2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34375

Infusing the Liberal Arts in First-Year Engineering: A Module on History, Professional Identity, and Courage

Dr. Melissa C Kenny, Wake Forest University

Dr. Melissa C Kenny is an Assistant Teaching Professor in the new Department of Engineering at Wake Forest University. Her scholarly interests include biomimetic engineering, biomechanics, and engineering education, particularly the first-year engineering experience and liberal arts-infused engineering education. She holds a PhD in Biomedical Engineering from Virginia Tech and a BS in Biological Engineering from Cornell University. She joined the faculty at Wake Forest in 2019.

Dr. Olga Pierrakos, Wake Forest University

Dr. Olga Pierrakos is Founding Chair and Professor of the new Department of Engineering at Wake Forest University - a private, liberal arts, research institution. As one of the newest engineering programs in the nation, she is facilitating the realization of building an innovative program aligned with the university mission of Pro Humanitate (For Humanity) and well-integrated within the liberal arts tradition. Her vision is to educate the whole person and the whole engineer with fearlessness and virtuous character. She is the PI on the Kern Family Foundation award to infuse character education across the WFU Engineering curriculum in partnership with the WFU Program for Leadership and Character and many colleagues across the university. With inclusion being a core value, she is proud that the WFU Engineering team represents 60% female engineering faculty and 40% female students, plus 20% of students from ethnic minority groups. Her areas of expertise include engineering identity, complex problem solving across cognitive and non-cognitive domains, recruitment and retention, PBL, engineering design, learning through service, character education in engineering contexts, etc. She also conducts research in cardiovascular fluid mechanics and sustainable energy technologies. Prior to joining Wake Forest University, Olga served as a Program Director at the National Science Foundation in the Division of Undergraduate Education and founding faculty of the Department of Engineering at James Madison University. She holds a BS and MS in Engineering Mechanics from Virginia Tech, and a PhD in Biomedical Engineering from the joint program between Virginia Tech and Wake Forest University.

Dr. Monique O'Connell, Wake Forest University

Monique O'Connell is a Professor of History and Chair of the History Department at Wake Forest University. Her scholarly work focuses on the history of Renaissance Venice and its empire, a topic that has taken her into the details of economic exchange, early print culture, political communication, classicizing rhetoric, clerical conspiracies, and the history of botany. She earned her undergraduate degree at Brown University (1996), her masters and Ph,D at Northwestern (1999, 2002) and did a post-doctoral fellowship at Stanford University before joining the faculty at Wake Forest in 2004.

Infusing the Liberal Arts in First-Year Engineering: A Module on History, Professional Identity, and Courage

Abstract

The global workplace and professional practice require engineers to tackle complex problems and decisions by functioning effectively on multidisciplinary teams, weighing factors across social and political considerations (along with technical facets), communicating with diverse stakeholders, and requiring a lifelong learning approach to every project. Grounded in a rich liberal arts tradition, Wake Forest University (WFU) launched a new engineering program in 2017 with a strong commitment to this practice of authentically integrating engineering fundamental knowledge to rich liberal arts knowledge. Together, we believe this combination of knowledge leads to better engineers. After all, four out of the seven ABET Student Outcomes that every accredited program must meet is inherently connected to liberal arts knowledge. In this paper, we describe a semester-long module within one of our required, first-year engineering courses that was co-designed by an interdisciplinary team to embody this strong liberal arts tradition. In this first year WFU Engineering course, students are introduced to the study and practice of engineering with an emphasis on the human-centered design process. Within this course, a semester-long module called "What is Engineering?" showcases (1) the intersection of history and engineering to emphasize global and societal contexts, (2) foundational knowledge to support the development of one's engineer identity (with historical contexts and engineer exemplars), and (3) the importance of courage as a virtue that is foundational to the practice of engineering. Within this module, which has been under development the past four years, engineering, history, philosophy, and professional identity come to life. Engaging lectures are followed by interactive learning activities and engaging assignments outside of class solidify the learning and students' understanding of key concepts. The driving motivation for this module, developmental approach to the learning activities, and lessons learned are described in this paper. The paper offers the potential to serve as a framework for development of similar collaborations between engineering and humanities, including an emphasis on character virtues within first-year engineering courses and how scalable projects like this are beyond a single course.

Motivation for A Modern and Whole Engineer

Engineering practice in the 21st century does not only involve technical knowledge in areas like math and science, but must also include an understanding of global and societal contexts in order to solve some of the grand challenges facing humanity. This task is made no less difficult by the necessity of multidisciplinary teams, diverse stakeholders, and innovative communication methods in an increasingly complex world. This vision for a modern engineer is reflected in the 2004 and 2005 National Academies publications of "The Engineer of 2020" [1] and "Educating the Engineer of 2020" [2]. For historical context, Figure 1 showcases the call for action as summarized in the Grinter Report of 1955 [3] to the call of action as summarized in the Engineer of 2020 reports of 2004 and 2005. Ultimately, all of these reports (starting in 1955) urged for a more well-rounded engineer. The Engineer of 2020 reports simply called for even more modern engineers.

Grinter Report (1955)

1. Strengthening the basic sciences
2. Identification and inclusion of six engineering sciences
3. Integrated study of engineering analysis, design, and engineering systems
4. Inclusion of elective subjects to develop the special talents of individual students
5. Integrate work in the humanistic and social sciences
6. High level of performance in the oral, written, and graphical communication of ideas.
7. Encouragement of experiments and experimentation
8. Strengthening of graduate programs

Engineer of 2020 (2004/2005)

1. Scientific insight
2. Problem solving capabilities
3. Ingenuity and creativity
4. Cross-disciplinary fertilization
5. Vision and leadership abilities
6. Curiosity
7. Conscience
8. Determination
9. Responsive curricula
10. Inclusive environments
11. Sustainable development
12. Academia and industry working together

Figure 1: A visual depiction of new competencies needed by engineers upon review of the Grinter Report (1995) and the Vision of the Engineer of 2020 Reports (2004 and 2005).

Even from an accreditation perspective, in 1997, ABET released Engineering Criteria 2000 which made it clear that engineering education needed to include these global, societal, economic, and environmental mindsets in future engineers [4]. The incorporation of what are commonly termed "soft skills" in engineering curriculum, including teamwork, communication, ethics, and social consciousness, were soon considered a necessity. Engineering coursework had already garnered a reputation as being content-heavy, so innovative and unique methods by which to weave technical knowledge with "soft skills" are becoming increasingly popular. In its current state, ABET Student Outcomes, which all engineering programs are required to show attainment of by their graduates, showcases further this need for a well-rounded engineer. Four of the seven ABET Student Outcomes, respectively 3, 4, 5 and 7 below, demonstrate learning reflective of a broader education beyond the traditional engineering technical areas.

- **ABET Student Outcome 1:** an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- **ABET Student Outcome 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.
- **ABET Student Outcome 3:** an ability to communicate effectively with a range of audiences.
- **ABET Student Outcome 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.
- **ABET Student Outcome 5:** an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- **ABET Student Outcome 6:** an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw

conclusions.

- **ABET Student Outcome 7:** an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

It is for all these reasons that engineering programs have begun to partner with the liberal arts more often than ever before. Infusion of liberal arts philosophies, methods, and content within engineering curricula provide an opportunity to merge the technical pieces commonly associated with engineering with a societal context that helps educate the ‘whole engineer’. The argument could be made that engineering itself is a modern liberal art. In 2017, the Wake Forest University (WFU) Engineering department was established with a commitment to this goal. This program is grounded in the liberal arts, with pieces of it woven throughout the entire curriculum to create more well-rounded engineers. In fact, one distinct way in which this program attempts to educate the whole engineer is through the incorporation of character development and virtue education throughout the curriculum. Support from the Kern Family Foundation has enabled WFU Engineering to infuse virtue modules across the curriculum. Such an effort is in partnership with the Program for Leadership and Character at WFU and colleagues across the university who bring diverse disciplinary expertise. The engineering faculty work collaboratively with philosophers, psychologists, artists, and humanists to take on this work. The work herein is one example of such a collaboration. Virtues that are infused across the WFU Engineering curriculum include curiosity, creativity, empathy, resilience, authenticity, courage, intellectual humility, virtues of teamwork, etc.

Like many engineering programs, we have established a first-year engineering experience consisting of two courses that first year students complete while also working on prerequisite courses. One of these courses, EGR 111: Introduction to Engineering Design, provides an introduction to engineering with a focus on the human-centered design process. This introductory engineering course is a unique opportunity to incorporate all of the pieces of educating the whole engineer within the first-year engineering experience. Thus, we attempted to provide a unique way to establish an interdisciplinary module which includes the liberal arts, character development, and human-centered understanding as students discover what engineering means to them. Specifically, in this paper, we describe a semester-long module within one of our required, first-year engineering courses that was co-designed by an interdisciplinary team to embody a strong liberal arts connection with engineering.

<u>WFU Engineering First Year Course Experience</u>

While it is a best practice and a common practice across many engineering programs to have projects within first year engineering courses, it is not common practice for first year engineering courses to infuse professional identity development, character development, engineering cultures, and a historical perspective of engineering practice. The vision for EGR 111 at WFU Engineering was set to bring all of these layers together - a project-based course focused on design thinking and a course that lays the foundation to the four themes of professional identity development, character development, engineering cultures, and a historical perspective of engineering practice. These four themes lay the foundation for the “What is Engineering?” module of EGR 111. How each activity and lecture (described later) applies to these four themes is shown in Table 1.

Table 1: A table describing how the theoretical knowledge from lectures and applied knowledge from course activities map to the four EGR 111 themes and ABET student outcomes.

Themes in EGR 111	**Theoretical Knowledge (Lectures)**	**Applied Knowledge (Course Learning Activities)**	**Mapped to ABET Student Outcome**
Professional Identity Development	Lecture 2a and 2b	Personal and Professional Interests & Goals Four Year Curricular Map 1:1 with Engineering Professor Interview an Engineer Individual Development Plan (IDP)	Mapping to Student Outcome 4 and Student Outcome 7
Engineering Cultures	Lectures 1, 2a, 2b, 3	In-class Debate	Mapping to Student Outcome 4
Historical Perspective of Engineering Practice	Lectures 1, 2a, 2b, 3	In-class Debate	Mapping to Student Outcome 4 and Student Outcome 7
Character Development	Lectures 1, 2a, 2b, 3	Courage in Engineering Education Reflection Pre-Modern Engineer Presentation	Mapping to Student Outcome 4

While the exact curriculum for EGR 111 has varied with each semester, it has always been geared towards specific student outcomes (SOs), as outlined by ABET [5]. The course focuses on SO #1, #2, and #3 with some technical problem solving and design challenges, but it was also our goal to provide examples of SO #4, and SO #7. In the case of these student outcomes, where ethical and professional responsibility, and an ability to be a lifelong learner are paramount, we developed a module titled “What is Engineering?”. The overarching purpose of this module is to allow first-year students to explore what engineering really means, both to society and themselves, as well as how they can find success in engineering practice. Students do this through several communication techniques, interactions with professionals, and development of learning strategies in order to provide exemplars for the required SOs.

The initial iteration (fall 2017) of the “What is Engineering?” module, led by Dr. Olga Pierrakos, focused more closely on helping students develop and explore academic and professional goals and dreams in the context of understanding the engineering profession broadly and understanding foundational knowledge that defines engineering practice. Students completed a personal statement of professional interests and career goals via a worksheet with questions pertaining to their current mindset, professional goals, and academic journey. They then developed a 4 year curricular map outlining the exact courses they would take to meet the education requirements of both the university and major of their choice. Each student then had a one-on-one meeting with an engineering faculty and an interview with a professional practicing engineer. Finally, students combined this knowledge into an “Individual Development Plan” which included a reflection of their current state and professional goals and how this changed across the semester. It also involved an updated 4 year curricular map, a plan of action for during their undergraduate education to achieve their goals, and their response to feedback from other individuals. These assignments and assessments were developed to not only help students better explore possible career and course options, but to help them discover how they can find this information and expand their network.

While this initial “What is Engineering?” module helped students to explore courses, engineering professions, and get advice on their future, it lacked a deeper, more contextual understanding of engineering practice. Thus, the engineering faculty utilized the strong liberal arts foundation at WFU to begin a mutual partnership with the Department of History, noting that several studies demonstrate that history and engineering are a good match for interdisciplinary pedagogy [4,6]. Dr. Monique O’Connell, a historian specializing in medieval and Renaissance Europe, was invited to serve as “Humanist in Residence” in the WFU Engineering program in the fall of 2018. The position was funded through WFU’s Mellon grant, whose one goal was intended to bring a series of humanists into close collaboration with the new Engineering program. Dr. O’Connell attended engineering classes, attended curriculum retreats, and met with engineering faculty to learn about their curricular structure and the goals of each individual course. She then proposed a series of modules across three different engineering courses, the most elaborate being in EGR 111 and described herein. We wanted history to be an integral component of the engineering curriculum, as emphasized in [8], and thus an integrated approach was very important to the engineering program. A stand-alone History of Engineering course, similar to what has been instituted at other institutions [4,7], was not something that was viable for the goals and vision of the WFU Engineering curriculum.

With this in mind, we began to incorporate a deeper intersection of history and engineering within the “What is Engineering?” module, with an emphasis on global and societal contexts. While students completed their professional development tasks, we developed and included a lecture series called “Engineering before Engineers” to encourage students to consider how the historical context of engineering may help them better understand current engineering practice. The development of this series is described in the next section.

Table 2: This table shows the activities throughout the module and the week they occur within a 15 week semester. Lectures show the week they occur and assignments include the week they are assigned and due. It also describes the learning outcomes for each activity. Activities are listed in chronological order.

Activity	Week Occurred	Learning Outcome(s) (in parentheses are the associated ABET Student Outcomes)
Personal and Professional Interests & Goals	Assign: Week 1 Due: Week 2	- Describe and reflect on current state and desired future states as a person, student, and professional. (SO7) - Reflect on one's personal values, educational goals, and professional aspirations. (SO7)
Lecture 1	Week 2	- Understand how art, science, and innovation have worked together historically in the development of scientific advancements. (SO4) - Reflect on the importance of courage in historical scientific advancement and compare this with similar character virtues like grit and perseverance. (SO4) - Reflect on the role of competition in advancement through history and how communication and character plays a role. (SO4) - Compare the conceptual development of an idea versus its implementation for advancing technology using historical case studies. (SO4)
Four Year Curricular Map	Assign: Week 2 Due: Week 5	- Reflect on one's academic interests and goals throughout the undergraduate academic journey. (SO7) - Create a four year curricular map to support degree completion and professional goals (including the identification of resources to support one's academic journey). (S07).
1:1 with Engineering Professor	Assign: Week 4 Due: Week 8	- Engage in a one-on-one conversation with an engineering professor to share personal interests, understand an example professional path, and inquire about professional paths of interest. (SO4 and SO7) - Reflect on one's personal and professional development for the coming year and develop an action plan. (SO7)
Lecture 2a	Week 7	- Understand how engineering innovations have evolved from a historical lens to meet societal needs, yet still evolving in complexity as scientific advancements have accelerated. (SO4) - Understand the historical evolution of US engineering education as influenced by European traditions of engineering education (France, Britain, Germany). (SO4) - Reflect on the pros and cons of the current state of the

		engineering profession, its status in the US, and impacts of engineering education on the state of professional practice. (SO4) - Reflect on the importance of courage as a virtue relevant in engineering practice and essential for engineers. (SO4) - Reflect on engineering practice from a global and cultural lens to understand diversity in problem framing and problem solving. (SO4) - Respect the diverse professional journeys of engineering practice. (SO4)
Lecture 2b with in-class debate	Week 8	- Reflect on professional identity and develop a more rounded historical perspective on engineering education. (SO4) - Understand the historical promise of science and engineering for improving lives and how this influenced the development of engineering education. (SO4) - Compare hands-on versus theoretical approaches to engineering education, while considering a motivation of business application and/or social benefit. (SO4) - Practice structured debate to argue for a given education faction, including discussion of evidence and counter points. (SO3)
Courage in Engineering Education Reflection	Assign: Week 8 Due: Week 9	- Compare and contrast on the development of engineering education through history and the various engineering education traditions. (SO4 and SO7). - Consider the role of courage in engineering education. (SO4 and SO7)
Interview an Engineer	Assign: Week 9 Due: Week 13	- Explore a relevant engineering career path by interviewing an engineer outside of the university setting to understand diverse paths of engineering training and experience. (SO7) - Practice informational interviewing skills as a way to build networks. (SO7 and SO3) - Create a profile of the interviewee which describes their professional path and current state, including a reflection on the conversation and advice provided. (SO7)
Pre-Modern Engineer Presentation	Assign: Week 11 Due: Week 15	- Define engineering, including the values and skills that engineers should possess. (SO4 and SO7) - Understand where engineering originated and how it has changed and developed through time. (SO4) - Practice good research and presentation skills to communicate information to an appropriate audience.

		(SO3)
Individual Development Plan (IDP)	Assign: Week 11 Due: Finals	- Understand the value and purpose of an individual development plan for personal and professional growth. (SO7) - Reflect deeply on personal and professional short-term and long-term goals accompanied by action items and evidence of achievement. (SO7) - Conduct a gap analysis to understand current and desired states as a person, as a student, and as a professional. (SO7) - Take part in a self and professional exploration of thinking about the role of engineering in one's journey. (SO7)
Lecture 3	Week 13	- Understand the interaction of science (abstract, theoretical investigation of how nature works) with technology (hands-on application) during the information revolution. (SO4) - Reflect on the societal driving forces behind the information revolution, including the common good, anarchy, profit, and national interest. (SO4) - Understand where inventions come from and compare individual genius versus structural collaboration in modern times. (SO4) - Reflect on the role of competition and cooperation in technological advancement, including open source versus proprietary work and the role of patents. (SO4) - Reflect on engineering reputations and the moral dilemmas and role of whistleblowers among engineers. (SO4)

<u>Descriptions of the Lecture Series</u>

Lecture 1 - The "Engineering before Engineers" section of the course developed gradually over two years of experimentation, from Spring 2019 to Spring 2021.This lecture series was designed to help students reflect on the roots of innovation, the formation of professional identity, and how the shifting relationship between technology and society creates distinct engineering cultures. In Spring 2019, the initial lecture series included two lectures, the first of which used three case studies-- the careers of Filippo Brunelleschi (1377-1446), Leonardo da Vinci (1452-1519), and Robert Hooke (1635-1703)-- to introduce EGR 111 students to the overlap between art and science, practices of design drawings, and problem solving on building sites in Early Modern Europe. These case studies were selected because they drew on Dr. O'Connell's expertise as a historian of the Italian Renaissance and because they effectively highlight the engineering culture of early modern Europe, where there was no set path for the professional development of an engineer. For Brunelleschi, da Vinci, and Hooke, there were only blurry distinctions between artistic and technological approaches, which helped students see the way that theory and practice were entangled in this particular engineering culture. After learning about the three cases through the lecture, students were asked to reflect on whether it was more important to have an innovative idea to solve a problem or to actually implement the idea.

Lecture 2a - The second lecture in spring 2019 actually had been included in EGR 111 from the very first offering of the course, fall 2017. This lecture, taught by Dr. Olga Pierrakos, has three parts that evolved as the course evolved: (a) a historical perspective of engineering through the lens of a timeline of engineering innovations from Renaissance time to modern times, (b) a related historical perspective of the timeline of establishment of engineering professional societies in the United States, (c) a perspective of engineering cultures as related to engineering education across three major traditions (French, British, and German) that influenced engineering education in the United States and examples of engineering cultures in other continents. Part (c) was inspired by the works of Dr. Gary Downey at Virginia Tech on engineering cultures [9]. The most recent evolution of this lecture included a new fourth thread (d) that was woven into all the parts of the lecture - courage as an essential virtue for the engineering profession and for engineers as professionals. This lecture connected historical perspectives and an understanding of the engineering profession from the lens of societal needs and engineering innovations. Students witnessed the history of engineering divided across four phases, each marked by a revolution: pre-scientific revolution, industrial revolution, second industrial revolution, and the information revolution. Seeing this complexity of engineering innovations over time in support of societal advancements, students gained a broader perspective of engineering as a profession and of the role that engineers play in being the levers of technological innovations and directly seeing the impacts of engineers in a global landscape of societal needs and advancements. With this renewed understanding of the profession and the role of engineers in society, students began to understand their role as engineering students. Part (c) then enabled links to engineering education to be made with a global perspective of understanding that not all engineers are educated in the same way across the world. The French, British, and German traditions of engineering education helped students understand how US engineering education came to be. The theoretical foundations of French engineering education were contrasted to the apprentice-approach to engineering education of the British tradition and the technic-approach to engineering education of the German tradition. Students began to understand that in the same way that a French engineer will not approach a problem in the same way as a British engineer or a German engineer or an Asian engineer, they too (as US engineers) will not approach a problem in the same way as the person next to them. These diverse cultural perspectives of understanding global practices of engineering practice enabled a broader conversation of reflecting on one's own diverse approaches to engineering practice in the classroom and allowed an open and easy conversation on inclusivity of practices to be understood and respected. The courage thread of this lecture enabled students to define courage for themselves, understand why courage is important in engineering practice, and why it is important for engineers to show courage. Exemplar engineers like Theodore von Karman and Allan McDonald were highlighted in this lecture for their courageous efforts and actions as engineers.

Lecture 2b and 3 - The second iteration of "Engineers Before Engineering", in fall 2019-spring 2020, expanded from two to four lectures, keeping the case studies from early modern Europe as Lecture 1 and the historical perspective of engineering education as Lecture 2a but adding two more sessions on the professionalization of Engineering Education in late 18th-19th century Europe and the US (Lecture 2b) and on the development of computer engineering in 20th century Silicon Valley (Lecture 3). Adding the third and fourth lecture developed the professional identity component of the module and provided a more rounded historical perspective on engineering practice. Lectures 2b and 3 continued the focus on the roots of innovation, but asked students to reflect on the continuing evolution of the role of engineers in society and their own ambitions as engineers. Lectures 1, 2b, and 3 used case studies focused on individual engineers, and in this iteration we used the case studies to reflect on a variety of character traits demonstrated in the careers and personalities of the featured engineers. For instance, Lecture 2b emphasized the different character traits we can see in the careers of James Watt (1736-1819) and John Smeaton (1724-1792), both pioneers in their fields but with distinct views on the social and commercial value of engineering. Lecture 3 highlighted a variety of positive and negative character traits visible in the careers of Silicon Valley founders Steve Jobs (1955-2011) and Elisabeth Holmes, (1984-present), both famous as technology innovators but without formal engineering education. Students then discussed the role of engineering education in character formation in a contemporary context.

The 2019-2020 version of the module added more interactive elements to the lectures, in order to better match the other hands-on elements of the course. In the Lecture 1 module in the fall, WFU hosted Dr. Pamela Long, an historian of science and technology in the Renaissance and the recipient of a Macarthur "Genius" grant for her contributions to the field [10]. Her work focuses on the co-evolution of artisans as scientific practitioners as well as authors and writers, and she also argues for the importance of the Renaissance in establishing a culture of information exchange and technological openness in scientific inquiry. Dr. Long's public lecture, required for EGR 111 students, described an interdisciplinary culture of engineering that broke down distinctions between theory and practice. The EGR 111 students then experienced this for themselves by getting diagrams from da Vinci's Madrid Codex, a manuscript containing text as well as technical drawings. We used the reproduction edition with translation and commentary [11]. Students were asked to try and recreate a particular drawing with pipe cleaners, cardboard, and other materials in order to determine if they thought the design represented an idea or a design meant to be built. This activity then sparked reflection on whether it was more important to have an innovative idea to solve a problem or to actually implement the idea.

In the Lecture 1 module in the spring, we decided that the da Vinci design drawing activity might be less effective if not paired with the expert guest lecture, so we swapped it for a brief lecture by Dr. O'Connell on Renaissance Engineering and then an activity where students were asked to design and build a model for the Dome of the Cathedral in Florence, and then to defend their model in a debate with the other student teams. The debate is inspired by a real historical moment. In 1418, the managers of the cathedral works in Florence were facing a significant problem: they had constructed the base of a dome for the new Cathedral but did not have an agreed-upon plan for completing the dome, which needed to have a diameter of 143 feet and be constructed atop the existing tambor, 140 feet in the air. To solve their problem, the cathedral wardens held a competition, declaring that "whoever desires to make any model or design for the vaulting of the main Dome of the Cathedral under construction by the Opera del Duomo-- for armature, scaffold, or other thing, or any lifting device pertaining to the construction and perfection of said cupola or vault-- shall do so before the end of the month of September. If the model be used he shall be entitled to a payment of 200 gold florins" [12]. In history, Brunelleschi's combination of persuasive presentation and technical mastery tied with Lorenzo Ghiberti's acknowledged skill as a goldsmith, although Brunelleschi's consistent innovation in technical construction problems eventually led to his being credited as the primary architect of the Dome. In our class activity, students were invited to imagine themselves as entering the 1418 competition. Each group was given an identical packet of pipe cleaners, wooden dowels, legos, and other ephemeral materials and a build sheet detailing the measurements needed. At the end of the activity, students needed to present a physical model as well as a verbal description of their model's features, and an Engineering professor from another course acted as the Cathedral master and selected the winning design. The pedagogical outcome of this activity was to illustrate to students the real-life lesson that the best design does not always win without a compelling presentation.

Our plans to add interactive sections to Lectures 2b and 3 were abruptly curtailed by the March 2020 COVID-19 outbreak and the WFU Campus shut-down. All students were sent home and all classes pivoted to remote learning, a transition that placed a great deal of pressure on both students and faculty. Lectures 2b and 3 were recorded and delivered to students asynchronously. A plan to include a more interactive element to Lecture 3 was put on hold, although we plan to return to it in subsequent iterations.

The 2020-21 module is an iteration of the 2019-2020 version. It retains the chronological scope and the thematic focus on the roots of innovation and the interaction between engineers and society, using the same set of case studies that take the class from the Italian Renaissance to Silicon Valley. Because WFU operated under COVID-19 restrictions for the entire academic year, the hands-on aspects of the earlier module had to be adapted to allow for virtual learning. To fit with the structure of the blended modality, two of the class sessions (lectures 1 and 3) became recorded asynchronous lectures with written reflection responses from students. The initial decision to do this was practical as we did not have a clear understanding how long it would take to get back to in-person classes. There are some benefits to recorded lectures; in particular it lessens the demand on faculty time and ensures that the Engineering Before Engineers series can continue in future semesters even if Dr. O'Connell is not available.

Lecture 1, on Renaissance Engineering, returned to an asynchronous recorded presentation to accommodate remote learning as well as faculty schedules. In order to preserve some interactive elements to the lecture series, we incorporated a synchronous discussion and debate into Lecture 2b on the professionalization of engineering education. The debate draws on the foundation of the Society for Engineering Education (ASEE's predecessor) at the Chicago World's fair in 1893 [13]. In the first part of the class, students listen to Dr. O'Connell's presentation on the different philosophies of engineering education developed in European contexts in the late 18th and early 19th centuries. The lecture ends with a description of the Chicago World's Fair, and the students are asked to imagine themselves in the role of engineers attending the fair and founding members of the society. There are five different factions arguing for different styles of engineering education; each faction connects to a historical figure with a distinct view on engineering education (James Watt, John Smeaton, Gaspard Monge, Honoré Blanc, and Franz Reuleaux). The examples are selected to highlight the very real debate between hands-on and theoretical education, the role of aesthetics, and the appropriate balance of social benefit versus personal profit.

The point of the exercise is emphatically not to re-enact events as they occurred in 1893. Rather, the debate draws on the pedagogy developed in Reacting to the Past [14]. By asking students to inhabit past perspectives, the exercise illuminates the problems faced by people of the past; like engineers of today, they were asked to solve problems with the knowledge and tools at their disposal. The Reacting to the Past pedagogy creates courses where students are more highly engaged, not passive recipients of knowledge. In the adaptation of that pedagogy for Lecture 2b, students are asked to synthesize the different viewpoints on engineering education that were available in 1893- to put their knowledge into action, and to make a persuasive case for their own assigned viewpoint. The debate draws out the different implications of each style of education. Two professors in the course choose the most effective case, and that group is declared the winner- emphasizing the point that persuasive arguments are important. We plan to keep this debate as part of the course in future.

To complement the lecture series, we also established a “Pre-modern Engineer” assignment which involved each student putting together a 3 minute oral presentation on a historical figure born before 1400 AD who they feel fits their definition of an engineer. Students must develop their own working definition of an engineer and relate their historical figure to this definition. They must introduce their historical figure, describe their worldly contributions within a historical context, and reflect on the engineering values their historical figure exhibits that they hope to develop. The purpose of this assignment is to encourage students to consider engineering within a historical context and how engineering has evolved over time. Students give their presentations on the last day of class for the semester.

Courage as a Character Virtue

Considered one of the four Cardinal Virtues, courage “brings order and excellence to the spirit” [15]. Courage is the virtue that enables us to respond with moral strength and agency - in situations that cause fear. Rate et. al (2007, p. 95)[16] suggest that courage reflects “(a) a willful, intentional act, (b) executed after mindful deliberation, (c) involving objective substantial risk to the actor, (d) primarily motivated to bring about a noble good or worthy end, (e) despite, perhaps, the presence of the emotion of fear.” Too much courage can lead to rash behavior, too little courage to cowardice. In engineering practice, courage equips engineers to fulfill their ethical and professional responsibilities, particularly ones that are potentially challenging or pose a risk to their careers. Courage enables engineers to tackle ambitious projects, to revolutionize established processes, to make difficult or unpopular decisions, to challenge the status quo, to achieve important moral aims, and further one’s own knowledge and abilities.

In EGR 111, we chose to highlight courage because it is a foundational virtue to so many other virtues and quite relevant to the existing content of the course. Courage was also a virtue that was lacking from our curriculum, but any character virtue could likely be used here. In fact, students could highlight character traits they wish to work on. This speaks to the versatility of this module as well as the diversity and breadth of character traits in engineering throughout history.

To incorporate courage into the lecture series, Dr. O'Connell re-worked the lectures to focus specifically on the virtue of courage. We used a three point definition of courage, as articulated in [17]:

- Not shrinking from threat, challenge, or difficulty
- Persisting in a course of action despite obstacles
- Capacity to use practical wisdom to assess risks

In Lecture 1 on Renaissance engineering, the focus was on innovation; in the new iteration, the students were asked to consider whether courage was necessary for innovation. The example of Filippo Brunelleschi's plan for the dome of the Florence Cathedral, and his daring execution of the building, became a place for students to discuss whether his actions demonstrated courage or foolhardy risk-taking. Similarly, the examples of Leonardo da Vinci and Robert Hooke became opportunities to ask students to reflect on how courage looks in practice and its relationship to risk-taking and to innovation. In Lecture 2a, Dr. Pierrakos weaved courage throughout the conversation on the historical and cultural perspectives of engineering professional practice and referenced exemplars like Theodore von Karman, Allan McDonald, and her own professional journey as an engineer. In Lecture 2b, Dr. O'Connell added discussions of courage to the examples of James Watt, John Smeaton, and Gaspard Monge, who each had different visions of the way engineers could and should contribute to society and pursued their own goals in the face of considerable obstacles. In Lecture 3, which looks at the rise of computer engineering, students had originally been asked to think about invention as a product of individual genius or structural collaboration. By looking at some of the narratives surrounding Silicon Valley's "founding geniuses" in terms of courage, students were able to think about the value of persisting if one doesn't fit the expected mold but also to interrogate the limits of courage, or when courage turns to risky or unethical behavior.

An additional, low stakes assignment was also added to encourage students to reflect and consider courage as a character trait. After Lecture 2b, which includes the debate on engineering educations, students had to respond to the following two reflection prompts:

1. Name one historical exemplar in the development of engineering education. How did this person use courage in order to accomplish their goals?
2. Name one more current exemplar in the development of engineering education - someone not discussed in class. How has this person used courage in their pursuits?

Within their "Pre-modern Engineering" presentations at the end of the semester, students also had to now describe how their pre-modern engineer exemplified the virtue of courage. We encouraged students, in this case, to define courage for themselves as well and to consider how that may tie into their definition of an engineer. The purpose of these additions to both assignments was to prompt reflection from the students and get them to consider how courage and engineering may interplay both historically and currently.

<u>Student Outcomes</u>

Although EGR 111 mapped to ABET Student Outcomes 1, 2, 3, 4, and 7, the "What is Engineering?" module in EGR 111 mapped explicitly to ABET Student Outcomes 4 and 7. Within the WFU Engineering curriculum, three threads define Student Outcome 4 and Student Outcome 7.

One of the explicit course goals within the syllabus for EGR 111 states “Demonstrate an understanding of the diversity of engineering problems (profession) and what engineers do (practice) through historical, contextual, cultural, and personal perspectives.” This course goal maps to ABET SO #4 and SO #7 as well and is accomplished through the “What is Engineering?” module. Students consider the historical and contextual perspectives of engineering through the “Engineering before Engineers” lecture series and pre-modern engineer presentation. They also reflect on courage as a character virtue inherent to those perspectives and how it fits with their own definition of an engineer. Students can then relate this to their own professional development and exploration within the Personal and Professional Interests & Goals worksheet, Individual Development Plan, and other assignments. By weaving a cultural understanding of engineering with the students’ own exploration of engineering as a potential career, we aim to improve the societal competency of our engineering students from the first year.

Evaluation

Assessment of student learning was first accomplished through the use of rubrics for graded assignments. In the case of the professional development assignments (Personal and Professional Interests & Goals worksheet, 4 year curricular map, 1:1 with Engineering Professor, Interview an Engineer, Courage Reflection, and Individual Development Plan (IDP)), basic rubrics were provided and grades were assigned based on completeness of tasks. Students were asked to provide thorough answers and reflections to the questions provided and points were assigned at three basic levels: full points for completion and thoughtfulness, partial credit for some answer but it lacks higher level thought, and no credit for not providing an answer. The same scaling was used for any reflection questions from lectures and for the courage reflection assignment.

For the pre-modern engineer presentations, assessment was based on the evaluation of at least 3 different faculty including an Engineering professor, a History professor, and a Librarian. These assessors were asked to provide a score from 1 to 5 (where 5 is excellent, 4 is good, 3 is average, 2 is poor, and 1 is deficient) in answer to four questions:

- How was the quality of the presentation and slides?
- How was the discussion of how the individual fits the given definition of an engineer?
- How was the description of the individual’s key contribution to society within a historical context?
- Did they connect the individual to the virtue of courage in some way?

The assessors also provided comments and feedback for the students. Scores for each question from each assessor were weighted equally and normalized to the total points for the assignment (usually 5% of the students’ total grade for the course).

Table 3: Example rubric for the professional development assignments, showing the rubric for the "Courage Reflection" assignment. Detailed comments and feedback were provided on the students' assignments as well.

Criteria	Full Credit (100%)	Partial Credit (~40-90%)	No Credit (0%)
Question #1: After your in-class debate on different methods of engineering education, what method do you think is the 'winner'? Did your opinion change at all during class or the discussions?	Answer is detailed with thorough reflection.	Answer lacks detail and/or reflection is cursory at best.	Answer is severely lacking or missing altogether.
Question #2: Name one historical exemplar in the development of engineering education. How did this person use courage in order to accomplish their goals?	Answer is detailed with thorough reflection.	Answer lacks detail and/or reflection is cursory at best.	Answer is severely lacking or missing altogether.
Question #3: Name one more current exemplar in the development of engineering education - someone not discussed in class. How has this person used courage in their pursuits?	Answer is detailed with thorough reflection.	Answer lacks detail and/or reflection is cursory at best.	Answer is severely lacking or missing altogether.

Table 4: Rubric for the Pre-Modern Engineer oral presentation. Students were assessed by at least 3 different faculty whose scores in each criteria were averaged to obtain their final score in that criteria. Detailed comments and feedback were also provided for each student.

Criteria	Excellent (5)	Good (4)	Average (3)	Poor (2)	Deficient (1)
How was the quality of the presentation and slides?	Slides are readable, neat, and contain appropriate visual elements with limited text. Student spoke clearly with modulation of voice and no physical distractions.	Slides are mostly readable, neat, and contain appropriate visual elements with limited text. Student spoke mostly clearly with modulation of voice and limited physical distractions.	Slides are readable but not very neat and contain few appropriate visual elements and/or too much text. Student spoke mostly clearly with some distractions.	Slides are difficult to read and disorganized. Lacking appropriate visual elements. Student does not speak clearly and has significant distractions.	Slides are unreadable, or missing entirely. Student is difficult to hear and understand.

How was the discussion of how the individual fits the given definition of an engineer?	Student provides a clear definition of an engineer and relates it to their individual directly. Student provides thorough justification and reflection.	Student provides a clear definition of an engineer and mostly relates it to their individual directly. Student provides some justification and reflection.	Student provides a definition of an engineer and mostly relates it to their individual although not directly. Student provides minimal justification and reflection.	Student does not provide a definition of an engineer or does not relate it to their individual at all. Student provides no justification and reflection.	Student does not provide a definition of an engineer.
How was the description of the individual's key contribution to society within a historical context?	Student describes their individual's key contribution in detail, relating it directly to the historical context. Student includes thoughtful reflection on the benefits of this contribution to society.	Student describes their individual's key contribution in some detail, mentioning the historical context. Student includes some reflection on the benefits of this contribution to society.	Student describes their individual's key contribution in some detail but does not mention the historical context. Student includes some reflection on the benefits of this contribution to society.	Student mentions their individual's key contribution but does not mention the historical context. Student includes no reflection on the benefits of this contribution to society.	Student does not describe the key contribution at all.
Did they connect the individual to the virtue of courage in some way?	Student explains, in detail, the connection between their individual and the virtue of courage. Student reflects on how this fits with the historical context and what it means to be an engineer in some way.	Student explains, in detail, the connection between their individual and the virtue of courage.	Student explains the connection between their individual and the virtue of courage with minimal detail.	Student mentions the virtue of courage but does not connect it to the individual.	Student does not mention the virtue of courage.

In addition, the students provided their own feedback and evaluation of the "What is Engineering?" module during the end-of-semester course evaluations. While these evaluations focus on the course as a whole, students did provide some feedback on the module. One of the major pieces of feedback after the first iteration in Fall 2019, was to "lessen the amount of WIE [What is Engineering] history of engineering lectures, and replace them with activities that convey the same knowledge." This was something we took into account in future iterations but were curtailed by the COVID-19 pandemic. We do hope to find new, innovative ways to use activities to make the lecture series more hands-on. Overall, course evaluations were positive towards the module, with some students citing it was specifically helpful. One student thought "the WIE [What is Engineering] module was very helpful for me to discover the different types of engineering, and understand more about whether I want to do engineering in the future." Another student "felt like [the] WIE [What is Engineering] module really helped me develop professional skills and interest in engineering." In the future, we hope to ask students more explicitly about the module in a separate end-of-module evaluation to get more specific feedback and reflection on the module.

Conclusions and Future Work

The "What is Engineering?" module described herein is a work-in-progress that we intend to continue to improve with each iteration based on both our own and student feedback. In future iterations of the course, one high priority is to diversify the case studies in the module lectures, bringing in more examples of women engineers. Gender is currently a theme in the lectures themselves, with particular emphasis on structural blocks that have in the past reduced diversity among engineers. The lectures need to balance giving an overview of historical context and development with spending time on individual exemplars. Lecture 3 highlights the role of women in the development of computing, but there is room for improvement. In next year's iteration, Dr. O'Connell plans to include Emily Roebling and the completion of the Brooklyn Bridge in Lecture 2, as her story lends itself to the virtue of courage.

We also plan to include more interactive pieces and hands-on activities in future iterations of the course. The move to recorded lectures during our forced pivot to remote learning during COVID-19 might have some hidden benefits, as it could allow us to essentially flip the classroom, offering the contextual presentations via recorded lecture and devoting class time to interactive activities and discussions. Our next step will be to add an interactive element to Lecture 3 on Silicon Valley and computer engineering.

Overall, we have found the module to be effective in introducing an understanding of historical, societal, and cultural contexts to new engineering students. The partnership here between Engineering and History allows for an infusion of the liberal arts to a first-year engineering course that would traditionally focus on more technical topics. This interdisciplinary module provides a unique method by which to establish themes of professional identity development, character development, engineering cultures, and a historical perspective of engineering practice. This module could be incorporated into other first-year engineering programs at other universities and has the flexibility to apply different values and virtues to fit with each engineering program.

Acknowledgements
We would like to acknowledge Dr. Kyle Luthy for his contributions to the initial development of this course module. We would also like to thank the Mellon Grant and the Kern Family Foundation KEEN award titled "Educating the Whole Engineer: Engineering Fundamentals, Character, and Entrepreneurial Education" for support for this work.

References

[1] National Academy of Engineering, "The Engineer of 2020: Visions of Engineering in the New Century," Washington, DC: The National Academies Press, 2004.

[2] National Academy of Engineering, "Educating the Engineer of 2020: Adapting Engineering Education to the New Century," Washington, DC: The National Academies Press, 2005.

[3] L.E. Grinter, "The Grinter Report," *Journal of Engineering Education*, 44(3), pp. 25-60, 1955.

[4] A. Genau and A. Millard, "Reclaiming General Education: History for Engineers," *Paper presented at 2018 ASEE Annual Conference & Exposition,* Salt Lake City, Utah. 10.18260/1-2--30919.

[5] "Criteria for Accrediting Engineering Programs 2019-2020" ABET.org. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2019-2020/#GC3 (retrieved March 8, 2021).

[6] P. Dias, "The Disciplines of Engineering and History: Some Common Ground," *Science and Engineering Ethics*, vol. 20(2), pp. 539-549, 2014.

[7] B.E. Niemi, "STEMstory: Integrating History of Technology in Science and Engineering Education," *Paper presented at 2018 ASEE Annual Conference & Exposition,* Salt Lake City, Utah. 10.18260/1-2--30993.

[8] E. Brue, "An Integral Approach to Teaching History Across the Engineering Curriculum," *Paper presented at the 2004 ASEE Annual Conference & Exposition*, Salt Lake City, Utah. 10.18260/1-2--13990.

[9] G. Downey, J.C. Lucena, B.M. Moskal, R. Parkhurst, T. Bigley, C. Hays, B.K. Jesiek, L. Kelly, J. Miller, S. Ruff, J.L. Lehr, and A. Nichols-Belo, "The Globally Competent Engineer: Working Effectively with People Who Define Problems Differently," *Journal of Engineering Education*, 95(2), pp. 107-122, 2006.

[10] "Pamela O. Long" macfound.org. https://www.macfound.org/fellows/class-of-2014/pamela-o-long (retrieved March 8, 2021)

[11] L. da Vinci, "The Madrid Codices, ed. and trans Ladislao Reti" New York: McGraw-Hill, 1974, http://leonardo.bne.es/es/Colecciones/Manuscritos/Leonardo/index.html (retrieved March 8, 2021)

[12] R. King, "Brunelleschi's Dome: How a Renaissance Genius Reinvented Architecture" New York: Walker & Co, 2000, pp. 1.

[13] "ASEE at 125," ASEE.org. https://www.asee.org/about-us/the-organization/our-history (retrieved March 8, 2021).

[14] M. Carnes, "Minds on Fire: How Role Immersion Games Transform College," Cambridge, MA: Harvard University Press, 2018, https://reacting.barnard.edu/ (retrieved March 8 2021).

[15] G.R. Beabout, "Ethics: The Art of Character," Bloomsburg, New York, 2018.

[16] C.R. Rate, "Defining the features of courage: A search for meaning," in *The psychology of courage: Modern research on an ancient virtue*, Washington, DC, US, pp. 47-66.

[17] R.M. Niemec, "Character Strengths Interventions: A Field Guide for Practitioners," Hogrefe Publishing, 2018, pp. 11 and 119.