WIP: Engineering History in the First-Year Engineering Experience Course

Dr. Bo Tao, Wentworth Institute of Technology

Dr. Tao is an associate professor in mechanical engineering. He is primarily involved in undergraduate engineering education in the thermal-fluids area at Wentworth Institute of Technology.

Dr. Haifa Salman El-Sadi, Wentworth Institute of Technology

Dr, El-sadi graduated from Concordia university- Montreal, she joined Pratt and Whitney after her graduation- aerodynamic department. On 2011, she joined Wentworth institute of technology- Boston, she developed an AIAA chapter and minor in aerospace at Wentworth Institute of Technology.

Dr. Gloria Guohua Ma, Wentworth Institute of Technology

Gloria Ma is a Professor in the Mechanical Engineering program at Wentworth Institute of Technology. She is actively involved in community services of offering STEM workshops to middle- and high-school girls. Her research interests include dynamics and system modeling, geometry modeling, project based engineering design, and robotics in manufacturing, artificial intelligent in Manufacturing, and engineering education.

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Introduction

Engineering is not just about designing and building; it is about understanding how past innovations, challenges, and failures have shaped the world we live in today. From the construction of ancient aqueducts to the development of cutting-edge technologies, engineering has always been deeply intertwined with human history, culture, and society. However, in engineering education, the rich history of mathematicians, scientists and engineers who made significant contributions which greatly improved human beings' lives are often overlooked.

Some researchers recognized these issues and worked on integrating historical content into engineering education [1-7]. Godoy [4] presents the development and application of an on-line module to learn historical perspectives in relation to an engineering topic. The conclusion argues that using story-centered approaches can enhance student engagement and understanding by presenting complex engineering concepts within historical and cultural contexts. London et. al. [5] presented an engineering education pioneers project, which introduces graduate students in the field of engineering education research. This study emphasizes the value of using these stories to inspire and motivate students to engage in engineering education research, which is proven to be very effective. Gaynor and Crebbin [6] claim that historical studies have considerable potential in the education of engineers. They argue that offering interesting case studies for students to consider and draw conclusions about the importance of an engineering practice that takes into account social and culture factors. Previous studies examining the perceived impact of incorporating historical figures and case studies in two junior-level courses have showed a marked positive response in students' perspectives in creative thinking and willingness to explore innovations in their engineering education [7]. Research also suggests that students require multiple reinforcements of the key materials to truly master them [8,9].

The objective of this paper is to introduce historical elements and engineering case studies early in students' college education, with opportunities for reinforcement in subsequent engineering courses, which helps deepen their understanding of these concepts. We configure the first-year engineering experience course, a 2-credit course that includes a one-hour lecture and a two-hour lab each week. This course is required for all first-year engineering students at Wentworth Institute of Technology. This study is based on data from 5 sections, with a total of 164 students. In this course, students are introduced to some of the greatest achievements in engineering, fostering pride in the major they have chosen. Grand Challenges [10] are utilized to expose them to the future of the engineering field, sparking excitement about their potential to address significant global challenges in the decades to come. It is a great opportunity to highlight the contributions of historical mathematicians, scientists, and engineers whose work has shaped our modern world. Their stories serve as valuable role models for aspiring engineers, offering insight into how their discoveries and inventions have advanced human life.

As a transition from the achievements of these historical figures to real-world engineering case studies, students can see how their work directly influences the outcomes of engineering decisions—both successful and otherwise. Successful engineering projects, like the development of the Transcontinental Railroad or the construction of the Hoover Dam, demonstrate how the

principles of material science, structural integrity, and innovative design—pioneered by these early engineers—can lead to monumental achievements that have shaped the modern world. While engineering failures are often difficult to witness, they too serve as invaluable learning opportunities. By examining failures like the Challenger Disaster, students can better appreciate the complexities and risks involved in engineering. Moreover, these case studies highlight how challenges and mistakes have led to the refinement and advancement of engineering principles.

In this paper, we addressed the development of historical figures and engineering case study assignments designed to encourage students to explore the contributions of key figures and analyze real-world engineering failures and successes. Some sample student works and reflections are discussed.

Future Engineer Inspiration of Historical Figures

In this assignment, students are instructed to choose a scientist, mathematician, or engineer who has made significant contributions to their field of interest, with a particular focus on their impact on engineering practice.

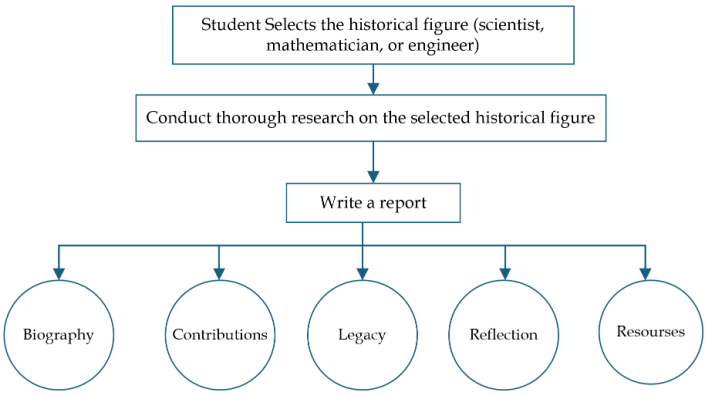

Figure 1. Historical Figures Assignment Workflow

The workflow of this assignment is outlined in Figure 1. Detailed instructions are summarized below:

- **Select a Figure: (Week 6)** Choose a scientist, mathematician, or engineer who has made significant contributions to their field, with a particular focus on their impact on engineering. Students may select someone from any era, but the chosen figures should be well-documented with substantial contributions to engineering.
- **Research:** Conduct thorough research on the selected figure. Use a variety of sources such as books, scholarly articles, reputable websites, and academic databases.
- **Write a Report:** Prepare a written report that includes the following sections:
  - **Biography:** Provide an overview of the individual's life, including their early years, education, and personal background.
  - **Contributions:** Detail the key contributions they made to their field. Explain their theories, inventions, discoveries, or methodologies and how these have impacted the field, with a particular focus on their impact on engineering.

- **Legacy:** Discuss the long-term impact of their work on modern science, mathematics, or engineering. Include any honors or recognitions they received and how their contributions continue to influence current practices or knowledge.
- **Personal Reflection:** Reflect on why you chose this individual and what you found most interesting or inspiring about their life and work.
- **References:** Include all the sources you used to gather information for this report. Be sure to follow the appropriate citation style (APA, MLA, Chicago, etc.).

- **Submit the Report**: (**the end of Week 9)**
- **Presentation: (Week 10)** Prepare a brief presentation (5 minutes) summarizing your report. This presentation should highlight the most significant aspects of the figure's life and contributions. Be ready to answer questions from your peers.

For this assignment, a list of historical figures across many engineering disciplines is provided, including Issac Newton, Anders Celsius, Nicolaus Otto, Michael Farraday, Henry Ford, Edward Jenner, George Stephenson, J. Robert Oppenheimer, George Boole, Werner Von Braun, and others. Alternatively, students may select a different figure, subject to approval by the instructor. The assignments of historical figures research and case studies were undertaken by a total of 164 students in five course sections, majoring in Biomedical, Civil, Electrical, and Mechanical Engineering.

The reasons students chose certain historical figures can be categorized into three main themes:

1. **Influence in their major**: Students were drawn to historical figures who had a significant impact on their field of study, whose work directly relates to their academic interests.
2. **Personal interest**: Some students chose historical figures based on their own personal curiosity or enthusiasm for a particular individual's achievements, reflecting a deeper personal connection to the topic.
3. **Recognized names from current classes**: Many students chose figures whose names they had already encountered in their course studies. Such an assignment gave them an opportunity to learn more about these influential figures beyond the surface level, expanding on their classroom knowledge.

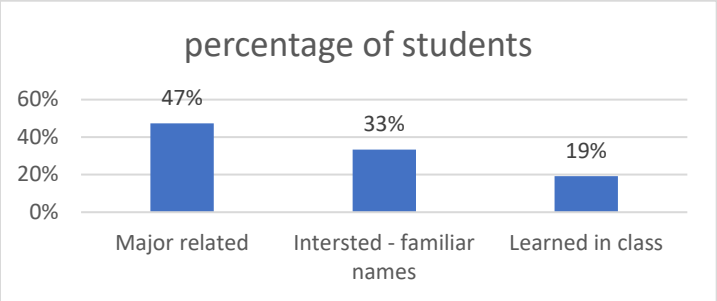

Figure 2. Distribution of Chosen Historical Figures

The distribution of the historical figures chosen by students as categorized above is shown in Figure 2, based on sample results from completed assignment of 164 students. Approximately 47% of students chose historical figures related to their majors, 33% selected figures based on their personal interest—many of whom are familiar names like Newton and Nobel— while 19%

chose historical figures they are studying in other courses, such as those related to physics and mathematics. A few highlighted responses stating the reasons for their choices, related to these categorized responses are summarized in Table 1. While Table 2 shows samples of a student's personal reflections on the individual and what they found most interesting or inspiring about their life and work.

Table 1. Student Sample Responses Stating Their Reasons for a Chosen Figure

Influence in their major	I chose **Edward Jenner** because I'm very interested in medical sciences and vaccines. My major is biomedical engineering, and vaccines were a huge advancement within the medical field.
	As I researched the legacy of **George Stephenson**, I became not only enlightened but very inspired. Originally, I had chosen to research him because of his vitality to my major and its history (Civil Engineering) but, the more I learned about him the more invested I became.
Personal interest	The main reason I chose to do this report on **Alfred Nobel** is because of how recognizable his name is and how little I knew about him.
	As someone with an enormous passion for spaceflight, **Werner Von Braun** was a natural choice as my topic for this assignment.
Recognized names from current classes	I chose this individual to do a report on because of how huge an impact he has had on the science we know today and how major his findings are. Although I mostly use Fahrenheit but there are sometimes, I use Celsius and now every time I do, I will think about **Anders Celsius** and how his research and findings led here.
	I personally chose **Euler** because I had heard his name so many times in class and found his work fairly interesting. Calculus is one of my favorite subjects, so I was always fascinated by how Euler's number has various applications as the natural or "default" number.

Table 2. Sample Student Reflections on Chosen Historic Figures

Student's choice	Student personal reflection	Reason for choosing the figure
Isaac Newton	Looking at all situations from a different perspective. The way he was able to find seven visible colors out of a plain white light shows his unique thought process. Isaac Newton's interest in mathematics and physics matches my own and is a direct result of me following the path of Mechanical Engineering.	Recognized names from current classes
Claude Louis Marie Henri Navier	Inspired by his Naiver-Stokes equations because I find it fascinating that he was able derive such a complex idea. Thanks to Navier, the world of math and science has a better understanding of the mechanics and physics of everything around us.	Influence in their major
Michael Farraday	The most interesting thing about Farraday was his commitment to his experiments. He once attempted an experiment 42 times – being successful on the 43rd attempt – solely because he extensively trusted his scientific intuition. I admire his reluctance to accept defeat regardless of the number of failures he encountered.	Influence in their major
Aprille Joy Ericsson	The fact that she strives for greater diversity and inclusion in STEM fields. The thing I admire most about her was the way she melded technical skills and talent with mentoring and outreach, building pathways for others to follow in her footsteps. It inspiringly elaborates on her journey, proving that engineering is not only an innovation but a trailblazing legacy for generations of empowerment.	Personal interest

Students' reflections demonstrated that they were inspired by the historical figures they researched. By incorporating these activities into the first-year engineering course, we can further inspire our students and help them develop the skills and knowledge they need to become successful engineers.

Case Studies

Case studies, on the other hand, provide students with real-world examples of how engineering principles are applied, helping them fill the gap between theoretical knowledge and practical applications. Different from the historical figure assignment, the case study assignment, assigned on week 11, requires students to work as a team (up to 4 members) and choose their own projects, subject to the instructor's approval. In this assignment, students not only research the case but also propose solutions to the case study, in this way, fostering critical thinking, problem-solving, and innovation. This approach aligns well with modern engineering practices, where engineers often build upon existing knowledge and technology.

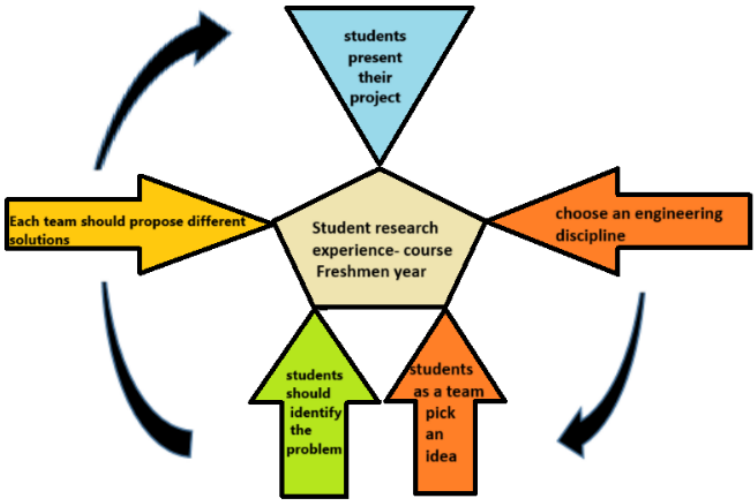

Figure 3. A schematic representation of the student case study process

The following instructions are provided for students to conduct a thorough engineering case study, as shown in Figure 3.

1. Identify the Case: Students choose a case that aligns with their interests and select a case that offers sufficient complexity to explore various engineering concepts.
2. Define the Problem Statement: What is the engineering challenge or opportunity? Identify the key factors and define the goals of the case study.
3. Gather Information: Students conduct a thorough literature review to understand the theoretical background and existing research.
4. Analyze the Case: Students analyze the problem and identify the critical factors that need to be considered and consider different approaches and evaluate their potential benefits and drawbacks.

5. Develop a Solution: Students develop a feasible solution to the problem and consider Constraint.
6. Document the Process and Results: Students write a clear and concise report and present their findings and conclusions.

A summary of sample student projects and their project solutions is listed in Table 3.

Table 3. Sample Student Projects Choices and Solutions

Engineering discipline	Project	Problem description	Solution
Civil	Sand Integration Filtration Tank (SIFT)	Increase water supply for areas with limited access to water	Upgrade the agitator to mix water and chemicals more effectively and use water quality sensor
Mechanical	The Challenger Disaster.	Increase safety measures on space shuttles to reduce the loss of life	Fix rubber O-ring, leak in booster, ensuring materials used are suitable for the weather they are in, O ring lost its elasticity because of freezing temperatures, Implement escape option for crew in case of future disasters
Electrical	Emergency Generators inside Hospitals	make emergency generators more reliable and more efficient	Voltage fluctuations can cause generators to unevenly distribute power to machines. implement coupling capacitors into the system. install Surge Protective Devices (SPDs) at key points like the main panel and Automatic Transfer Switch (ATS)
Biomedical	Enhancing Hearing Aids	improve the functionality of hearing aids and user comfort	Better battery, make them last longer when outside for longer periods of time. Improving signal processing which modifies the normal sound waves into amplified sounds. Implement machine learning to detect feedback from hearing aids.

Discussion

Historical figures and their work are essential for understanding engineering case studies. The principles and equations developed by historical figures are not just abstract concepts, but powerful tools that engineers use to analyze and solve real-world problems. On the other hand, modern engineering is built upon the foundational knowledge laid down by these historical figures. Their discoveries and insights continue to inform engineering practices today. The students use case studies as concrete examples of how the theories and equations developed by historical figures are applied in practice. For example, one team worked on a case study about Hyatt Regency Hotel Walkway Collapse. They tied it to earlier work by structural engineers like Robert Hooke, a historical figure, who developed the concept of elastic materials. They appreciated how his foundational principles helped engineers learn from such disasters and better understand material stresses and failure prevention.

About 47% of students chose the historical figures based on their majors, and 33% selected figures based on their personal interest—many of whom are familiar names, while 19% chose historical figures they are studying in other courses. Students are fascinated by their achievement. Through presentation, students learn about more than 30 historical figures, including their biographies, contributions, and legacies across various disciplines.

The reflections on historical figures have been overwhelmingly positive. Students appreciate the opportunity to explore real-world engineering applications and learn about the lives of historical figures. Many pioneers faced numerous challenges and setbacks before achieving their breakthroughs, and their perseverance and resilience in the face of failure remind students that these figures were human—more than just names in math, science, and engineering. The project is worth 10% of the final grade, and many students find it genuinely interesting. While we acknowledge that some students may write positive reflections to please the instructor for a better grade, we hope their reflections are motivated by genuine engagement rather than this sole intention. To more effectively assess these reflections, improved assessment tools should be developed.

Engaging students in research is a powerful way to enhance their learning experience. By providing opportunities for students to conduct case studies from different disciplines of engineering as research. A good example is one of the case studies undertaken by one multidiscipline team that is listed in Table 3 - "Enhancing Hearing Aids". The team defined the problem as improving both the functionality of hearing aids and user comfort. After conducting some research, they proposed several solutions: 1) A better battery to ensure longer usage when outdoors for extended periods; 2) Enhancing signal processing to convert normal sound waves into amplified sounds; 3) Implementing machine learning to detect feedback from hearing aids. When asked about their takeaways from the project, students shared that it inspired them to apply what they will learn in engineering to help improve the quality of life for others. After completing projects like this one, students should develop essential skills in critical thinking, problem solving, and communication.

Conclusion and Future Work

In this paper, we presented an approach to integrating historical figures and case studies into the first-year engineering experience course. The reflections have been positive, students thoroughly researched one historical figure and are exposed to more than 30 others.

From the students' reflections we can conclude that incorporating historical figures into a first-year experience course can be an effective way to engage students and inspire their learning. Highlighting the contributions of historical figures can inspire students' curiosity and passion for learning, in addition to encouraging students to analyze the challenges and their solutions offered by historical figures. We believe that when students encounter these historical figures in their future studies of various engineering disciplines, they will be able to connect them with the individuals' stories, helping them gain a deeper understanding of the content.

Case study proposals for interdisciplinary engineering projects challenge students to think critically, inspire creativity, and provide valuable guidance on more versatile solutions. Incorporating case studies into engineering education fosters interdisciplinary collaboration, highlights real-world applications, and encourages students to explore the ethical implications of engineering decisions and the broader responsibilities of engineers to society. Moreover, this

approach motivates students to think innovatively and develop creative solutions to complex problems, leaving a positive and lasting influence on their educational journey.

There are several aspects that will be further explored beyond the initial work presented here.

- Diverse Representation: Expand the selection of historical figures to include individuals from diverse cultural, geographical, and gender backgrounds. This ensures that students are exposed to a variety of perspectives and contributions, promoting inclusivity and a broader understanding of engineering's global impact.
- Modern Engineering Challenges: Create assignments that draw parallels between the challenges faced by historical figures and current engineering problems. This approach can help students (especially freshmen starting out) see the relevance of historical lessons in addressing modern issues.
- Better Assessment of Impact: Design surveys to measure the impact of introducing historical figures on students' critical thinking and engineering's societal role. These types of feedback results should better inform us for curriculum refinement.

References

[1]. N.H. Zaman, "Why Science and Engineering Need to Remind Students of Forgotten Lessons from History", "The Conversation", URL: https://theconversation.com/why-science-and-engineering-need-to-remind-students-of-forgotten-lessons-from-history-61356, August 15, 2016. Accessed 1/14/2025.

[2]. C. Barboza, "The Contribution of History to Engineering Education", proceeding of international conference on Engineering Education, Ric De Janeiro, Brazil, August 1998.

[3]. J.K. Brown, G.L. Downey and M.P. Diogo, "The Normativities of Engineers: Engineering Education and History of Technology", Technology and Culture Vol. 50, No. 4, pp. 737-752, 2009.

[4]. L.A. Godoy, "Introducing Engineering Students to Historical/Cultural Perspectives through Story-Centered On-Line Learning", Creative Education, Vol 2. No. 2, pp. 63-70, 2011.

[5]. J. London, K. Yasuhara, A. Carberry, C. Allendoerfer, A. Ayela-Uwangue, S.N. Cruz, E. Lee, M. Huerta, R. Abhyankar, and W. Huang, "The Pioneers' Stories as a Tool for Introducing Graduate Students to The Engineering Education Research Community, "Advances in Engineering Education, Spring 2021.

[6]. A. Gaynor and G. Crebbin, "How Can Engineers Learn from The Past? A Potential Role for History in Engineering Education", International Journal of Engineering, Social Justice, and Peace, Volume 2, Number 2, pp. 43-54, 2013.

[7]. G. Ma and B. Tao, "Pilot Study: Incorporating the study of engineering history into engineering courses", 2024 ASEE annual conference, Portland OR. June 23-26,2024.

[8]. M. Tamer, "Repetition, repetition, repetition", Cambridge (MI): Harvard Graduate School of Education, Ed Magazine; 2010 https://www.gse.harvard.edu/news/ed/10/01/repetition-repetition-repetition, accessed Feb. 2025.

[9]. John B. Carroll, "Problems of Measurement Related to the Concept of Learning for Mastery", Educational Horizons Vol. 48, No. 3, The Psychology of Learning, pp. 71-80, 1970.

[10]. NAE Grand Challenges for Engineering, https://www.engineeringchallenges.org/challenges.aspx, accessed Feb. 2025.