab Emirates, Prague, Malaysia, Singapore, and Argentina.

Since my retirement from ExxonMobil in March 2017, I have worked and are giving back to my alma mater as an Adjunct Professor teaching Senior Design and Professionalism at Prairie View A&M University, since Fall September 2017.

Education Bachelor of Science – Electrical Engineering Master of Science – Electrical Engineering Prairie View A&M University University of Texas - Austin

ExxonMobil Work History 1982 to 2017 – ExxonMobil Corporation; during this time have been assigned 17 different job positions of increasing responsibility from my initial assignment to Executive positions in ExxonMobil’s Oil/Gas Production, Refining, Business Planning, and Information Technology business segments.

Three notable assignments during my career include:

1. Project and Operations Manager for world-wide call center Responsibilities include: strategy development, business justification, project oversight, staffing, and process development required to implement a follow the sun 24x7 global call center department with locations in Moncton Canada, Kuala Lumpur Malaysia and Curitiba Brazil.

2. Led Technology design team for ExxonMobil’s new Spring, Texas campus (near Woodlands) Responsibilities include: original concept development, technology recommendations, budget development, gaining Senior Management endorsement and initial project management to deliver state of the art technology and business advantage collaboration capability for the 10,000+ residents at the ExxonMobil campus that opened in 2014. As an aside, many of my team’s recommendations have now been implemented in ExxonMobil affiliates around the world.

3. America’s Operations Manager Responsibilities include: Manager for ExxonMobil Information Technology operations in Canada, U.S.A, and South America. This geography accounts for over 60% of ExxonMobil’s worldwide locations.

Additional Duty ExxonMobil Engineering Recruiting Team Captain at UT-Austin (1985 to 1995) Responsibilities include: working on campus to identify new Engineering recruits

Awards and Honors Former Member of NSBE Region V advisory board Former Texas Alliance for Minorities in Engineering Advisory board Retired member from the Board of Directors for the Houston A+ Foundation

I am is a registered Professional Engineer in Texas.
I have been recognized with the Distinguished NACME Alumni award and Texas-Ex Distinguished African-American award.

Personal Information Native Houstonian from 5th Ward Married – 40 years, two adult children and one moody mini-Schnauzer named Tiger I enjoy playing the piano and regular working out Member of St. Monica’s Catholic Church

Prof. Sarhan M. Musa, Prairie View A&M University
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Abstract

Capstone senior design courses in electrical and computer engineering must give the underrepresented students the opportunity to learn about the real-world engineering. In electrical and computer engineering programs at Prairie View A&M University (PVAMU), senior design courses considered as the bridge between the academia classroom and engineering practices in industries. This paper gives a unique and effective way of teaching capstone senior design courses in electrical and computer engineering at PVAMU for underrepresented students. This paper also documents a process where ABET (the Accreditation Board for Engineering and Technology) outcomes can be implemented to enhance students learning. The influence instructors’ experiences through the combinations of industry and academia play a major and important factor to map the ABET student outcomes and how the projects are evaluated. Other underrepresented universities may benefit from the lessons learned of this work.

Introduction

It’s understandable that for any undergraduate engineering student their primary goal is to obtain that first job after graduation. We have observed that our students here at Prairie View A&M University (PVAMU), are as technically prepared from the engineering curriculum as any student from any other University. Most capstones instructors have the same opinion that final projects for engineering majors should stress professional skills as well as design education through a variety of teaching paradigms. It has been observed that using the theory in the engineering curriculum has produced graduates with far less experience in the practice of engineering and design than those of year’s past. Also, the ability to function as a member of a team is measured by several instructors to be an important skill of today’s engineers.

The approach is used when teaching this course is to emphasize those qualities that will enable them to not only get a job but to have a rewarding career. Whether the individual remains at one company, or they change companies throughout their work career – through experiences there are three characteristics that are critical for continued growth and success in industry. These characteristics are:

- **Intelligence** – the ability to be analytical, the ability to apply knowledge, and the ability to acquire new knowledge
- **Integrity** - being honest, high morals and adherence to ethics
- **Soft Skills** – ability to communicate with a wide range of individuals from engineers to non-engineers, and the ability to work well with others in a team setting
Capstone Senior Design is the only course in our engineering curriculum that gives the students an opportunity to get exposed and work on all three characteristics at the same time before entering the work world.

Class Schedule ABET Outcome Requirements for Electrical and Computer Engineering Senior Design at PVAMU

The capstone course is titled Senior Design and Professionalism I taught in the Fall semester, and Senior Design and Professionalism II taught in the Spring semester. Each semester the course lecture is on Wednesday for one hour and course lab on Thursday for 3 hours. The ABET outcome requirements for each semester are listed below as in Table 1.

<table>
<thead>
<tr>
<th>Course</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEG 4247 Senior Design I</td>
<td>X</td>
</tr>
<tr>
<td>ELEG 4248 Senior Design II</td>
<td>X</td>
</tr>
</tbody>
</table>

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership. Create a collaborative and inclusive environment, establish goals, plan tasks

ETHICS – Teaching the Importance of Professional Integrity

Our Senior Design course for ECE (Electrical and Computer Engineering) students at PVAMU require that we teach two semesters of ethics, and that we give the students an assignment each semester that will reinforce the topic. Engineering Ethics are without a doubt the most important of all professional characteristics. Industry superiors may be willing to give a student the benefit of doubt when it comes to communications skills or perceived intelligent level, but an individuals’ Ethical adherence has no room for doubt. The instructor will explain later in this section that in addition to what the instructor call “text-book” Ethical teaching, the ability to add real world observations and ramifications dealing with a lack of personal integrity can have on an individual’s continued employment status and or career.
ELEG 4247 Fall Semester Ethics Assignment

Our Fall Semester the lecture on ethics covers many topics, among these included are:
(1) How personal Moral values can influence their Ethical value
(2) Why Ethics are important in the Engineering Profession
(3) We cover IEEE Code of Ethics, Software Engineering Code of Ethics, Fundamental Engineering Cannon
(4) Talk in class about a couple of Ethical scenarios

The topic though that get the most amount of discussion is one we call “Thin Ice” as shown in Figure 1.

Real World Implications of a lapse in personal Integrity

There is always a lot of classroom energy when we talk Ethics and personal Integrity, but this “textbook” conversation gets real for the students when I bring in some real workplace situations that have caused loss of employment for those who took a short-cut on Professional Integrity.
Examples like:
- Falsification of lab test
- Invoice Splitting
- Stealing
- Improper use of company credit card
The instructor can mention to the class that he has seen and or has had to terminate employment in some of these situations, and it is very sad to see a person earning 5 and 6 figure salaries with many years of service to lose their jobs.
While it is very important to teach “textbook” Ethics, the instructor thinks the benefit of real-world situations will make it more meaningful to the students.
In the instructor career with ExxonMobil, he has seen more people lose their jobs over what he considers “lapse in personal integrity” than he has seen a violation of Engineering Codes and Standards.
The Ethics assignment in our Fall Semester is an individual assignment not a Team assignment like all other Senior Design activity. The reason the instructor has the individual assignment is he wants to get a gauge of each person’s level of awareness and understanding of Ethics and Personal Integrity.

**ELEG 4248 Spring Semester Ethics Assignment**

For the Spring Ethics Assignment, each team is given a scenario that they analyze and develop a report presentation in class. The instructor prefers to have this presented and discussed in class vs grading as a report. The instructor thinks everyone will benefit when the larger class is involved in the discussion.
As part of the assignment, each team is asked to present/discuss these items:

Your Presentation Deck must include:
- Team Introduction Slide w Picture
- Copy of the actual scenario assigned
- Use Bullet Points to Describe the scenario If needed to make it clear to the audience
- Describe the Ethical Issue
- What are the consequences of the action is carried out?
- What are the correct actions to be taken?
- What did you learn?
- Reference appropriate Fundamental Cannon in your discussions

Presentation Deck must include discussion (where appropriate):
1. Global Impact: The student is able to investigate a given problem, and explain how proposed action could have implications or be adopted in different parts of the world
2. Societal Impact: The student is able to investigate a problem, and explain any societal factors and issues if the action being questioned is implemented
3. Economic Impact: Describe any economic factors associated with this ethical scenario.
4. Environmental Impact: Investigate and describe any a given environmental impact.
5. Safety Impact: Describe any safety issues you uncovered in the scenario
6. Conclusion and Recommendation
Figure 2. shows example of Team Ethics Scenario.

- **Ship or Not to Ship**
  Rachel works as a Quality Assurance Engineer at a large electronics company. She is responsible for the final testing of her company’s servers and is part of a team which decides when new products will be shipped to distributors for sale.
  Rachel’s company has a contract with another company which makes the chips which are incorporated into the servers Rachel’s company makes. The business model for this product is to release a new generation server approximately every six months, meaning Rachel has a limited timeframe to conduct her Quality Control tests.
  Because there is such a short amount of time between the release of each next new product, the Quality and Assurance department cannot perform every possible test on the servers to ensure they are defect free. Rachel will not ship a product if there is any possibility that the server could malfunction and cause physical harm to the customer. However, she will ship a product that has a higher likelihood of failure resulting in data loss for the customer, because she knows that if she doesn’t, her company’s competitor will.

Figure 3. shows the student ethical concerns for the scenario

- The ethical concern for Rachel’s dilemma lies with the IEEE fundamental codes of ethics cannons one, three, and six.
- Each cannon referenced is as stated:
  1. To accept responsibility in making decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.
  2. To be honest and realistic in stating claims or estimates based on available data.
  3. To maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience, or after full disclose of pertinent limitations.
- In reference to these codes, Rachel begins to question her ethical way of thinking over business performance.
  - Is this an ethical way to conduct business?
  - How should she determine when to ship a product with known defects?
Figure 4 shows the impact of consequences of the scenario.

It has been noticed during the time teaching this course, that some students can be a bit naive about the implications and seriousness of not following a strong moral code. Some students might be more willing to accept the “grey area” of a situation where in industry – the Company Brand and Integrity leave little room for grey area. We think by adding some real-world examples to reinforce the “textbook” lecture on ethics will provide a stronger basis and enable students to relate the value that personal integrity will have in their careers. Note to classroom instructors: We understand the experience of the instructor in industry at a high enough management level has given him many examples and experiences that can share with the students. We suggest that if you don’t have personal experience and actual example of poor ethical decisions that you reach out to your network of professional industry partners to either join a lecture or give you some examples you can use in your classroom lecture.

**Senior Design Oral Presentations – Teaching the need for good oral communications skills**

Every senior project team has 3 main deliverables required to satisfactorily complete the course. In no particular order:
- Deliverable 1 - a final and working design project.
- Deliverable 2 - a final written report.
- Deliverable 3 - a final oral team presentation.
In teaching this course, it has been noticed that it’s probably the oral presentation aspect of final deliverables that causes the most anxiety in students. Up until this point in their coursework, most students have only had to perform well on homework and exams, all that have been in a private written type of setting. Now in Senior Design they must stand up in front of a large group of individuals and talk about their work. Good oral communication skills are probably the most relatable soft skill in industry, and one that engineering students get the least amount of preparation or advice. The other aspect of a final oral presentation is the presentation slides themselves. Engineering students get little training on how to develop a quality PowerPoint presentation, so time in class is devoted to providing them some guidance and or methods the instructor has seen used in industry.

**How to improve Presentation Slides**

To develop a final oral project presentation, these are the topics we include in our final presentation (I will show an example of some of these topics)

- **Topic 1 - Introduction and Objective**
- **Topic 2 - Proposed Deliverable**
- **Topic 3 - Customer/Marketing and Engineering Requirements**
- **Topic 4 - Project Comparison of other Solutions Available**
- **Topic 5 - Project Impact on Health/Safety, Society/Culture, Economics, Environmental, Technical**
- **Topic 6 - Project Planning**
- **Topic 7 - Project Parts**
- **Topic 8 - Design Constraints and Assumptions**
- **Topic 9 - Codes and Standards**
- **Topic 10 - Project Preliminary Design and Design Evolution**
- **Topic 11 - Project Final Design with Demonstration**
- **Topic 12 - Literature Review Summary**
- **Topic 13 - Recommendation and Conclusions**

If there are 40 students in class, then there are probably 40 ideas on how to represent these topics in a PowerPoint final presentation. After covering the intent of each topic/section – we talk in class and show examples which have been collected over time to demonstrate the target we are attempting to deliver.

**Don’t overload your presentation deck with too many words**

Tell the students – your oral presentations should be a discussion with your audience and don’t be overly wordy on your presentation slides.

Tell them that the ability to have just the right amount of text and not too much text is more of an art form and not a strict science. It takes time; practice and observing how other presentations are done. You don’t want to give the attendees a reading assignment as they will be reading your slides and not listening to the speaker. Below is an example, can be shared with the class.
This is actually a very thorough explanation of a Safety/Environmental Impact Assessment but is too wordy for a PowerPoint Presentation.

A Lot Of Text

- Accidents with gasoline are a major cause of thermal burns in the U.S. It has been reported that gasoline-related burns account for 13,000 – 15,000 ED visits per year.
- Gasoline vapors/fumes can lead to carbon monoxide (CO) poisoning, according to Consumer Product Safety Commission (CPSC) 820 people have died from CO poisoning from 2009-2019.
- Crude Oil, the substance used to produce gasoline, is also very harmful to environment and difficult to transport. According to research done by the National Oceanic and Atmospheric Administration during the Deep Horizon Accident, oil sank into ground water, caused over 170 stillborn in dolphin population, and lesion and sore on +20% of fish in gulf.
- The aim of this project is a product that uses non-harmful gases and water to maintain power, in order to replace dangerous gasoline.

Figure 5. Example of too much text in a PowerPoint

Now here is the same explanation of a Safety/Environmental Impact Assessment but with fewer words and an emphasis on the most critical message to convey as in Figure 6.

Same Explanation with reduced text

- Gasoline accidents account for 13,000 – 15,000 ED visits per year.
- 820 people have died from gasoline vapors/fumes.
- Deep Horizon Accident, oil sank into ground water, caused over 170 stillborn in dolphin population, and lesion and sore on +20% of fish in gulf.
- This project goal is a product that uses non-harmful gases and water to maintain power.

Figure 6. Same PowerPoint with fewer words on the slide

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Own Your Presentation

The instructor should inform the students that each person on the team will be required to present some aspect of the final oral presentation. Once you have been assigned a section of the team presentation – then they should own those pages. The instructor should tell them don’t just memorize your slides, but they need to know it like they know their last names. In other words, know the information cold.

At PVAMU ECE senior design course, there are a couple of slides that I think are the most challenging to cover. We call the slide below: “The Matrix” as in Table 3; this is one of the most detailed and important slides in the final oral presentation. It is developed to cover the marketing/customer requirements, the engineering design to meet that requirement and why that engineering requirement was selected. This slide was nicknamed the Matrix because the following:

(1) It’s in a matrix table format
(2) When presenting it the speaker needs to be able to slow down and take the audience through each aspect in a clear and comprehensive manner.

Table 3. Example of the matrix slide

<table>
<thead>
<tr>
<th>Marketing Requirement</th>
<th>Engineering Requirement</th>
<th>Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real time detection of faces with and without face masks.</td>
<td>Edge Computing System: Nvidia Jetson Nano Developer Kit.</td>
<td>Nvidia Jetson Nano Developer Kit is a powerful computer that lets you run applications like image classification and object detection.</td>
</tr>
<tr>
<td>Highly accurate face masks detection</td>
<td>Train a deep learning model for high facemask detection accuracy</td>
<td>Reliable Image classification and object detection model.</td>
</tr>
<tr>
<td>Alarm system through sound.</td>
<td>User manual which provides clear instructions on the system implementation.</td>
<td>Anything over 85 dB is considered damaging to human ears.</td>
</tr>
<tr>
<td>Easy to implement and use.</td>
<td>A User-End interface. A screen showing a green rectangle for people with mask and a red rectangle for people without mask</td>
<td>Easily implementable by anyone using the instructions.</td>
</tr>
<tr>
<td>Screen showing face mask detection.</td>
<td>A User-End interface. A screen showing a green rectangle for people with mask and a red rectangle for people without mask</td>
<td>Real time monitoring.</td>
</tr>
<tr>
<td>Lightweight and compact system design.</td>
<td>Nvidia Jetson Nano: 70 x 45 mm dimension and 8.8 ounces weight.</td>
<td>System should be easily transportable.</td>
</tr>
<tr>
<td>Cost efficient.</td>
<td>Price would not exceed $400.</td>
<td>The system should be affordable.</td>
</tr>
</tbody>
</table>
Another very comprehensive slide we develop is the product comparison slide as in Table 4.

This slide is developed to compare the student project design/cost to other options that might already be available. This slide is designed to reinforce literature research and to also put together in once slide a summary of cost along with Pro’s/Cons of various options.

Table 4. Example of product comparison slide

<table>
<thead>
<tr>
<th>Design Options</th>
<th>Initial Cost</th>
<th>Continuous Fees</th>
<th>Pros</th>
<th>Cons</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Threat Detection System</td>
<td>$140</td>
<td>No Monthly Fee</td>
<td>- Weapon Detection</td>
<td>- No remote monitoring</td>
<td>N/A</td>
</tr>
<tr>
<td>(Our Design)</td>
<td></td>
<td></td>
<td>- Machine Learning (ML)</td>
<td>- Twice subscription needed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Real Time Tracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Light Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Text Notifications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GW Security</td>
<td>Starts at $400 to $6000</td>
<td>No Monthly Fee</td>
<td>- 4K Resolution</td>
<td>- No Remote Viewing</td>
<td>GWsecurityusa.com</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Uses ML</td>
<td>- Heavy Camera Equipment</td>
<td>BBB.com</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Right Vision</td>
<td></td>
<td>Amazon.com</td>
</tr>
<tr>
<td>Deep Sentinel</td>
<td>$400 to $1200</td>
<td>Monitoring Fee $60 to $200 per month</td>
<td>- Uses ML</td>
<td>- No Weapon Detection</td>
<td>Deepsentinel.com</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Motion Detection</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Wi-Fi or Ethernet connection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SimpliSafe</td>
<td>Starts at $700</td>
<td>Monitoring Starts at $15 per month</td>
<td>- Smoke, water, carbon &amp; motion sensors</td>
<td>- No ML feature to enhance system</td>
<td>Support.simplisafe.com</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Smart home Integration</td>
<td></td>
<td>Simplisafe.com</td>
</tr>
<tr>
<td>Cove Smart</td>
<td>Starts at $200</td>
<td>Monitoring $16 per month</td>
<td>- A+ rating</td>
<td>- No smart ML features available</td>
<td>Covesmart.com</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Environmental Sensors</td>
<td></td>
<td>BBB.com</td>
</tr>
</tbody>
</table>

In order to cover the above slides and convey your message – it’s critical that the student owning these slides, or any other slides take time before the presentation to really work to own the material.

Some tips we offer students to owning their presentations:
1. Recognize upfront that you can’t wing it and you will need to prepare for it
2. Develop a script and sequence order of how you want to cover the material
3. Create Natural Sections – what topics are be together before you pause
4. Be able to guide the audience as you present
5. Slow down and don’t rush
6. Don’t adlib– stick to the prepared script and order you have planned

**Practice – Practice – Practice**

These presentations need to be well-rehearsed. The individuals and the teams need to absolutely practice – and we don’t mean the week prior to the final presentation. Teams should start to practice together their presentation very early in the Fall semester. Even if the material is still changing, the early adoption of public speaking starts to make the student more comfortable with presenting before
a large group. As part of this course – the instructor will sometimes have a team present to him in a rehearsal format. They absolutely need to practice, and they absolutely need to get constructive feedback early so they can work on any gaps. Practice gives them confidence and makes the presentation more compelling and informative to the audience.

Practice Sessions allow the student and teams to:
1. Gain Confidence
2. Get Feedback
3. Get used to projecting their voice and even hearing their voice
4. Get an idea of how much time it will take to cover material
5. Learn to focus on the audience and not stare at the video screen

Students who have completed internships and/or participation in clubs in the past are more likely to work well in teams, to value communication skills, to identify as engineers, to be confident in their engineering skills, and to complete the course in the spring.¹⁰

**Summary and Conclusions**

In summary, we have described the senior design course as the bridge between the academia classroom and engineering practices in industries with ABET implantations for the electrical and computer engineering department at Prairie View A&M University. The methodology discussed in the paper has made it possible to spot problems encountered by students in the senior design course, by this means facilitating adjustment in course content and delivery, and formulation of plans to assist student’s improvement. The methodology also made it possible to document students’ performance in the ABET outcomes for accreditation. Furthermore, we have showed that the instructor industrial experiences can provide a simple approaches and effective way of teaching capstone senior design courses for underrepresented students to enhance their learning.
References


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Mr. Turner serves as Instructor of the Electrical and Computer Engineering Department at the Prairie View A&M University. Vewiser is a retired Executive from ExxonMobil. Before joining ExxonMobil, Mr. Turner attended Prairie View A&M where he received a Bachelor of Science in Electrical Engineering, and then the University of Texas- Austin to obtain a Master of Science degree in Electrical Engineering. Mr. Turner’s tenure at ExxonMobil lasted 35 years and during this time he rises through the ranks of his company to achieve Executive status. Mr. Turner is also a registered Professional Engineer in Texas.

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Sarhan serves as Professor of the Electrical and Computer Engineering Department at the Prairie View A&M University. His research interests are in AI/ML, computational methods in power systems and energy, control systems, computer networks, and engineering education.