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GIFTS: Activities for Exploring Beauty and Elegance in Engineering in a First-Year Seminar

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Motivation

This GIFTS paper discusses an activity where students can explore the concepts of beauty and elegance and their relationship with engineering and the students' own interests. Part of the purview of many first-year engineering (FYE) seminars and other introductory courses is to help students understand the field of engineering in more depth and to help students appreciate how they can connect with and be successful in engineering. Some incoming students view engineering as job-focused and transactional or have been directed into engineering fields away from career paths more traditionally associated with self-expression, to increase their future earnings or career stability. The National Academy of Engineers' Changing the Conversation [1] suggests that perceptions of engineering work can potentially influence career choices in teenagers. The First-Year Seminar at Campbell University approaches helping students understand engineering with a 'something for everyone' approach that examines engineering from many perspectives and asks students to identify and build on whichever set of perspectives connects best to their interests and career plans. To this end, a set of activities examining beauty and elegance in engineering was created to focus on creative and aesthetic aspects of engineering, and other positive impacts of engineering related to experiences of beauty.

While not typically considered a core first-year topic [2], exploring the concepts of beauty and elegance with first-year engineers broadens and enhances their understanding of engineering and provides additional avenues for their individual interests and values to mesh with the field. This may also help to retain some students unsure about their commitment to engineering.

Objectives

The objectives of this set of activities are to enhance student appreciation and understanding of creative aspects of engineering design and other areas of engineering along with various positive impacts that engineering might have in the world, and potentially help them see connections between their values and interests and various engineering careers.

Practical Implementation Details

The activities are composed of a pre-class assignment done by each student individually, a roughly one-hour set of in-class activities and discussions, and a set of two short written reflections in a follow-up homework assignment. Overall, this topic is given most of the class time during one class week in a semester-length one-credit course meeting once per week for an hour and twenty minutes. In the author's context, this class contains about 60 students who are exclusively engineering majors and is facilitated by a single instructor and two or more undergraduate peer mentors but could be scaled for larger or smaller classes without large changes. This set of activities is usually run late in the semester when a rapport has been established between the students and the instructor, time-sensitive academic success content has already been addressed, and the students are less self-conscious speaking in front of peers.

The pre-class assignment tasks students with identifying three items, structures, products, or systems of any sort with some connection to engineering that they find to be beautiful or elegant, providing an image of each one, and writing a few sentences about why they find it to be

beautiful or elegant. Students are not provided with a definition of beauty or elegance – their selections are based on their own feelings and impressions. This results in a wide range of submissions and rationales that point to a wide variety of ways that beauty or elegance can be manifested in human endeavor.

After students submit the pre-class assignment, the instructor harvests 10-20 sets of images and text rationales from them to populate the class slides while anonymizing student contributions. Submissions have ranged from simple materials like anodized aluminum, to megastructures like bridges and large buildings, to various cars and aircraft, to specific medical technologies (sometimes with a personal impact on a student or their loved ones), to dresses with AI-controlled LED illumination patterns. A variety of items and rationales selected better sustains the class discussions. The use of current student materials for discussions has appeared successful at driving engagement. While data is not available to substantiate this claim, knowing that the photos and rationales come from peers in the room seems likely to enhance engagement – students do not know if their materials will be discussed ahead of time – there is anticipation each time a new example is shown.

During class, the instructor facilitates large-group and small-group discussions around the concepts of beauty and elegance anchored by the student-generated materials, seeking to highlight a wide variety of ways that beauty and elegance might be observed, appreciated, or caused in or by technical or engineering works. In small groups, students discuss the current example on the screens and assemble thoughts and responses inspired by it, prior to all-class discussion where the instructor calls on students to share results from their small groups and requests clarifications and asks follow-up questions. Students are asked to go beyond the rationale provided for the image selection and try to pull out a more general principle or concept of beauty and/or elegance from each example. Some potential principles are written into the course slides and are always discussed (for example – a solution that neatly solves several challenging engineering problems simultaneously with creative and insightful flair would often be termed ‘elegant’) while others emerge from the students. Even after several years of this activity, new ideas and interpretations continue to be brought up by students in discussions.

Some ways that beauty or elegance might be found in engineering work previously identified by students include: the form and tactile feel in use of an excellent tool, pleasing aesthetic forms of bridges, a sense of perfection and human potential expressed in complex systems such as internal combustion engines, and the positive impact on life experiences by items like medical, educational, consumer, and transportation technology. One example of medical technology would be in saving and extending lives – students note it is difficult for dead people to experience beauty so extending life with technology is likely a net gain for human experiences of beauty. An example of consumer technology facilitating beauty might be a camera, able to capture and share natural beauty across time and space, or to document events like weddings and birthday’s that would be found beautiful by those with an attachment to the people involved. Other students found beauty in contrarian or innovative solutions to problems in general – which some students described as illustrative of the potential worth and impact of a single engineer.

The breadth of approaches, observations, and principles relating to beauty and elegance illustrated by this limited sample is desirable, as the point of the class is not to converge on a

definition of beauty but rather for each student to find examples, methods, and possibly wider principles that are meaningful to them. An individual student's findings could potentially inform or expand their appreciation for what engineering can be and accomplish, offer them places to integrate engineering with their existing identities or interests, or influence career planning.

After class, students are assigned to write reflections based on prompts relating to the in-class discussion topics. The reflection assignment has two prompts, with a required response length of 400-600 words. The full reflection prompts are too long to reproduce in full here, to offer students many options for their responses, but some key text from each prompt is given below:

> "Did your understanding of art and beauty as a part of human work and life, including the work of engineering, change or increase? What was new and surprised you?"
>
> "Choose one of your three examples of engineering beauty…what makes this example a beautiful representation of engineering? How might this example influence or inspire how you approach engineering?"

The reflection assignment uses the online peer-assessment software Peerceptiv. Students evaluate anonymized submissions from other students against a rubric. Peer grading requires students to engage with the ideas and conclusions of other students, potentially enhancing their own understanding of the material. Thus, the peer grading of the reflections constitutes the final educational component of this set of activities. Peer grading also makes assessment of several dozen written reflections a week practical for a single instructor.

Assessment Methods

Informally assessing outcomes, student work on the pre-activity, and post-activity reflections has demonstrated engagement with and understanding of the topics. Past results on the pre-activity have been excellent, representing a wide range of interesting areas, many of which the instructor would not have considered and some of which the instructor was unaware of. Many of the reflections contain statements from students that the activities expanded their understanding of what the work of engineers can mean or accomplish beyond providing a paycheck. The quality of in-class discussions has variability, with greater engagement from some cohorts than others. Some years the in-class activities have been received with enthusiasm, while other years have required more intervention from the instructor to facilitate meaningful discussions.

One quantitative assessment of this set of activities is conducted through an online, anonymous end-of-class survey soliciting student feedback on the relative impact of each topic the class covers. This survey yields a small amount of extra credit and in the year for which IRB approval was obtained to use the results in publication 46 of 51 students completed the survey, a response rate of 90%. In the survey, students ranked the fifteen class topics in impact on them from 1 (highest impact) to 15 (lowest impact). The survey prompt is "Please order the class topics / sessions in terms of their impact or importance to you, with the most impactful or important class topics first and less impactful or important topics / sessions at the bottom."
To generate the 'Impact Score' shown in Table 1, the number of students selecting a rank (ex. 5 students) for a topic is multiplied by the rank (ex. 4^{th} rank) to generate a sum (ex. 20 student-ranks), then the sum of all these multiplications for a given topic is taken. To place the results in

perspective and remove the units, the best (lowest) overall resulting sum for any topic is divided by the result for each topic to determine the proportion of the maximum impact achieved by each week. Therefore, an 'Impact Score' of 0.58 says that that topic was ranked by students on average with 58% of the impact of the most impactful week.

Topic	Impact Score		Topic	Top 3
Week 9 - Self and Time Management	1		Week 9	26
Week 8 - Stress Management and Mid-term Check-in	0.74		Week 8	19
Week 6 - Learning Science & Strategy	0.65		Week 6	13
Week 7 - Academic Career Planning & Advising Walkthrough	0.62		Week 7	12
Week 10 - Professional Communications	0.6		Week 0	11
Week 11 - Professional Ethics	0.58		Week 10	8
Week 3 - Lifelong Learning and Professional Organizations	0.55		Week 11	8
Week 1.5 - Engineering Techniques for Success (Night event)	0.54		Week 1.5	6
Week 12 - Personal and Professional Values in Engineering	0.53		Week 3	6
Week 4 - Academic Ethics	0.53		Week 4	6
Week 5 - Effective Teams & Valuing Diversity	0.46		Week 13	6
Week 0 - Tartan Engineer (orientation)	0.44		Week 2	5
Week 13 - Beauty, Elegance, and Self-Expression in Engineering	0.42		Week 12	5
Week 1 - Images of Engineering (What is engineering?)	0.42		Week 5	4
Week 2 - What Does a Campbell University Education Mean	0.37		Week 1	3

Table 1 – Impact Survey Results

The score for Week 13 (Beauty's week) sits in the bottom (least impactful) third of the results, but with 42% of the impact of the best performing topic it falls within the normal range of impact for a topic in the class overall. For a topic potentially viewable as fluffy or extraneous this result suggests that these activities are perceived as having meaningful value by students.

As discussed in the Motivation section, one goal of the course overall is to provide a wide variety of opportunities for students to find ways to integrate their personal interests and values with an engineering identity and career path. The course is intended to have 'something for everyone' where a range of student needs can be addressed. In the 'Top 3' section of Table 1, the count of students rating a given topic in their top 3 most impactful topics is shown. Week 13 – Beauty has 6 students ranking it in their top 3 topics, which is equal or greater than eight out of fifteen course topics. This shows that Beauty and Elegance in Engineering as a topic can be substantially impactful for a subset of students, who might not be as well served by other topics.

It is not necessary for this topic to be the most impactful topic to be worth considering as part of a first-year engineering course or experience. By demonstrating similar impact and reaching some students that may not be reached as effectively by other course topics or activities, the potential value of these activities around beauty and elegance in engineering is clear. Instructors or course designers may find value in implementing or adapting these activities for use in their own FYE course sequence.

References

[1] National Academy of Engineering. 2008. Changing the Conversation: Messages for Improving Public Understanding of Engineering. Washington, DC: The National Academies Press. https://doi.org/10.17226/12187.

[2] Reid, K., Reeping, D., & Spingola, E. (2018). A taxonomy for introduction to engineering courses. *The International journal of engineering education*, *34*(1), 2-19.