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Building Informed Designers with Engineering Problem Framing Tools

Dr. Todd France, Ohio Northern University

Todd France is the director of Ohio Northern University's Engineering Education program, which strives to prepare engineering educators for grades 7-12. Dr. France also helps coordinate the first-year engineering experience at ONU. He earned his PhD from the University of Colorado Boulder in Architectural Engineering, and conducted research in K-12 engineering education and project-based learning.

Dr. J. Blake Hylton, Ohio Northern University

Dr. Hylton is an Assistant Professor of Mechanical Engineering and Coordinator of the First-Year Engineering experience for the T.J. Smull College of Engineering at Ohio Northern University. He previously completed his graduate studies in Mechanical Engineering at Purdue University, where he conducted research in both the School of Mechanical Engineering and the School of Engineering Education. Prior to Purdue, he completed his undergraduate work at the University of Tulsa, also in Mechanical Engineering. He currently teaches first-year engineering courses as well as various courses in Mechanical Engineering, primarily in the mechanics area. His pedagogical research areas include standards-based assessment and curriculum design, including the incorporation of entrepreneurial thinking into the engineering curriculum and especially as pertains to First-Year Engineering.

Dr. Patrick James Herak, The Ohio State University

Dr. Herak is a five time graduate of The Ohio State University: BSE (Science Education), MS (Env Sci), MS (Civil Eng), MA (Foreign, Second, and Multilingual Education) and PhD (STEM Education). As an undergrad he was a member of The Ohio State University Marching Band for 5-years and can still be found playing with the TBDBITL Alumni Band.

While at university, Dr. Herak had several jobs including as a lab assistant (in Science Education, Mechanical Engineering and Entomology) as well as a GTA (in Science Education and the first-year Engineering Program). He also worked for 4-summers on the show staff for the Columbus Zoo, training various species of birds and other animals.

Dr. Herak was a secondary science teacher for 18-years, primarily for Westerville City Schools. However, he did take a leave of absence to teach at Aldenham School near London (UK). Dr. Herak has served as an adjunct professor at Central Ohio Technical College (Environmental Science) and adjunct professor position at Ashland University - Columbus Branch (Science Education), a position he still currently holds. Dr. Herak currently serves as a Senior Lecturer in the College of Engineering at The Ohio State University.

Dr. Herak has presented at education conferences at the state, national and international level including the Science Education Council of Ohio, National Science Teachers Association, International Consortium of Research in Science and Math Education, First Year Engineering Education conference and American Society for Engineering Education conference.

Sherri Youssef, The Ohio State University

Sherri Youssef is pursuing her Masters of Science degree in the Department of Mechanical and Aerospace Engineering and is involved in the Department of Engineering Education as a Graduate Teaching and Research Associate at The Ohio State University. She completed her Bachelors of Science in Materials Science and Engineering at The Ohio State University as well in May of 2018.

Workshop: Building Informed Designers with Engineering Problem Framing Tools

Introduction

In introductory engineering courses, both at the high school and college levels, instructors often rely on a design process framework to guide students through contextualized projects. With a tendency to immediately embark on ideating potential design solutions, coupled with the prominence of "making" as a means to capture the interest of novice designers, students may skim through (or completely ignore) the initial phase of design. In other words, fully defining the problem to address may not be prioritized.

In this workshop, presenters will provide tools to help instructors guide burgeoning engineering students through the oft-overlooked "problem framing" phase of design. Problem framing encapsulates a number of critical aspects of design, including the identification of a) a need or opportunity, b) stakeholders, including direct users, who can influence key design decisions, c) a deliverable's form and function, d) information to gather to more comprehensively understand the problem, e) design constraints which limit design options, and f) metrics that will allow for potential design solutions to be evaluated for quality.

As part of a multi-year investigation within a diverse school district that supports multiple high schools (including traditional and engineering-focused programs), the presenters have generated problem-framing support tools. These tools, and their accompanying activities, will be disseminated at the workshop for those interested in improving students' practices from "beginning designers" to "informed designers," as defined by Crismond and Adams [1].

Intended Audience

While intended for instructors of first-year engineering design courses, the workshop can provide a framework for any educator employing a design process as part of a class project. The presented materials can benefit those who currently facilitate, or are interested in facilitating, open-ended projects that necessitate problem identification and/or opportunity recognition at the outset, but may be challenged to do so by any of the following obstacles:

- Students electing to pursue identical/similar design solutions as classmates in an open-ended project (i.e., lack of creativity)
- Students generating design solutions that do not address the most critical aspects of a problem (e.g., "fun" projects that do not actually serve a purpose)
- Students failing to take into consideration the viewpoints of all of those affected by an issue (i.e., lack of empathy)
- Students presenting solutions without justification for design decisions and/or without a clear method for evaluating the quality of their own projects (e.g., no basis for comparison)

In addition, educators with research interests in the high school/college engineering threshold are encouraged to attend. The presented project affords a viewpoint of this critical juncture of the

engineering career pathway, when students are first introduced to the design process. Student sample answers will demonstrate separation across a spectrum of students with and without engineering course experience, shedding light on opportunities to better align introductory coursework with professional engineering viewpoints. Constructive feedback for the presenters on the problem-framing tools and activities is highly encouraged.

Provided Materials

Presenters will facilitate an abbreviated version of a multi-day classroom intervention designed to systematically break down key components of the problem framing process. Attendees will be tasked with participating in activities to identify stakeholders' impacts and the ensuing research that would further inform future design decisions. Attendees will also be introduced to four problem-framing tools (detailed below), and will receive these tools and supporting activity instructions for use in their own classrooms.

Problem Framing Canvas

This multi-layered worksheet is intended to help students organize their broader thoughts about the problem framing process. Sections of this worksheet include space for identifying a specific opportunity to address (with consideration of stakeholders) and to reflect upon current alternatives in the market. Students are also compelled to explicitly state future research questions, how they will evaluate the quality of their forthcoming designs, and the broader impacts their work might have on society.

Opportunity Recognition Canvas
Again, thinking about their key stakeholders, students use this worksheet to consider particular contexts in which others might face obstacles. As part of their information gathering activities, students are asked to rate each stakeholder's *severity* (how significantly they are affected), *utility* (the extent that they affect our design choices), and *capability* (our ability to obtain their feedback).

Stakeholder Profile Canvas
This worksheet compels students to take a deeper dive into each key stakeholder's needs, wants, and pains, among other characteristics about the particular context. This worksheet is intended to foster empathy and discover opportunities in which students, as engineers, might be able to improve the lives of stakeholders.

Specification Source Model

Largely adopted from the Constraint Source Model [2], this tool was designed to elicit deeper consideration of various facets influencing a design project. For a given scenario, students are expected to judge the broader implications with respect to areas such as environmental concerns, maintainability, and ergonomics. This directed reflection is intended to compel students to consider different viewpoints of their projec, and can reveal key design aspects that may have otherwise been overlooked.

Workshop Timeline

The hour-long workshop is intended to serve as a mutually-beneficial session for attendees to gain insight into novice designers' approaches towards problem framing and to receive immediately deployable classroom tools. The anticipated workshop timeline is shown below in Table 1 (each topic will last ~5 minutes).

Table 1. Anticipated Workshop Timeline

Topics	**Purpose**
Workshop purpose, Summary of previous project iteration, Introduce Problem Framing Canvas	Establish importance of problem framing in engineering design, Identify common student misconceptions and instructor challenges, Overview of organizing key problem framing elements
Introduce Opportunity Recognition Canvas, Stakeholder Profile Canvas	Framework for establishing opportunities to address, Identify environmental factors that may influence stakeholders
Breakout groups – Stakeholder Profile Canvas	
Debrief – Stakeholder Profile Canvas	Participants share ideas & perspectives
Revisit Opportunity Recognition Canvas	Identify stakeholder *severity*, *utility*, and *capability*, Guide students towards an "opportunity statement"
Breakout groups – Opportunity Recognition Canvas	
Debrief – Opportunity Recognition Canvas	Participants share ideas & perspectives
Problem Framing Canvas "Market" section	Note any obvious answers (in practice, this section requires more research time)
Problem Framing Canvas "Assumptions," Specification Source Model	Format to guide students towards filling in information gaps, Elicit considerations about design limitations & evaluation methods
Breakout groups – Specification Source Model	
Debrief – Specification Source Model	Participants share ideas & perspectives
Problem Framing Canvas "Constraints," "Metrics," and "Broader Impacts"	Discuss purposes and challenges of establishing pre-determined evaluation methods
Closing thoughts & questions	Provide feedback on project and discuss deployment in own classrooms

References

[1] D. P. Crismond and R. S. Adams, "The informed design teaching and learning matrix." *Journal of Engineering Education*, vol. 101.4, pp. 738-797, 2012.

[2] J. Estell and J. B. Hylton, "Incorporating the Constraint-Source Model into the First-Year Design Experience," in *First-Year Engineering Experience Conference, Daytona Beach, FL, USA, August 6-8, 2017.*