# Bringing Contemporary Issues and Topics into an Electromagnetics Course

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Abstract

Electromagnetism describes foundational principles in the field of electrical engineering. However, in a typical course, the connection to modern engineering topics can easily be missed while focusing on complex mathematics, physics and the mechanics of vector algebra. A final project in an electromagnetics course at Valparaiso University was developed to highlight the continued significance and applicability of this field of study. For this assignment, student pairs selected and presented a reputable article reporting on a contemporary issue directly related to an electromagnetic device, concept or system that was of interest to them.

This project provided students with an opportunity to connect course concepts with modern applications while practicing effective verbal and written communication on advanced technical topics. Allowing students to self-select topics brought autonomy to the course and the freedom to research an application that aligned with their individual interests. Additionally, students gained exposure to a wider range of modern electromagnetics applications including wireless charging, the Tesla solar roof, cellular networks, RFID applications and MRI technology.

This paper presents the details of this project and its implementation in a senior-level electromagnetics course. Samples of student work, instructor and peer assessment of verbal presentations and assessment of the written reports are presented. Further, we provide a brief qualitative analysis of the student experience with this project. Overall, the exercise was well received with impressive and engaging student presentations. This lesson could be further improved by incorporating additional electromagnetic applications throughout the course and highlighting their ethical and societal impacts. These examples will improve students' ability to identify the larger impacts of their chosen topics.

## Project Overview

Connecting theory learned in the classroom with real world applications is a key component of engineering education and provides contemporary relevancy for the learner. James Clerk Maxwell laid the foundation for the entirety of electrical engineering when he provided the equations describing the interactions of electromagnetic fields in the late 1800s [1]. This small set of equations, known as the Maxwell Equations provides the foundation for modern technologies that surround us everyday. Nevertheless, it is common for electromagnetics courses to overlook the many practical applications of electromagnetic theory as the course focus naturally shifts towards the difficult mathematical formulation that support the theories at the heart of the course. For many students, electromagnetics is viewed as abstract and conceptually difficult [2] lacking a concrete connection to practical engineering problems [3].

To combat this view and bring contemporary relevancy to the course, a project was developed to emphasize modern usage of electromagnetics while simultaneously assessing student outcomes of the ABET professional skill 3j: knowledge of contemporary issues. For this project, students identified and presented an article from a reputable source that reports on a contemporary issue directly related to an electromagnetic device, concept or system. Students completed this project in self-selected pairs and were given the autonomy to choose a topic based on their interests.

This project was implemented in a senior-level electromagnetics course at a small, undergraduate institution in the Midwest. There were 40 students enrolled over two sections of the course with all students completing this project. Of the 40 students, 30 were Electrical Engineering majors and 10 were Computer Engineering majors. This project was implemented in the fall 2016 and presented during the last week of a 14-week semester.

There are two main components of this project. Students verbally presented their article and wrote a short essay. These components gave students the opportunity to practice multiple types of technical communication skills. For the verbal presentation, students described the operating principles of the identified technology and related their findings to course concepts during a 3-6 minute presentation. The verbal presentation was given in front of their peers using presentation software to provide visuals. For each presentation, students completed a peer-assessment that was summarized and provided to the presenter. For the essay component, students wrote three paragraphs that 1) summarized the technical information provided in the article 2) identified potential effects of the technology on the engineering profession and 3) discussed societal impacts.

Verbal Presentation Component

Students were given the following guidelines for the verbal presentation. *The presentation will focus on describing how the technology works and the way it relates to the concepts covered in the electromagnetics course. The presentation requires a title slide that should include presentation title, team members' names, date, and an interesting visual related to the topic. The body of the presentation should include a few slides describing the operating principles and the electromagnetics concepts. The end of the presentation should summarize the main points. The presentation should include cited sources for technical information and figures.*

Assessment of Verbal Presentations with Samples of Student Work

Students received feedback from both the instructor and their peers in the form of a peer review. The instructor evaluated six topics shown in Table 1.

Table 1: Rubric for instructor's assessment of verbal presentation.

| **Topic** | **Description** | **Points** |
|---|---|---|
| 1 | Clear beginning and ending with title slide and summary | 10 |
| 2 | Explanation of electromagnetics principle | 10 |
| 3 | Clearly conveyed the "how it works" component | 15 |
| 4 | Overall flow and engaging presentation | 5 |
| 5 | Evaluation of peers presentation | 5 |
| 6 | Summary of peer evaluations of the presentation | 5 |

Topic 1 assessed the title slide, introduction and conclusion of the talk. A presentation that met expectations had an appropriate beginning and ending and included all components required by the presentation guidelines. The average score for the Topic 1 was 9.3/10 and the distribution is shown in Figure 1(a). Over half the presentations received full marks for Topic 1. Minor deductions were taken for missing required items on the title slide or for a missing or lacking summary slide. Presentations that exceeded expectations included practical motivations in the introduction and further applications as part of the conclusion. Examples of slides from student presentation are shown in Figure 1. Figure 1(b) shows an overview slide for a presentation on 5G Cellular Networks and Figure 1(c) shows a summary slide for wireless virtual reality (VR) headset presentation.

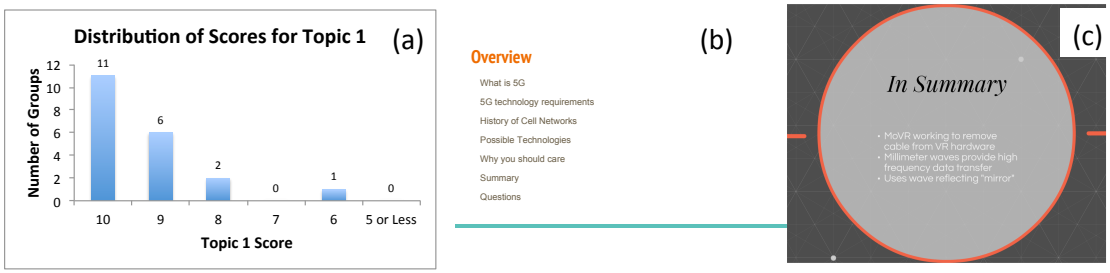


Figure 1: (a) Distribution of scores for Topic 1 evaluating presentations for a clear beginning and ending that includes a summary slide. Examples of student work for beginning and ending of presentation. (b) An overview given near the beginning of a presentation on 5G cellular networks and (c) a summary slide for wireless VR headsets are shown.

Topic 2 assessed the explanation of an electromagnetic principle related to the topic and connection to course topics. Although all student groups included some discussion of electromagnetics concepts, this topic received the most deductions. Presentations that did not meet expectations did not clearly relate the electromagnetics concepts to the topics discussed during the course. However, 7 of the 20 groups received full points with an average score of 8.15/10. More presentations would have met expectations by improving the connections to fundamentals learned in the course with additional information, equations and diagrams. Figure 2(a) shows the score distribution for Topic 2 and slides from student presentations showing how the electromagnetics principles learned throughout the course relate to (b) robotic MRI and (c) supercapacitors.

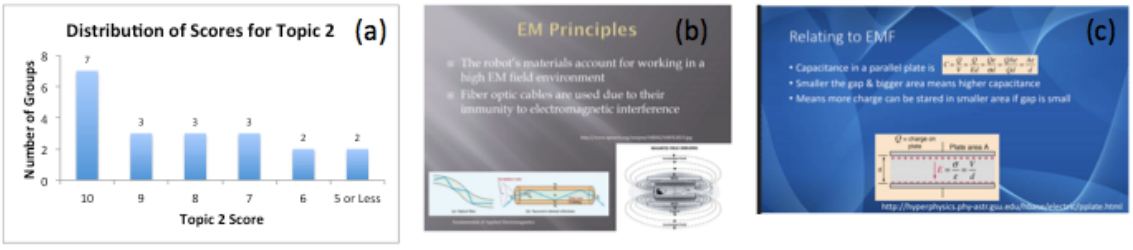


Figure 2: (a) Score distribution for Topic 2 and examples of student work showing slides that relate electromagnetics course principles to applications in (b) robotic MRI and (c) supercapacitors.

Topic 3 assessed the main body of the presentation including an explanation of how the device, concept or application works. The average score for this topic was 13.4/15. Scores were based on the use of visuals, the clarity and thoroughness of the technical details, and for citations included in the presentation. Figure 3(a) shows the point distribution for Topic 3 and Figure 3(b) gives an example of student work for a slide showing how EM-Sense works.

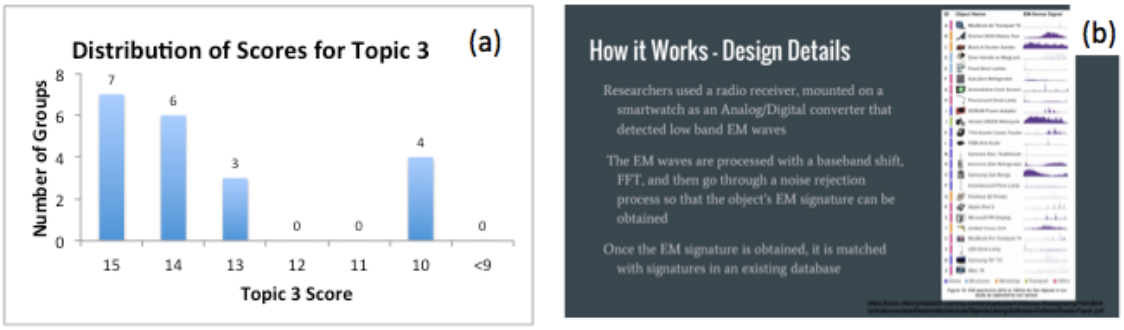


Figure 3: (a) Instructor evaluations of Topic 3 and (b) example of student work showing "How it Works" for EM-Sense.

Topic 4 assessed the presentation's overall flow and how well it held the audience's interest. The majority of the presentations were engaging and the average score in this topic was 4.75/5 with the distribution shown in Figure 4(a). A couple presentations that did not meet expectations could have been more engaging by incorporating better visuals throughout and improving presentation delivery. Another presentation that did not meet expectations needed better organization to improve flow. Topics 5 and 6 assessed students' evaluation of their peers' presentation and reciprocally for peer evaluations of their presentations. Since all students attended and gave feedback for each presentation and all groups received reasonable feedback and suggestions, all students received full marks for both of these topics. The instructor's assessment of the verbal presentation component had an average total score of 45.6/50 with the distribution is shown in 4(b). Student presentations were generally very well done and effective. Making clear connections to course content including major theories and relevant equations could further improve presentations.

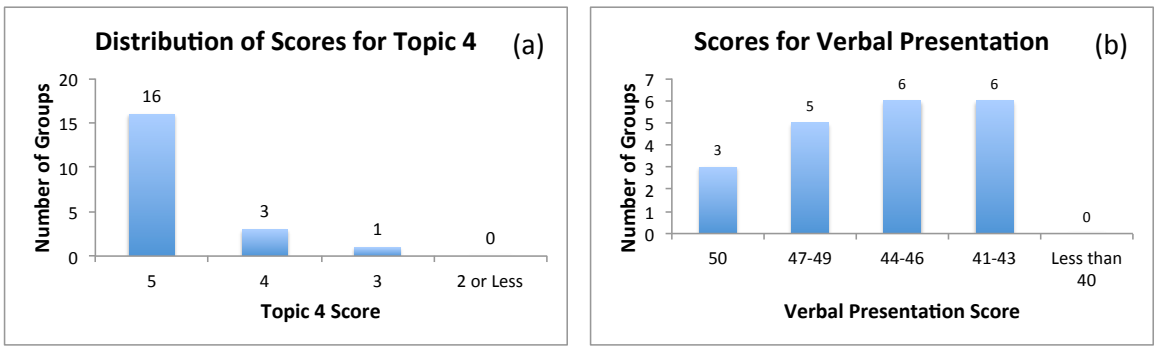


Figure 4: (a) Distribution of Scores for Topic 4 and (b) total score for all topics evaluated in instructor's assessment.

Students assessed their peers' presentations. They were prompted by the question: "What advice would most improve this presenters' next performance?" In response to this question, students

provided 230 meaningful suggestions to their peers. Around 24% of the comments addressed Topics 1-4 from the instructor's evaluations described above. Some samples of comments addressing these topics are given:

- "Explain more on how the mirror works"
- "Explain why millimeter waves are preferred over other waves"
- "Relate concepts more carefully to your topic"
- "More on how it relates to EMF"
- "I enjoyed the clips. Some more information on EM concepts would help."

Many comments (36.5%) were concerned with the verbal presentation delivery and gave suggestions on improvement. Peer comments in this category include the following:

- "Speak louder and review the presentation beforehand"
- "More energy"
- "More confidence at start of presentation"
- "A little more concise at times when talking off the slide"
- "Speak less monotone"

Peer comments also commonly suggested improvements to slides and visuals. Around 31% of advice concerned the presentation visuals. Examples of student comments include:

- "Graphs need to be bigger"
- "Make sure text isn't covered by images"
- "Better picture organization"
- "Make font more visible. Difficult to see white text on light background."
- "Limit text on some slides"

Around 9% of peer comments gave only positive feedback on a presentation. Examples of these responses include:

- "Great use of phone prop"
- "Overall, great presentation, I enjoyed the impact slide"
- "Great job!"
- "Very in depth presentation"
- "Good explanation of device"

According to both peer and instructor assessment of the technical content of the presentations, improvement is most needed in clearly explaining a course concept. Peer advice for improving presentation delivery and visuals is beneficial for improving students' communication skills.

Written Report Component

Students were given the following guidelines for their project. *The essay based on the contemporary issue article will be one-page and consist of three paragraphs. In the first paragraph, summarize the technical information given by the article. In the second paragraph, describe the effect this issue will have on the engineering profession. These effects could include the development of new supporting technologies, new ethical considerations and/or new types of engineering work that will need to be done. In the third paragraph, summarize the impacts of society including increased efficiency, health concerns or new business opportunities.*

Assessment of Written Reports with Examples of Student Work

Each paragraph of the written component of the assignment was assessed for one of the university's defined sub-criteria regarding ABET Student Outcome 3j: knowledge of contemporary issues. There are several challenges in finding appropriate methods to assess student knowledge of contemporary issues [4]. The main objective of this project is to emphasize modern electromagnetic applications and identify connection to fundamental principles. Therefore, a natural extension of this project is to assess student understanding of the factual knowledge related to the contemporary issue, the effects of the issue on the engineering profession, and its impact on society outside of engineering. Our assessment rubric is divided into four categories: exceeds, meets, progressing and unsatisfactory.

The first paragraph of the written essay was assessed for factual knowledge. To meet expectations, knowledge of the facts related to the issue and an ability to succinctly summarize are necessary. Assessment results show that almost all students (95%) met or exceeded expectations. Figure 5 gives a sample of student work summarizing factual knowledge of a contemporary issue article.

Nikola Tesla was one of the founders of wireless charging. He theorized that electromagnetic fields could be used to transfer power from one object to another. The foundation of wireless charging is based on inductance. When current passes through an inductor, an electromagnetic field is produced around the inductor. This field is able to induce a voltage in a nearby object, thus allowing power to be transferred between two devices. The problem with this technology is that electromagnetic field strength decreases rapidly as the distance between devices increases, which makes it difficult to transfer power over great distances. Recent advances in technology have helped make wireless charging more efficient. As electronics have gotten smaller, more coils of wire are able to be wrapped around an inductor. Since the amount of charge transferred is proportional to the number of turns around an inductor, an increase in wire loops would allow for more power to be transferred. Some wireless charging devices have featured transmitters that dictate if a device should receive power. This allows a device to communicate with the charging station. A device is then able to tell the charging station that it is authorized to receive power, and is able to specify how much power needs to be transferred. This increases efficiency of wireless charging, since a charging station is only generating power when it is needed, and for devices that need to be charged.

Figure 5: Sample of student work demonstrating factual knowledge of a contemporary issue.

Students' ability to identify effects on the engineering profession was slightly weaker. To meet expectations, students needed to understand how the contemporary issue affects the engineering profession including how it could lead to development of new technologies, systems and products or lead to the development of new ethical issues. 70% of students met or exceeded expectations in this category. Presentations that did not meet expectations needed more details and specific examples of effects on engineering. An example of student work analyzing effect on engineering is given in Figure 6.

The MoVR system demonstrates the ability of engineers to scale and repurpose existing technologies. Millimeter waves are by no means a new technology, since we see their application in radar and satellite transmission. However, MoVR introduces this concept to a much smaller scale and opens new potential for its application. Additionally, we could see this type of technology used in Internet of Things applications because of its ability to track and reflect multiple signals within the same space.

Figure 6: Sample of student work analyzing the contemporary issues effect on engineering.

To meet expectations for identifying the issues potential effects on society, an awareness of the issues effects on society outside engineering potentially impacting the safety, health and welfare of the public must be shown. Students' performance analyzing the effects on society was similar to their performance identifying effects on engineering with 75% meeting or exceeding expectations. In general, more groups could meet expectations for this sub-criteria by including more details and specific examples. A paragraph showing a student pair's summary of the issues' effect on society is given in Figure 7.

Not only can these capacitors change engineering, they can greatly improve society as a whole. As was mentioned earlier, these capacitors can be put into pacemakers and other medical devices. This can reduce the cost of healthcare and make certain treatments more widely available. It also has applications in the energy industry. Since it will take much less room to store energy and cost less to do so, it can reduce the cost of energy in general and since it has low power loss, it can be much more than todays technology.

Figure 7: Sample of student work summarizing the effect on society.

Students' ability to analyze the effect of contemporary issues could be improved by incorporating more electromagnetic applications throughout the course and highlighting their ethical and societal impacts. Exposing students to more examples would better prepare them to identify broad impacts.

Analysis of the Student Experience

Students were given a survey after the conclusion of the course when the majority of them had graduated and entered the workforce. The student feedback shows this project successfully connected electromagnetic topics learned in class with modern engineering applications. Student feedback regarding this project includes:

- "I learned about new topics in electrical engineering and how the information I was learning in class applied to those topics."
- "I learned through the project that there were more real life applications to the homework that I was doing. I felt that the project showed how the homework could be applied to real issues."
- "The project helped in making that connection [between modern engineering applications and electromagnetics principles learned in class]. So often in classes

we get caught up in the details of what we are learning that we forget why we need to learn it."

## Conclusion

This paper presents a project for an undergraduate electromagnetics course that links modern engineering applications to fundamental electromagnetic principles learned in the course. Students presented a reputable article that reports on a contemporary issue directly related to electromagnetics. This project also assessed students' knowledge of a contemporary issue corresponding to ABET Student Outcome 3j. Overall, student presentations exceeded expectations. Students provided a modern perspective on electromagnetics by linking contemporary issues with concepts learned in the course. This project highlights the importance of incorporating contemporary issues to provide students with a better understanding and appreciation of electromagnetics principles. In the future, incorporating more examples of modern electromagnetics applications throughout the course and highlighting their effects and impacts would better prepare students to engage the course material.

## References

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