Aesthetics and Emotional Engagement:

Why it Matters to Our Students, Why it Matters to Our Professions

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***Abstract*— This document provides background and context for a special session which will take the form of a guided discussion, using a hands-on flow visualization exercise as focal point. The session has several goals: to foster conversation and document ideas about how the aesthetic qualities of engineering topics can be used to deliberately draw the emotional engagement of students; to gauge how the FIE community currently views the aesthetics of engineering, and brainstorm new visions for how aesthetics could be used to improve recruitment and retention of a diverse student population as well as lead to innovative methods for the teaching and learning of core engineering content; to explore the feasibility of viewing aesthetics-driven emotional engagement as a necessity and not an ancillary benefit in course design.**

Keywords—aesthetics, art, affect, design, fluid mechanics, flow visualization, engagement, engineering, physics, education

I. INTRODUCTION

The terms 'art' and 'science' have been linked ever since the advent of the university system in medieval times. Originally they were closely related; in Greek and Latin the meaning of 'art' encompassed all human activities, including fine arts, crafts and sciences. Since then, the fields have grown far apart. In the 18th century in Western culture, the concept of 'fine arts' was invented, while crafts and engineering were relegated to 'applied arts'[1]. Soon after, as the advent of photography freed visual art from its duty to record accurately, emotion became more prized in fine arts with the development of Expressionism, while objectivity came to be more and more prized in science. Today, 'art' is used to refer to primarily fine art, created for aesthetic purposes. The STEM disciplines, in contrast, are ever more dedicated to solving all manner of problems. Is there any helpful relationship between the two? Is there any cost to divorcing them?

This dichotomy has been famously framed as CP Snow's "Two Cultures"[2], although the liberal arts are referred to rather than fine arts. We propose a more accurate framing for the context of engineering education we call "Twain versus Feynman". Mark Twain wrote about his experiences of being a Mississippi river boat pilot, describing how the river lost all its beauty as he learned to read the ripples for shifting sandbars and the eddies for dangers to his boat [3]. He gained the technical expertise needed for his work, but "all the grace, the beauty, the poetry had gone out of the majestic river!" In contrast, Richard Feynman has described his experience of viewing a flower with increased scientific expertise as an enriching one [4]. Do our students get caught in a "Twain" place, able to solve problems but unable to find satisfaction or emotionally engage the work? How can we elicit a more "Feynman" reaction?

The field of aesthetics may provide a useful bridge. Aesthetics is often defined as the philosophy or study of beauty, and can thus be used as a metric of art. One can apply an aesthetic to determine if a particular artifact is, in fact, art and rate it good or bad [5]. However, aesthetics can also be separated from the concept of art. Palmer et al. [6], in their psychology-based review of visual aesthetics, define "*aesthetics to be the study of those mental processes that underlie disinterested evaluative experiences that are anchored at the positive end by feelings that would accompany verbal expressions such as 'Oh wow! That's wonderful! I love it!' and at the negative end by 'Oh yuck! That's awful! I hate it!'*". Such a definition easily can be extended from responses to visual stimuli to responses to other stimuli such as engineering education, or any art, in the original sense of the word. This behavioral definition of aesthetics is closely related to Dewey's [7]. When we are interested in a student's affective response to engineering topics and the activities of science, perhaps we can use aesthetics as a type of framing. However, in contrast to the aesthetics of visual art, where there is a large interrelated body of work linking human affective response and perception to the form, content and philosophy of visual art, the aesthetics of STEM disciplines are relatively unexplored. Notable exceptions include aesthetic aspects of architecture, computer game design, and industrial design. Instead, cognitive gains, technical competence, utility, and objectivity are our most highly prized virtues. Despite improvements, the complexity of the problems that remain call for a broader approach; we propose aesthetics and the attendant emotional engagement as possible solutions to long standing problems in diversity, technical literacy, and retention.

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Fig. 1. An example of the aesthetic of beauty in fluid flow. Travis Ochsner, Grant Meaux, Shane Weigel 2011

Flow visualization (flow vis) is one example of an engineering topic that closely couples content and aesthetics. Although interesting images of fluid flows are used in all undergraduate fluids texts and courses, generally they illustrate engineering applications which can distract from the inherent attractiveness of the fluid physics. However, an innovative course at the University of Colorado encourages students to create aesthetic images of fluid flows, supported by technical course content on imaging. MCEN 4151/5151 / Film 4200 / Arts 5200: Flow Visualization [8] is a technical/studio elective offered to both graduate and undergraduate engineering, photography and film majors. Students work in mixed teams, but all students are expected to both exert conceptual control as artists, and document accurately as scientists. This course has been shown to improve attitude towards a notoriously difficult topic [9]. Also note that this course is more fully described in a FIE 2015 Work In Progress paper by Goodman, Hertzberg, and Finkelstein.

Flow vis can be used as an aesthetic bridge between art and science beyond the formal classroom as well. FYFD [10] is a surprisingly popular blog about fluid physics on Tumblr, and the Flow Visualization Facebook group [11] is continually growing. Flow visualization can contribute strong messages of science content within the community of physics and fluid mechanics researchers, but when communicating outside this community it is the aesthetics of fluid flows that carries the greatest weight, and is thus able to attract at least initial attention for recruitment. In fact, the FYFD blogger, Nicole Sharp, received so many queries about careers in fluid mechanics that she added a special section to answer them.

A closer look at the aesthetics of flow visualization may be helpful as a model for considering the aesthetics of other engineering topics. They can be grouped into four categories: beauty, power, destruction and oddness. These categories are currently based on anecdotal observation of the predominant choices certain populations make when given the opportunity to share examples of visual representations of fluids, and are thus assumed to engender positive affect and meet with aesthetic approval. These populations include students in the Flow Visualization course, other undergraduate mechanical engineering students at CU Boulder, and members of the open Facebook group ‘Flow Visualization’. Unless otherwise noted, these images are from student work in the Flow Vis course.

Figure 1 shows an example of a beautiful fluid flow. The Saffman-Taylor fingering instability results when a less viscous fluid, dyed water in this case, is injected into a more viscous fluid (honey) in a Hele-Shaw cell [12]. The apparatus is simple to construct and the procedure is easy to

carry out, but the results are evocative. Beauty is the most established aesthetic, and some may argue that there is no other valid aesthetic.

Fig. 2. The aesthetic of power as embodied by the Space Shuttle Endeavour as it lights up the night sky, embarking on the first U.S. mission dedicated to the assembly of the International Space Station.

The aesthetic of power is perhaps a product of modern technology's control over fluid flows. This aesthetic is exemplified by the precision of shock waves and the impressiveness of rocket exhaust, as shown in Figure 2 [13]. A particularly joyful example is the Shock Wave Jet Truck, a tractor-trailer with three large jet engines mounted on the back that makes appearances at air shows [14]. In contrast to the aesthetic of power, the aesthetic of destruction is focused on the loss of control resulting from the dark side of man and nature. Watching explosions, tornadoes, tsunami and wildfires elicits both fear and delight. Examples range from the ever-popular WD-40 flame (Figure 3, [15, p. 2]) to the Discovery Channel's series "Destroyed in Seconds" [16], which features destruction from many sources, but many are the direct or indirect result of fluid mechanics gone wild.

Lastly, the observed populations took particular delight in fluid behavior that just seems downright odd. Oobleck, a suspension of corn starch in water, stiffens to a solid when pounded, but yields like thick soup to gentle force. When constantly agitated by vibration, it deforms into a range of shapes, from holes to small peaks, as shown in Figure 4 [17]. Other examples of this aesthetic include ferrofluids in magnetic fields [18], the Kaye effect that makes shampoo leap [19] and the bizarre behavior of raisins in soda pop (yes, try this at home) [20].

Other examples of aesthetics in engineering might include the quirky mechanics of an intricate Rube Goldberg device, the precision, sharp corners and shine of a finely machined aluminum part, the Geiger-like piping layout of a complex chemical manufacturing plant, and the creepy life-like behavior of some robotic insects. Aesthetics need not be applied to physical artifacts only. An example of an abstract might be a spectacular dynamic parts sourcing system or even a well-timed joke in a lecture. We invite participants to think beyond the classic 'elegant solution' aesthetic.

New emphasis is being placed on students' emotional engagement, in works such as *The Whole New Engineer* [21] and in studies relating emotion to cognitive gains [22], [23]. Issues of affect, emotion, and identity are tangled, but certainly overcoming engineering stereotypes, which often highlight being socially awkward or emotionally stunted, requires transformation of our cultural practices in education. Acknowledging that aesthetics is a valid motivation for science and engineering may provide an important avenue for increased inclusion of diverse thinkers; conversely, ignoring the aesthetic dimension of engineering may suppress the enthusiasm and creativity engineers have for their work. How can we lead more students to Richard Feynman's joyous reaction that, "There are all kinds of interesting questions that come from a knowledge of science, which only adds to the excitement and mystery and awe of a flower. It only adds. I don't understand how it subtracts" [4]?

Fig. 3. The aesthetics of destruction inform this example of flaming WD-40. Dustin Scaplo, Chris Bonilha, Grant Bovee, James Palmer, 2006.

Despite the success of the Flow Visualization course, efforts to extend this success to other subdomains have been only partially successful. A first attempt to pull Flow Vis teaching methods into a new domain resulted in Perceptions of Design, a course that asked students to find and photograph objects with interesting design elements. This course did not result in greater student engagement and did not seem to improve students understanding of design. After three semesters, it was discontinued. A new course, Aesthetics of Design, was first offered in May 2014, where students explored a personally-defined design aesthetic while building a project [24]. Although a few students found

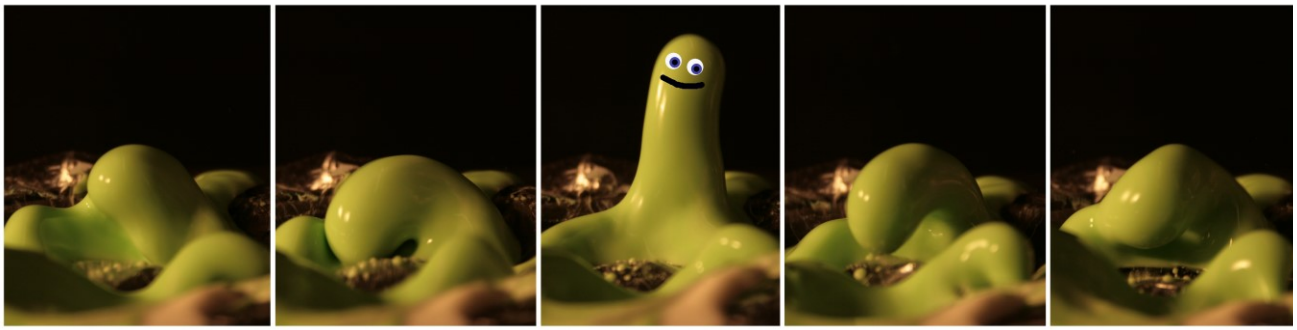

Fig. 4 The aesthetics of oddness are embodied in the behavior of oobleck on a loudspeaker. The face has been added with the permission of the image authors, Matthew Phee, Austin Edwards, Andrew Bornstein, Tyler Coffey, Steven Hendricks, 2011.

reflecting on design choices, in the form of assigned blog posts, to be off-putting, most of them relished the opportunity to design with fewer constraints and were able to articulate their aesthetic in a final paper accompanying the project.

II. Special Session

This workshop aims to generate and collect a wide range of perspectives on what aesthetics means in the context of engineering practice and education, and explore how aesthetics can usefully generate emotional and intellectual engagement with engineering topics.

Participants will be in small groups (4-6 people). They will be given a small (but beautiful) fluid dynamics experiment to perform. This will be used as a discussion starter for the role of aesthetics in comprehending specific physics concepts and improving student engagement. Facilitators will circulate to assist discussion where needed and document report-out using video.

Questions to be addressed:

- What are the aesthetics of your discipline? What is beautiful, or interesting or attractive? What do you find fascinating about it?
- Has deep understanding of your discipline enhanced or detracted from your aesthetic appreciation?
- Are you Twain or Feynman? Why? What experiences shaped you?
- How might we study and then use this?

III. Conclusion

Aesthetics and the resultant emotional engagement are topics that are not well-represented in engineering education research. In addition, many engineering educators are uncomfortable with these topics. We hope that in the process of facilitating this special session we will begin to establish a community of researchers and practitioners who can help move this area forward. This engagement will be possible only with the degree of interaction afforded by an FIE Special Session. Finally, this discussion, and the video record of it, can be the seed participants take home to begin this conversation at their own institutions.

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