The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41544

Incorporating History Lessons into a Second-Year Mechanical Engineering Seminar

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Introduction

Unlike the other major professions with which engineering shares a common set of principles (e.g., medicine, law, and teaching), there are very few examples of engineering in popular American culture, especially considering how frequently the other professions appear in media and various forms of entertainment. Unfortunately, even fewer of those examples can reasonably be thought of as realistic or authentic, which limits the opportunities for the public to truly understand and appreciate what engineering actually is. As a consequence, it is a fairly well-known phenomenon that the vast majority of high school students who pursue engineering do so because someone in their life is an engineer or someone close to them (e.g., a parent, teacher, or family friend) recognized their affinity for mathematics and science and encouraged them to pursue the profession. Other less commonly cited motivations for pursuing engineering are job prospects post-graduation, general interest in engineering, and a desire to contribute to society. While these motivations portray a general understanding of how engineering is perceived as a job, they do not mean that they have a meaningful understanding of the profession. In fact, the literature suggests that most students do not actually understand the nature of engineering practice upon entering a program, nor do they have any knowledge of the history of the profession (e.g., why many practicing civil engineers need a professional license to work in the U.S.) [1-11]. For example, consider this student's perspective,

> *"Honestly, no, I had no idea what engineering was, I was just like, 'Okay, math and science school; we got it,' and then like somehow that just kind of became synonymous with engineer-, with that definition. They're like, 'Oh you can be an engineer,' I'm like, 'Okay, I guess so?' And I only really got a feel for what I'd be doing [after I got] up here....I don't know what it [engineering] is." (p. 12, [12])*

This frame of mind is pervasive among students in their first year of a program. However, there is also evidence to suggest that students still do not understand the nature of engineering practice upon graduating from an engineering program, especially when their engineering design experience is limited to a single capstone project undertaken in their final year [13-15].

Despite the fact that engineering and scientific knowledge has grown at an astonishing rate over the past century, engineering still only nominally requires 4 years of training (i.e., a bachelor's degree) to be able to enter and operate in the engineering workforce. For comparison, the number of years of training needed to practice law has increased from 4 to 7 and to practice medicine has increased from 3 to 10 over the same time period. Given the breadth and depth of the technical knowledge students need to master, there are very few opportunities to incorporate additional non-technical material into most technical courses, especially the engineering science courses [7, 16]. These engineering science courses occupy much of the middle two years of a typical engineering program and serve as the underpinning for advanced specialization courses as well as in the engineering design process. As a result, students are learning engineering science content without being primed to consider it with a more holistic perspective of how this material is used in the broader engineering design process, which considers many complex relationships between clients, stakeholders, and society.

One aspect of engineering education that has recently been identified and highlighted by discipline-based education researchers is the fact that engineering has mainly been taught in an apolitical and asocial vacuum [17]. Specifically, graduates from an engineering program leave with the overall impression that engineering decisions made in the real world are completely objective and without bias. General consensus in the field firmly believes that engineering and science can be separated from political and social concerns as long as “rigorous” engineering and scientific methods of design and inquiry are followed. But if we consider some recent history of engineering, we find many examples and exceptions that disprove this supposed neutrality rule [18-20]. From the Space Shuttle Challenger disaster [21] to the Volkswagen “Dieselgate” scandal [22] to Democratic Republic of Congo conflict minerals ethics [23] to COVID-19 vaccinations [24], decisions regarding and perceptions of engineering and science are often at the mercy of domestic and international political and social considerations. A primary objective for this work is to reframe how students view their undergraduate engineering education, specifically as it relates to developing a deeper understanding and appreciation of the true nature of engineering practice.

This work aims to partially fill this void in our educational discourse by enculturating students into the engineering profession by describing where we have been as a field to better understand where we are now and how they as future professional engineers can lead us to where we need to be. Many of the major problems that future engineers face extends beyond the borders of any one country (for example, climate change, creating a resilient globalized supply chain, sustainability, and equity and access to basic essential services like medical care and clean water). Engineering students should be educated about the depth and complexity of this reality. It should also be noted that many students (especially women) tend to leave engineering after their first or second year due to significant drops in their self-efficacy and the perception that struggling with the material means they are not a good fit for the major [25]. Importantly, it has been shown that providing historical examples about the struggles of accomplished scientists like Albert Einstein, Marie Curie, and Michael Faraday can aid in reconstructing 9th and 10th graders’ perceptions of who belongs in STEM [26]. Thus, engagement with the historical examples offers a unique opportunity to explore how students’ perceptions of engineering practice change and whether a better understanding of what engineering is leads to gains in intention to persist in an engineering program.

There are very few studies in the literature that have investigated the impacts of exposing students to the history of the profession or the impacts of contextualizing engineering science and judgement on students’ understanding of engineering practice. The work presented here centers on the curriculum development and redesign of a required second-year seminar that historically focuses on the specifics of the program.

Methods

In the Mechanical Engineering program at the University of Iowa, second-year students are required to attend a program seminar intended to educate students about the program and profession for which they are currently being trained. This seminar meets one time a week for 50-minutes and serves as an opportunity for students to get better acquainted with what they can expect from their next 3+ years in the program in terms of coursework and potential extracurricular activities. As a result, the seminar has been limited in recent years to a third of the semester that focused specifically on the aspects of the program itself (e.g., required curriculum, technical electives, and student design groups). Following an internal grant provided by the Office of International Programs, the seminar was redesigned for the Fall 2023 semester to also include context for engineering as a profession with an emphasis on engineering domestically and internationally. The topics for each week are presented in Table 1 below. Enrollments in the course over the past decade range from 98 to 150 students, with a mean of 118. In the Fall semester of 2023, enrollment was typical with 116 students. At the end of each semester, students enrolled in the associated courses are invited to participate in a survey, which consists of Likert-type items regarding their intention to persist and open-ended questions regarding their perceptions of the nature of engineering practice. The open-ended questions will be coded and analyzed, the preliminary results of which will be presented here.

Table 1: Scheduled topics with brief descriptions of what is covered by the seminar.

Week	Topic	Description
1	Introduction	Introducing the class to the instructor, brief description of the topics covered in the course, illuminating some of the possible career pathways for mechanical engineers.
2	International Beginnings of Formal Engineering Education	Description of how, where, and why formal engineering education came to be with emphasis on the military origins and how that influenced the profession's trajectory.
3	Differentiating STEM Fields	Discussing how science, technology, engineering, and mathematics are different from but related to one another and the consequences of the Morrill Land Grant Acts.
4	Accreditation and Professional Licensure	Context for what happens when engineers fail (e.g., St. Francis Dam Failure and Quebec Bridge Collapses) and the history of how accreditation and professional licensure are safeguards to prevent as many future failures as possible.
5	Engineering Subdisciplines	Documenting how different engineering subdisciplines branched off from civil engineering as STEM fields advanced as well as possible specialization areas for students in the ME department.
6	Occupations vs Professions	Discussing how professions are held to different standards than occupations, the Code of Ethics for engineering, and the role of professional engineering societies.
7	Engineering in Public Policy	Diving into how public policy, particularly priorities of any given administration, influences all engineering sectors with emphasis on how the military industrial complex invariably relates to job prospects post-graduation.
8	History of Engineering at [name of university]	Covering the establishment of engineering programs at the university, the ways they have (or have not) changed over the years, and how engineering at the university has served the wider public in recent years.
9	Certificates	Discussing one of the unique specialized certificate programs that is offered through the ME department and job prospects with that certificate.
10	Communication	Describing the importance of the different modes of communication (e.g., design reviews, memos, and codes) what happens when engineers fail to communicate well.
11	The Job Search	A presentation about the different resources available through the College of Engineering to find an internship, co-op, and/or job following graduation.
12	Engineering and the Economy vs the Environment	Documenting different types of engineering companies, how engineering can affect the environment, the importance of sustainability, and how engineering contributes to and drives economies.
13	Higher Education in Engineering	Discussing how different advanced degrees (in and outside of engineering) can help someone pursue different career pathways and a panel of current graduate students.
14	Wrap-Up and Reflection	Students can ask any remaining questions they may have about the program and reflect on what they learned about the nature of engineering practice over the semester.

Example Lecture: Week 3 – Differentiating STEM Fields

Since the first year of most engineering programs consists of mainly science and mathematics courses, it was pertinent to explicitly describe how engineering is different from these fields and how technology interacts with them. The lecture extended these topics to also cover STEAM, where the 'A' stands for art. The notion of combining art into these fields that are usually viewed as inartistic has discovered a resurgence in the importance of its role in engineering. It was viewed as important to acknowledge to the students the benefits of being a well-rounded engineer that is capable of more than just mathematics and science. In 1875, a prominent American mechanical engineer for his time, Alexander Holly, argued that all the great engineering successes he was witness to were the result of art rather than science [27]. In fact, he maintained that the aim of college education was to train "*artisans of good general education*," emphasizing that "*the art must precede the science*" [27].

This viewpoint was pervasive in his time, as can also be seen as alluded to in the Morrill Act of 1862, which helped create more than 50 land grant universities to "*benefit the agricultural and mechanical arts*" [28]. An early amendment to this act included engineering in this effort. These new land-grant institutions opened opportunities to farmers and other working people who had been excluded from higher education. To facilitate this initiative, the federal government contributed land to public education (or private education in the cases of MIT and Cornell University). How this land was procured highlights the terrible cost of a movement that engineering, and the US, greatly benefits from to this day. Much of the land was taken from Native American tribes in which it was ceded through treaties (many of which remain unratified), agreements, and forcible seizures. Tribes were often forced to sign treaties ceding land because of their living conditions or threats of violence, and the federal government often failed to uphold its end. Over 10 million of the 17 million acres provided were expropriated from tribal lands. This land was given to these institutions to either use for their educational activities or sell it and use the proceeds as startup funds. Today, 500,000+ acres remain in trust for at least 12 universities, in defiance of that understanding. In the 2019 fiscal year alone, those lands produced more than $5.4 million in revenue [29]. Even though the University of Iowa is not a land-grant institution, the lands it inhabits is located on the homelands of a number of tribes. At this point in the lecture, the university's Indigenous Land Acknowledgement was read to recognize a significant cost borne by a small group of people that ultimately facilitated the engineering field, as well as the entire country, to reach present day's heights.

However, it was important to note that while these public institutions certainly opened up possibilities for many people who were historically excluded from higher education, these opportunities were not enjoyed by all members of the public equally. For context, the American Civil War over states' rights to own slaves occurred between 1861-1865, which means people of color were excluded from these institutions discriminatorily and pervasively. Thus, the Second Morrill Act of 1890 was aimed specifically at the former Confederate states and sought to rectify this discrimination. It required states to either establish separate land-grant institutions for black students or demonstrate that admission was not restricted by race. Unlike the first act, this second one granted money instead of land and resulted in the establishment of 19 historically black colleges and universities. In a similar vein, an additional 36 tribal colleges and universities were designated as land-grant institutions in 1994 to primarily serve Native American populations that are typically located in remote, underserved communities that lack access to higher education. These institutions include culturally relevant curriculum and programs so that Native American students and communities can take pride in their cultural and historical identity.

Land grant institutions transformed engineering education in the US and boosted the country into a position of leading in technical education. There were about 7,000 engineers in 1880, or about 0.01% of the US population of just over 50 million. By 1900, there were roughly 40,000 engineers, or about 0.05%

of the US population of 76.2 million. By 1911, the US was graduating about 3,000 engineers per year (population of 92.2 million) whereas Germany, another leader in technical education, was only graduating 1,800 engineers per year (population of 65 million). Note that in just 50 years after the passage of the original Morrill act, the US became a leader in technical education and training engineers. This positive trend continued in 1920 with 136,000 engineers and in 2000 with 1.7 million engineers.

We then turned our attention back to differentiating STEM fields. From the NRC, a key feature of science is its dedication to seek understanding of the natural world [30]. Science is seen as the pursuit of knowledge for the sake of knowledge. Engineers frequently use this knowledge in their analyses to better understand how their designs will behave under different operating conditions and use that insight to iterate on their designs. Next, technology is a little more nebulous compared to the very well understood definition of science. The definition presented to the students was also offered by the NRC – technology is intended to make modifications to the natural world to meet human wants and needs [30]. It can be viewed as any product or process that simplifies life, which in the present day can be viewed as software or computer/industrial architectures. Technology is sometimes the output of engineering, but it also facilitates engineering. Next, AAAS defines mathematics as the science of patterns and relationships [31], to use logic to understand and prove relationships between quantities and objects, which may not relate to real phenomena. Mathematics is unique in that it provides an exact language for science, technology, and engineering. Thus, we arrive at the definition of engineering from ABET, or engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to economically utilize the materials and forces of nature for the benefit of mankind. This definition nicely summarizes the lecture.

Example Lecture: Week 7 – Engineering and Public Policy

To illustrate how politics influences engineering, this lecture starts by listing the imperatives of engineering defined by an engineer turned historian, Eugene Ferguson. Mechanical engineer by training and founding member of the Society for the History of Technology, Dr. Ferguson's book, *Engineering and The Mind's Eye*, argued that the engineering education system that ignores nonverbal thinking will produce engineers who are ignorant how the real world differs from the mathematical models constructed in academic minds [32]. The imperatives served as a characterization and a criticism of the field. They are as follows: 1) strive for efficiency, 2) design labor-saving systems, 3) design control into the system, 4) favor the very large, the very powerful, or –in electronics– the very small, and 5) tend to treat engineering as an end in itself rather than as a means to satisfying human need. Most of these imperatives can be traced back to engineering education's military origins. At this point, the lecture highlighted how many engineering endeavors operate at very large scales that require government funding or satisfy government priorities. For students interested in higher education beyond their Bachelor's, engineering and public policy Master's programs were offered as options for people who feel passionately about this intersection.

A refresher on American civics was then covered to better help students understand the mechanisms through which the government and public policy influence the trajectory of engineering. First, we discuss how the federal budget is a part of public policy, specifically as a bill that needs to be approved by both the legislative and executive branches of the government. Students are reminded that everyone in both of those branches are supposed to advocate for whatever is in the best interests of their constituents. The bills are developed with input from the heads of various departments and units within the government. It is then highlighted that the federal government is consistently the largest funder of research and provided more than half (53%, or around $45 billion) of the total funds spent on research in the US in 2019. Six agencies provided more than 90% of that federal support for research and development, namely: 1) Department of Health and Human Services (HSS), 2) Department of Defense

(DOD), 3) Department of Energy (DOE), 4) Department of Agriculture (USDA), 5) National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF) [33]. The heads of the first four organizations are members of the US President's Cabinet, though they are confirmed by the Senate. The heads of the last two organizations are nominated by the President with input from the Senate, who are then confirmed by the Senate. Thus, we can see how the priorities of any given administration contribute to the direction of engineering through academia.

The lecture then continued by taking a closer look into the DOD's federal budget for the 2023 fiscal year with special attention paid to the categories of procurement and research, development, testing, and evaluation [34]. We looked at the list of the top DOD defense contractors and compared that with the companies that are profiting the most from war by monitoring military-related hardware sales. We then introduced the military industrial complex (MIC), or the informal alliance between the military and the defense industry that supplies it. Together, both parties act together as a vested interest that invariably influences public policy. The military obtains advanced weapons and technology while the providing defense industry is paid for supplying it. We briefly discussed the fact that this symbiotic relationship is not a new one but was first identified by President Dwight D. Eisenhower, who warned of its potentially detrimental effects in his 1961 farewell address. Before the end of the Cold War, there were dozens of significant defense contractors. However, following a meeting between the heads of these companies and the Pentagon spurred a great consolidation in the defense industry [35]. In the wake of the post-Cold War era, the peace meant a significant drop in defense spending, more than 15%. The leaders of the Pentagon recognized this trend and encouraged the defense industry to consolidate. Today, dozens of significant defense contractors became five enormous companies: Boeing, General Dynamics, Lockheed Martin, Northrup Grumman, and Raytheon. It was pointed out that these companies look like standard additions to any engineering career fair. The lecture offered suggestions that collectively could lead to dismantling the Iron Triangle like campaign-finance reform, removing the revolving door between the weapons industry and government, generally shedding more light on the defense industry's funding of political campaigns, think tanks, and Hollywood, and prioritizing investments in the jobs of the future in areas other than defense like green technology and public health.

The lecture then describes another specialization area offered through the ME department called the artificial intelligence, modeling, and simulation (AIMS) certificate programs. A subset of ME faculty were awarded a grant through the Department of Education (providing yet another opportunity to highlight the importance of public policy in guiding engineering education and curriculum) to develop these programs. Pertinent to this seminar's audience, the undergraduate certificate aims to teach students the importance of uncertainty quantification, the various types of combinations of machine learning approaches (e.g., modeling and simulation assisted machine learning and machine learning assisted modeling and simulation), and how hybrid models can be used to design intelligent complex machines.

Example Lecture: Week 10 – Communication

This final example lecture focused on the realities of engineering practice with respect to communication. For example, new engineers report spending 60% of their time interacting with other people, about 32% of which is verbal and the remaining 28% is in writing [14-15]. Engineers observed in that study had little hands-on involvement. This fact highlights how engineers' work is indirect and frequently emerges through other people. The instructor took the opportunity to highlight that many engineering jobs will not involve a hands-on component the way people frequently conflate engineers with mechanics. Thus, it is essential for an engineer to possess strong communication skills to avoid preventable situations like the National Oceanic and Atmospheric Administration (NOAA) satellite mishap [36]. Table 2 lists several important modes of communication that engineers employ.

Table 2: Modes of communication covered by the lecture.

Mode	**Definition**
Design Reviews	A way for teams to communicate their progress and concerns about a design
Inspections	Contain numerous photographs depicting an artifact to help the audience visualize an artifact's condition
Presentations	Verbally and graphically present designs/results to colleagues
Public Meetings	Communicate what plans or decisions are being made on a project
Lab Reports	Factual presentations of experiment results completed in a lab or simulation
Project Notebooks	Contains notes of all your work for longer projects
Progress Reports	Communicate the status of work or when a milestone is reached
Proposals	Present a topic to be researched or a plan of action – convince recipient that a particular engineer or firm is the right choice for the job
Operating Procedures	Ensure that the artifacts they create are properly utilized and maintained
Specifications and Codes	Codes help engineers write specifications for a design – sometimes technicians read specifications to help them maintain equipment
Emails, Memos, Business Letters	Every project you work on will demand that you communicate with other engineers and clients about your work
Policy Statements	Specific procedures that help ensure safety for operations

Throughout the course, the instructor provided students with examples of "The Good, the Bad, and the Ugly of Engineering." This teaching strategy is an attempt to incorporate real examples of engineering that have changed our way of life in ways we often do not readily recognize (Good), engineering that failed in ways that usually cause injuries or deaths (Bad), and engineering that was irresponsible or unethical in some way (Ugly). Each one of the modes of communication described in Table 2 is accompanied by an example of either Bad or Ugly Engineering to emphasize the importance of honing their communication skills while progressing through the ME program. Examples included the F-35 Lighting II fighter jet, I-35 Mississippi River Bridge Collapse, Hyatt Regency Walkway Collapse, Bjork-Shiley Convexo-Concave (BSCC) Heart Valve, Sapa Profiles aluminum scandal, Mariner 1 rocket mishap, Goodrich Aircraft Brake Scandal, Japan Air Lines 123 disaster, Volkswagen Defeat Devices scandal, Florida International University (FIU) Pedestrian Bridge Collapse, and Bhopal Disaster. A couple brief descriptions of the examples are offered next.

The Sapa Profiles aluminum scandal was used as an example of Ugly Engineering for the Lab Reports mode of communication. The company faked test results and provided faulty or lesser quality materials to hundreds of customers over nearly two decades [37]. The company falsified certifications after altering the results of tensile tests designed to ensure the consistency and reliability of extruded aluminum. One of the biggest customers affected by this falsehood was NASA, for which they incurred more than $700 million in losses and two failed satellite launch missions. The Taurus XL rocket was supposed to deliver satellites studying the Earth's climate during missions carried out in 2009 and 2011. The clamshell structure of the rocket fused together during the ascent through the atmosphere and could not open to release the satellites. Norsk Hydro ASA, the parent company of Sapa Profiles, agreed to pay $46 million to NASA, the DOD, and other wronged customers. Additionally, Sapa Profiles pleaded guilty to one count of mail fraud and was permanently barred from US federal government contracting.

Next, the Mariner 1 rocket mishap was used as an example of Bad Engineering for the Project Notebooks mode of communication [38]. In 1962, the Mariner 1 rocket was built to conduct the first US planetary flyby of Venus. Unfortunately, shortly after liftoff, errors in communication between the rocket and ground-based guidance systems caused it to drastically veer off course and had to be destroyed by range safety. In the subsequent investigation, it was found that the hand-written guidance equations contained an "R" instead of the "$\bar{R}$" that should have been in its place. The variable, R, denoted the rocket's *instantaneous* distance from the platform in the horizontal plane. The bar notation indicated an *averaged* distance, which removed spurious estimates from sensor noise. Since the bar notation was missing, the software based on those equations was incorrect. The resulting commands caused the rocket to make unnecessary course corrections that threw the spacecraft off course.

Finally, the FIU Pedestrian Bridge Collapse was used as an example of Bad and Ugly Engineering for the Emails, Memos, and Business Letters mode of communication. The bridge was built using accelerated bridge construction methodology [39]. With this approach, elements of the bridge are prefabricated elsewhere and then lifted into place. This approach is meant to be more cost effective, reduce inconvenience due to road closures, and overall faster construction time. Due to missing analyses as well as poor design choices and construction techniques, the bridge collapsed only 5 days after the bridge's main span was completely assembled and lifted into place, killing 6 people and injuring 10 more. Pertinent to this lecture, the subsequent OSHA Investigation Report highlights that every partner involved in the project was aware of cracks in the bridge growing daily for reasons they did not understand, and yet not one exercised appropriate engineering judgement to close down the road below for the safety of motorists and construction workers alike. In part, this failure of judgement was due to failure to communicate between various parties, like when the engineer of record left a voicemail with the Florida Department of Transportation about the growing cracks that was not received until after the collapse.

Results and Discussion

In Fall 2023, 116 students were enrolled in the required mechanical engineering program seminar. The response rate for the survey distributed at the end of the semester was about 74%, or 86 students. Of those students, 13 students chose not to answer the open-ended question at the end of the survey asking them to share their perceptions of the nature of engineering practice. Of the 73 students that did share their perceptions, there were nine themes that appeared in multiple answers. Organized from most common to least common, the themes were: 1) problem solving, 2) improving designs or improving the human condition, 3) utilizing knowledge, 4) ethics, 5) safety, 6) complexity, 7) efficiency, 8) collaboration, and 9) specific career pathways.

Forty-two students (or 58%) explicitly stated that the nature of engineering practice includes or relates to solving problems. For example, consider this student's perspective that highlights the problem-solving theme as well as the importance of utilizing knowledge (mentioned by 18 students, or 25% of the respondents),

> *"I think being a professional engineer is someone who obviously solves problems. But mainly as a group with others and has to think outside the box. That's why the majority of our classes are hard I believe not so much because we are gonna need to use a lot of the things we learned but we are learning how to think and solve problems*."

This interpretation of the rigor of an engineering program is unusual. This student reframed the difficulty of the curriculum not as a way to weed students out, but instead as an opportunity to learn how to think critically about and how to interpret complex problems.

The second most mentioned characteristic of the nature of engineering practice related to improvement with 39 students (or 53%) highlighting its importance. Here is an interesting perspective that mentions problem-solving, improvement, safety, complexity, and specific career pathway themes offered by another student,

> *"Being an engineer means to ask questions that have no answers. It is to problem-solve and dissect global issues and make improvements to elements around the world. I hope to be working with vehicles or machines to improve safety and global impact. I also want to help manage climate change."*

It is unusual for engineering students to understand this early in their programs that engineering problems do not necessarily have "right" answers like what they are used to seeing in their math and science courses. This student highlights the fact that engineering problem solving does not happen in a vacuum – that solutions have to be considered with respect to the context in which they are being applied. This student was among 13 others (19%) who identified how complex the types of problems they will likely be asked to solve as engineers. Also, this student's desire to work on solutions to managing climate change is likely something they entered the program with, but it seems their experiences in the program thus far have confirmed that engineering as a profession is a suitable career path given their passion and interests. Only 8 students (11%) mentioned a specific career path in their description of the nature of engineering practice.

Ethics and safety were identified at similar frequencies by 16 (22%) and 15 (21%) students, respectively. For example, consider this student's takeaway from the course that highlights problem-solving, improvement, safety, and ethics,

> *A great definition of engineering I learned from the seminar is "creative design under constraint". I think I will be problem solving for solutions to benefit the safety and welfare of the public as an engineer.*

Every lecture, the students were reminded that their duty as future engineers is to consider the safety and welfare of the public when they are practicing engineering. We talked about how a code of ethics also acts as protection for them when they are faced with a difficult situation to do what is right versus what their superiors want. This attention to their duty to the public was also reiterated by other students as well.

The final two themes to be discussed are efficiency and collaboration, which were mentioned by 12 (16%) and 9 (12%) students, respectively. Consider this student's interpretation that highlights problem-solving, improvement, ethics, efficiency, and collaboration,

> *I believe that being a professional engineer means that you keep the up most ethics and standards in your pursuit of a better, more innovative future in your field. I believe the majority of the problems I will be facing as a professional engineer will be in regard to developing working solutions that are cost effective, time effective, stay within the constraints of the consumer and government regulations, and have the appropriate engineering staffing to get the job done.*

While this student's response is one of the more thorough in the dataset, it is offered as evidence of the potential for students to grasp a more holistic understanding of what the profession is early on in their academic career.

Conclusion

The purpose of this work was to describe the curriculum development and redesign of a required second-year seminar for students in the Mechanical Engineering program that historically focused on the specifics of the program itself. With data collected from an open-ended question on a survey distributed on the last day of class, preliminary evidence does suggest that some students are possibly updating their perceptions on what it means to be a member of the engineering profession. Future work includes conducting semi-structured interviews with students to better understand how the seminar influenced their perceptions and what other activities or experiences also contribute to those changes as well.

References

[1] S. Condoor, "Importance of teaching the history of technology," *IEEE Frontiers in Education Conference,* vol. 1, pp. T2G7-T2G-10, 2004.

[2] K. C. D'Alessandro, M. K. Swenty and W. N. Collins, "Integrating History into Engineering Curriculum," *American Society for Engineering Education - Southeast Section,* pp. 1-7, 2014.

[3] N. Dabbagh and D. A. Menascé, "Student perceptions of engineering entrepreneurship: An exploratory study," *Journal of Engineering Education,* vol. 95, no. 2, pp. 153-164, 2006.

[4] M. Davis, "Defining “Engineer:" How To Do It and Why It Matters," *Journal of Engineering Education,* vol. 85, no. 2, pp. 97-101, 4 1996.

[5] A. Picon, "Engineers and engineering history: Problems and perspectives," *History and Technology,* vol. 20, no. 4, pp. 421-436, 2004.

[6] A. Gaynor and G. Crebbin, "How can engineers learn from the past? A potential role for history in engineering education," *Int. Journal of Engineering, Social Justice, and Peace,* 2(2), 43-54, 2013.

[7] A. Genau and A. Millard, "Reclaiming General Education: History for Engineers," *American Society for Engineering Education,* pp. 1-10, 2018.

[8] P. Giangrandi and C. Mirolo, "Enhancing the General Background of CS Students through a Computing History Course," *ACM SIGCSE Bulletin,* vol. 40, no. 3, pp. 301-305, 2008.

[9] G. Gooday, "U-rated not X-rated: Reassessing how science students could benefit from learning history of science," *BSHS Annual Conference,* pp. 1-9, 2010.

[10] D. Koliopoulos, S. Dossis and E. Stamoulis, "The Use of History of Science Texts in Teaching Science: Two Cases of an Innovative, Constructivist Approach," *The Science Education Review,* vol. 6, no. 2, pp. 44-56, 2007.

[11] J. Pleasants and J. K. Olson, "What is engineering? Elaborating the nature of engineering for K-12 education," *Science Education,* vol. 103, no. 1, pp. 145-166, 1 2019.

[12] G. Lichtenstein, H. Loshbaugh, B. Claar, T. Bailey and S. Sheppard, "Should I Stay or Should I Go? Engineering Students' Persistence Is Based on Little Experience or Data," American Society for Engineering Education, pp. 1-22, 2007.

[13] S. Sheppard, A. Colby, K. Macatangay and W. Sullivan, "What is Engineering Practice?*," International Journal of Engineering Education, vol. 22, no. 3, pp. 429-438, 2006.

[14] J. Trevelyan, "Mind the Gaps: Engineering Education and Practice," Australasian Association for Engineering Education, pp. 383-390, 2010.

[15] J. Trevelyan, "Transitioning to engineering practice," European Journal of Engineering Education, vol. 44, no. 6, pp. 821-837, 11 2019.

[16] H. J. Passow, "Which ABET competencies do engineering graduates find most important in their work?," Journal of Engineering Education, vol. 101, no. 1, pp. 95-118, 2012.

[17] E. A. Cech, "The (Mis)Framing of Social Justice: Why Ideologies of Depoliticization and Meritocracy Hinder Engineers’ Ability to Think About Social Injustices," Engineering Education for Social Justice: Critical Explorations and Opportunities, vol. 10, pp. 67-84, 2013.

[18] W. T. Lynch and R. Kline, "Engineering Practice and Engineering Ethics," Science, Technology, & Human Values, vol. 25, no. 2, pp. 195-225, 1998.

[19] A. E. Slaton, "Engineering improvement: Social and Historical Perspectives on the NAE's "Grand Challenges"," International Journal of Engineering, vol. 1, no. 2, pp. 95-108, 2012.

[20] A. E. Slaton, "Meritocracy, technocracy, democracy: Understandings of racial and gender equity in American engineering education," Int. perspectives on engineering education, 2015, 171-189.

[21] C. F. L. Heimann, "Understanding the Challenger disaster: Organizational structure and the design of reliable systems," American Political Science Review, vol. 87, no. 2, pp. 421-435, 1993.

[22] J. C. Jung and E. Sharon, "The Volkswagen emissions scandal and its aftermath," Global Business and Organizational Excellence, vol. 38, no. 4, pp. 6-15, 5 2019.

[23] S. M. Lord, B. Przestrzelki and E. Reddy, "Teaching social responsibility: Conflict minerals module for a circuits class," World Engineering Education Forum - Global Engineering Deans Council, Albuquerque, New Mexico, 2018.

[24] J. Khubchandani, S. Sharma, J. H. Price, M. J. Wiblishauser, M. Sharma and F. J. Webb, "COVID-19 Vaccination Hesitancy in the United States: A Rapid National Assessment," Journal of Community Health, vol. 46, no. 2, pp. 270-277, 4 2021.

[25] R. Marra, B. Bogue, D. Shen and K. Rogers, "Those Who Leave-Assessing Why Students Leave Engineering," American Society for Engineering Education, pp. 1-15, 2007.

[26] X. Lin-Siegler, J. N. Ahn, J. Chen, F. F. A. Fang and M. Luna-Lucero, "Even Einstein struggled: Effects of learning about great scientists' struggles on high school students' motivation to learn science," Journal of Educational Psychology, vol. 108, no. 3, pp. 314-328, 2016.

[27] A Holley, “The Inadequate Union of Engineering Science and Art,” Trans AIME, IV, 191-2, 201.

[28] Act of July 2, 1862 (Morrill Act), Public Law 37-108, which established land grant colleges, 07/02/1862; Enrolled Acts and Resolutions of Congress, 1789-1996; Record Group 11; General Records of the United States Government.

[29] Cambridge University. "The Great University Land Grab." Cambridge University News. Available: https://www.cam.ac.uk/stories/great-university-land-grab#article. Accessed: February 8, 2024.

[30] NRC. (1996). The national science education standards. National Academy Press.

[31] AAAS. (1993). Benchmarks for science literacy. Oxford University Press.

[32] Ferguson, Eugene S. "Engineering and The Mind’s Eye." Cambridge, MA: MIT Press, 1992.

[33] National Science Foundation. "Science and Engineering Indicators 2023 - Chapter 7: Academic Research and Development." National Center for Science and Engineering Statistics. Available: https://ncses.nsf.gov/pubs/nsb202326. Accessed: February 8, 2024.

[34] USAspending.gov. "Budget Function Explorer." USA Spending. Available: https://www.usaspending.gov/explorer/budget_function. Accessed: February 8, 2024.

[35] J Mintz. "How a Dinner Led to a Feeding Frenzy." The Washington Post, July 4, 1997. Available: https://www.washingtonpost.com/archive/business/1997/07/04/how-a-dinner-led-to-a-feeding-frenzy/13961ba2-5908-4992-8335-c3c087cdebc6/. Accessed: February 8, 2024.

[36] NOAA, N. "PRIME Mishap Investigation Final Report." NASA, September 13 (2004).

[37] U.S. Department of Justice. "Aluminum Extrusion Manufacturer Agrees to Pay Over $46 Million for Defrauding Customers, Including the United States, in Connection with Test Result Falsification Scheme." Press Release Number: 19-411, April 23, 2019.

[38] NASA. "Mariner 1." NASA Science, 2023. Available: https://science.nasa.gov/mission/mariner-1/.

[39] National Transportation Safety Board (NTSB). "Investigation of March 15, 2018 Pedestrian Bridge Collapse at Florida International University, Miami, FL." NTSB/HAR-19/02, October 22, 2019. Available: https://www.osha.gov/sites/default/files/2019-12/2019_r_03.pdf.